A System Dynamics Exploration of Port-City Development
the Case of Tema, Ghana

Jorrit van den Houten - Model databank

For use with the MSc thesis system dynamics model
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1 Model Specification

In this section a full overview of model equations and dynamic hypotheses is provided. The specification is structured around the model structure, following the different sub-models.

1.1 Port submodel

Figure 1 depicts the port sub-model as specified in Vensim. The port submodel consists of three stocks (port capacity, port throughput and National GDP), three flows affecting these stocks and various variables and constants. The properties and model equations of the port sub-model variables are specified in Table 1 below.

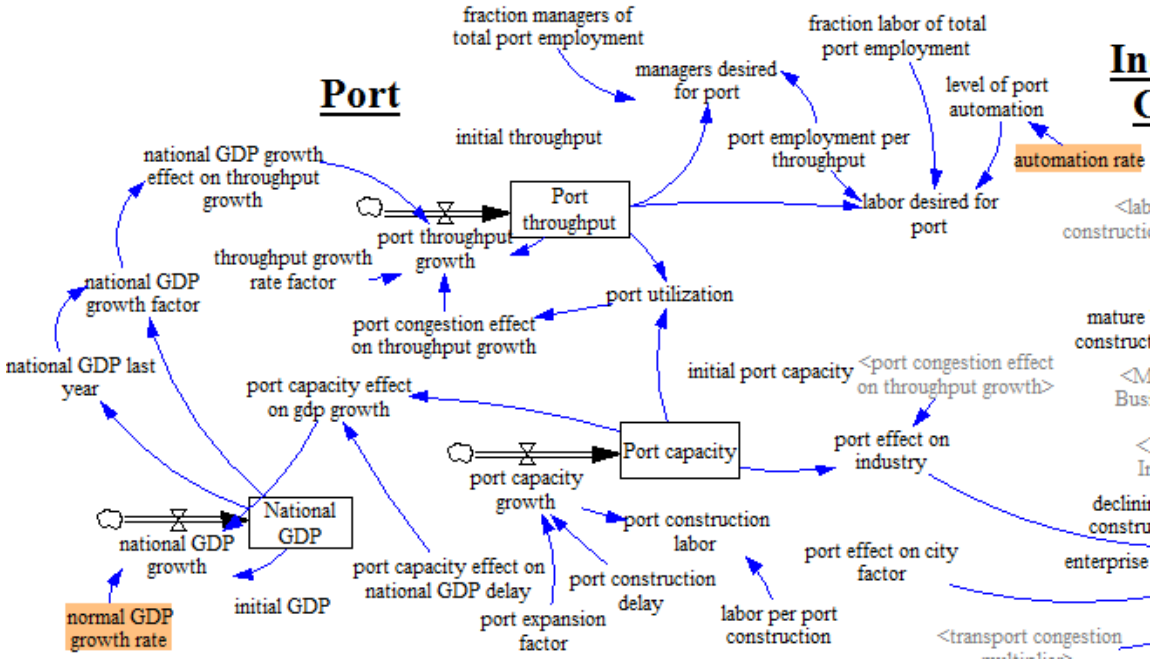


Figure 1. The port sub-model as specified in Vensim.

Table 1. Port sub-model variable specification

Variable	Units	Type	Equation	Comment/Hypothesis
Port capacity	kton/year	Stock	port capacity growth	Port cargo handling capacity
port capacity growth	kton/year /year	Flow	0+(PULSE(1987,port construction delay)*3286/port construction delay +PULSE(2007,port construction delay)*6050/port construction delay +PULSE(2015,port construction delay)*27500/port construction delay)*port expansion factor	Expansion of port capacity due to three expansion projects over the years (1987, 2007, 2015), based on Coquart, 1998; APM Terminals, 2015; Pedersen, 2001.
port construction delay	Year	Constant	5	Average construction time for port capacity expansions.
initial port capacity	kton/year	Constant	5476	Estimation of initial port capacity (based on Coquart, 1998).
Port throughput	kton/year	Stock	port throughput growth	
initial throughput	kton/year	Constant	1940	Port of Tema throughput in the year 1966 (Hilling, 1969)
port throughput growth	kton/year /year	Flow	Port throughput * port congestion effect on throughput growth * national GDP growth rate*throughput growth rate factor	Port throughput is driven by GDP growth, limited by capacity constraints, and potentially affected by competition and international trade
port congestion effect on throughput growth	-	Lookup	port utilization ([(0,-10)-(1.2,1)],(0,1),(0.3,1),(0.6,1),(0.7,0.95),(0.8,0.75),(0.9,0.1),(0.95,0.01),(1,0),(1.05,-10))	Multiplier reducing the potential throughput growth rate to zero with rising port congestion, so it cannot exceed port capacity. Strong negative growth is added to correct inconsistent (extreme) parameter settings. See Figure 3 below.

throughput growth rate factor	-	Constant	1	Scaling variable useful for modelling external influences on port throughput (e.g. competition from other ports) and sensitivity analysis.
port capacity effect on GDP growth	-	Lookup	DELAY1(Port capacity, port capacity effect on national GDP delay) ([(0,1)-(30000,1.25)],(0,1),(500,1.0025),(1000,1.01),(2000,1.03),(5000,1.06),(10000,1.09),(15000,1.1),(20000,1.1),(30000,1.1))	Port infrastructure capacity stimulates the national economy, but with diminishing returns (max. 10% higher GDP growth rate). See Figure 2 below.
port capacity effect on national GDP delay	Year	Constant	5	The boosting effect of port capacity presence on national economic growth takes a few years to manifest
National GDP	US Dollar/ year	Stock	national GDP growth	National GDP in current US dollars (World Bank, 2017)
initial GDP	US Dollar/ year	Constant	2.1263e+009	Ghana's GDP in 1966 (World Bank, 2017)
national GDP growth	US Dollar/ Year/Year	Flow	National GDP*normal GDP growth rate*port capacity effect on gdp growth	National GDP growth, disaggregated in a normal growth rate and a port-effect.
normal GDP growth rate	-	Constant	0.0694	Derived average annual GDP growth rate (World Bank, 2017), adapted to exclude modeled port effects
national GDP last year	US Dollar/ year	Auxiliary	DELAY_FIXED(National GDP,1,initial GDP)	Computes last year's GDP to assess GDP growth factor
national GDP growth rate	-	Auxiliary	(National GDP-national GDP last year)/national GDP last year	Computes a yearly actual GDP growth rate, driving throughput growth

port utilization	-	Auxiliary	IF THEN ELSE(Port capacity<>0 , Port throughput/Port capacity, 2)	Port utilization as fraction of maximum capacity. Zero capacity sets utilization to 2 to drive down any (wrongly specified) throughput
port effect on industry	-	Lookup	Port capacity*port congestion effect on throughput growth, [(0,0)-(10000,2)], (0,1),(500,1.02),(1000,1.1),(3000,1.8),(4000,1.98),(5000,2),(10000,2)	Port infrastructure presence stimulates local industry, but only if the available capacity is significant (Park and Seo, 2016) and with diminishing returns. Port congestion reduces the stimulating effect. The strength of the multiplier effect is an estimation based on Merk (2013) *(See* Figure 4 *below, and paragraph 4.8)*
port effect on city factor	-	Constant	1	Factor scaling the effect of the port on the city (industry, transport, employment), useful for sensitivity analysis.
port employment per throughput	jobs/(kton/Year)	Constant	0.5	Nominal employment generated directly by the port, per throughput, as based on Rodrigue, Comtois and Slack (2017)
fraction managers of total port employment	-	Constant	0.088	Fraction managers of total employment in the harbor, estimation partly based on field research by Agbesi Gadzedzo (2009) and Obilie-Odei (2006).
managers desired for port	Worker	Auxiliary	fraction managers of total port employment*port employment per throughput*Port throughput	Direct employment for *managerial-professionals* in the port.
fraction labor of total port employment	-	Constant	0.912	Analogous to the *fraction managers of total port employment*. Assumption is that non-managers are laborers. A nominal figure: port automation can subtract from the actual labor employment.
labor desired for port	worker	Auxiliary	fraction labor of total port employment * port employment per throughput * (1-level of port automation) * Port throughput	Calculates the amount of jobs for laborers based on port throughput and degree of automation. Increasing automation of cargo handling reduces the amount of labor required for this. Increasing

				cargo volumes requires additional *labor* (as well as *managerial-professional*) employment.
level of port automation	-	Constant	0.05 + RAMP(automation rate, 2017 ,2047) Sensitivity analysis: 0.05+IF THEN ELSE(automation rate<>0 ,RAMP(automation rate, 2016 ,2016 + 1/automation rate), 0)	Representing the degree of port automation, with a value between 0 (no automation) to 1 (fully automated port). Nominal value is low, reflecting the practice that most containers are opened and unloaded by hand (Obilie-Odei, 2006). The formula is adapted to level out at 1 if automation rate is varied.
port construction labor	worker	Auxiliary	port capacity growth*labor per port construction	Port construction labor varies with the scale of the expansion
labor per port construction	worker/ ((kton/Year)/Year)	Constant	0.25	Estimation of the amount of laborers required for construction of the port, based on Ship-technology.com (2017).

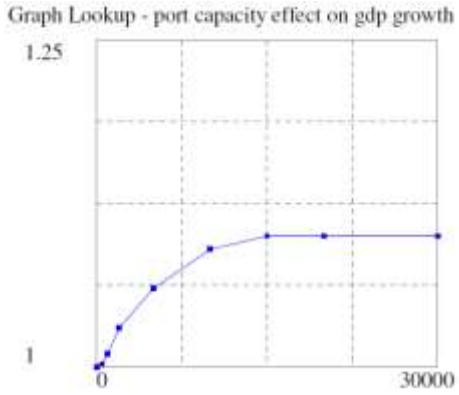


Figure 2. Port capacity effect on GDP growth lookup function

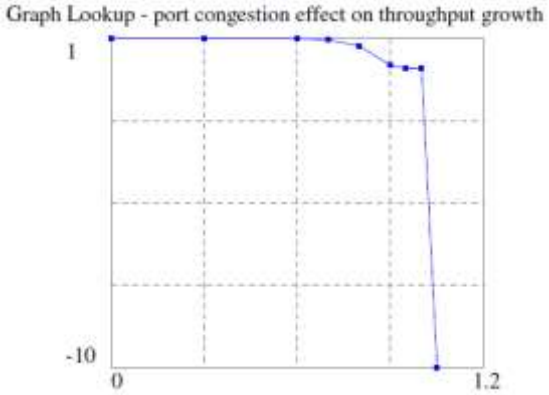


Figure 3. Port congestion effect on throughput growth lookup function

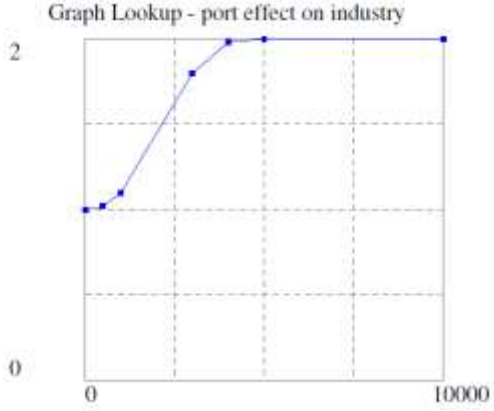


Figure 4. Port effect on industry lookup function.

1.2 Transport sub-model

In this paragraph the transport sub-model is specified. Figure 5 shows what it looks like in Vensim. The sub-model roughly has a section modelling the infrastructure capacity (supply) and its dynamics of growth and decay, and a section determining the demand for transport infrastructure. The two sections meet in the *infrastructure utilization*, which denotes urban congestion. Model key performance indicators are indicated in blue, external factors used in the scenario analysis are marked orange.

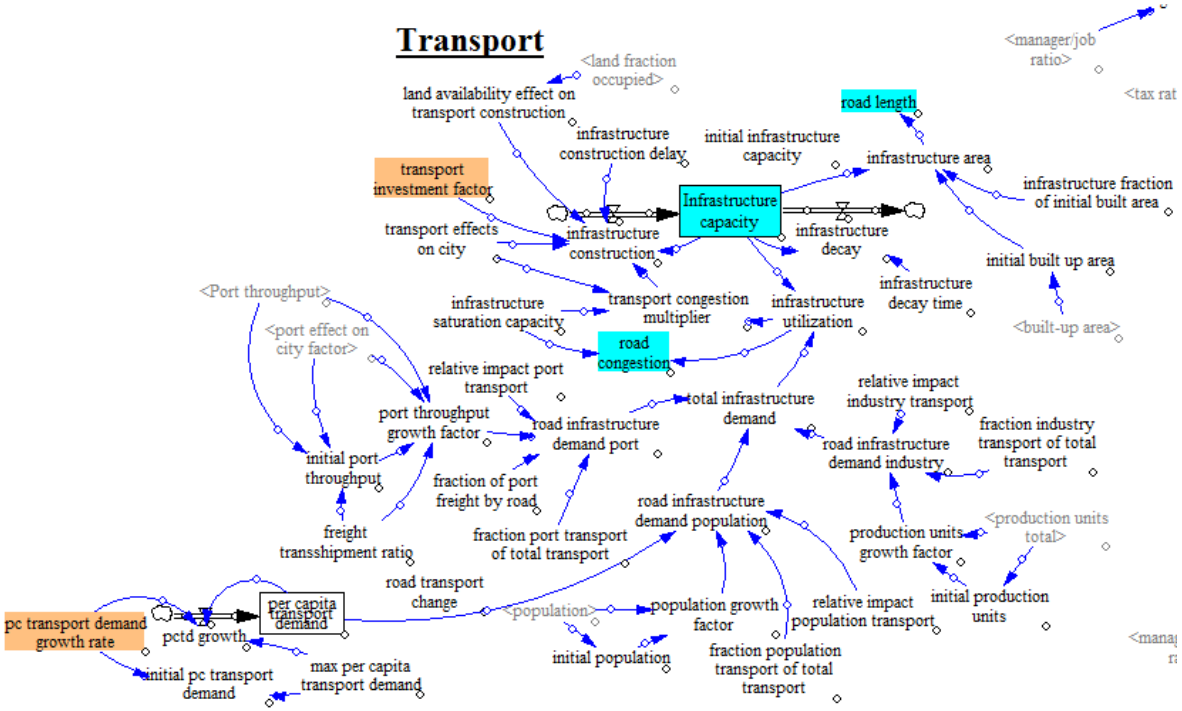


Figure 5. Transport sub-model as specified in Vensim

Table 2. Transport sub-model specification

Variable	Units	Type	Equation	Comment/Hypothesis
Infrastructure capacity	-	Stock	infrastructure construction-infrastructure decay	Current infrastructure capacity, expressed as a dimensionless factor. Increases through

				construction, decreases due to infrastructure decay over time.
initial infrastructure capacity	-	Constant	1.5	At the start of the simulation infrastructure capacity is assumed to be ca 1.5 times initial demand (specified to have a value of ca 1)
infrastructure construction	1/year	Flow	(Infrastructure capacity*land availability effect on transport construction*transport investment factor*transport effects on city*(1-transport congestion multiplier))/infrastructure construction delay	Road construction is driven by transport demand through congestion: the inverse of its constraining effect is used. The level of investment is scaled by the *transport investment factor*. Construction in reaction to congestion does not happen instantly, but with a time delay.
infrastructure decay	1/year	Flow	Infrastructure capacity/infrastructure decay time	Transport infrastructure decays over time, lowering capacity.
infrastructure decay time	year	Constant	40	Average time it takes for infrastructure to decay, reducing capacity. Damaged roads can be and are still used in Tema (hence the long decay time) but failing road quality is cited as a major hindrance for both population and local industry (e.g. Agyemang, 2013; Oxford Business Group, 2013).
transport investment factor	-	Constant	5	Scales the magnitude of road investments in response to a certain level of congestion. Value is calibrated to reflect plausible response to congestion levels. It is used to assess sensitivity to investment level and model mobility of capital (e.g. FDI) for investments.
infrastructure utilization	-	Auxiliary	total infrastructure demand/Infrastructure capacity	Utilization rises with increasing demand or decreasing capacity (for example due to decay). Models demand instead of actual use, so its value

				can exceed 1 in the model (analog to the volume capacity (v/c) ratio (e.g. Brebbia, 2007).
transport congestion multiplier	-	Lookup	transport effects on city * infrastructure utilization / infrastructure saturation capacity, [(0,0)-(4,1)],(0,1),(0.5,1),(0.9,1),(1,0.98),(1.5,0.66),(1.75,0.55),(2,0.5),(3,0.5)	Lookup function relating the utilization of the transport network and its saturation capacity to a resulting congestion effect having a value of 1 (no congestion) to 0.5 (use at or above saturation capacity). See Figure 6 below.
road congestion	-	Auxiliary	MAX(infrastructure utilization-infrastructure saturation capacity, 0)	Monitor for congestion, i.e. the level of utilization above the *saturation capacity*.
infrastructure saturation capacity	-	Constant	0.8	Transport utilization level at which infrastructure becomes saturated and the effects of congestion become apparent *(various sources).*
transport effects on city	-	Constant	1	Scaling variable affecting the impact of road transport infrastructure on the model (congestion, land area). (0 = no effects, 1 = nominal effects). Can be used to assess sensitivity.
total infrastructure demand	-	Auxiliary	infrastructure demand industry + infrastructure demand population + infrastructure demand port	Population movements, industrial movements and port freight movements add up to a total infrastructure demand. An increase in either of these will increase total infrastructure use.
road infrastructure demand port	-	Auxiliary	port throughput growth factor*fraction port transport of total transport*fraction of port freight by road*relative impact port transport	Demand is increased with rising port throughput, subject to the fraction of freight that is transported by road (e.g. instead of by rail). *Relative impact of port transport*
fraction port transport of total transport	-	Constant	0.25	As data on actual traffic flows in Tema are not available, this value is estimated. The assumption is made that initially, port freight forms a quarter of the total road transport in the city.

fraction of port freight by road	-	Constant/ Auxiliary	0.95 (Or: 0.95+RAMP(road transport change/10, 2015 , 2025)	The absence of a well-functioning rail system means the majority of freight is transported by road (98% countrywide, Oxford Business Group, 2012). Lowering this fraction could decongest the infrastructure system. Can be constant or changed using ramp or step function
road transport change	-	Constant	0 [Or: any value between -0.95 an 0]	Rate of (yearly) fractional change for ramping or stepping down *fraction of port freight by road* in policy or sensitivity analysis.
relative impact port transport	-	Constant	2	The relative impact of trucks and heavy vehicles on traffic infrastructure use is higher than for passenger cars (passenger car equivalent units, e.g. Adams, Zambang, and Opoku–Boahen, 2014; Adnan, 2014).
port throughput growth factor	-	Auxiliary	IF THEN ELSE(initial port throughput<>0,Port throughput*(1-freight transshipment ratio)*port effect on city factor/initial port throughput,0)	Growth of port freight, expressed as a factor of the initial freight volume. Note that this value of throughput excludes transshipment, which doesn't leave the port by land. An if-then-else clause avoids division by zero errors in sensitivity analysis.
initial port throughput	kton/ year	Auxiliary	SMOOTH(Port throughput*(1-freight transshipment ratio)*port effect on city factor, 1e+009)	Initial port freight volume entering Tema (at the start of the model run, excluding transshipment).
freight transshipment ratio	-	Constant	0.015	Freight volume that is unloaded at Tema harbor, but is consequently shipped again. Computed from Ghana Ports and Harbours Authority (2016), assumed constant.
infrastructure demand population	-	Auxiliary	population growth factor*fraction population transport of total transport*per capita transport demand	Population infrastructure demand rises with population growth and increases of per capita road

				transport demand (for example increasing car ownership).
population growth factor	-	Auxiliary	population/initial population	Population size expressed as a factor of the initial population
initial population	person	Constant	SMOOTH(population, 1e+009)	Population size at the start of the model run (1966 in model time). Smoothing over infinite time leaves the initial value of the population as a constant in the model.
fraction population transport of total transport	-	Constant	0.5	As data on actual traffic flows in Tema are not available, this value is estimated. The assumption is made that initially, population transport forms half of the total road transport in the city.
relative impact population transport	-	Constant	1	Analog to passenger car equivalent units, it is assumed that population transport consists of motorbikes, cars (taxi and personal) and buses, averaging to a value of 1 (Adams, Zambang, and Opoku–Boahen, 2014). Shifts due to increased car ownership are captured in *per capita transport demand*
per capita transport demand	-	Level	pctd growth	Reflects increasing car ownership levels and the resulting increased traffic volumes in the city (Faah, 2008; Obeng-Odoom, 2010). The variable represents demand relative to 2016 level (value of 1), in a logistic growth pattern.
pctd growth	-	Flow	pc transport demand growth rate*(max per capita transport demand-per capita transport demand)/max per capita transport demand*per capita transport demand	Logistic growth of per capita transport demand.

max per capita transport demand	-	Constant	2	Estimation of the maximum level per capita transport demand can attain compared to 2016 level (i.e. the 'carrying capacity' of the logistic growth pattern).
pc transport demand growth rate	-	Auxiliary	0.05	Maximum growth rate of the logistic function *per capita transport demand*. Car ownership levels in GAMA are currently rising with ca. 8% per year (World Bank, 2015; Faah, 2008), but it is assumed that this increase reduces some demand for bus and taxi use. A growth rate of zero results in a constant value of 1.
initial pc transport demand	-	Auxiliary	max per capita transport demand/(1+(max per capita transport demand-1)/(EXP(-pc transport demand growth rate*50)))	Algebraically derived initial value for the *per capita transport demand* logistic growth function, based on the growth rate and pass through point (2016, 1) constraint.
infrastructure demand industry	-	Auxiliary	fraction industry transport of total transport*production units growth factor*relative impact industry transport	Demand increases with growing industry in the city. Note that generated transport per production unit over time is assumed to be constant this way, as data on this is unavailable.
production units growth factor	-	Auxiliary	production units total/initial production units	Growth of industry expressed as a factor of the amount of industry present at the start of the model run.
initial production units	Product-ive unit	Constant	SMOOTH(production units total, 1e+009)	Amount of industry in the city at the start of the model run. Smoothing leaves the initial number of production units as a constant in the model.
fraction industry transport of total transport	-	Constant	0.25	Fraction of total transport that is industry generated transport, analogous to population and port related transport. The different fractions add up to 1.

relative impact industry transport	-	Constant	2	The relative impact of trucks and heavy vehicles on traffic infrastructure use is higher than for passenger cars (passenger car equivalent units, e.g. Adams, Zambang, and Opoku–Boahen, 2014; Adnan, 2014).
Infrastructure area	Ha	Auxiliary	Infrastructure capacity*initial built up area*infrastructure fraction of initial built area	Transport infrastructure occupies its own area, increasing in size with increasing capacity.
infrastructure fraction of initial built area	-	Constant	0.10	Assumed value. Schroeder and Strongman (in Mass, 1974) assume a value of 25-30% of total built up area for transport related infrastructure, but this is a figure for American cities and includes parks and extensive parking spaces. Since European and developing country cities are denser, a lower value is taken.
initial built up area	Ha	Constant	SMOOTH("built-up area",1e+009)	Takes the initial built up area (i.e. excluding infrastructure) to assign an area to the initial infrastructure capacity, which is further scaled by infrastructure capacity growth.
road length	km	Auxiliary	infrastructure area*10000/(3.65*1000)	Converts the area taken by road infrastructure (Ha) to a total road length (km), taking an average road width of 3.65 meters (based on Shuo, 1999). This is used for validation purposes and to provide a more relatable indicator of infrastructure capacity.
land availability effect on transport construction	-	Auxiliary with lookup	land fraction occupied, ([(0,0)-(1,1)], (0,1),(0.5,1),(0.65,0.98),(0.75,0.95),(0.9,0.75),(0.95, 0.5),(0.98,0.25),(1,0))	Land scarcity limits the construction of road infrastructure. If no land is available, construction drops to zero. See Figure 7.

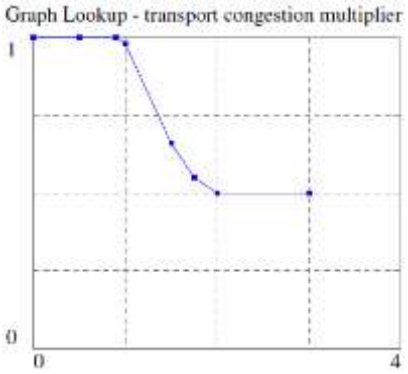


Figure 6. Transport congestion multiplier lookup function

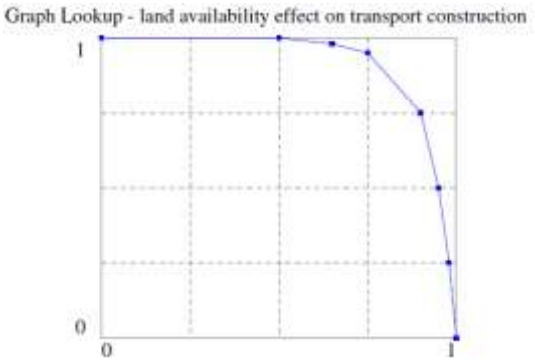


Figure 7. Land availability on transport construction lookup function

1.3 Land section

The land section is adapted from Forrester's model and amended to explicitly model land use by type. The land section sub-model is depicted in Figure 8. Again, model KPI's are depicted in blue, the exogenous factor used in scenarios in orange. The city land area is made up of available land, housing, industry, infrastructure (roads) and green space. The specification of the model is listed in Table 3 below.

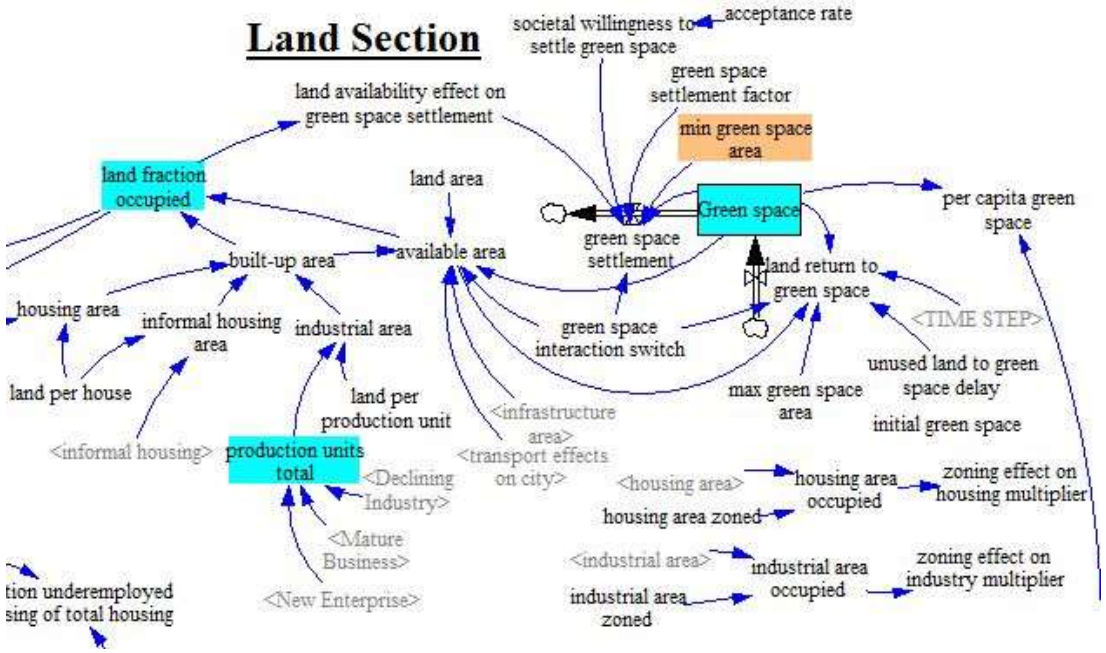


Figure 8. Land section sub-model in Vensim

Table 3. Land section sub-model specification

Variable	**Units**	**Type**	**Equation**	**Comment/Hypothesis**
Green space	Ha	Stock	land return to green space-green space settlement	The amount of green space in the city system, measured in hectare (Ha). This includes undeveloped land around the city that has ecological value. It is subject to a minimum and maximum size, and can diminish with settlement and grow with regeneration when land lies fallow.
initial green space	Ha	Constant	4199	Estimation of the size of Sakumo and Chemu lagoons around the year 1966 (Kangeri, forthcoming).
green space settlement	Ha/year	Flow	land availability effect on green space settlement*societal willingness to settle green space*green space interaction switch*(Green space-min green space area)*green space settlement factor	When little land is available for development, green space becomes more interesting as land for settlement and loses green space classification. This is mediated by societal willingness to settle green space. Settlement drops to zero when green space runs out, or when land is readily available. The green space settlement factor can be used for sensitivity analysis or to represent a proximity effect, increasing the relative likeliness of development of green space if it is near the urban center
land return to green space	Ha/year	Flow	IF THEN ELSE(max green space area<>0,MIN(green space interaction switch*available area*((max green space area-Green space)/max green space area)/unused land to green space delay, available area/TIME STEP), 0)	A portion of the land that is not used for developments will return to green space status after an average time. If the amount of green space approaches the maximum area that can be considered green space, conversion drops. Likewise, when developments are widespread, little land falls back to green space due to use.

				Formulated to prevent overshoots into negative green space.
land availability effect on green space settlement	-	Lookup	land fraction occupied, ([(0,0)-(1,1)],(0,0),(0.05,0),(0.1,0.02),(0.2,0.1),(0.8,0.9),(0.9,0.98),(0.95,1),(1,1))	When land is readily available, green space is not settled. When no land is available, pressure is high to settle green space. See Figure 9 below.
green space interaction switch	-	Constant	1	Used for switching on and scaling the effects of green space settlement in the model. A value of 0 means green space occupies no space and does not affect the available land. Can be used for scaling impacts and sensitivity analysis
societal willingness to settle green space	-	Auxiliary	0+RAMP(acceptance rate, 1966 ,1966 + (1/acceptance rate))	In Tema, historically Sakumo (and Chemu) lagoon were seen as local deities and revered. Initially, the settlement of the lagoons was considered taboo (Clottey, 2015; Adegun, 2017). Nowadays this effect, though present, is less widespread and strong due to urbanization, Christianity, and migration (Adegun, 2017; Slinger et al., 2017). This variable represents the societal attitude towards the development of green space, increasing from 0 over time to a value of 1.
acceptance rate	-	1/year	0.02	Rate of acceptance of the settlement of green space. By default set to increase to 1 over a period of 50 years.
green space settlement factor	-	Constant	2	Factor scaling green space settlement, used for sensitivity analysis. As land use in the model is not spatially explicit, this variable could also be used to represent a 'likeliness' of green space settlement or a proximity effect; e.g. green space that is closer to the urban center is preferred over available land

				farther away, as seen in Tema (Mariwah, Osei and Amenyo-Xa, 2017). Hence, a value of 2.
max green space area	Ha	Constant	4199	Maximum area that could return to green space status if left fallow. Set to the initial value of green space in 1966 model time. Could be adapted to take into account ecosystem tipping points.
min green space area	Ha	Constant	50	The minimum size of green space, that cannot be effectively converted to developed land even under high land scarcity. Taken here to be the current open water area of what is left of Sakumo and Chemu lagoon (Kangeri, forthcoming).
unused land to green space delay	Year	Constant	15	Average amount of time for undeveloped land to revert to green space. This is assuming that no tipping points are past with development and land can return to former green space state.
land area	Ha	Constant	16700	Total land area for Tema in the model. It is equal to the size of the Tema Acquisition Area (167 km^2) the area designated for development by the Tema Development Corporation in 1952 (Clottey, 2015; Acquah, 2001). It includes Ashaiman (45 km^2) (Ghana Statistical Service, 2014a).
available area	Ha	Auxiliary	land area-"built-up area"-green space interaction switch*Green space-infrastructure area*transport effects on city	Available land is derived from the total land area and the land occupied by developments (housing, industrial, road infrastructure) or green space. Diminishing green space adds to available land for development and vice versa.
built-up area	Ha	Auxiliary	housing area + industrial area + informal housing area	Implicitly used in Forrester's original model, it models the space occupied by housing and industrial units. Informal housing space is added to this. Note that this does not include transport

				infrastructure area as that is initially derived from this variable.
land per house	Ha	Constant	0.0405	Converted from Forrester's Imperial acres, and checked with actual Tema figures (Mazeau, Scott and Tuffuor, 2012; see Ch **Fout! Verwijzingsbron niet gevonden.**)
housing area	Ha	Auxiliary	housing units total*land per house	Area of formal housing developments (premium housing, worker housing, underemployed housing).
housing units total	Housing unit	Auxiliary	Premium Housing + Worker Housing + Underemployed Housing	Addition of all formal housing units in the city.
informal housing area	Ha	Auxiliary	informal housing*land per house	Area of informal housing in the model. Informal housing is taken to have the same area per housing unit, but generally a higher population density (Mazeau, Scott, and Tuffuor, 2012).
land per production unit	Ha	Constant	0.080937	Converted from Forrester's 2 acres (1 acre = 0.0405 hectare).
production units total	Productive unit	Auxiliary	New Enterprise + Mature Business + Declining Industry	Total number of productive units of industry in the city.
land fraction occupied	-	Auxiliary	"built-up area"/(available area+"built-up area")	The land fraction occupied is adapted to subtract green space and infrastructure area from the total available land. Land area already built-up however is still part of the total area.
housing area zoned	Ha	Auxiliary	20040 [Or: Any value > 0]	Zoning policies could set aside land available for housing developments, and (theoretically) restrict formal housing developments in the city. Set to a value above city land area if no zoning is to be modelled to avoid impacts on the model.

housing area occupied	Ha	Auxiliary	housing area/housing area zoned	Analogous to *land fraction occupied*, the fraction of designated housing area zoned that is currently occupied by housing. Note that this by definition excludes informal housing
zoning effect on housing multiplier	-	Auxiliary with lookup	housing area occupied, ([(0,0)-(1,1)] ,(0,1),(0.5,1),(0.7,0.95),(0.8,0.85),(0.9,0.6),(1,0))	The limiting effect of zoning on new (formal) housing developments. Adapted from Forrester's *land multiplier* lookups. See Figure 10 below.
industrial area zoned	Ha	Auxiliary	20040 [Or: any value >=0]	Zoning policies could set aside land available for industry developments, and restrict industry developments around the city. Set to a value above city land area if no zoning impacts are to be modelled.
industrial area occupied	-	Auxiliary	IF THEN ELSE(industrial area zoned<>0,industrial area/industrial area zoned,1)	Analogous to *housing area occupied*, but for industry. Formulated to avoid division by zero error, for instance when starting the model without industry present (the same is not possible for housing).
zoning effect on industry multiplier	-	Auxiliary with lookup	industrial area occupied, ([(0,0)-(1,1)], (0,1),(0.5,1),(0.7,0.95),(0.8,0.85),(0.9,0.6),(1,0))	The limiting effect of zoning on new industrial enterprise developments. Adapted from Forrester's *land multiplier* lookups. See Figure 11 below.
per capita green space	m^2/person	Auxiliary	Green space*10000/population	Green space area is converted to square meters and divided by the urban population number to arrive at per capita green space. This is a common indicator of urban green space amount in literature.

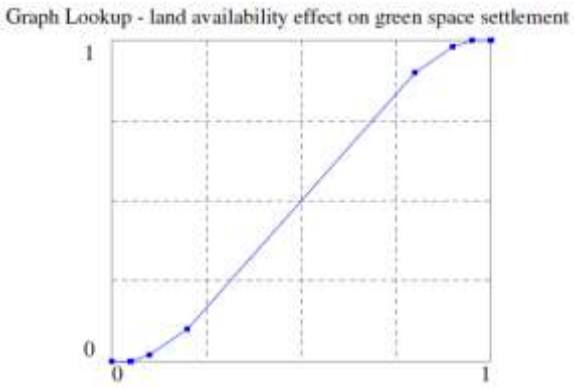


Figure 9. Land availability effect on green space settlement

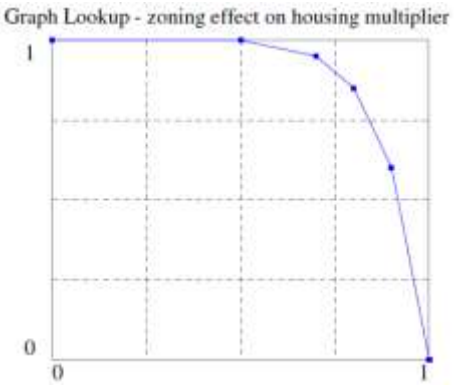


Figure 10. Zoning effect on housing multiplier lookup function

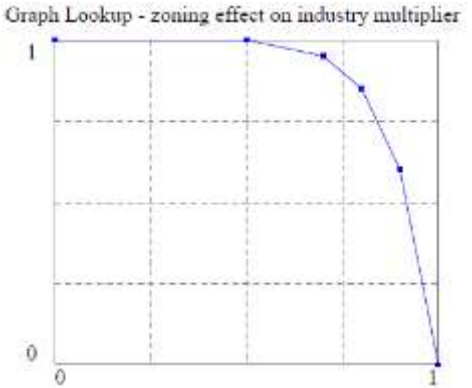


Figure 11. Zoning effect on industry multiplier lookup function

1.4 Informal housing Specification

Informal housing is more spread out throughout the model, but the main variables are depicted in Figure 12. They are specified and explained below in Table 4.

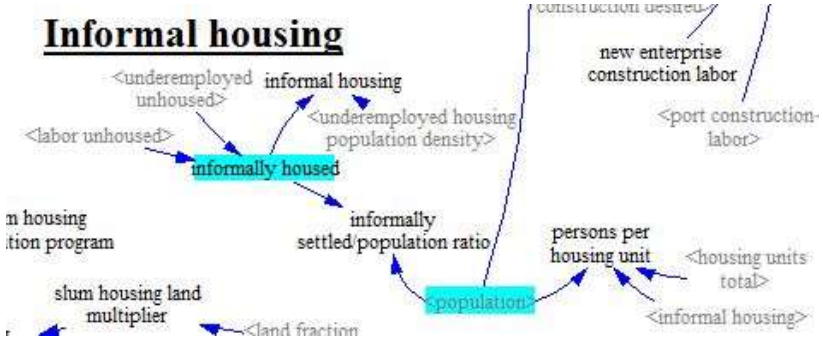


Figure 12. Informal housing sub-model in Vensim

Table 4. Informal housing sub-model specification

Variable	Units	Type	Equation	Comment/Hypothesis
informally housed	person	Auxiliary	labor unhoused + underemployed unhoused	Informally housed are made up of unhoused worker and underemployed families (Mazeau, Scott and Tuffuor, 2012).
labor unhoused	person	Auxiliary	MAX((Labor*labor family size)-(Worker Housing* "worker-housing population density"), 0)	The number of unhoused working class people is determined by the amount that is present minus the the amount that can be housed in available formal worker housing. It is set to a maximum of 0 to prevent negative informal housing (Sanders, Slinger and Van Daalen, 2009).
underemployed unhoused	person	Auxiliary	MAX((Underemployed*underemployed family size)-(Underemployed Housing*underemployed housing population density),0)	Analogous to labor unhoused, but for underemployed families.

informal housing	housing unit	Auxiliary	informally housed/underemployed housing population density	The number of informally constructed houses. The informal housing is assumed to have a similar occupancy as underemployed housing (Mazeau, Scott and Tuffuor, 2012).
informally settled/population ratio	-	Auxiliary	informally housed/population	Fraction of the city population living in informal settlements, i.e. the relative amount of people living informally. Useful for policy analysis and validation purposes.
persons per housing unit	Person/ housing unit	Auxiliary	population/(housing units total+informal housing)	The average occupancy of a housing unit. Can be used for model validation (Ghana Statistical Service, 2014b).

1.5 Informal work

An informal work section is added to monitor city population formal employment versus the total potential workforce. It should be noted that (formal) service industry and the public sector are not explicitly represented in the model, so the numbers for formal employment are based on industry only. The sub-model is depicted in Figure 13, the specification is provided in Table 5. Informal work sub-model specificationTable 5.

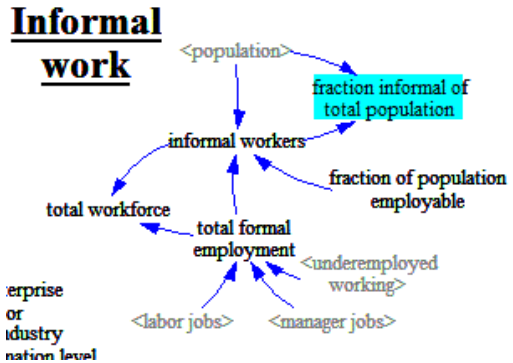


Figure 13. Informal work sub-model in Vensim

Table 5. Informal work sub-model specification

Variable	Units	Type	Equation	Comment/Hypothesis
informal workers	worker	Auxiliary	(population*fraction of population employable)-total formal employment	Derived from the amount of people that form the potential workforce minus the amount formally employed in the model. The modeler therefore makes the assumption that everybody that is able to work and not formally employed is an informal worker
fraction of population employable	-	Constant	0.75	Three quarters of the population is assumed to be a potential worker, rough figure based on local data for Tema and Ashaiman (Ghana Statistical Service, 2014a, b).
fraction informal of total population	-	Auxiliary	informal workers/population	Fraction of the total population informally working. For monitoring purposes.
total formal employment	worker	Auxiliary	labor jobs + manager jobs + underemployed working	Total amount of formal jobs in the model, based on Forrester's definitions.

1.6 Industry Chain Specification

Part of Forrester's original Urban Dynamics model (Forrester, 1970), it has been adapted slightly to include model additions. The sub-model is displayed in Figure 14 and specified in Table 6 below.

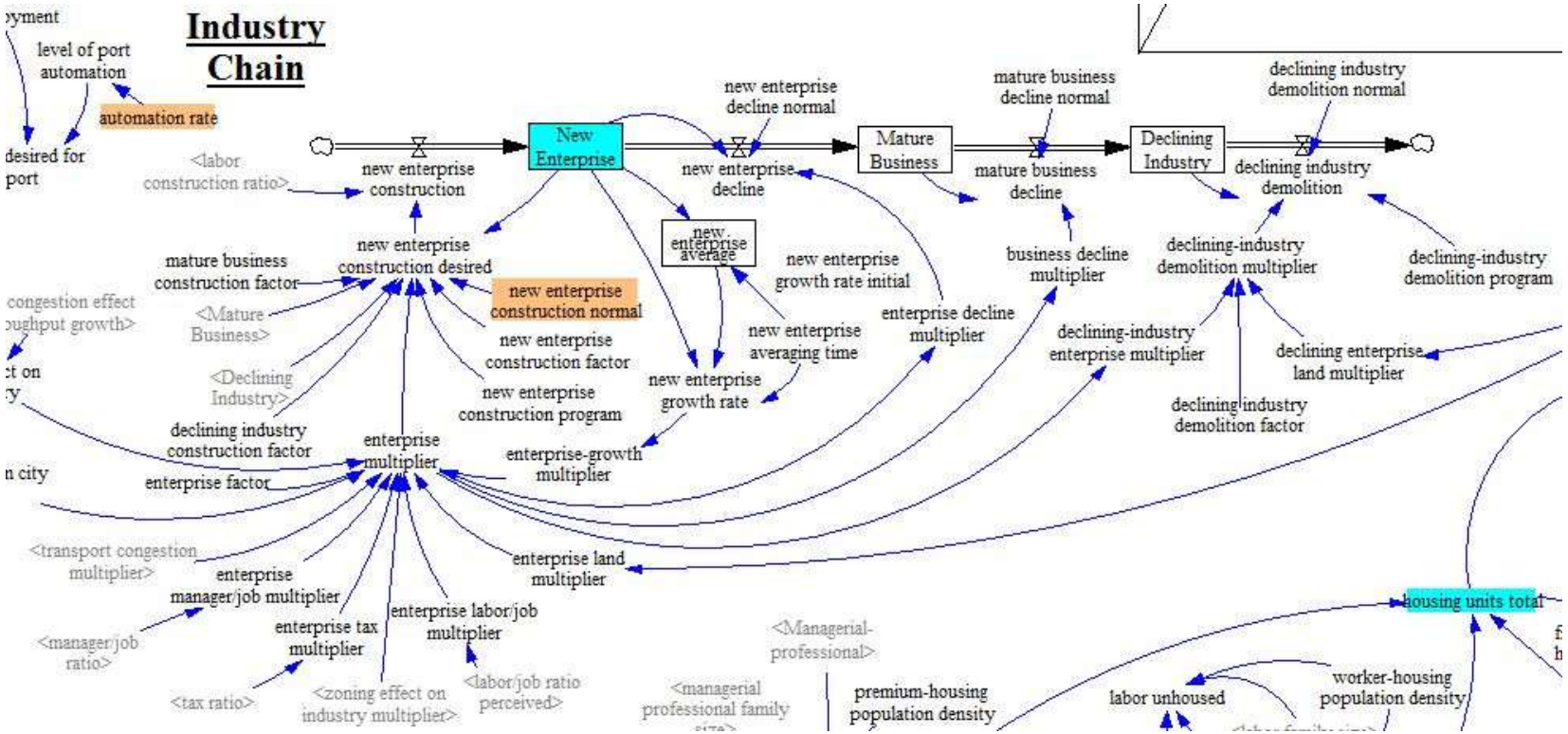


Figure 14. Industry chain sub-model in Vensim

Table 6. Industry Chain sub-model specification.

Variable	Units	Type	Equation	Comment/Hypothesis
New Enterprise	Productive unit	Stock	new enterprise construction-new enterprise decline	initial value: 455 (see Appendix A).

new enterprise construction	Productive unit/Year	Flow	new enterprise construction desired*labor construction ratio	
new enterprise decline	Productive unit/Year	Flow	new enterprise decline normal*New Enterprise*enterprise decline multiplier	
enterprise decline multiplier	-	Auxiliary with lookup	enterprise multiplier, [(0,0)-(10,10)], (0.125,2),(0.25,1.8),(0.5,1.5),(1,1),(2,0.7),(4,0.5),(8,0.5)	
new enterprise construction desired	production unit/Year	Auxiliary	(new enterprise construction normal * (new enterprise construction factor*New Enterprise + mature business construction factor *Mature Business + declining industry construction factor*Declining Industry) * enterprise multiplier) + new enterprise construction program	
new enterprise construction normal	1/Year	Constant	0.05	
new enterprise construction factor	-	Constant	1	
mature business construction factor	-	Constant	0.5	
declining industry construction factor	-	Constant	0.3	
new enterprise construction program	Productive unit/Year	Auxiliary	0	
enterprise multiplier	-	Auxiliary	"enterprise manager/job multiplier" * enterprise land multiplier * "enterprise labor/job multiplier" * enterprise tax multiplier * "enterprise-growth multiplier" * enterprise factor * transport congestion multiplier * (1+	Effects of transport congestion, port infrastructure presence and land zoning policies have been added to this equation. Port impact is formulated to be scalable proportionally to *port effect on city factor.* Road

			IF THEN ELSE(port effect on city factor <1, port effect on city factor*(port effect on industry-1), (port effect on industry-1)*(port effect on city factor*2-1))) * zoning effect on industry multiplier	congestion depresses new enterprise settlement (Agyemang 2013).
enterprise manager/job multiplier	-	Auxiliary with lookup	"manager/job ratio", [(0,0)-(10,10)], (0,0.1),(0.25,0.15),(0.5,0.3),(0.75,0.5),(1,1),(1.25,1.4),(1.5,1.7),(1.75,1.9),(2,2)	
enterprise tax multiplier	-	Auxiliary with lookup	tax ratio, [(0,0)-(16,10)] ,(0.25,1.3),(0.5,1.2),(1,1),(2,0.8),(4,0.5),(8,0.25),(16,0.1)	
enterprise labor/job multiplier	-	Auxiliary with lookup	"labor/job ratio perceived", [(0,0)-(21,10)],(0,0),(0.25,0.05),(0.5,0.15),(0.75,0.4),(1,1),(1.25,1.5),(1.5,1.7),(1.75,1.8),(2,1.8)	
enterprise land multiplier	-	Auxiliary with lookup	land fraction occupied, [(0,0)-(10,10)],(0,1),(0.1,1.15),(0.2,1.3),(0.3,1.4),(0.4,1.45),(0.5,1.4),(0.6,1.3),(0.7,1),(0.8,0.7),(0.9,0.4),(1,0)	Note that this is independent of any zoning policy effects.
enterprise-growth multiplier	-	Auxiliary with lookup	new enterprise growth rate , [(-0.2,0)-(10,10)], (-0.1,0.2),(-0.05,0.6),(0,1),(0.05,1.4),(0.1,1.8),(0.15,2.2)	
new enterprise growth rate	-	Auxiliary	(New Enterprise - new enterprise average) / (New Enterprise * new enterprise averaging time)	
new enterprise average	productive unit	Stock	(New Enterprise-new enterprise average)/new enterprise averaging time	
new enterprise growth rate initial	-	Constant	0.03	
new enterprise averaging time	Year	Constant	10	

Mature Business	productive unit	Stock	new enterprise decline-mature business decline	Initial value: 0
mature business decline	Productive unit/year	Flow	mature business decline normal*Mature Business*business decline multiplier	
mature business decline multiplier	-	Auxiliary with lookup	enterprise multiplier, [(0,0)-(10,10)], (0.125,2),(0.25,1.8),(0.5,1.5),(1,1),(2,0.7),(4,0.5),(8,0.4))	
Declining Industry	Productive unit	Stock	mature business decline-declining industry demolition	Initial value: 0
declining industry demolition	Productive unit/year	Flow	(declining industry demolition normal)*(Declining Industry)*("declining-industry demolition multiplier")+"declining-industry demolition program"	
declining industry demolition normal	1/Year	Auxiliary	0.03	
declining-industry demolition multiplier	-	Auxiliary	"declining-industry enterprise multiplier"*declining enterprise land multiplier*declining industry demolition factor	
declining-industry enterprise multiplier	-	Auxiliary with lookup	enterprise multiplier, [(0.125,0.4)-(8,4)], (0.125,0.4),(0.25,0.5),(0.5,0.7),(1,1),(2,1.6),(4,2.4),(8,4)	
declining industry demolition factor	-	Constant	1	
declining enterprise land multiplier	-	Auxiliary with lookup	land fraction occupied, [(0.8,1)-(1,6)], (0.8,1),(0.85,1.2),(0.9,1.6),(0.95,2.2),(1,6)	
"declining-industry demolition program"	Productive units/year	Auxiliary	0	

1.7 Housing Chain Specification

The housing chain sub-model is taken from Forrester and adapted to include port, infrastructure, and zoning effects. It describes the construction and aging of housing units in the city. Certain parameters have been altered to better reflect Tema conditions. The sub-model as specified is depicted in Figure 15, and the specification is listed in Table 7.

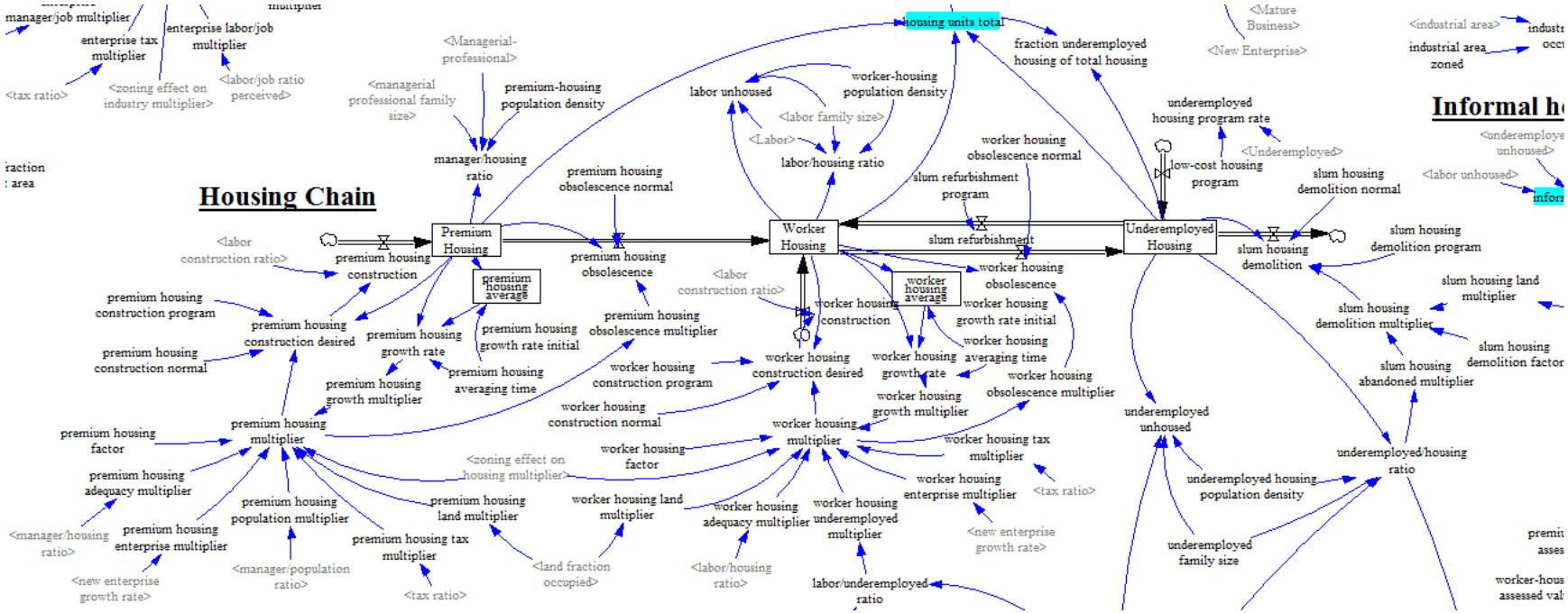


Figure 15. Housing Chain sub-model as specified in Vensim

Table 7. Housing chain sub-model specification

Variable	Units	Type	Equation	Comment/Hypothesis
Premium Housing	Housing unit	Stock	premium housing construction-premium housing obsolescence	Housing for manager-professional class. Initial value: 973 (see Appendix A).

premium housing construction	Housing unit/year	Flow	labor construction ratio*premium housing construction desired	
premium housing obsolescence	Housing unit/year	Flow	premium housing obsolescence normal*Premium Housing*premium housing obsolescence multiplier	
premium housing construction desired	housing unit/Year	Auxiliary	premium housing construction normal*Premium Housing*premium housing multiplier + premium housing construction program	
premium housing construction program	housing unit/Year	Auxiliary	0+PULSE(1966, 4)*0.1*1750/4+ PULSE(1970, 11)*0.1*7380/11	Housing construction program by Tema Development Corporation between 1966 and 1981, derived from Acquah (2001) (Appendix A).
premium housing construction normal	1/Year	Constant	0.02	Reduced from Forrester's original model value of 0.03 to reflect reduced formal housing construction in the face of informal housing possibilities.
premium housing multiplier	-	Auxiliary	premium housing adequacy multiplier*premium housing land multiplier*premium housing population multiplier*premium housing tax multiplier *premium housing enterprise multiplier*premium housing growth multiplier*premium housing factor*zoning effect on housing multiplier	Amended to include zoning policy effects on housing development
premium housing factor	-	Constant	1	
premium housing adequacy multiplier	-	Auxiliary with lookup	manager/housing ratio, [(0,0)-(10,10)], (0,0),(0.25,0.001),(0.5,0.01),(0.75,0.2),(1,1),(1.25,3),(1.5,4.6),(1.75,5.6),(2,6)	
new enterprise growth rate	-	Auxiliary with lookup	new enterprise growth rate, [(-0.2,0)-(10,10)], (-0.1,0.2),(-0.05,0.6),(0,1),(0.05,1.4),(0.1,1.8),(0.15,2.2)	

premium housing population multiplier	-	Auxiliary with lookup	manager/population ratio, [(0,0)-(10,10)], (0,0.3),(0.02,0.7),(0.04,1),(0.06,1.2),(0.08,1.3),(0.1,1.3)	
premium housing tax multiplier	-	Auxiliary with lookup	tax ratio, [(0,0)-(16,10)], (0.25,1.2),(1,1),(4,0.7),(16,0.3)	
premium housing land multiplier	-	Auxiliary with lookup	land fraction occupied, [(0,0)-(10,10)] ,(0,0.4),(0.1,0.9),(0.2,1.3),(0.3,1.6),(0.4,1.8),(0.5,1.9),(0.6,1 .8),(0.7,1.4),(0.8,0.7),(0.9,0.2),(1,0)	
premium housing growth multiplier	-		premium housing growth rate, [(-0.2,0)-(10,10)], (-0.1,0.2),(-0.05,0.6),(0,1),(0.05,1.4),(0.1,1.8),(0.15,2.2)	
premium housing growth rate	1/Year		(Premium Housing-premium housing average)/(Premium Housing*premium housing averaging time)	
premium housing average	housing unit	Stock	(Premium Housing-premium housing average)/premium housing averaging time	
premium housing averaging time	Year	Constant	10	
premium housing growth rate initial	1/Year	Constant	0.03	
premium housing obsolescence normal	1/Year	Constant	0.03	
premium housing obsolescence multiplier	-	Auxiliary with lookup	premium housing multiplier, [(0,0)-(10,10)], (0.125,2.8),(0.25,2.6),(0.5,2),(1,1),(2,0.5),(4,0.3),(8,0.2)	

Worker Housing	Housing unit	Stock	premium housing obsolescence+slum refurbishment+worker housing construction-worker housing obsolescence	Initial value: 9727 (derived from Acquah, 2001, see appendix A).
worker housing construction	housing unit/Year	Flow	worker housing construction desired*labor construction ratio	
worker housing construction desired	housing unit/Year	Auxiliary	worker housing construction normal*Worker Housing*worker housing multiplier+worker housing construction program	
worker housing construction program	housing unit/Year	Auxiliary	0+PULSE(1966, 4)*0.9*1750/4+ PULSE(1970, 11)*0.9*7380/11	Housing construction program by Tema Development Corporation between 1966 and 1981, derived from Acquah (2001).
worker housing construction normal	1/Year	Constant	0.01	Lowered from Forrester's 0.03 to reflect poor formal housing construction levels in Tema.
worker housing multiplier	-	Auxiliary	worker housing adequacy multiplier*worker housing land multiplier*worker housing underemployed multiplier*worker housing tax multiplier *worker housing enterprise multiplier*worker housing growth multiplier*worker housing factor*zoning effect on housing multiplier	Amended to include zoning policy effects on worker housing construction
worker housing factor	-	Constant	1	
worker housing land multiplier	-	Auxiliary with lookup	land fraction occupied, [(0,0)-(10,10)], (0,0.4),(0.1,0.9),(0.2,1.3),(0.3,1.6),(0.4,1.8),(0.5,1.9),(0.6,1.8),(0.7,1.4),(0.8,0.7),(0.9,0.2),(1,0)	
worker housing adequacy multiplier	-	Auxiliary with lookup	labor/housing ratio, [(0,0)-(10,10)], (0,0),(0.25,0.05),(0.5,0.1),(0.75,0.3),(1,1),(1.25,1.8),(1.5,2.4),(1.75,2.8),(2,3)	

worker housing underemployed multiplier	-	Auxiliary with lookup	labor/underemployed ratio, [(0,0)-(10,10)], (0,0.5),(1,0.8),(2,1),(3,1.2),(4,1.3),(5,1.3)	
worker housing enterprise multiplier	-	Auxiliary with lookup	new enterprise growth rate, [(-0.2,0)-(10,10)], (-0.2,0.3),(-0.1,0.7),(0,1),(0.1,1.2),(0.2,1.3),(0.3,1.4)	
worker housing tax multiplier	-	Auxiliary with lookup	tax ratio, [(0,0)-(16,10)], (0.25,1.2),(1,1),(4,0.7),(16,0.3)	
worker housing growth multiplier	-	Auxiliary with lookup	worker housing growth rate, [(-0.2,0)-(10,10)], (-0.1,0.2),(-0.05,0.6),(0,1),(0.05,1.4),(0.1,1.8),(0.15,2.2)	
worker housing average	Housing unit	Stock	(Worker Housing-worker housing average)/worker housing averaging time	Initial value: *worker housing growth rate initial*
worker housing growth rate initial	1/Year	Constant	0.03	
worker housing averaging time	Year	Constant	10	
worker housing obsolescence	Housing unit/year	Flow	worker housing obsolescence normal*Worker Housing*worker housing obsolescence multiplier	
worker housing obsolescence multiplier	-	Auxiliary with lookup	worker housing multiplier, [(0,0)-(10,10)], (0.125,2.2),(0.25,2),(0.5,1.6),(1,1),(2,0.7),(4,0.5),(8,0.4)	
worker housing obsolescence normal	Housing unit/year	Constant	0.025	40 Years. Adapted from Forrester value of 0.02 (50 years), as many former worker estates in Tema have already degraded into slum status within 40 years of construction (UNCHS (HABITAT), 2003).

slum refurbishment program	Housing unit/year	Flow	slum refurbishment program*Underemployed Housing	Added to the model to analyze this policy option
slum refurbishment program	1/Year	Constant	0	Can be increased to include a slum refurbishment intervention
Underemployed Housing	housing unit	Stock	"low-cost housing program"+worker housing obsolescence-slum housing demolition-slum refurbishment	Initial value: 50 (estimation derived from Acquah, 2001).
low-cost housing program	housing unit/Year	Flow	0	
underemployed housing program rate	housing unit/Year /worker	Auxiliary	"low-cost housing program"/Underemployed	
slum housing demolition	housing unit/Year	Flow	slum housing demolition normal*Underemployed Housing*slum housing demolition multiplier + slum housing demolition program	
slum housing demolition normal	1/Year	Constant	0.02	
slum housing demolition program	housing unit/Year	Auxiliary	0	
slum housing demolition multiplier	-	Auxiliary	slum housing abandoned multiplier*slum housing land multiplier*slum housing demolition factor	
slum housing demolition factor	-	Constant	1	
slum housing abandoned multiplier	-	Auxiliary	"underemployed/housing ratio"	

slum housing land multiplier	-	Auxiliary	land fraction occupied, [(0,0)-(10,10)], (0.8,1),(0.85,1.2),(0.9,1.6),(0.95,2.2),(1,6)	
"underemployed/ housing ratio"	-	Auxiliary	(Underemployed*underemployed family size)/((Underemployed Housing)*underemployed housing population density)	
underemployed housing population density	Person/ housing unit	Constant	18	Adapted from Forrester's value to reflect Tema conditions (calculated and adapted from Mazeau, Scott and Tuffuor, 2012)
manager/housing ratio	-	Auxiliary	("Managerial-professional"*managerial professional family size)/(Premium Housing*"premium-housing population density")	
premium-housing population density	Person/housing unit	Constant	4	Adapted to Tema conditions: one household per housing unit (Ghana Statistical Service, 2014b).
labor/housing ratio	-	Auxiliary	(Labor*labor family size)/((Worker Housing)*"worker-housing population density")	
worker-housing population density	-	Constant	8	Adapted to Tema conditions: roughly two households per housing unit (Ghana Statistical Service, 2014b).

1.8 Employment Chain Specification

The employment chain is taken from Forrester and models the dynamics over time of the city workforce. A detailed specification and explanation can be found in Forrester (1970).

There are some minor adaptations to include the effects of the port and transport on jobs and migration, to adapt the model to Tema demographic conditions.

The sub-model as specified in Vensim is depicted in

Figure 16, and the specification changes and adaptations listed in Table 8.

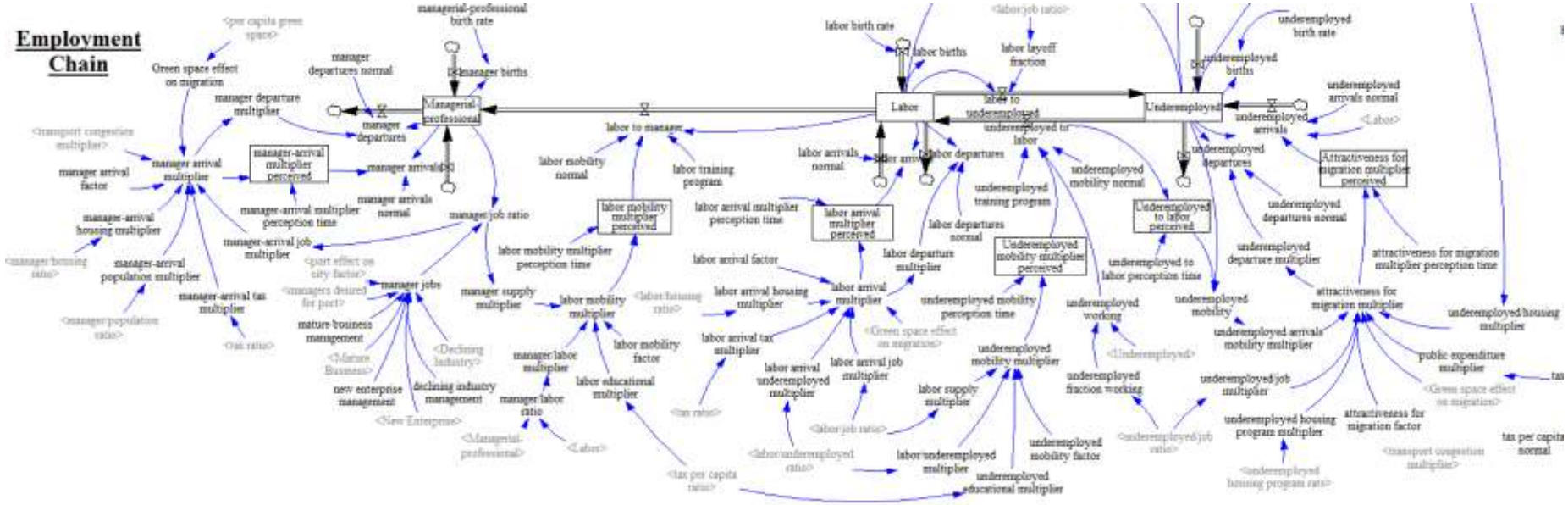


Figure 16. Employment Chain sub-model in Vensim.

Table 8. Employment Chain sub-model specification adaptations

Variable	Units	Type	Equation	Comment/Hypothesis
manager arrival multiplier	-	Auxiliary	"manager-arrival population multiplier"*"manager-arrival job multiplier"*"manager-arrival tax multiplier"*"manager-arrival housing multiplier" *manager arrival factor*transport congestion multiplier*Green space effect on migration	Modeling assumption: the attractiveness of the city for managerial-professional class is decreased by traffic congestion and green space disappearing through encroachment.

Green space effect on migration	-	Auxiliary with lookup	LOG(per capita green space,10), ([(-1,0)-(10,10)],(-1,0.9),(2,1))	Shrinking per capita green space decreases urban attractiveness for managerial-professionals, through disappearance of green space itself and by lowering the quality of green space through increased urban pressures (Douglas, 2012; Cilliers et al., 2013; Appiah and Yankson, 2012). See Figure 17 below.
manager jobs	worker	Auxiliary	New Enterprise*new enterprise management+ Mature Business*mature business management+ Declining Industry*declining industry management+ port effect on city factor*managers desired for port	Amended to include manager jobs generated directly by the port.
managerial-professional birth rate	1/year	Constant	0.017	Crude birth-rate – crude death rate. Estimated value (Ghana Statistical Service, 2014b), adapted from Forrester. See Appendix A.
labor birth rate	1/year	Constant	0.017	Crude birth-rate – crude death rate. Estimated value (Ghana Statistical Service, 2014b), adapted from Forrester. See Appendix A.
Underemployed birth rate	1/Year	Constant	0.02	Crude birth-rate – crude death rate. Estimated value (Ghana Statistical Service, 2014b), adapted from Forrester. See Appendix A.
labor arrival housing multiplier	-	Auxiliary with lookup	"labor/housing ratio" ([(0,0)-(10,10)] ,(0,1.3),(0.5,1.2),(1,1),(1.5,0.75),(2,0.6),(2.5,0.55),(3, 0.525))	Adapted from Forrester: the deterring factor of housing shortage is made half as strong, in light of the possibility of informal settlement (See: Model validation, Figure 18).
Labor arrival multiplier	-	Auxiliary	labor arrival job multiplier*labor arrival underemployed multiplier*labor arrival tax multiplier*labor arrival housing multiplier *labor arrival factor*((Green space effect on migration+1)/2)	Analog to managerial-professional, reductions of green space are modelled to decrease attractiveness of the city to worker families. As worker families have a higher probability of migrating for economic reasons such as employment opportunity, the effect is reduced by averaging with one.

underemployed/ housing multiplier	-	Auxiliary with lookup	“underemployed/housing ratio” ([(0,0)-(10,10)] ,(0,2.5),(0.25,2.4),(0.5,2.2),(0.75,1.7),(1,1),(1.25,0.7), (1.5,0.6),(1.75,0.55),(2,0.525))	Adapted from Forrester: again the deterring factor of housing shortage is made half as strong, in light of the possibility of informal settlement (See: Model validation, Figure 19 below).
attractiveness for migration multiplier	-	Auxiliary	underemployed arrivals mobility multiplier* "underemployed/housing multiplier"* public expenditure multiplier* "underemployed/job multiplier"* underemployed housing program multiplier* attractiveness for migration factor* ((Green space effect on migration+1)/2)	Adapted to include effects of green space encroachment. Some underemployed benefit from green space presence for its resources, for example through fishing in the Sakumo Lagoon (Cilliers et al, 2013; Tyroller, 2016; Pauly, 1976; Gbogbo, Oduro, and Oppong, 2008). As the number of beneficiaries in Tema is limited (ca. 300 fishermen), the impact is reduced through averaging with 1 (rather than specifying a new lookup function).

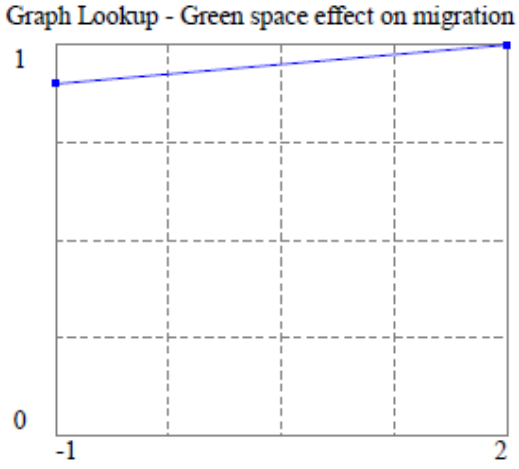


Figure 17. Green space effect on migration lookup function specification.

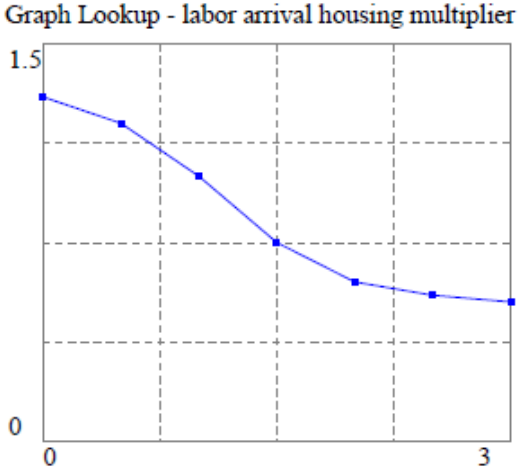


Figure 18. Labor arrival housing multiplier lookup function specification

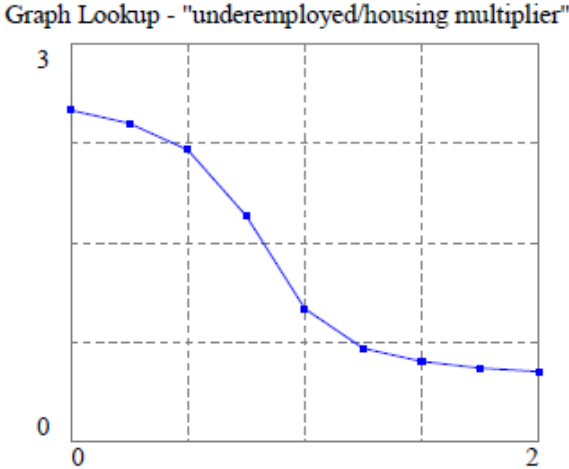


Figure 19. Underemployed/housing multiplier lookup function specification

1.9 Tax section

The tax section is specified from Forrester's model description (1970), displayed in figures 20 and 21 below. Some minor changes are made to parameter values, and some variables have been added as key performance indicator (indicated in blue).

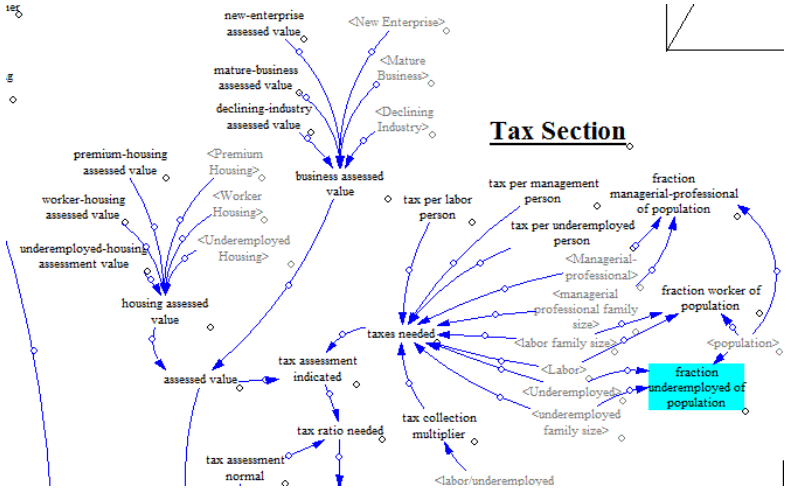


Figure 20. Tax section specified in Vensim (top part)

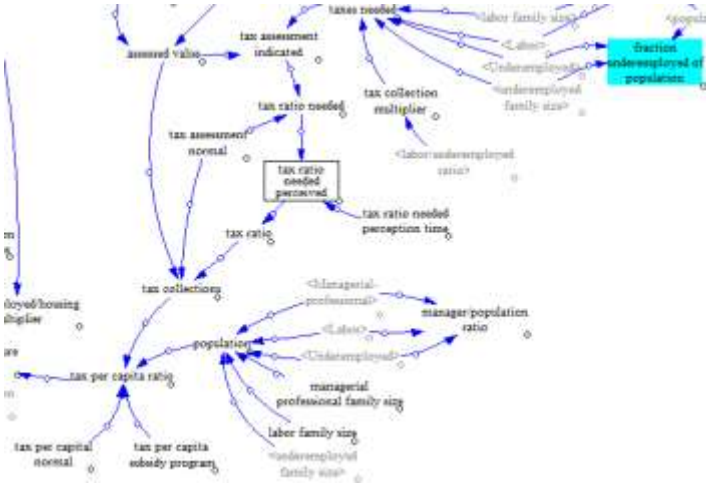


Figure 21. Tax section specified in Vensim (bottom part)

Variable	Units	Type	Equation	Comment/Hypothesis
premium-housing assessed value	thousand dollars/ housing unit	Constant	30	Estimation, adapted from Forrester
worker-housing assessed value	thousand dollars/ housing unit	Constant	15	Estimation, adapted from Forrester
underemployed-housing assessed value	thousand dollars/ housing unit	Constant	5	Estimation, adapted from Forrester

housing assessed value	Thousand dollars	Auxiliary	Premium Housing*"premium-housing assessed value" + Underemployed Housing*"underemployed-housing assessment value" + Worker Housing*"worker-housing assessed value"	
new-enterprise assessed value	thousand dollars/ productive unit	Constant	500	Unchanged from Forrester in absence of local estimates.
mature-business assessed value	thousand dollars/ productive unit	Constant	300	Unchanged from Forrester in absence of local estimates.
declining-industry assessed value	thousand dollars/ productive unit	Constant	100	Unchanged from Forrester in absence of local estimates.
business assessed value	thousand dollars	Auxiliary	New Enterprise*"new-enterprise assessed value"+Mature Business*"mature-business assessed value"+Declining Industry*"declining-industry assessed value"	
assessed value	thousand dollars	Auxiliary	business assessed value+housing assessed value	
tax per labor person	dollars/ person/ Year	Constant	200	Taxes needed per labor person
tax per management person	dollars/ person/ Year	Constant	150	Taxes needed per managerial-professional person

tax per underemployed person	dollars/ person/ year	Constant	200	Taxes needed per underemployed person. Adapted from Forrester value (300) to reflect the lack of a social welfare policy in Ghana.
taxes needed	dollars/ Year	Auxiliary	(tax per management person*managerial professional family size*"Managerial-professional"+tax per labor person*Labor*labor family size+tax per underemployed person*Underemployed*underemployed family size)*tax collection multiplier	
tax collection multiplier	-	Auxiliary with lookup	"labor/underemployed ratio" ([(0,0)-(20,10)] ,(0,2),(0.5,1.6),(1,1.3),(1.5,1.1),(2,1),(2.5,0.9),(3,0.8),(20,0.8))	
tax assessment indicated	dollars/ Year/thousand dollars	Auxiliary	taxes needed/assessed value	
tax ratio needed	-	Auxiliary	tax assessment indicated/tax assessment normal	
tax assessment normal	dollars/ Year/ thousand dollars	Auxiliary	50	
tax ratio needed perceived	-	Level	(tax ratio needed-tax ratio needed perceived)/tax ratio needed perception time	
tax ratio needed perception time	Year	Constant	30	
tax ratio	-	Auxiliary with lookup	tax ratio needed perceived ([(0,0)-(16,10)] ,(0.25,0.3),(0.5,0.5),(1,1),(2,1.8),(4,2.8),(8,3.6),(16,4))	

tax collections	dollars/ Year	Auxiliary	assessed value*tax assessment normal*tax ratio	
tax per capita ratio	-	Auxiliary	((tax collections/population)+tax per capita subsidy program)/tax per capital normal	
population	person	Auxiliary	"Managerial-professional"*managerial professional family size + Labor*labor family size+ Underemployed*underemployed family size	
manager/population ratio	-	Auxiliary	"Managerial-professional"/(Labor+Underemployed)	
tax per capita subsidy program	dollars/ person/ Year	Constant	0	
tax per capita normal	dollars/ Year/ person	Constant	250	
fraction underemployed of population	-	Auxiliary	Underemployed*underemployed family size/population	
fraction worker of population	-	Auxiliary	(Labor*labor family size)/population	
managerial-professional family size	Person/ worker	Constant	4	Adapted from Forrester to reflect that in Tema the average family size is 4 persons per household (Ghana Statistical Service, 2014b).
labor family size	Person/ worker	Constant	4	Adapted from Forrester to reflect that in Tema the average family size is 4 persons per household (Ghana Statistical Service, 2014b).

underemployed family size	Person/ worker	Constant	3	Adapted from Forrester to reflect that underemployed in Tema seem to have a slightly smaller household size than working class families (Ghana Statistical Service, 2014b; Acquah, 2001; Mazeau, Scott and Tuffuor, 2012).

1.10 Job section

The job section (Figure 22) is taken from Forrester's specification (1970) and amended to include port direct employment and industry automation, which is an external factor in scenarios analysis (depicted in orange).

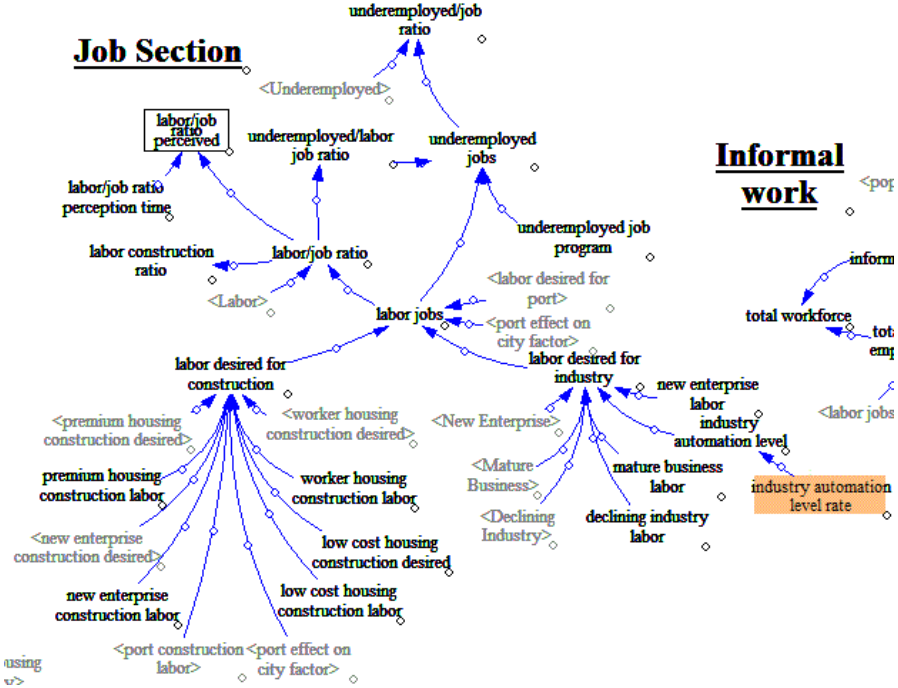


Figure 22. Job section specified in Vensim.

Table 9. Job section specification

Variable	Units	Type	Equation	Comment/Hypothesis
premium housing construction labor	worker* Year/ housing unit	Constant	2	
worker housing construction labor	worker* Year/ housing unit	Constant	1	
low cost housing construction labor	worker* Year/ housing unit	Constant	0.6	
new enterprise construction labor	worker* Year/ housing unit	Constant	20	
low cost housing construction desired	housing unit/year	Constant	0	
labor desired for construction	worker	Auxiliary	premium housing construction desired*premium housing construction labor+worker housing construction desired*worker housing construction labor + new enterprise construction desired*new enterprise construction labor+low cost housing construction desired*low cost housing construction labor + port construction labor*port effect on city factor	Amended to include labor jobs from port construction

new enterprise labor	worker/ productive unit	Constant	20	
mature business labor	worker/ productive unit	Constant	15	
declining industry labor	worker/ productive unit	Constant	10	
industry automation level	-	Auxiliary	0+RAMP(industry automation level rate, 2017 , 2047)	Added to the model to simulate labor job losses due to (potential) automation.
industry automation level rate	1/Year	Constant / Auxiliary	0 [Or standard policy value: 0.02]	Reflects the progressive automation of industry. A rate of 0.02 represents progression from zero to full automation over a period of 50 years from 2017, or partial automation when run shorter.
labor desired for industry	worker	Auxiliary	(New Enterprise*new enterprise labor+Mature Business*mature business labor+Declining Industry*declining industry labor)*(1-industry automation level)	Amended with the impacts of industry automation.
labor jobs	worker	Auxiliary	labor desired for construction+labor desired for industry+port effect on city factor*labor desired for port	Amended to include labor jobs generated directly in the port
labor/job ratio	-	Auxiliary	Labor/labor jobs	
labor/job ratio perceived	-	Auxiliary	("labor/job ratio"-"labor/job ratio perceived")/"labor/job ratio perception time"	
labor/job ratio perception time	Year	Constant	5	

labor construction ratio	-	Auxiliary with lookup	"labor/job ratio" ([(0,0)-(10,10)] ,(0,0),(0.5,0.5),(1,0.9),(1.5,1.1),(2,1.15))11	
underemployed jobs	Worker	Auxiliary	labor jobs*"underemployed/labor job ratio" + underemployed job program	
underemployed job program	Worker	Constant	0	Potential policy by Forrester
underemployed/labor job ratio	-	Auxiliary with lookup	"labor/job ratio" ([(0,0)-(10,10)] ,(0,1.15),(0.5,0.8),(1,0.5),(1.5,0.25),(2,0.1))	
underemployed/job ratio	-	Auxiliary	Underemployed/underemployed jobs	

2 Model verification and validation tests

Model verification and validation tests are performed to uncover errors in modelling specification, identify limitations of the model, and assess the validity of model inferences. Through systematic testing the implications of model boundary demarcation, conceptualization, and specification are evaluated, the impact of uncertainty on the model is assessed.

Modelling testing steps as defined by Sterman (2000) are used as a guide, in addition with notions on the validity of model inferences described by Shadish, Cook, and Campbell (2002) (i.e. threats to validity). The testing serves not to "defend" the model and cover up its weaknesses, but to challenge its quality and correctly determine its usefulness.

Despite the fact that Forrester's model has been verified and validated by him and others in the past (e.g. Forrester, 1970; Alfeld, 1975; Mass, 1974), the verification and validation tests will include Forrester's original model.

Per sub-model the following tests will be carried out:

1. Boundary assessment ("adequacy", Sterman (2000)),
2. Structure assessment
3. Dimensional consistency
4. Parameter assessment
5. Extreme conditions

Additionally, the model will be checked for integration errors, behaviour will be evaluated, a full sensitivity analysis is performed and model internal, construct and external validity are evaluated.

2.1 Port sub-model

Boundary assessment

In assessing the boundaries of the port sub-model it is important to keep in mind that the aim of modeling the port is to assess its impacts on the city, rather than the other way around. The sub-model contains the following exogenous constants:

- *fraction managers of total port employment*
- *fraction labor of total port employment*
- *labor per port construction*
- *port construction delay*
- *port capacity effect on national GDP delay*
- *normal GDP growth rate*
- *throughput growth rate*
- *level of port automation/automation rate*

Employment is assumed to vary linearly in proportion to port throughput (*fraction managers of total port employment, fraction labor of total port employment*) and port construction (*labor per port construction*), respectively. Keeping in mind the aim of the sub-model, no feedback links regarding for instance the availability of labor are modelled. In the case of port labor employment, a policy option of introducing automation to port operations is added to the model, potentially affecting employment.

A potential feedback loop that is not included is the effect of local industry on port throughput. Including such an effect would require data or assumptions on the port freight generated by local industry. Adding this feedback loop would introduce more complexity and potential errors, while not contributing to answering the modelling aim of the sub-model (port effect on city).

GDP growth rate is included as a driver of port throughput. The effect of the port on national GDP is also included. This feedback could be omitted, but doing so would lead to little change in (sub-) model behavior or model complexity (slightly lower throughput growth rates, temporarily leading to lower employment and congestion, but higher industry boosting effects cancelling that out). It is included to represent the local-global mismatch (Merk, 2013) of port presence, facilitating understanding and discussion.

In reality, port throughput also depends on competition from other nearby ports. The model concerns a single city and its port, so development of those other ports are considered exogenous. The effects of competition can be included through varying the exogenous *throughput growth rate*.

Port automation level (or rate if specified as a gradual increase) can be considered constant, a stakeholder policy or as an externally driven uncertain factor, depending on the modeling point of view that is assumed. In this study it is treated as an exogenous factor which can change as a result of technological advancement.

Structure

The port sub-model is conceptualized and specified based on the concepts found in the literature. The level of aggregation chosen to focus on port impacts on the city rather than internal port operations. It is for instance implicitly assumed that port congestion is mainly influenced by the rate of *port throughput* to *port capacity*, ignoring the potential effects of automation on port capacity and efficiency. While including such concepts might provide a more realistic picture of port operations, such disaggregation would also increase model complexity, detracting from the actual modeling questions.

Policy decisions implicit in the sub-model include the hiring of labor and managers. As discussed, these vary with port throughput. In the case of labor, this rationality resembles the way laborers are informally hired on a daily basis (Obilie-Odei, 2013).
Expansions of the port are not modeled as endogenous to the sub-model, thus reflecting the relatively discrete and local nature of port expansion projects (as opposed to averaged continuous expansion over time).

One relation that is not modeled is the potential beneficial effects of the *level of port automation* on *port capacity*. Again, doing so would require data on the magnitude of this effect without adding to model usefulness. Automation is however included as having a direct impact on employment.

Dimensional consistency

Sub-model equations should be dimensionally consistent, without resorting to the use of parameters having no real world meaning. A units check of the sub-model revealed some minor errors that have

been corrected. Note that workers have the neutral unit “employee”, rather than Forrester’s use of “men” (even though the majority of port workers are male). Growth rates and –factors are modeled as dimensionless, as is the *port utilization* fraction.

A dimensional anomaly remains in the *port construction* rate, which models the increase of port capacity due to expansion to happen over a period of time (*port construction delay*) instead of all at once. Actual (total) increases are put in as numbers in the equation, leading to a units mismatch while the equation is sound (this is checked). An alternative way of modelling that removes the errors would be to introduce three separate model variables, one for each port expansion (capacity increase) and given this the units kton/year.

Several multiplier effects are included in the sub-model which are considered to be relating variables with different units to each other. While technically both variables should be normalized and then related in order to be dimensionally sound in a units check, for the sake of model legibility and size this is not done (following Forrester’s use of multipliers).

Parameter assessment

All parameters in the port sub-model resemble real world counterparts, and where possible are based on actual parameter values. For instance, port construction is assumed to take place over periods of five year averagely, the make-up of port labor is based on empirical findings. *Throughput growth rate* is an exemption, where the variable is not made to represent a real world counterpart. Instead of defining total throughput growth, which is mainly driven by GDP growth in the model, it has an additive or subtractive effect to that main driving effect.

The multipliers offer implicit parameters. The *port capacity effect on GDP growth* has been estimated, and in effect the *normal GDP growth rate* parameter had to be compensated for the sub-model to correctly model GDP growth. Other multiplier effects model diminishing returns of port presence and the effects of congestion on port growth. These effects all have tangible real-world counterparts, even though the actual values might be estimations. Lookup functions regarding port operations have been calibrated to provide realistic sub-model behavior.

Extreme conditions

-The formulation of *port congestion effect on throughput growth* allowed for initial port throughput to be higher than the port capacity and remain that way. The congestion multiplier effect is changed to include a reducing effect, forcing throughput levels to capacity level.

-The specification that *port utilization* equals zero if *port capacity* is zero (which would otherwise cause division by zero error) would lead to throughput not being reduced to match zero capacity. Changed to have a value of 2 if port capacity is zero. In combination with the previous adaptation this acts to constrain throughput.

-The formulation of *port effect on industry* prevents the aforementioned adaptations to adversely affecting city industry. At worst, the port will still have no (boosting) effect on local industry.

-However, extreme values of the *port effect on industry* factor does not scale port impacts on the city, but scales congestion effects, effectively reducing them. Simply applying them to the *enterprise multiplier* where port presence impacts industry does not suffice, as this would effectively scale not only

port effects but all other multiplier effects as well. To resolve this, the effect is reformulated to correctly scale the port effect on enterprise construction only.

-As expected, a construction delay of zero results in a division by zero error. This is not corrected in the model, as instantaneous construction of the port would be nonsensical in the real world, and would require infinite resources. The error serves as a reminder of this. Likewise, a large construction time can lead to a situation of continuous improvement of the port, with which full utilization is never reached and the attracting effect on industry remains constant. This scenario is not very realistic, but plausible.

-The model handles extreme GDP growth up to the computation limits of Vensim. Sustained negative GDP growth eventually leads to zero GDP and zero port throughput.

-The model responds well to shocks in policy such as the level of automation. Using a short construction delay time is in essence a shock to port capacity, but this is modelled adequately both with regards to port throughput and construction labor required.

2.2 Transport sub-model

Boundary assessment

The transport sub-model has the following (exogenous) constants:

- *infrastructure fraction of initial built area*
- *fraction industry transport of total transport*
- *fraction population transport of total transport*
- *fraction port transport of total transport*
- *fraction of port freight by road*
- *initial infrastructure capacity*
- *freight transshipment ratio*
- *infrastructure saturation capacity*
- *transport investment factor*
- *infrastructure decay time*
- *pc transport demand growth rate*
- *max per capita transport demand*

The choice of the transport sub-model boundary excludes the explicit modeling of rail infrastructures. The relationship between different transport modalities in the urban area is represented instead by the variable *fraction of port freight by road*, and is left as a policy option. Rail infrastructure and transport of goods and persons is not assessed in detail. Adding more detail by expanding boundaries to include rail would add to model complexity without making the model more useful for answering the modelling questions regarding congestion.

The majority of the other constants serve mainly to define initial conditions. The actual *freight transshipment ratio* varies slightly in reality. However, it is assumed that this behavior is not driven by processes in the city and no feedback loops are omitted.

The infrastructure decay time is taken to be constant. In reality, decay of infrastructure can be a function of road use, existing road quality and weather/climate influences. This could be an interesting avenue for further research. However, the aggregate nature of the model precludes a more detailed modelling of the transport network and doing so would not make the model more useful for its purpose

in this model. Road decay time has a relatively modest and predictable impact on model behavior (see sensitivity analysis graphs).

The variables regarding per capita transport demand are specified as uncertain, exogenous factors. In reality, average per capita transport demand could be a function of the city's socio-economic make up, rising with increasing proportions of managerial-professional and worker classes. In addition, average wealth of all groups separately might increase. To avoid unnecessary complexity and increasing model data needs, these potential links are not modeled in favor of a general figure for growth rate, dependent on the uncertain driver *economic environment* (see Appendix D. scenario analysis).

Structure

The road transport sub-model is modeled at a high level of aggregation, based on road network macro capacity (Shuo, 1999). Transport demand and supply are modelled in a conceptual, dimensionless way. This is partly a necessity due to low data availability: this conceptual approach lowers the need for data on such quantities as trips per person, transport generated per production unit. Moreover, it also serves to keep model complexity down.

A downside of the approach is that variable quantities are less relatable, as transport *Infrastructure capacity* is modeled as a dimensionless factor. While this is translated in the model into more meaningful metrics such as *infrastructure area* and *road length*, potentially important feedback effects of congestion on generated trips are omitted (Armah, Yawson, and Pappoe, 2010).

Important to note is the implicit assumption in the model that transport generated per production unit and port freight shipped remains constant over the time horizon of the model. Data availability issues complicate a more detailed modelling of this, but it could be explored in further research.

Basic laws are adhered to: port freight is all accounted for, as transshipment rates and freight moved by rail is detracted from road transport. In the case of industry it is assumed that all transport occurs by road. Transport infrastructure does not appear out of nowhere, but is constructed and decays over time. One variable that warrants interest is the *infrastructure utilization*. The way this variable is formulated, and the absence of feedback mechanism on the amount of trips allows for this variable to go above one, or more than full utilization. While not possible in reality, the variable *infrastructure utilization* can be thought of as the ratio of *potential* demand vs. infrastructure supply. The impact of congestion on *new enterprise construction* and manager migration will have some constraining effect.

Policy decisions modeled in the sub-model include investment in new transport infrastructure. This is based on the experienced congestion, and includes a time delay that is appropriate for large-scale infrastructure investments. A consequence of this is that investments are not done proactively, and will be in reaction to actual congestion increases rather than projected increases. While land availability has a limiting effect on infrastructure construction, the model is not spatially disaggregated. This does not correspond to the real situation in cities where in urban centers there is simply no space for additional road infrastructure. However, for the purpose of answering modelling questions it is a reasonable approximation.

Dimensional consistency

The sub-model makes extensive use of dimensionless factors and multipliers. As these are automatically dimensionally consistent, this does not make for a very useful verification test in this sub-model. One dimensional anomaly concerns the *road length* variable. In order not to clutter the model with constants, a conversion is carried out from hectare to km using constants in the equation, causing a dimension error in the software package. Additionally, the way Vensim models smoothings as a delay causes a mismatch between initial values for population, port throughput and industry, and their current values. This is however not a conceptual error.

Parameter assessment

Despite the extensive use of dimensionless variables and parameters, almost all variables and parameters have real world counterparts. One exception is the *transport investment factor*. This parameter relates congestion and current infrastructure capacity to additional infrastructure investments. Since all involved variables are dimensionless, no clear meaning can be derived from this investment factor. It scales the level of construction to experienced congestion, in a way embodying the availability of resources for construction or willingness to invest.

This way of modelling investment is preferred over a natural infrastructure growth rate, as this would have absolutely no bearing on reality. In contrast, the use of a decay rate is appropriate, as infrastructure decay is a function of total infrastructure area and not of policy decisions.

Extreme conditions

-An initial infrastructure capacity of zero results in a division by zero overflow error, as utilization is not defined. However, as infrastructure investment is made dependent on existing capacity, no additional investments are carried out despite demand. As the sub-model would lose its meaning under this extreme condition, the error is left in as a warning.

-Very high levels of initial infrastructure capacity could potentially exceed land availability (although this would effectively mean that the whole of the land area is made into asphalt).

-An infrastructure decay time of zero leaves a division by zero error, but as this would equate to the whole of the road network disintegrating in an instant (which is unlikely), this error is not solved.

-The *fraction … transport of total transport* variables effectively scale the contributions of port, population and industry to the total transport demand. The fractions are assumed to add up to one, providing extreme values for these can therefore mean that initial infrastructure supply is exceeded.

-Extreme conditions testing reveals that the *freight transshipment ratio* does not affect model behavior, except when that ratio is exactly one. A doubling in port traffic with a stable rate of transshipment is still a doubling in traffic. Hence, only changes in transshipment rates will have an impact on model behavior.

-Unrealistically high values of the *infrastructure saturation capacity* lead to nonsensical utilization and investment. This is not a fault of the equation formulation. The *transport congestion multiplier* lookup effect is formulated to be defined when (potential) utilization exceeds a value of one.

-Transport investment factor scales infrastructure investment. Zero reaction to congestion leads to escalating utilization as potential demand growth is not completely stifled. Extreme investment levels on the other hand are prevented by the absence of congestion due to ample road adequacy.

-*transport effects on city* is modeled as an on/off switch only, not as a scaling variable outside little adjustments

-The sub-model reacts naturally to policy shocks such as the decrease of the *fraction of port freight by road* or *transport investment factor.* Sudden changes in these variables can however lead to utilization levels exceeding one.

2.3 Land use (green space) sub-model

Green space encroachment is modeled in the land use sub-model. Forrester's original specification of land use in the model is amended to explicitly include green space area.

Boundary assessment

The following is a list of (exogenous) constants in the sub-model:

- *land area*
- *land per house*
- *land per production unit*
- *initial green space area*
- *max green space area*
- *min green space area*
- *unused land to green space delay*
- *green space interaction switch*
- *societal willingness to settle green space / acceptance rate*
- *green space settlement factor*

The variables land area, land per house and land per production unit are as Forrester defined them, with the land area of the city set to the area of the original Tema Acquisition Area (167 km^2, Acquah, 2001). It is possible that the area per housing unit is dependent on land availability, e.g. in the form of the appearance of high-rise buildings like in Ashaiman (Zakaria, 2014), creating a feedback loop that is excluded in the present formulation. However the magnitude of such an effect is unknown, so housing area is assumed to be constant in this study.

Green space encroachment is modelled as a function of land availability, in turn influenced by the development of the city. It is possible that the values for minimum and maximum (potential) green space area would change over the time horizon of the model, for example due to climate change or ecosystem changes. However, this falls outside of the scope of this study, as including these effects would not contribute to model usefulness for answering the research questions.
The factor *societal willingness to settle green space* is assumed to vary linearly over time. An alternative formulation could be to base this variable on the extent to which green space has already been settled, introducing a feedback.
The *green space settlement factor* is assumed to be constant, scaling the actual settlement of green space. It could be used to relay the likeliness of green space settlement, based on a proximity effect, even though the model is not spatially explicit. A feedback effect of land availability is however already included in the *land availability effect on green space settlement*.

Structure

The formulation of the land use section resembles real life classification of land use. One exception is the exclusion of the *infrastructure area* from the *built-up area*. This is done to facilitate the possible exclusion of infrastructure effects from the calculations without giving a skewed value for the *land*

fraction occupied. Basic laws are adhered to: all types of land use add up to the full *land area* at all times.

In order to increase the rationality of policy decisions in the model, the variable *societal willingness to settle green space* is added to the model. In reality, green space settlement (which is essentially a policy of developers and/or informal settlers) is mitigated by social acceptability of green space settlement, reflecting the traditional view in Tema that the lagoon is a local deity (Adegun, 2017; Tyroller, 2016). As traditional beliefs are discarded, willingness to settle green space increases (the variable climbs from 0 to 1 over a period of 50 years).

Dimensional consistency

The main dimension for land area used in the model is hectare (ha, 10000 m^2). All land use areas add up to the total land area. A units check reveals no unit inconsistencies in the land section.

Parameter assessment

The model section makes use of several dimensionless concepts. Although they do not represent tangible quantities, they do represent qualitative effects which are present in reality (e.g. *societal willingness to settle green space*). The *unused land to green space delay* parameter represents an average time delay for this process, as in reality the restoration of green space might readily take place in some areas, while nearly impossible in others. The model does not account for local differences of the sort, as this does not add to model usefulness.
The parameter value of *land per housing unit* is checked against real data from Tema neighborhoods. Provided that the literature used the same manner of defining a house (Forrester, 1980), Forrester's original figure (converted to hectare from acres) provides a fair estimation. *Land per production unit* is less clear, as the definition of what constitutes a production unit is less universally transferable. This means that the amount of productive units might not reflect the actual number of industrial enterprises that are present, but this does not mean that the area associated with industry is off as well.

One omission from the model is the use of land for agricultural and recreational needs. While these uses can coincide with green space land, adding these concepts does not add to problem understanding. In Tema, land that is not used for urban developments has been used for agriculture despite urban designation (Acquah, 2001).

Extreme conditions

-Applying extreme conditions to the land use model yields plausible results. Stating an initial value of green space of zero, unused land returns to green space status up tol the stated maximum. While the presence of tipping points might prevent green space from returning after it has been destroyed or lost, for the purposes of this model (where green space is mostly declining due to encroachment) it is a fair rendition of the process.

-The model allowed for the initial green space to be larger than total land area of the city. As this makes no sense, the formula for initial green space is amended to prevent this.
-Stating a maximum green space area of zero yields a division by zero error, which is corrected.

-It is noted that it is possible for green space area to rise slightly above the stated maximum at very low levels of *max green space area*. The land return to green space attains a slight negative value in order to return to maximum value. However, this effect does not significantly affect model behavior, and is not experienced at higher values of max green space area.
-Extremely high values of *max green space area* leads to situation where the large green space area is kept in balance by equally rising settlement ratios.

-A high *land per production unit* predictably leads to industry forming a larger part of the land use, also due to increased industrial activity resulting from the synergy effect. The same is true for the *land per house* variable. The model still produces plausible results. Lowering these variables to zero results in the omission of these areas in the model and stifled growth, but no model errors.

-Reducing *land area* to extremely low values can lead to nonsensical results in combination with a *min green space area*, resulting in negative available space. As fixing this error would introduce more clutter than it would be worth, this error is left for the modeler to assess. Very high values of land area yield no problems.

-Extreme values for the green space settlement factor have a plausible result. High levels lead to faster green space settlement, and a value of zero leads to no green space settlement at all, effectively modelling green space conservation!

2.4 Informal housing

Boundary assessment

The informal housing section contains only one constant factor:

- *underemployed housing population density*.

As the amount of informal housing is derived from the difference between actual density and this typical housing population density, it does not make sense to make this constant a variable in the model. The section itself models the feedback effect of overcrowding on urban (informal) development. The amount of informal housing however is affected by formal housing construction, and the deterring effect of limited formal housing availability on migration.

Structure

Informal housing is assumed to house all laborers and underemployed workers and their families that cannot be housed in formal housing developments, according to their standard occupancy densities. The implication of this is that informal settlements can sprout up easily and instantly (which seems to be the case, World Bank, 2013), but also that they effectively vanish if abandoned. These houses are easily demolished (and rebuilt), and it makes sense that land near the city is most coveted for formal redevelopment.

-The model assumes that workers and underemployed for which there is no formal housing will always settle informally.

Dimensional consistency

The informal housing section is found to be dimensionally consistent, with every parameter and variable having a real world meaning.

Parameter assessment

The only parameter in the section is the *underemployed housing population density*, which is a tangible concept and calibrated for Tema.

Extreme conditions

Unless *population* or *underemployed housing population density* decline to zero, all equations remain sensible.

2.5 Informal work

Boundary assessment

The informal work section contains only one constant:

- *fraction of the population employable*.

The question whether this specification is appropriate hinges on whether this fraction changes over time, whether it is affected by other variables in the model, and whether model validity and usefulness is threatened by ignoring such variation.

Factors affecting this fraction could be population life expectancy, health, average age. These factors could well change over the timespan of the simulation, for instance with increases in medical resources or food quality and supply. However, of interest for the modelling effort is not the impacts of these effects but rather the impacts of port infrastructure expansions and potential interventions. Moreover, changing this constant would not affect model behavior outside this sub-model. Since health interventions are not part of the modelling scope, the fraction of the population employable will remain constant.

Structure

The sub-model derives the extent of the informal sector by comparing formal employment with potential total employment. Formal employment is set by Forrester to be equal to one formal worker per family, no more. This severely impacts the informal work sector, as it can effectively only change with the proportional presence of underemployed families. This limits the validity of *fraction informal of total population* KPI. However, the direction of the causal relationship is plausible (less formal employment means an increase in informal employment and vice versa). The presence of industry and the port in Tema could indeed be related to the lower incidence of informal economy in Tema compared to Accra (Arup, 2006).

Dimensional consistency

The sub-model is dimensionally consistent.

Parameter assessment

The only parameter in the sub-model is the *fraction of population employable*. This factor has a real world counterpart and is based on actual local data (Ghana Statistical Service, 2014b).

Extreme conditions

-Extremely low values of *fraction of population employable* (< 0.35) may cause the potential model workforce to be below the actual amount of people working, and result in the amount of informal workers becoming negative. This however won't affect model behavior.

2.6 Industry chain

This sub-model is part of Forrester's original Urban Dynamics model and verified by him (Forrester, 1970). Model verification assesses the appropriateness of Forrester's specification for this study.

Boundary assessment

Constant factors in this model subsection are:

- *mature business construction factor*
- *declining industry construction factor*
- *new enterprise construction factor*
- *new enterprise construction normal*
- *new enterprise decline normal*
- *mature business decline normal*
- *declining industry demolition normal*

These factors are assumed constant over the model runtime. However, their impacts are moderated by other variables in the model where that is appropriate (e.g. business decline).

Structure

The appropriateness of modelling business structures as an aging chain has been debated and defended (Mass, 1974). For the purposes of this model (basically a land use model) the level of aggregation is deemed appropriate. It is important to keep in mind that the sub-model models business structures (e.g. newly constructed factories), not individual businesses (start-ups vs. very old businesses).

The aging chain specification conforms to the basic physical and conservation laws. The way policy decisions are modeled (for instance the construction of a new business) is plausible and based on information that is actually perceivable, such as past trends of business growth (Forrester, 1992).

Dimensional consistency

The main unit used in the sub-model is the productive unit, a standard business structure occupying 0.081 ha of land. Other units are derived from this, or are dimensionless. No unit errors are found.

Parameter assessment

The extensive use of dimensionless multipliers complicates the comparison of parameters with real-world values. Lack of empirical base has been a common critique on Forrester's model, but is has nonetheless been shown to correctly approximate urban development in case studies regardless (Mass, 1974; Alfeld, 1995).

Extreme conditions

Running the sub-model in Vensim results in a number of 'lookup out of bounds'-errors, meaning that parameters attain values that are outside the range of specified values of multiplier lookups. These

errors are the result of Forrester's original model specification, but do not result in distorted model behavior.

2.7 Housing Chain

This sub-model is part of Forrester's original Urban Dynamics model. Apart from some parameter value adjustments and variable additions, it has not been significantly altered.

Boundary assessment

The sub-model contains the following constants:

- *premium housing construction normal*
- *premium-housing population density*
- *premium housing obsolescence normal*
- *worker housing construction normal*
- *worker-housing population density*
- *worker housing obsolescence normal*
- *premium-housing averaging time*
- *worker housing averaging time*
- *underemployed housing population density*
- *underemployed family size*
- *slum housing demolition normal*

Normal housing construction and obsolescence rates are moderated by other model variables, incorporating feedback effects. Housing densities represent the typical densities of the respective housing types and are therefore assumed to be constant. In Forrester's original model they were conceptually separate from the actual (implicit) housing population densities resulting from population and housing figures. In this model this difference is used to represent explicitly the amount of informal housing (worker housing, underemployed housing).
Average family size might change over time with socio-economic and -cultural factors. These are partly modeled by specifying family sizes for each worker class separately.

Structure

Empirical evidence from Tema suggests that formal housing in the city indeed ages and degrades over time, sheltering a different class of residents. An example is the housing built for workers degrading within 40 years to become 'slum estates' (UNCHS (HABITAT), 2003). The differences in housing occupancy rates in Tema (Ghana Statistical Service, 2014b; Mazeau, Scott,Tuffuor, 2012) further subscribes the appropriateness of disaggregating housing in multiple types.

The sub-model conforms to conservation laws: all formal housing has to be constructed or demolished to 'enter' or 'leave' the system. Modeled decision rules seem a plausible capture of the behavior of actors in the system: the construction of housing is moderated by the demand for such housing and the supply of labor and land. The impact of these moderating effects is explored in the sensitivity analysis.

Dimensional consistency

The main unit used in this sub-model is the housing unit. Units for other variable are derived from this, or dimensionless. No unit errors are found in the sub-model.

Parameter assessment

Several parameters have been employed in this sub-model. Parameters such as construction and obsolescence rates have real-world meaning. Others, such as the dimensionless multiplier lookups are less grounded in hard (quantitative) data. This might have consequences for model inference validity.

Extreme conditions

The model does not run with initial values of premium and worker housing, or housing densities set to zero. This is a result of the way Forrester specified the sub-model. Some of the multiplier lookups used in the sub-model are not explicitly defined for the whole range of input variables. This is present in Forrester's original specification of the model, and leads to error messages in Vensim, but doesn't impact model behavior.

Care is to be taken with values of demolition programs. Forrester specification of these can potentially lead to more houses being demolished than are present and therefore result in negative housing stocks, which should not be possible. The occurrence of this effect must be evaluated, or an alternative specification used where actual stock levels are taken into account.

2.8 Employment Chain

This sub-model was part of Forrester's original Urban Dynamics model. Apart from some parameter value adjustments, it has not been significantly altered.

Boundary assessment

This sub-model contains the following constants:

- *Manager arrivals normal*
- *Labor arrivals normal*
- *Underemployed arrivals normal*
- *Manager departures normal*
- *Labor departures normal*
- *Underemployed departures normal*
- *Managerial-professional birth rate*
- *Labor birth rate*
- *Underemployed birth rate*
- *Mature business management*
- *New enterprise management*
- *Declining industry management*
- *Labor mobility normal*
- *Underemployed mobility normal*
- *Manager-arrival multiplier perception time*
- *Labor mobility multiplier perception time*
- *Labor arrival multiplier perception time*
- *Underemployed mobility perception time*
- *Underemployed to labor perception time*

The effects of normal arrival and departure rates are assumed to be constant over the model run, but are moderated by various processes endogenous to the model affecting actual arrival and departures. Net birth rates are assumed to be constant over the model run, following Forrester. Nationally, both crude birth and death rates in Ghana have gone down significantly since 1960 (World Bank, 2017a; World Bank, 2017b), resulting in a minor decline of net birth rate. It is assumed these changes are not the result of effects endogenous to the model, e.g. no feedback loops are omitted by modelling birth rates as constant model parameters.

Structure

The employment sub-model assumes workers to belong to one of three classes; managerial-professional, labor or underemployed. The appropriateness of this specification and level of aggregation has been debated and defended (Mass, 1974; see discussion on construct validity).
Decision rules implicit in the model (such as the advancement of workers to managerial positions or the laying off of workers) are plausible and based on available information or trends. The impacts of numerical variations of the strengths of these effects on model behavior are assessed in the sensitivity analysis. Basic laws conservation of matter (workers) are adhered to.

Dimensional consistency

The main unit of the sub-model is the worker (adapted from Forrester's use of the unit 'men' for employment). Sub-model equations are consistent and raise no errors. However, again several dimensionless multipliers have been used by Forrester in an attempt to capture soft policy decisions and processes.

Parameter assessment

The dimensionless parameters used by Forrester to model migration of workers into the city and between worker classes all sound plausible, but offer limited possibilities of comparison with real-world data. This will have consequences for the validity of model inferences. Other parameters such as birth rates and per business manager employment have real-world counterparts.

Extreme conditions

The model does not run with initial level of *workers* and *underemployed* set to zero, analog to housing stocks. Care should be taken with the definition of underemployed training and labor training programs (policies), which set to extremely high values could lead to negative number of underemployed and labor workers in the model. This is inherent to Forrester's original specification of the model. The model can be adapted to take into account stock sizes regarding these programs.

The sub-model reacts plausibly to shocks in parameters and policies applied to it.

2.9 Integration Error

The suitability of the integration method and time step is assessed by checking model behavior for integration errors. Numerical Integration errors arise when (1) an inappropriate integration method is selected, or (2) the chosen time step is too large to adequately calculate model dynamics, resulting in averaging, overshoots and possibly oscillations.

The integration method selected is Euler, because potential intervention options involving STEP or PULSE functions may result in instances of non-differentiability, resulting from such discontinuous events. This makes a Runge-Kutta 2 or 4 method less suitable for this model, as these methods may average out discontinuous changes (Sterman, 2000).

Analysis prescribes the use of the finest time step, 0.0078125. As a result, model computing time is increased somewhat, especially in sensitivity testing, but not above acceptable limits on the computers used for modelling.

Due to its relatively dynamic nature, informally housed is used as an indicator of time-step adequacy. Comparing two similarly set up model runs with time step 0.0078125 and 0.0625 shows a minor difference.

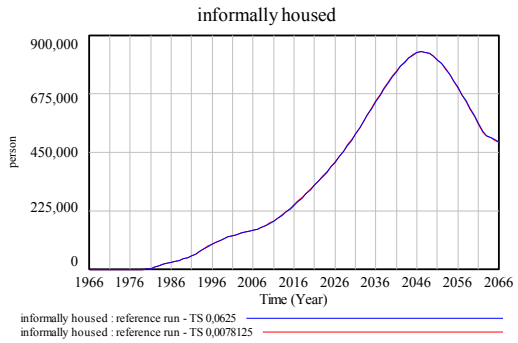


Figure 23. Comparing model results for timestep 0.0078125 and 0.0625

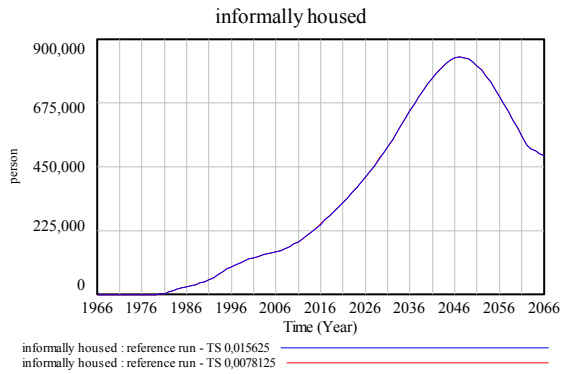


Figure 24. Comparing model results for timesteps 0.0078125 and 0.015625.

2.10 Behavior reproduction

Hypothesis	**Verdict**	**Comment**
H1: urban development leads to green space encroachment	Success	Development of the city leads to reduction of green space (Figure 34)
H2: port expansion will lead to increased encroachment into green space	Success	Following expansion encroachment happens at a faster pace, arriving 10% sooner at full encroachment (Figure 34
H3: port expansion will lead to increased congestion	Success	Infrastructure utilization rises after port expansion, both due to freight and increased industry and migration (Figure 35), despite additional investments (Figure 36).
H4: port expansion will lead to increased informal settlement	Success	The model correctly reproduces the attractive effect of port expansion resulting in increased informal settlement (Figure 37).
H5: port capacity expansion will stimulate local industry	Success	The stimulating effect of port presence is translated in the model as increased amount of new enterprises following the expansion (Figure 38).
H6: protecting green space will reduce urban development	Success	Protection of 1000Ha of green space has a slight adverse effect on industry and housing development (Figures 39 and 40).

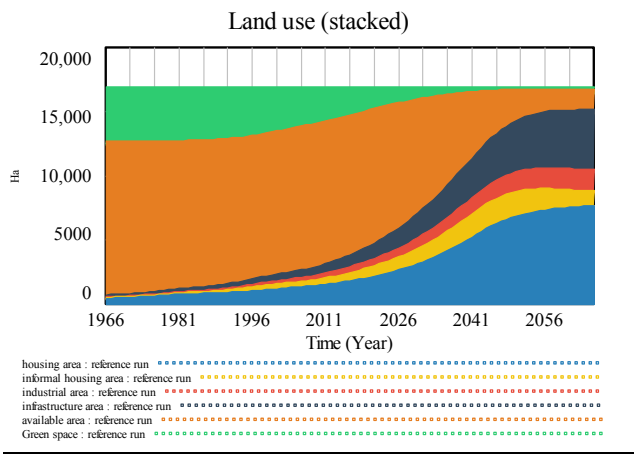


Figure 25. Urban land use distribution over time. Legend: Green space (green), available area (orange), road infrastructure (grey), industry (red), informal settlement (yellow), housing (blue)

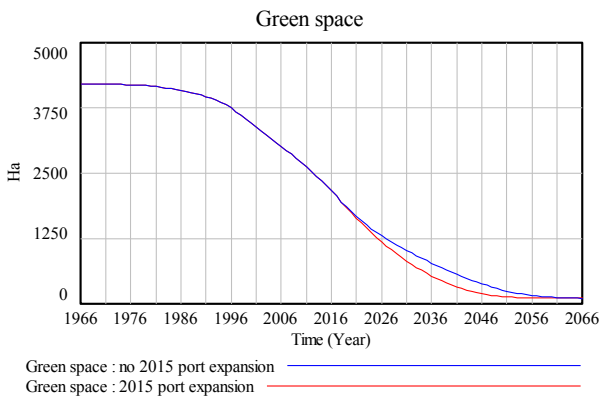


Figure 26. Accelerated green space encroachment following port expansion (red).

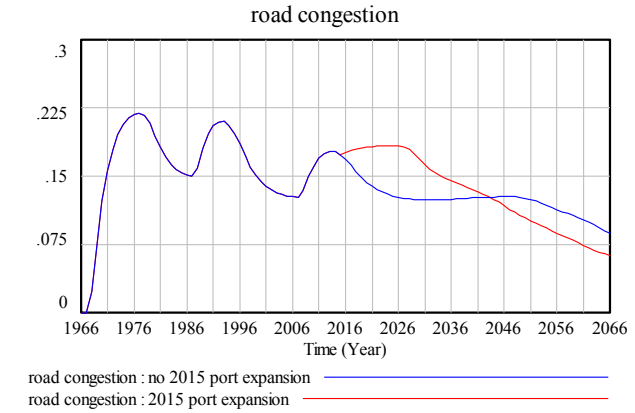


Figure 27. Increased congestion following port expansion, despite additional investments

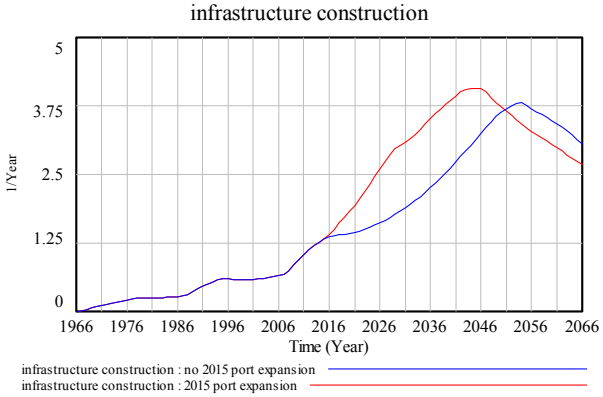


Figure 28. Increased infrastructure construction following port expansion

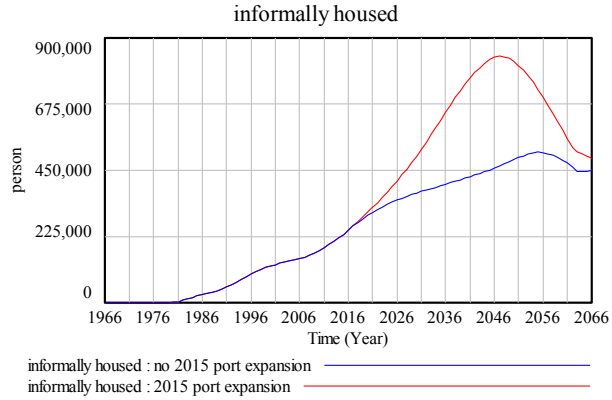


Figure 29. Increase in informally housed after port expansion.

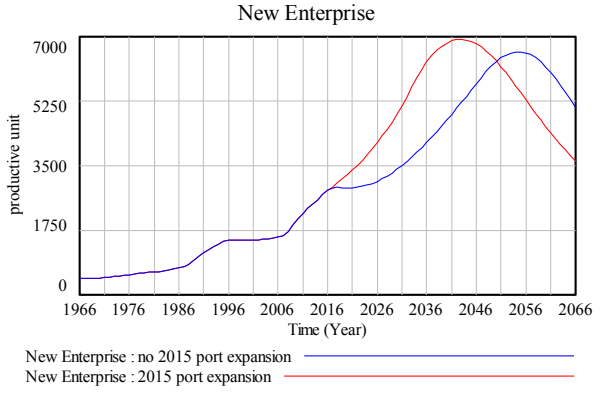


Figure 30. New enterprises in the city increases due to increased port capacity supply.

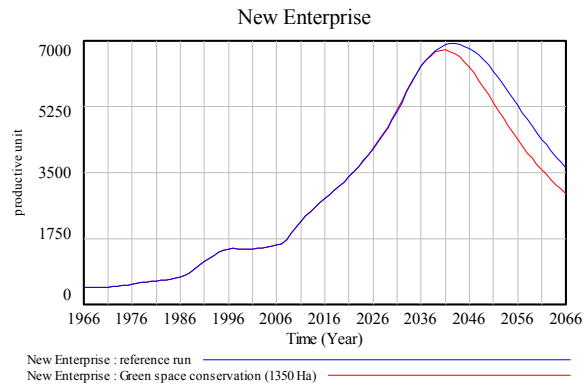


Figure 31. Protection of 1350 Ha of green space resulting in slight reduction of industrial development

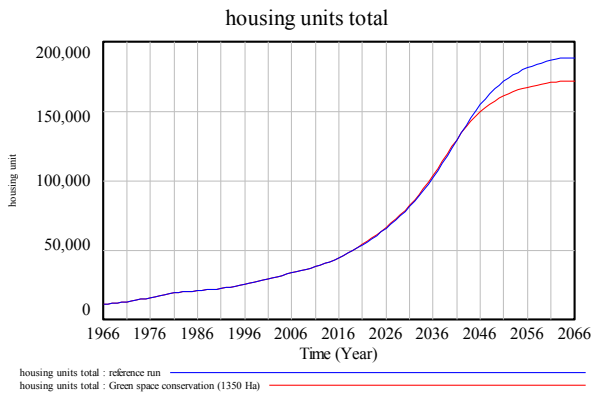


Figure 32. Reduction of housing stock in reaction to green space protection (1350 Ha).

Below is the behavior reproduction of the model before the adjustment of Forrester's assumptions on informal housing, and the addition of green space impacts on migration links after expert feedback. The graphs below have been used in the interview with ms. d'Hont.

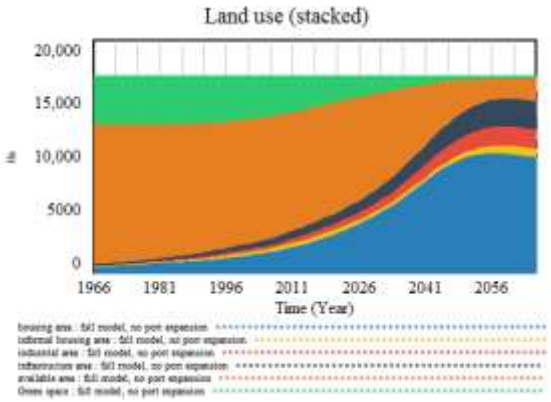


Figure 33. Green space encroachment due to urban development

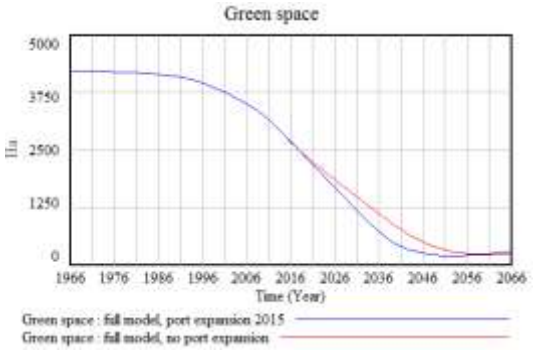


Figure 34. Accelerated green space encroachment following port expansion

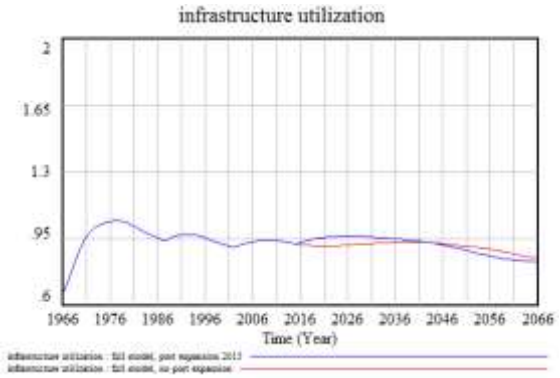


Figure 35. Increased congestion following port expansion despite additional investments

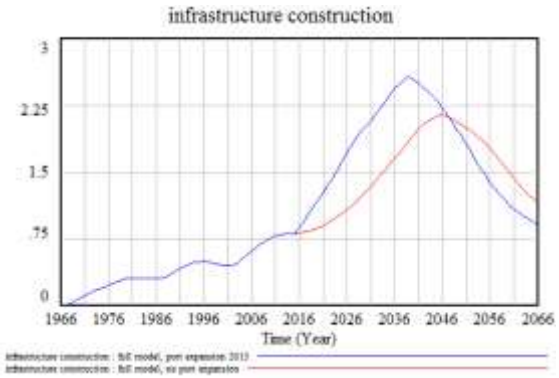


Figure 36. increased infrastructure investments following port expansion

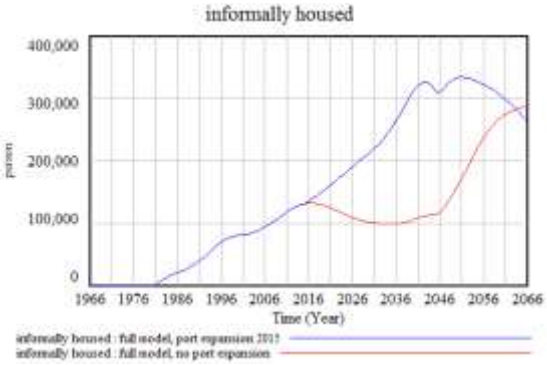


Figure 37. Increase in informally housed after port expansion.

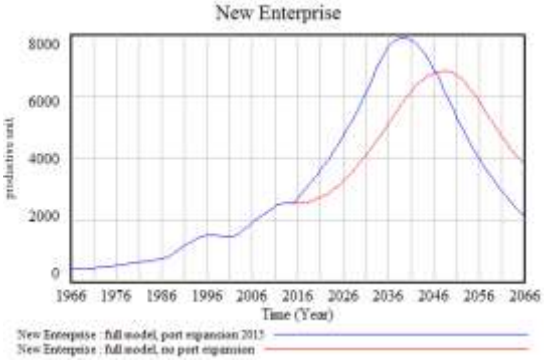


Figure 38. New enterprises in the city increases due to increased port capacity supply

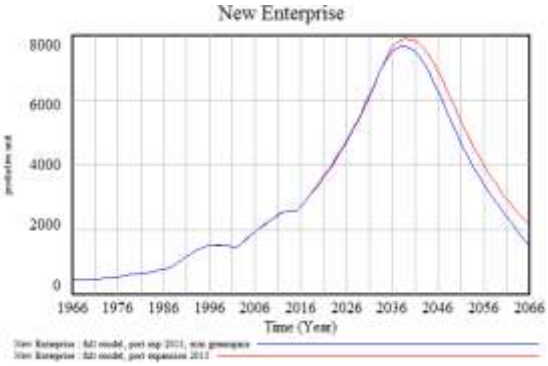


Figure 39. Protection of 1000Ha green space resulting in slight reduction of development

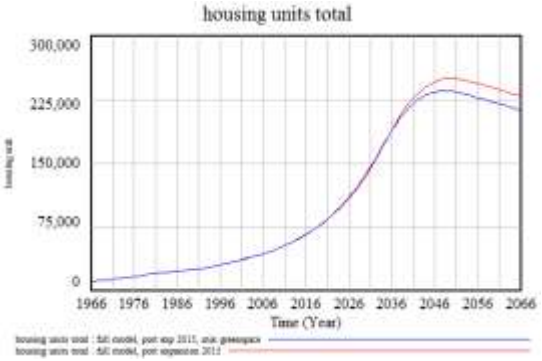


Figure 40. Reduction of housing stock in reaction to green space protection (1000 Ha)

2.11 Sensitivity analysis

The sensitivity analysis covers some 220 parameters and 12 model KPI's. The resulting 250 pages of graphs are too voluminous to include in this document. Therefore, they are added in a separate image databank.

The discussion here will focus on the most important sensitivity analysis results, and present some indicative visuals. The discussion is grouped per sub-model for structure.

The analysis shows that the port parameters can have significant impact on model behavior. This mainly occurs through stimulation of local industry and employment, as expected. Presence of port infrastructure speeds up urban development. An interesting discovery is that limitations on port throughput despite large capacity can have a substantial beneficial effect on the city: relatively less congestion, while local industry can profit maximally from the present port infrastructure (Figure 41)

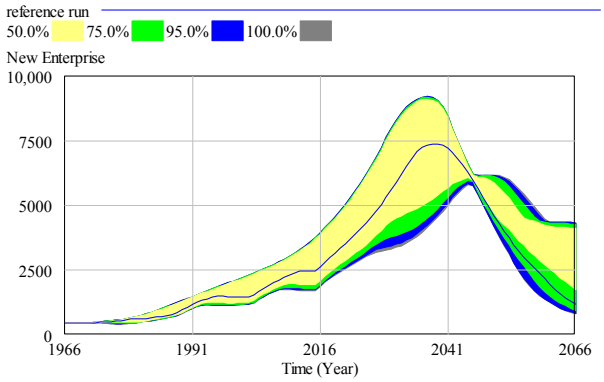


Figure 41. New enterprise stock vs. variations in port throughput growth rate factor [-0.2, 2].

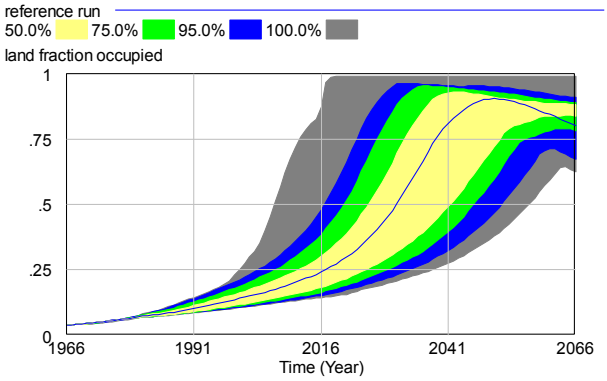


Figure 42. Land fraction occupied vs. multivariate variation of port sub-model parameters (all plausible values, 1000 runs).

Combining all plausible parameter values (e.g. outside port of Tema values) yields plausible results for urban development (Figure 42). Depending on the port, the stagnation phase of the city could be attained at a significantly earlier time.

Land area is identified as a variable with serious impact on model behavior (Figure 43). Not only is the absolute development in terms of population size and industry establishment affected, as the land area can sustain a smaller city, but relative development is affected as well. As a result of Forrester's model specifications, the same city on a smaller land area develops much faster and vice versa. That means that absolute development figures are altered as well. Hence, care is to be taken in defining city land area. Too big of an area might result in no development at all, while too small a land area might result in an overestimation of development dynamics. It might be context-dependent how much land is considered part of the city.

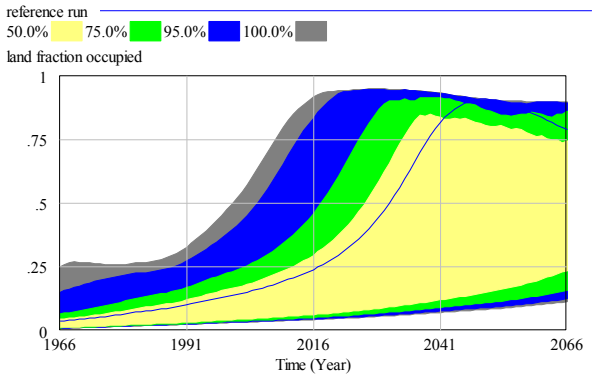


Figure 43. Land fraction occupied vs. land area (-300%, +300%)

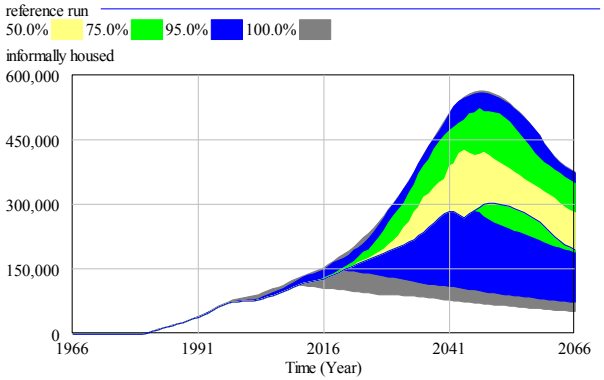


Figure 44. Informal housing vs. housing area zoned [1000 Ha – no zoning restrictions]

Another interesting finding is the modeled impact of zoning policies. While housing zoning policies can greatly affect developmental speed by reducing premium and worker housing levels, a spike in informal housing can be observed. Note that this result is obtained even with Forrester's original model assumptions that housing scarcity halts migration, which does not hold in developing country context (see F.12 Internal validation). The updated model might see even bigger increases in informal housing, reducing zoning effectiveness. Industrial zoning policies are flagged as potentially effective for reducing green space encroachment, as limited employment opportunities might drive people to migrate to other cities, slowing development.

The transport sub-model shows mainly numerical impacts to the model, partly due to the built-in intervention of infrastructure construction: the model adjusts to congestion by building more roads. The rate at which this happens does however influence model behavior (Figure 45).

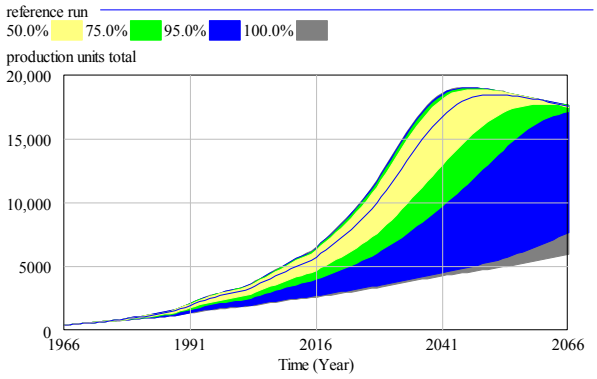


Figure 45. Land fraction occupied vs. transport investment factor [1-10]

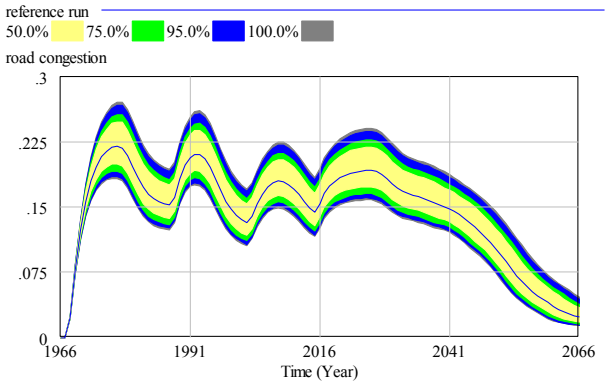


Figure 46. Road congestion vs. transport investment factor [+/- 10%]

The nominal value of the variable *transport investment factor* linking congestion levels to infrastructure investments (the validity of which is scrutinized further in this chapter) is uncertain. Investigating what is an appropriate value reveals the impact this variable has. However, a 10% percent variation of the variable around the default value mainly influences congestion levels (Figure 46), as other indicators show a slight numerical sensitivity.

There are many estimated parameters in this sub-model. However, the analysis shows that uncertainty regarding these parameters is less of an issue, as their influence remains mostly numerical in nature. Care is to be taken interpreting model results especially later in model runs however.

Transport effects on city can be used for minor variations only due to the way it is defined.

Industrially, the model is most sensitive to factors affecting New enterprises, as they make up most of the models industry initially, employ the most residents and influence the construction of new housing. Specifically, the model is sensitive to initial values of New Enterprises (Figure 47).

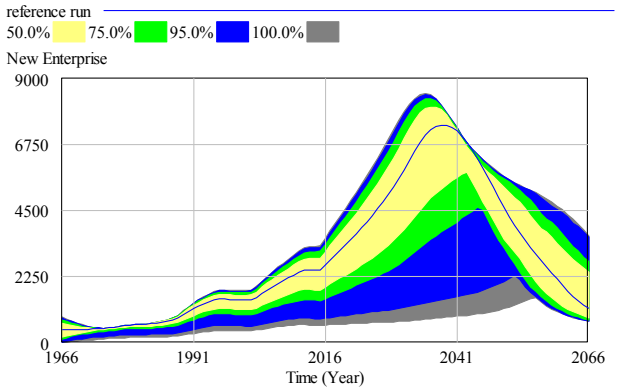


Figure 47. New enterprise vs. New enterprise initial value [0 – 900 productive units]

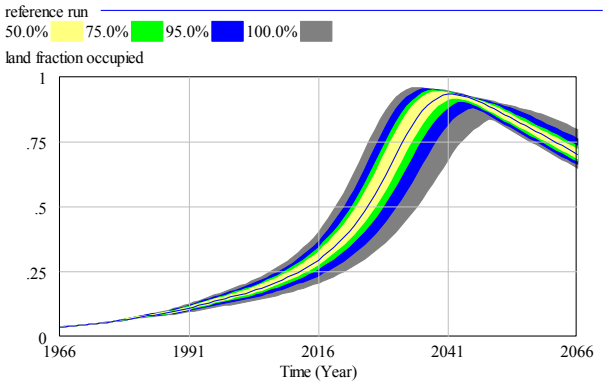


Figure 48. Land fraction occupied vs. all industry sub-model parameters [multivariate, +/-10%]

The model shows numerical sensitivity to Forrester's lookups, in some cases more than 15% at the equivalent of 20% variation of parameter values. These effects increase towards the end of the model run, which is again an indication that the model should not be used for numerical predictions.

Housing initial values have a large impact on model behavior. This is especially true for worker housing, as this makes up the brunt of formal housing in the model (Figure 49).

Note that having initial housing figures that are very disproportionate to the initial population, adversely affects the area associated with infrastructure. This would reduce validity of inferences based on this construct and other model behavior. Conclusion: defining initial housing conditions should take into account population, or initial road infrastructure capacity should be compensated accordingly in order to retain validity of model inferences.

worker housing construction normal is very influential to model behavior. It affects urban growth, shifting peaks and reducing stagnation effects (busts) (Figure 50). It inversely affects informal housing, with lower formal construction leading to increased informal settlement.

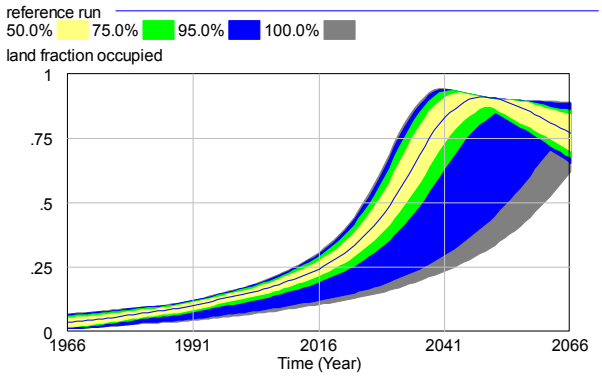


Figure 49. Land fraction occupied vs. initial values for worker housing [973, +/- 100%].

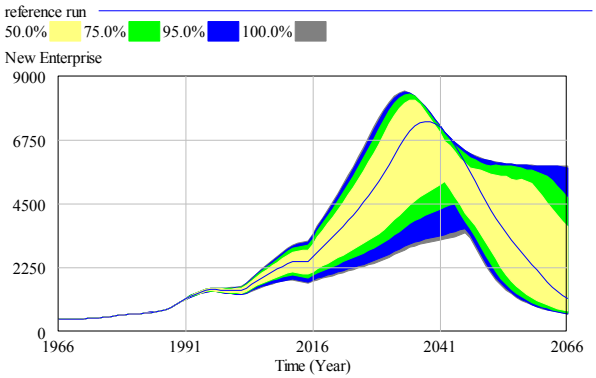


Figure 50. New Enterprises vs. worker housing construction normal [0.02, +/- 50%]

Housing programs can have a significant impact on urban dynamics, both numerically and behaviorally. Especially initial values have a large impact on urban development through compound effects over time (e.g. growth rates).

The sub-model contains a significant amount of variables with little influence on model behavior. Further research could explore the impact and value of removing these variables to improve model size and complexity (Stonebraker, 1972).

In the employment sub-model, variables affecting *Labor* influence the model most, especially growth rates, arrival rates etc. These also have a behavioral impact, shifting peaks for new enterprises, land fraction occupied and housing.

As can be expected, informal housing is sensitive to migration of labor and underemployed. *Underemployed mobility normal* (Figure 51) has a similar influence, attracting more migration, but its impact is mostly numerical.

Multivariate sensitivity shows development trajectories between rapid development with strong stagnation and slow but steady development are possible. In extreme cases, development stagnates at a very early stage, leaving the city undeveloped .

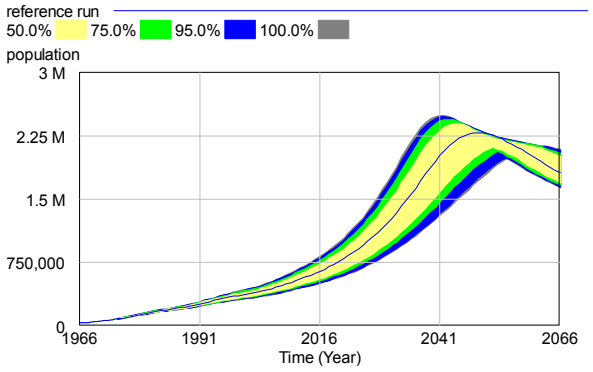


Figure 51. Population vs. Underemployed mobility normal (0.1 +/- 20%)

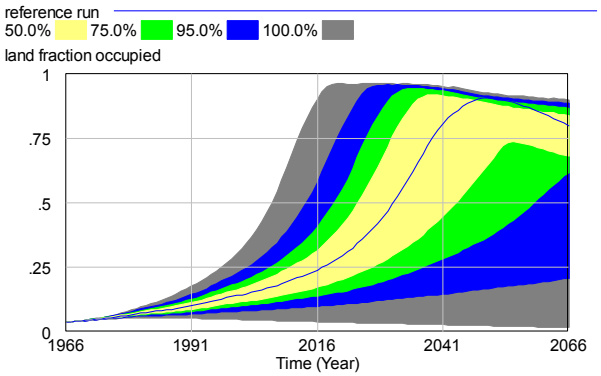


Figure 52. Land fraction occupied vs. employment submodel parameters (multivariate, all plausible values)

The influence of the Job section is modest, for most sub-model parameters. Strong influencers are labor employed per New Enterprise and per Mature Business, as these make up most of the industry in the city. However their influence is mostly numerical only.

Industry automation has a stronger influence, potentially significantly altering urban industrial development and employment, with consequences for urban socio-economic climate (Figure 53)

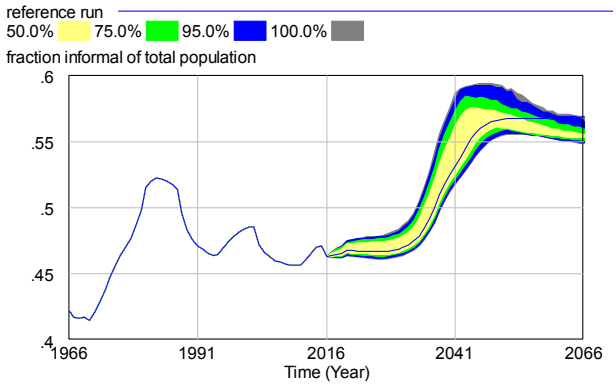


Figure 53. Fraction informal of total population vs. industry automation level rate (0 - 0.03)

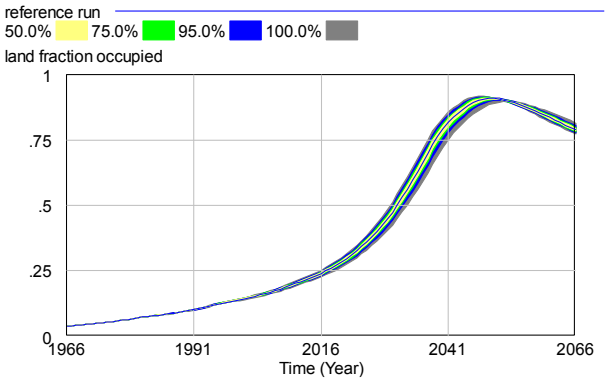


Figure 54. Land fraction occupied vs. tax section parameters (multivariate, +/-10%)

The tax section displays a mainly numerical impact. The assessment of value of New Enterprises has some peak-shifting impact on peaking indicators such as population, land fraction occupied and New Enterprises, but small variations do not significantly affect model behavior (Figure 54).

2.12 Model validation

Where model verification is concerned with whether the model and causal relations are correctly specified and implemented, model validation actually focuses more on the validity of inferences made from the model. This is related to the third research question: *does the constructed model adequately simulate (port city) urban development issues in a developing country?*

As Shadish, Cook and Campbell note (2002), validity is not property of a design or a methodology (e.g. a model), but only of inferences made from or using these. There are no methods to guarantee the validity of model inferences, and the assessment of validity always entails fallible human judgements. It is not possible to completely prove or disprove all inferences made from the model. Therefore, the validity of modelling inferences is not absolute, but rather a matter of degree.

The question of validity is two-fold: a) “are the model results a valid representation of the development of the port city of Tema?” and b) “are model results a valid representation of the development of other port-cities in developing countries?”

Three types of validity will be discussed: internal validity, construct validity, and external validity.

2.13 Internal validity

The question of validity can be disaggregated into internal validity and external validity, each posing different types of validity questions. Internal validity pertains to the validity of claims about causal knowledge. In white-box models, causal relations are presumed to be known or at least specified to be in a certain range of uncertainty. In system dynamics models, uncertainty regarding for instance parameter values and appropriateness of model structure and conceptualization can reduce confidence in the validity of model outcomes and conclusions. As such, limited availability of input data and information, or uncertainty regarding model parameters is a threat to the validity of model inferences.

Choosing the system dynamics modelling methodology, with its modest data needs and clearly trackable assumptions, in itself partly mitigates this. Additionally, Forrester’s paradigm of urban development being a resultant of endogenously generated behaviors further limits the need for detailed information on urban (spatial) processes without affecting the validity of modeling inferences. That is, as long as assumptions and specifications made in the model hold for this particular city and context. How certain and robust the modelling assumptions and parameters are over all possible ranges for input variables and model behaviors, determines internal validity and what kind of inferences can validly be made based on the model, e.g. precise numerical predictions or (more likely) more broad behavioral inferences.

The sensitivity analysis shows that model behavior is numerically sensitive to uncertainty regarding parameter specifications, but is behaviorally fairly robust to changes in model parameters. The model shows plausible outcomes for a wide range of specification and parameter values. In general, model outcomes are sensitive to the specified initial conditions: low values of initial population, housing etc. lead to slowed development on the basis of compound effects like growth rates. It is therefore important to get reliable data on initial urban conditions, which can be a challenge (see Appendix A), and not to start the model from ‘zero’.

Due to various compound effects (such as growth rates and arrival rates) and uncertainty regarding the effects of land scarcity, numerical uncertainty increases towards the end of model runs. This means that the model should not be used for precise quantitative conclusions predictions. Rather, it should be interpreted qualitatively, based on trends and behavior, and with the limitations of the modelling methodology in mind (Forrester, 1970; Sterman, 2000).

The variable *informally housed* appears especially sensitive behaviorally around its peak, so appropriate care must be taken when interpreting model outcomes for this variable.

Another way of assessing the validity of model inferences is by comparing the results of model simulation with data on the actual historical development of the city of Tema. As discussed, model limitations must be taken into account in this exercise; it cannot be expected to follow precisely historical developments numerically. Rather, comparisons should be done qualitatively.

It is important that the comparison is done with the aim of uncovering flaws in the model so it can be improved, rather than using historical data to prove and defend the model's validity, which shields it from criticism and the modeler from learning.

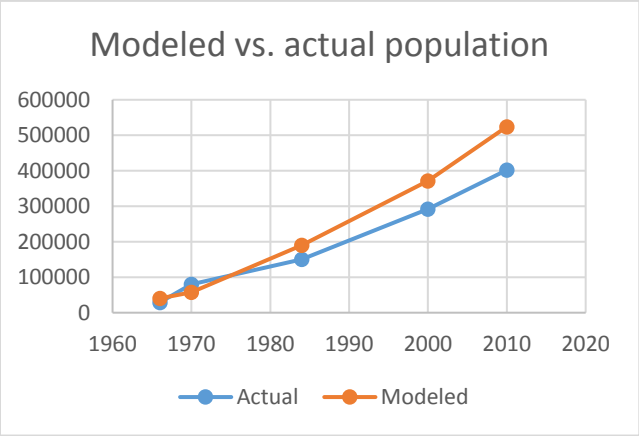


Figure 55. Actual vs. modeled population

Table 10. Actual vs. modeled population

Year	Actual	Modeled
1966	29000	40300
1970	80000	57420
1984	150000	191500
2000	292000	370400
2010	402000	517500

Figure 56 and Table 10 show estimations of actual population figures, based on the 2010 Housing Census (2014b and 2014a), compared with modeled results. The model seems to underestimate the initial explosive growth of the city, while overestimating long term urban growth. One reason for this could be political instability and economic depression in the 70's and 80's reducing urban growth during that time (Yankson and Bertrand, 2012). This reveals a mismatch between Forrester's conceptual stance of relative attractiveness driving urban development, and absolute (global) circumstances influencing development. It could indicate that the model should be adapted to include such absolute effects.
On the other hand, the discrepancy could be explained by the inconsistencies in reported population figures: the World Bank cites much higher estimated population figures for 2000 and 2010: 447,472 and 633,011 urban inhabitants respectively, which are above the modeled figures. At any rate, both series show similar, exponentially rising trends.

Figure 56 and Table 11 show the actual and simulated annual port throughputs, with actual throughput lagging behind the modeled one. Reasons for the difference can be the stagnation of the crisis years in the 1980's not being modeled in the standard modelling run. Secondly, inefficiencies in port operations lowered attractiveness of the port and throughput figures during that time (Coquart, 1998). Port inefficiencies have not been emulated in the model. Thus, the modeled output is consistently on the high side, more limited by (physical) port capacity. However, similar trends are observed. Consequences for modeling inferences will then be mostly numerical in nature. While throughput figures could be tailored to fit actual figures (for instance by simulating temporary economic downturn over the model run), this would only result in marginally improved model performance, and add to a false sense of precision.

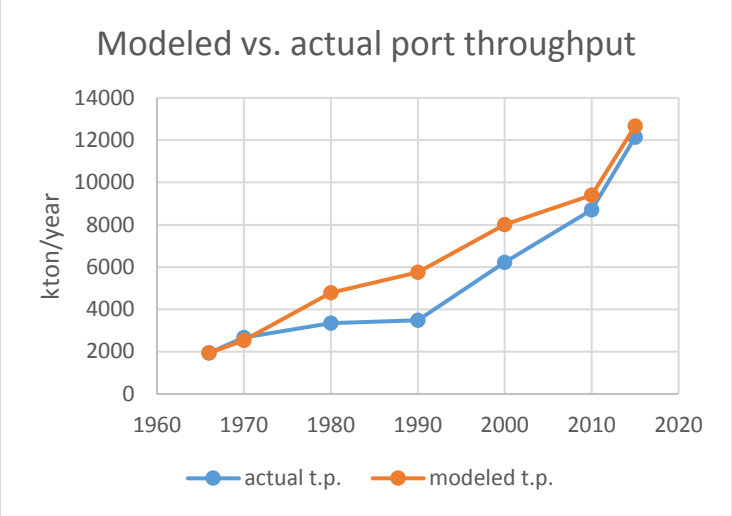


Figure 56. Modeled vs. actual port throughput

Table 11. Modeled vs. actual port throughput

Year	Actual throughput	Modeled throughput
1966	1940	1940
1970	2665	2533
1980	3344	4790
1990	3477	5754
2000	6220	8008
2010	8697	9393
2015	12145	12670

Road infrastructure

Road infrastructure warrants special attention due to the way it is modeled using dimensionless growth factors and with relatively little data input. Data on the extent of road infrastructure provision in Tema is limitedly available and somewhat contradictory. One governmental source places the total length of roads in the Tema metropolitan area at around 1900 kilometers, apparently excluding 'expressways' (see Figure 57). The 2010 housing census however cites a total road length (including Kpone-Katamanso district which is partly outside of the modelling area scope) of only 1237 km, however this figure seems to exclude what is now Ashaiman district (Ghana Statistical Service, 2014b). The modeled road length (assuming an average road width of 3.65 meters) is 1499 km (2008) and 2034 km (2014), which is between the cited figures. Nevertheless, there is a possibility that the figure in Figure 57 is higher because it includes Kpone-Katamanso district. Then, the model might present an inflated picture of actual road construction. This is to be considered in the analysis.

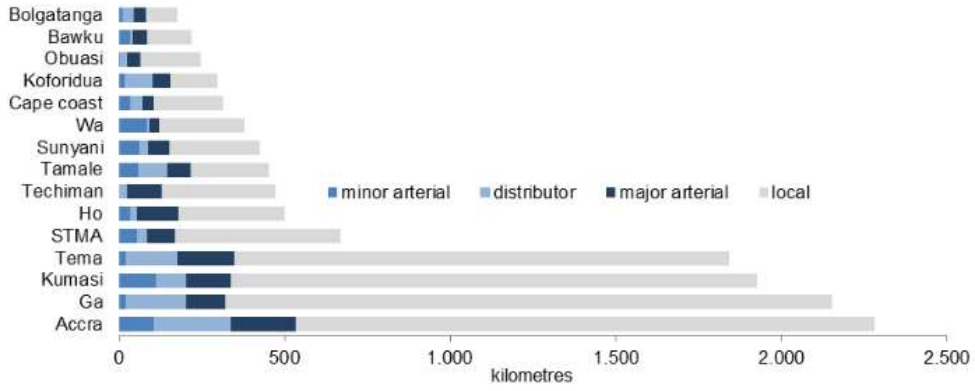


Figure 57. Length of urban roads in major towns and cities in Ghana. NSDF Study 2014 based on Department of Urban Roads, Annual report 2008, excluding expressways (Government of Ghana, 2015).

2.13.1.1 Informal work

Despite being modeled somewhat crudely (see the discussion on construct validity), the model places the percentage of the population that is active in the informal sector roughly between 45 and 55%. Of the modeled active workforce, 55-72% get their income in the informal economy. In reality, 70-80% of the workforce in the GAMA area works informal, however it is estimated that this percentage is slightly lower in Tema (Arup, 2006). Indeed, the 2010 Housing Census states 65.4% of the workforce is employed informally.

2.13.1.2 Informal housing

In 2009 it was estimated that 55% of population living in informal housing (GAMA area). In the model, this percentage at that time is much lower, at 21% (102,500 of 498,000). Although it is possible that Tema has higher formal living percentage than Accra, it seems that the model systematically underestimates the extent of informal settlement.

Table 12 compares the population of Ashaiman (Tema's largest informal settlement) to modeled results, which are consistently low numerically. Behaviorally, informal settlement starts late, as it is mainly driven by housing availability. The model correctly captures the housing shortage which began around the 1980's (Acquah, 2001). However, in reality by that time already a significant proportion of Tema had settled informally, despite the prior housing abundance. That is an indication that a limitation in housing availability is not the only driver of informal settlement, but that one or more confounder effects are present, for instance poverty among laborers (which is not explicitly modeled). Nonetheless, shortage of housing has been cited as a major driver of informal settlement around Tema (Owusu, 1991).

This systematic mismatch of model behavior and actual patterns necessitates a re-examination of the validity of model assumptions. It seems that Forrester's original modelling assumptions on housing availability limiting migration to the city are not valid for Tema and possibly developing country cities in general. In other words, low formal housing availability doesn't deter people from settling in the city informally, erecting their own shelter.

In order to improve model inference validity, these causal relationships are included in the model by altering Forrester's *housing availability* multiplier lookups, halving the deterring effect of housing shortage on *labor* and *underemployed* class. Normal *premium* and *worker housing construction rates* are adjusted downward to reflect the reduced formal construction. This shifts the housing stock in favor of informal settlement at the cost of formal worker and premium housing and better reflect actual causal relations in the city without significantly affecting the speed of urban development.

Table 12. Informal settlement: Ashaiman population vs. modeled results

Year	*Ashaiman population*	Informally housed (modeled)	Informally housed (alternate model)
1960	2624	-	-
1970	22549 *(0.28)*	0 *(0.00)*	0 *0.00)*

1984	50918 *(0.34)*	13110 *(0.07)*	18,080 (*0.10)*
2000	150312 *(0.52)*	75390 *(0.20)*	124,100 *(0.34)*
2010	190972 *(0.48)*	107200 *(0.21)*	176,700 *(0.37)*

Table 12 shows informal settlement figures for the adjusted model. While improving causal relationships improves precision is still not attained (nor can be expected of the model), it provides a more valid picture of informal housing and informal housing stock (11,780 modeled vs. 17,021 actual). The possibility should be noted that not all of Ashaiman comprises of informal settlement, and not all informal settlement around Tema is situated in Ashaiman. A stagnation of growth in Ashaiman does not necessarily mean informal settlement doesn't increase elsewhere around Tema, e.g. in the lagoon.

Other indications of model inference validity include the average number of *persons per housing unit*. The model value for this is 10.5 (2010 model value) vs 7.1 in Tema and 10.9 in Ashaiman (Ghana Statistical Service, 2014a, b). This might be related to the nominal housing densities for premium and worker housing being too high. However, the difference could also be ascribed to variation in the definition of what constitutes a housing unit in the cited census (e.g. Schroeder and Strongman caution against this in Mass, 1974). Alternatively, the difference can be attributed to an overrepresentation of what Forrester called the underemployed, for which no real-world counterpart is defined in census data. At any rate the model provides a plausible figure.

2.13.1.3 Land use

Less realistic is the picture for land use. *Built-up area* combined with *infrastructure area* seems very low compared with estimations by Mariwah, Osei and Amenyo-Xa (2017) and Kangeri (forthcoming) (ca. 100 km^2 vs 38 km^2 modeled, 2015 values), and general notions that the metropolitan area is mostly urbanized (Aarup, 2006). While population density per km^2 in the model is plausible (2875 person/km^2, 2010 model value compared to 4222 and 3361 person/km^2 for Ashaiman and Tema Metropolitan, derived from Ghana Statistical Service 2014a,b), the associated modeled value of *land fraction occupied* of 0.17 appears low. It should be noted that the model does not explicitly represent public spaces such as squares and market places, and public institutions such as schools, government buildings, fire and police departments and the like. Also not included are service establishments such as restaurants and offices. Moreover, despite the extent of urbanization, urban density in Tema might double or triple to approach Accra city values.

Green space area in the model decreases to 2058 ha (2017 value), which is relatively high when compared with real world estimations of the Sakumo lagoon size and RAMSAR site (ca 1400 hectare) (Kangeri, forthcoming; Kufogbe, and Amatekpor, 1997; Gbeckor-Kove, Gordon and Mensah, no date). The earlier mentioned discrepancies with land use and the relative proximity of the lagoon to Tema communities and the coast might explain the increased settlement observed.

While the difference could be explained by a mismatch in the definition of what constitutes built up area, the consequences for the validity of model inferences could be significant, providing an overall overestimation of urban size and population later in the developmental stage. Particularly, it could mean

that the stagnation phase observed in model behavior will set in much earlier than indicated in model runs. Care should be taken when interpreting model results, and active debate on the validity of underlying modelling assumptions should be encouraged with model use (Shadish, Cook and Campbell, 2002).

2.14 Construct validity

Construct validity pertains to how concepts are defined and how they are measured. Using a particular construct (like *congestion*) can frame debate about results, raise expectations, increase relatability of outcomes, and facilitate making policy recommendations people and policy makers understand. However, validity of model inferences can suffer when constructs used are ambiguously defined, or are not what is actually measured (or simulated).

The validity of model inferences can be improved by providing a clear description or explication of constructs used in the modeling effort, including the object of interest (developing country port city), outcomes of interest, model concepts and variables, interventions, and contextual factors. Secondly, attention should be paid whether the instances chosen or defined for these aspects adequately match these descriptions. On a unit level, this means assessing how Tema compares to the used definition of a port city in a developing country. For model conceptualizations, it means assessing if concepts like *Green space* and *road congestion* are modeled in a way that is consistent with their definitions. Does the definition of constructs have consequences for the validity of inferences based on them?

The following is a short assessment of model construct validity, per sub-model.

2.14.1.1 Port sub-model

Port throughput, commonly measured in kton/year, is often used as a key performance indicator for port performance. As containerization is on the rise, the use of TEU as a measure of port (container) throughput becomes more prevalent, and cargo tonnage may present an erroneous view of port performance (Rijkure, 2016). However, for reasons of simplicity the model does not make this disaggregation. A more specific measurement of port throughput could make the sub-model more realistic, but would not add validity to model inferences at this level of modelling.
Port capacity as a concept is more tricky. In the model it is simply defined as the upper yearly cargo handling capacity, measured in kton/year. However, in reality it involves a variety of notions like port efficiency, disaggregated cargo handling times and even berth depths and sizes, limiting the type of ships that can be serviced (Park, Yoon, and Park, 2014). As such detail does not serve the research questions, it is not disaggregated in the model. To avoid misunderstanding, especially in discussions with port experts, it must be made clear how this construct is defined within the model.
level of port automation is modeled only as an impact on employment. In reality, automation goes hand in hand with port expansions and increases in capacity and efficiency, in term increasing port attractiveness for ships and therefore throughput. Modelling such more detailed causal links does not suit modelling questions of this study (which focus on the impact of port expansion on the city), and is for the benefit of model succinctness. This could however raise questions in discussions with experts, and careful explication is needed.
throughput growth rate factor does not resemble an easily recognizable real-world concept, but serves to model other outside influences on port throughput such as international economic climate and competition from other nearby ports, affecting port utilization.
Port utilization is simply the ratio of port capacity that is currently used, again dismissing more detailed

aspects of port capacity.
port effect on industry ties in to Forrester's construct of relative attractiveness which itself required careful explanation and defense (Forrester, 1970). To correctly interpret this effect as it is modelled, one has to be aware of this broader concept.

2.14.1.2 Land section sub-model

Green space is a construct that can encompass a wide range of land types. It can be defined as "land that consists predominantly of unsealed, permeable, 'soft' surfaces such as soil, grass, shrubs and trees" (Swanwick, Dunnett and Woolley, 2003 p.97). However a wide range of definitions and types of (urban) green space exist, including wetlands, parks and gardens, and open water. Moreover, it carries notions of public accessibility and recreational and ecological value. It is not necessary to discern between types of green space in the model in order to assess impact of urban and port developments. However, to avoid confusion it may be necessary to define what the construct of *Green space* means, in contrast to (other land use types such as) *available land* and *built-up area,* as confirmed by interview experience (Appendix G). As green space takes away from available area, widening its definition in the model will affect modeled urban development, as this is partly driven by land directly available. It is therefore important to make that distinction conceptually that green space is distinct from undeveloped or set-aside wasteland which could be readily developed.

Available area is undeveloped land that is not green space or already developed. It might include agricultural land and unproductive grasslands which do not warrant the status of green space.
societal willingness to settle green space is a construct encompassing social and cultural values regarding the settlement of green space. As those values might originate and differ locally, the concept of *societal willingness to settle green space* can be context dependent.
green space settlement factor is a construct that captures the likeliness of green space settlement as a factor, e.g. twice the amount of green space settlement for the same remaining land availability. It can serve as a proxy for spatial proximity of green space to urban centers, but must be defined clearly to avoid misinterpretation.
max green space is mean to capture the concept that not all land could by itself revert to the status of green space after it has been abandoned. For instance, the presence of tipping points in eco-system degradation could mean that green space once developed cannot revert back to its former status without active restoration efforts. Alternatively, lands could lack the properties to become green space at all.

2.14.1.3 Transport sub-model

Infrastructure capacity is modeled as a dimensionless construct in order to keep model complexity down and limit data needs. This way of modelling makes the construct somewhat less relatable. However, it facilitates the derivation of congestion as a function of supply and demand without needlessly complicating the model. The variable *road length* is added to provide a more relatable translation of infrastructure supply, which can be compared to real-world data.

Road congestion is a concept for which no single useable definition exists (European Conference of Ministers of Transport, 2007). It can include notions of subjectivity, personal expectations, and contextual factors. In this study it is simply defined as the situation where the (theoretical) demand for road space exceeds the supply (European Conference of Ministers of Transport, 2007). Average demand that is, as the modelling level doesn't allow for detailed modelling of periodical fluctuations commonly

associated with congestion (e.g. rush hour). This modelling choice is however of little consequence for the validity of inferences based on it. Causal relations still hold, meaning that congestion increases when demand for road space increases (or supply of it decreases).

Total infrastructure demand refers to the demand for road transport, which should be clearly conveyed when using the model. As explicated, demand does not disaggregate into peak demand or individual trips, as data on such concepts is scarcely available without adding to model strength. Simple causal relations are chosen: population road demand rises proportionally with the size of the population, port road demand with the increase of port throughput transported by road.

Transport investment factor is a construct that has no clear real-world counterpart. It relates the level of congestion to investments in road infrastructure. The concept therefore embodies notions such as willingness to invest, the availability of resources or funds for road construction, and the proportional amount of road construction in reaction to a certain level of congestion. As *infrastructure capacity* is modeled as dimensionless, the construction of roads is relatively meaningless without a lengthy conversion to kilometers of road length. One consequence of this is that the notion transport investment cannot be effectively calibrated based on real world data. That means that the validity of model inferences from this sub-model must be assessed using the converted *road length*, which can be compared to actual data. Regardless of the definition of this factor, the basic causal relation between road supply, demand and congestion still holds: no investments lead to increasing congestion with increasing demand.

per capita transport demand reflects the increase of car ownership in Ghana with rising economic wealth, which is one major cause of congestion in Ghanaian cities (World Bank, 2015). It is important to note that *road infrastructure demand population* does not disaggregate between trips in cars or in taxi's or buses. Increase of car ownership might coincide with fewer trips per bus or taxi, but only an aggregate (lower) increase in per capita transport demand is defined.

2.14.1.4 Industry Chain

The industry chain is modeled as an aging chain of *productive units*: New enterprises, Mature Businesses, and Declining Industries. Forrester defined these constructs by their respective properties (assessed value, typical employment profiles). It is important to note that this construct does not refer to businesses themselves (e.g. start-ups) but to business structures: actual buildings and their inventories, covering an area of 2 acres (Forrester's definition). This way of defining the construct of industries has relatively little bearing on the real world situation. Where housing units actually have a typical area, tied to the occupancy rates and household sizes, industries come in various sizes and are not bound by such notions. This means that the construct of a *productive unit* as defined by Forrester, while a useful construct, is not a valid base for making inferences on the amount of businesses actually present in a city. However, the same does not apply to modeled employment, as this is in fact related to the area of business structures (i.e. one company occupying twice the land area can be assumed to employ twice as many workers and managers).

The appropriateness of modelling businesses this way, and using an aging chain has been debated (for instance Mass, 1974), although critiques often seem to stem from the misinterpretation that New enterprises denote newly started businesses (start-ups) instead of buildings. This goes to show that care should be taken in explicating these constructs.

The constructs of New enterprises, Mature business and Declining industries are not well defined in terms of what type of enterprises they include. The characteristics as defined by Forrester can include a wide range of industries such as manufacturing, production and heavy processing of resources. Forrester's definition however does not seem to extend to include service and retail industries, due to their differing characteristics regarding employment and 'housing'. To what extent does this omission of service and retail industry reduce validity of model inferences?

There are two arguments concerning this. One is that service industry plays a modest role early in port-city development, when there is still a high dependency of the urban economy on maritime and port functions, or additional attracted industrial activities. Later diversification of the urban economy to include a service economy then reduces dependence of the urban economy on its port, as it becomes a more 'general city' (Ducruet, 2006). The impact of not regarding the service industry in the model then depends on the developmental stage of the port city that is being simulated. Tema, intended to become the industrial center of Ghana (Hoyle and Hilling, 1970) still serves as the industrial hub of Ghana (Ghana Statistical Service, 2014b).

Another argument concerns the relevance of the service industry to the modelling and research questions. It is stated that employment impacts of port expansions in port regions are more substantial in the industrial than in the service sector (Rodrigue, Comtois, and Slack, 2017), suggesting that a focus on industry is validated. However, there is also some contradicting research stating that the service sector would benefit most from port expansion (Eltalla, 2016). However, this can still mean that the associated employment impacts of industrial stimulus are larger.

Another sector that is not considered is the transport sector. Employing about 8.8 percent of Tema residents (Ghana Statistical Service, 2014), it forms a substantial industry (larger than fishing and construction). Based on the available data it is however impossible to disaggregate between transport generated from the port and from industrial activities. Instead, it can be constructed as being captured in industrial and port employment.

2.14.1.5 Housing Chain

The housing chain also employs an aging chain structure, dividing the housing stock into three groups. Housing units are defined by their land area and occupancy rates. As housing ages it degrades into 'lower' forms of housing, with higher occupancy rates serving other socio-economic classes. The actual rates of obsolescence (aging) of housing are related in the model to the demand for housing of that type. The construct of housing obsolescence as used by Forrester is appropriate for Tema. Lack of funds have resulted in the degradation of former worker housing estates into 'slum estates' within a time period of forty years UNCHS (HABITAT), 2003).

The constructs of premium housing, worker housing and underemployed housing, while relatable, are not used in the same way in census data on Tema. In the model, *premium housing* is defined to house only *managerial-professional* families, *worker housing* only labor class families and *underemployed housing* only underemployed class. In reality, this distinction is not so strict; a significant proportion of original slum dwellers were actually formally employed (Owusu, 1991). However, the question is if the basic causal mechanisms like different housing types attracting different kind of urban residents still holds. That it indeed seems the case that slum estates turn into 'underemployed housing', housing low-income resident at high occupancy rates (e.g. Mazeau, Scott and Tuffuor, 2012; UNCHS (HABITAT), 2003; Paller, 2012) increases confidence in the validity of inferences based on these constructs.

Alfeld (in Mass, 1974) cautions against imposing on the model constructs based on different principles. The construct of *housing unit* is at risk for this: what constitutes a housing unit may differ between for instance census data (Ghana Statistical Service, 2014b), alternate sources (e.g. Mazeau, Scott, and Tuffuor, 2012) and Forrester's use of the construct. It is important to keep this in mind when comparing figures (for instance on housing occupation) or validating model outcomes.

2.14.1.6 Informal housing

Informality is a common construct, and can be defined as "opposed to the laid down rules or the accepted norms" (Obeng-Odoom, 2011). It is most prevalent in how people find shelter (informal housing) and income (informal economy). In terms of informal housing, an estimated 46% of the urban population is living in slums: informal housing is a common construct, typified by insecure land tenure rights and low service infrastructure provision (UNHCS (HABITAT), 2003; Paller, 2012). In the model informal housing rates are derived from the total population and the extent of the 'formal' housing stock as defined by Forrester. Conceptually, that means there are two types of slums, *underemployed housing* and *informal housing*. This conceptualization is preferred to one where informal settlement just adds to *underemployed housing*, as using that construct would limit informal housing to the *underemployed* class.

2.14.1.7 Employment Chain

Originally, Forrester flat out defined the workforce to be comprised of men, supporting their families at home. This construct has been made somewhat more inclusive in this study by adopting the more neutral unit of measurement of 'worker' instead. However, the definition still limits families to having only a single formally employed member. This has consequences for the validity of inferences regarding informal work in the city.

The constructs of workers used in the model, e.g. Managerial-professional, Labor and Underemployed, are not all terms used as such in census data. The validity of the construct of Underemployed has been criticized and defended before, based on its value of usefulness and appropriateness (Goodman, in Mass, 1974). Within this modelling study, the category is amended to include informal workers. The validity of this construct is based on the assumption that the unemployed don't enjoy welfare support like in Forrester's model, and should work informally to gain an income. Note that originally the construct only applied to men (or family head supporting non-workers). As many women work either formally or in the informal sector, it is not appropriate to take the underemployed category as the total of informal workers, prompting the need to derive this in another way.

Managerial and professional are categories discerned in census data (Ghana Statistical Service, 2014b) and relatable as such. This construct can be used to validate model inferences.

2.15 External validity

External validity raises the question to what populations, settings, and variables the effects found in the study can be generalized (Shadish, Cook and Campbell, 2002). Model inferences may be more or less valid under different circumstances, settings or units. For instance, the question must be raised whether conclusions from the modelling study on Tema would apply in the same way for other developing country port cities.

There exists a trade-off between local and general validity of modelling inferences. Tailoring the model to represent Tema can increase the validity of modeling inferences for this city. However, conducting

policy experiments in one (restricted) setting limits generalizability of the modeling outcomes to other port-cities and different circumstances. The sensitivity analysis and scenario analysis address this by investigating model behavior under a variety of settings and contexts. In this case, an ideal model would be particular enough to yield conclusions valid to Tema, but general enough to adequately describe developing country port cities in general.

Modelling assumptions play a key role in the assessment of external validity. The question to what extent modeling conclusions can be generalized to hold for other port cities in developing countries comes down to whether the modelling assumptions still hold and apply in these cities. More precisely, threats to the validity of model inferences stem from potential interactions of model causal relationships stemming from variations in (1) Units, (2) Modeling outcomes, (3) outcomes, (4) settings, and through (5) context-dependent mediation (Shadish, Cook and Campbell, 2002). These interactions are explicated in Table 13.

Table 13. Sources of threats to validity of model inferences

Source	Comment
Unit variations	Model causal relations and inferences might not hold in other kinds of units, e.g. other port cities in different stages of development (diversification)
Intervention variations	Model causal relations and inferences might not hold if interventions are implemented partially or in combination with others, etc.
Differences in outcomes	Do interventions have beneficial effects on other KPI's (closely) related to the ones studied?
Setting variations	Model causal relations and inferences may be present under certain circumstances but not in others not studied
Context-dependent mediation	There may be explanatory mediators of a causal relationship present in one condition but not the other, influencing causal relationships and results, reducing model inference validity.

Differences in the port cities themselves (unit variations) could for instance be related to the stage of development, size, diversification of the urban economy and port prominence vs. urban prominence (e.g. Ducruet, 2006). Alternatively, there may be differences in context (settings): economic climate, technological development, population car ownership, rural economic state, outside the range studied. Thirdly, there may be differences locally in preferred (model) outcomes and values regarding for example the loss of green space. This would have consequences for what constitutes beneficial interventions and the interpretation of modelling results. Context-dependent mediation might for instance occur if changes in the model context (unit studied, settings) cause essential processes (not) to take place. For instance, due to differences in land tenure rights and social standards in the developed world, a housing shortage would not lead to significant increases of informal housing there, restricting model inference validity.

Shadish, Cook and Campbell (2002) state five principles for making causal generalizations from studies, which can be employed in the assessment of external validity of modeling inferences in this study.

2.16 Conclusions

Model verification and validation shows that the model is relatively robust behaviorally over a wide range of parameter settings. The stability of the model suggests that it can be used to model a wide variety of developing country port cities, and that model inferences are generally stable.

Due to the model's sensitivity to initial conditions, care must be taken to provide correct figures for industry, housing and population. Comparison of modeling results with historical figures shows approximation and plausible outcomes for most indicators, but less favorable for some, most notably the land area occupied. The limitations of the model concerning the modelled sources of employment (only 'industry') and land use means that a partial picture is presented, which can skew model outcomes. This could negatively affect external validity and generalization of model inferences for port cities with lower port prominence and more diversified economies.

In conjunction with the limited validity of some used constructs (for instance *fraction informal of total population*, *production units*, and *infrastructure capacity*), this means that care is to be taken when interpreting model outcomes, especially for these constructs.

As the model is numerically sensitive to parameter changes especially later in the model runs, it should not be employed to make precise predictions of urban development. Rather, model inferences should be of a qualitative nature, taking into account model limitations. Doubts regarding modeled land impacts of urban development means that timing of certain behaviors like peaking and stagnation might occur earlier than modeled.

That said, the model verification and validation process increased confidence in the validity of model and sub-model behavior. Sensitivity testing suggests the model can be used to model urban development of a wide range of potential developing country port cities. Model shortcomings and consequences of these for outcome interpretation have been identified and documented. The process tested the validity of model assumptions and produced concrete improvements where these were shown to be lacking.

Uncertainty regarding modeling assumptions and strength of causal relations, general model shortcomings, and the potentially ambiguous interpretation of some used constructs all suggest the encouragement of open debate on these subjects when using the model with stakeholders or applying it to alternative case studies (Shadish, Cook and Campbell, 2002).

3 R-code for model data-analysis

This section contains the R-code used for model analysis.

Software requirements: The code was used with R 3.4.1, and R-studio 1.0.153.

Vensim model dataset exportation settings:

Export as: .csv
Save list: preferably the KPI's used in the analysis, but others are possible
Time running: down

The script working directory needs to set to the folder containing the exported model output datafiles.

The code:

```
#Set working directory and load necessary libraries
setwd("O:/Afstuderen/Models final/")
library(fmsb)
library(radarchart)
library(formattable)

#load runs
refrun <- read.table("reference run.csv", header=TRUE, sep=",",
stringsAsFactors=FALSE)
policy <- read.table("Slum housing demolition program (200).csv",
header=TRUE, sep=",", stringsAsFactors=FALSE)

graphtitle<-"Low cost housing program (200) (unweighted)"

##Choose weighting!
#Weights<-c(0,0,0,3,2,1,-2,-2,-2,-1,-3)
Weights<-c(0,1,1,1,1,1,-1,-1,-1,-1,-1)

#Reduced port by road & pc road demand.csv

refrun
policy
#create years of interest, choose discount factor
range = seq(2017,2057, by=1)
discountingfactor<-0.0

#Set up results table and weights
Scores<-policy[0,]

# Add Weights to table!
for (i in 1:ncol(Scores)){
  Scores[1,i]<-Weights[i]}
Weights<-Scores
Weights
Scores<-policy[0,]
Scores

#Create results
years = range   # this can be changed to something else
```

```
pol<-c()
ref<-c()
scor<-0
rowcounter<-1

#Create results: for every year and every KPI value, calculate the relative
change between reference and intervention, and apply discount rate.
for (j in 1:ncol(Scores)){
  rowcounter<-1
  for (i in (years-1965)){
    pol[rowcounter]<-policy[i,j]
    ref[rowcounter]<-refrun[i,j]
    scor[rowcounter]<- (pol[rowcounter]-ref[rowcounter])/ref[rowcounter]
    scor<-scor[rowcounter]*(1-discountingfactor)^(i-52)
    Scores[rowcounter,j]<-scor
    rowcounter<-rowcounter+1}}
Scores

#add model years to table
count<-1
for(i in years){
  Scores[count,1]<-i
  count<-count+1}
Scores

#Weighing radarchart effects: Weigh the deviation scores, add 1
Normscores<-Scores
for (i in 1:ncol(Normscores)){
  print(i)
  Normscores[,i]<-Scores[,i]*abs(Weights[,i])+1} # abs for same direction
Normscores[,1]<-Scores[,1]
Normscores

Meanscores<-Weights
for(i in 2:ncol(Scores)){
  Meanscores[,i]<- mean(Scores[,i])}
Meanscores<-Meanscores[-1]
Meanscores

#Sum weights to divide by later
Weights
Weightsum<-sum((abs(Weights[-1])))
Weightsum

#Weigh Mean scores, add them up
Meanscores<-Meanscores*(Weights[-1])
Meanscores
Totalscore<-sum(Meanscores)  #/ncol(Meanscores)
Totalscore<-round(Totalscore, 3)
Totalscore   #percent

 ##RadarChart: define years to plot##
years2 = c(2017, 2027, 2047)
Normscores2<-Normscores[ Normscores$Time %in% years2, ]
Normscores2

d<-data.frame(Normscores2)
```

```
d.T <- t(d[,2:ncol(d)])
colnames(d.T) <- d[,1]
labs<-rownames(d.T)
##plot radarchart
e.T<-cbind(as.character(labs), as.data.frame(d.T))
chartJSRadar(scores = e.T,labelSize=12, width=610, height=500,
scaleStepWidth=0.5, maxScale=1.5, main = graphtitle, polyAlpha = 0.1,
scaleLineWidth=5)
##end##

##MCA table##
library(formattable)
Meanscores

Resultstable<-t(Meanscores)
Resultstable
colnames(Resultstable)<-"Score"
Resultstable

Weights.T<-t(Weights[-1])
colnames(Weights.T)<-"Weight"
Resultstable<-cbind(Weights.T, Resultstable)
Totalscore<-cbind(1,Totalscore)
Totalscore
Resultstable<-rbind(Resultstable, Totalscore)

Resultstable
Resultstable<-data.frame(Resultstable)
Resultstable[,2]<-percent(Resultstable[,2],digit=1)


formattable(Resultstable, list(
  Score = formatter(
    "span",
    style = x ~ style(color = ifelse(x < 0 , "red", "green")),
    x ~ icontext(ifelse(x < 0, "arrow-down", "arrow-up"), x))
  ))
#Restate discounting factor to check
discountingfactor
```

4 Sensitivity analysis

Developing countries are relatively data-poor environments, which makes formulating quantitative models a challenging task. Lack of data on parameters and even model structure introduces uncertainty in the model and could even reduce a model to plausible nonsense (Pruyt, 2007; Nuthmann, 1994 in Pruyt, 2007).

A complete sensitivity analysis is performed to assess the sensitivity of model behavior to alternative values of model parameters and model structures. Model outcome changes for several model KPI's are evaluated. This includes numerical sensitivity, and behavioral sensitivity to variations of model parameters.

-To be studied: values of constants, lookup function shapes, initial values of stocks.
-Change values for this particular case, or to investigate whether the model provides plausible results for other case-study contexts.

The KPI'S selected for the sensitivity analysis are:
New Enterprise, production units total, land fraction occupied, Green space, population, fraction informal of total population, informally housed, housing units total, fraction underemployed of population, infrastructure capacity, road congestion.

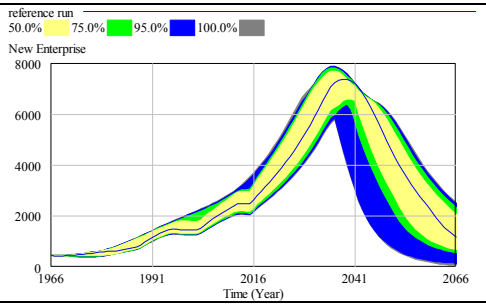
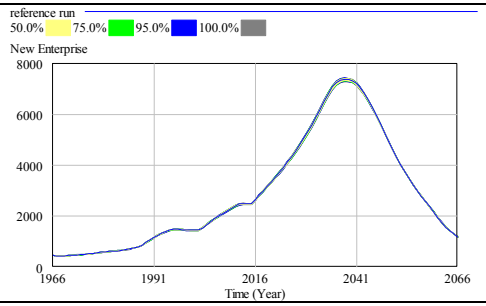
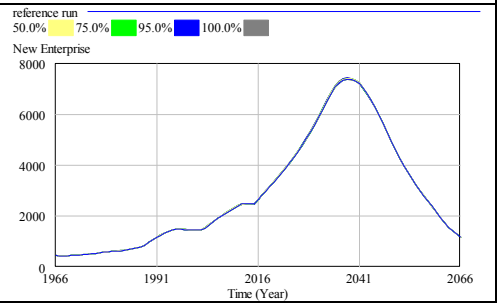
All testing will take the full model with 2015 port expansion as a reference run.

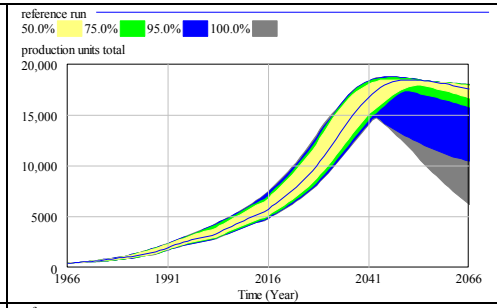
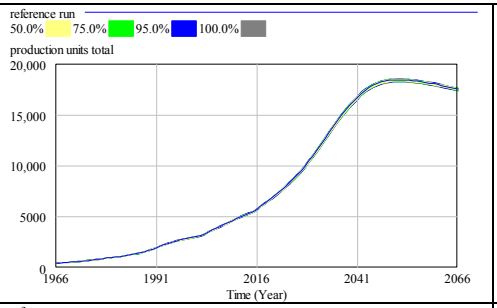
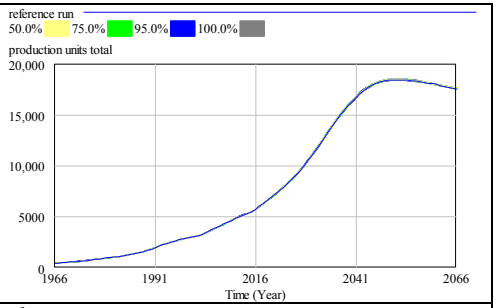
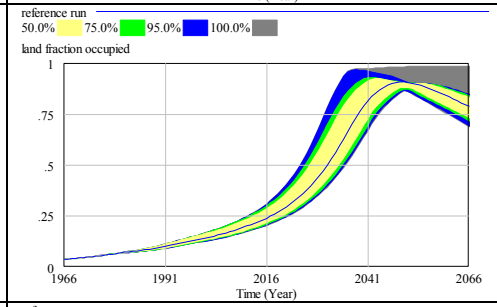
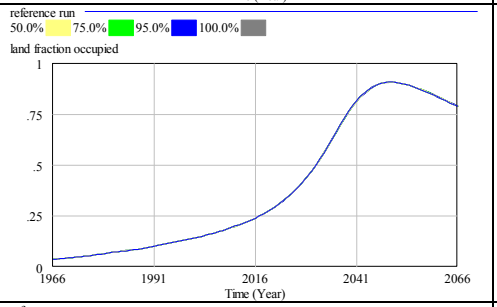
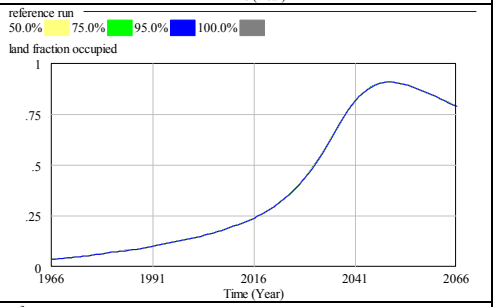
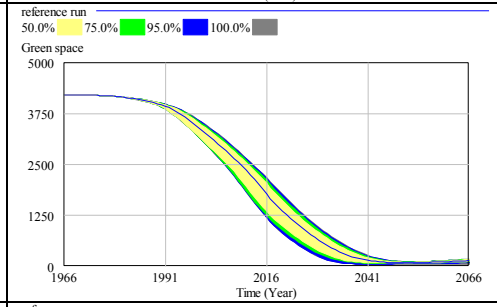
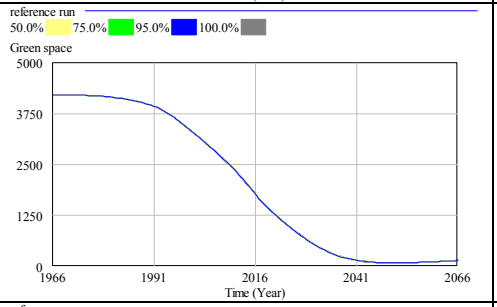
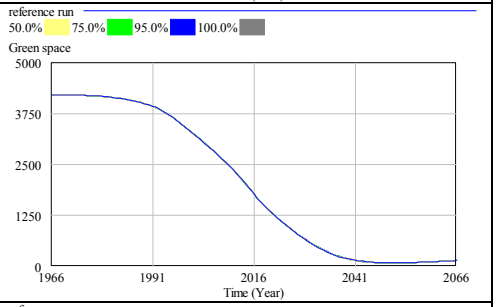
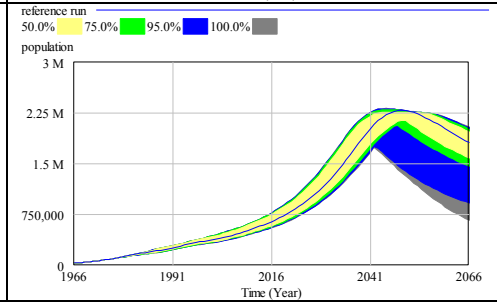
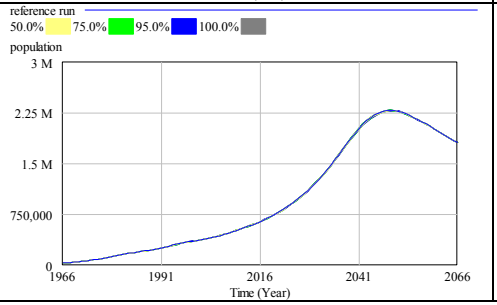
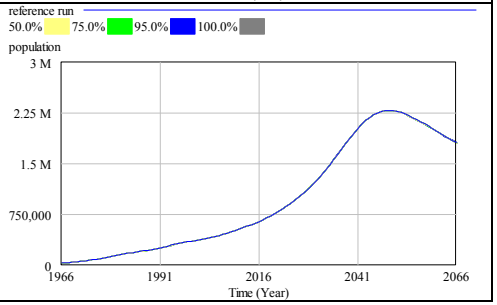
The sensitivity testing was performed with a version of the model without green space impacts on migration, and with Forrester's inappropriate assumptions on housing shortages deterring migration to the city that were corrected afterwards.

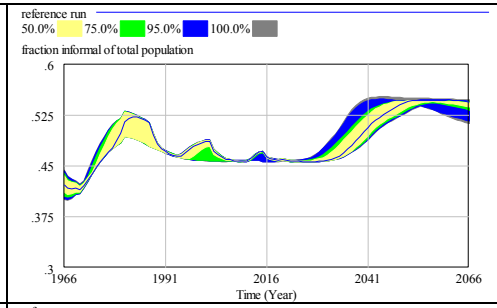
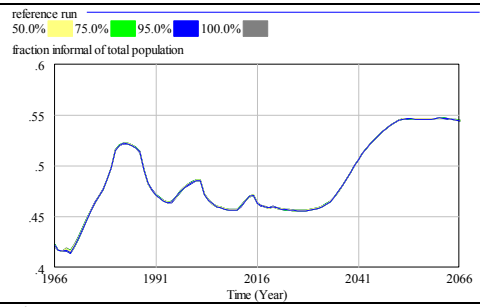
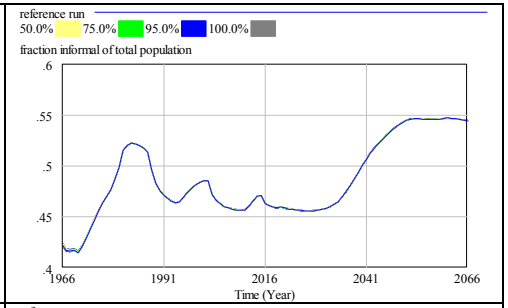
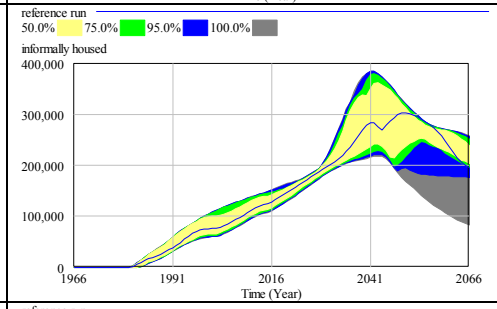
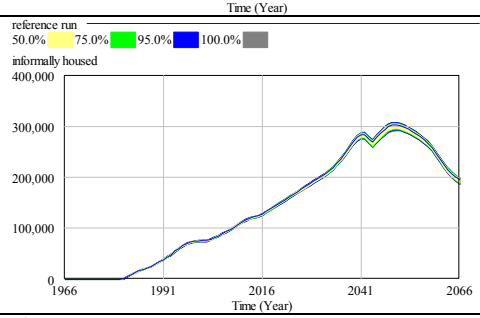
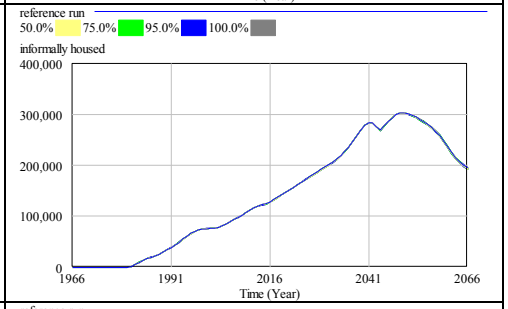
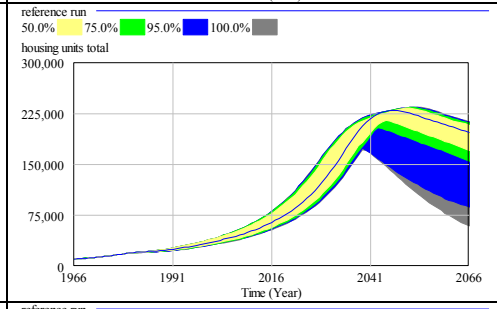
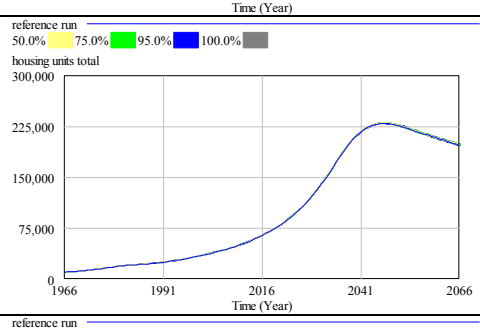
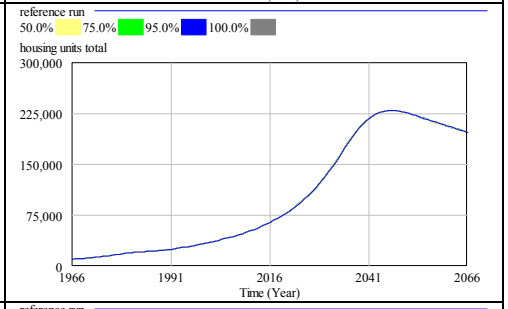
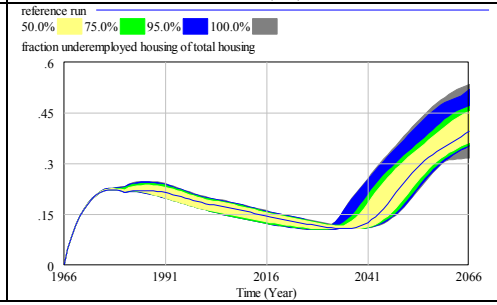
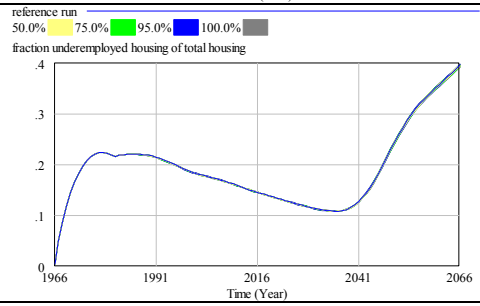
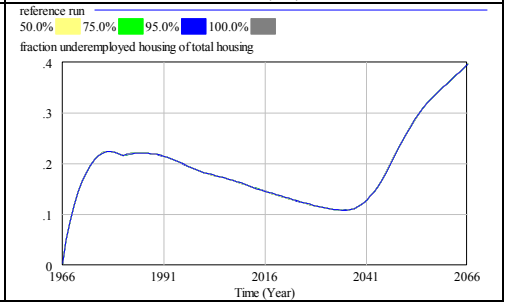
4.1 Port sub-model sensitivity

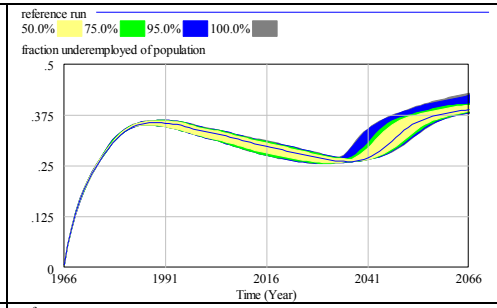
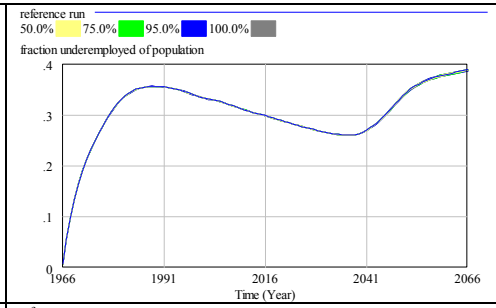
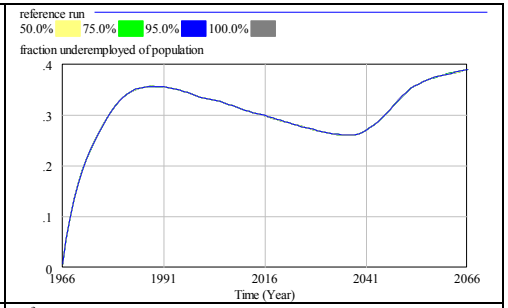
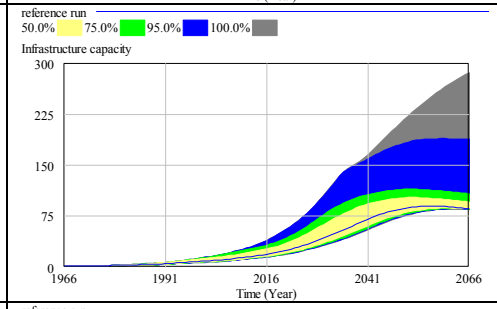
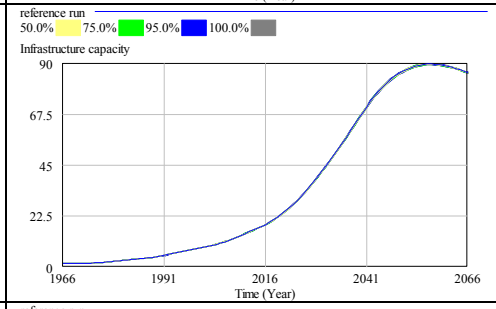
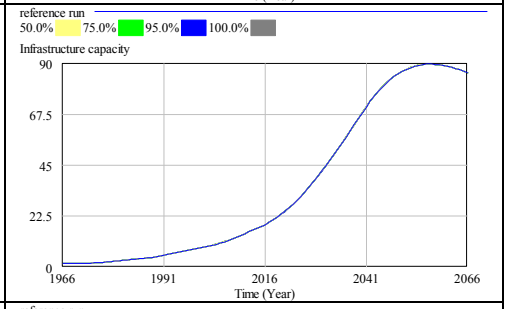
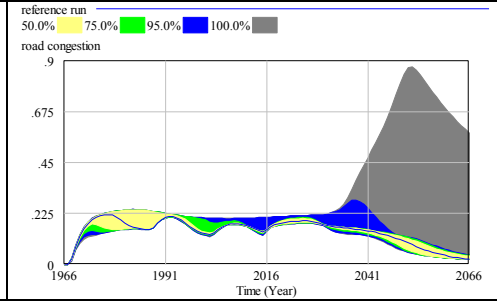
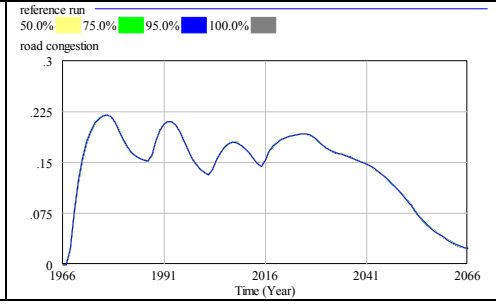
Port sub-model parameters:

- *initial throughput*
- *fraction managers of total port employment*
- *fraction labor of port employment*
- *level of port automation*
- *port employment per throughput*
- *initial port capacity*
- *port effect on city factor*
- *labor per port construction*
- *port construction delay*
- *port capacity on national GDP delay*
- *initial GDP*
- *normal GDP growth rate*
- *throughput growth rate factor*
- *port capacity growth (flow)*
- *port effect on industry (lookup)*
- *port congestion effect on throughput growth (lookup)*
- *national GDP growth effect on throughput growth (lookup)*

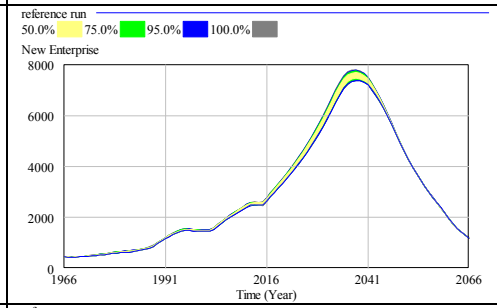
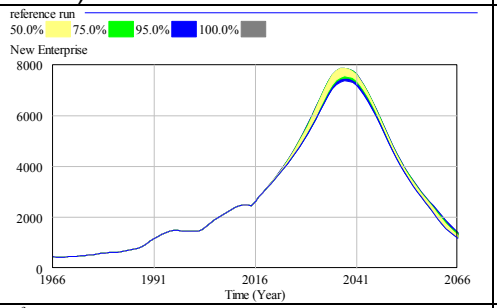
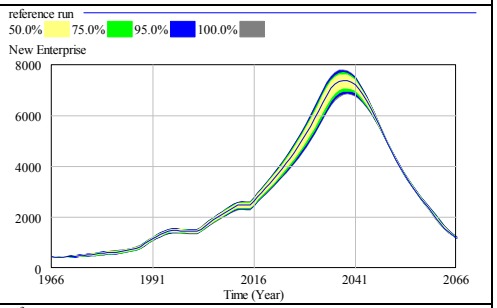
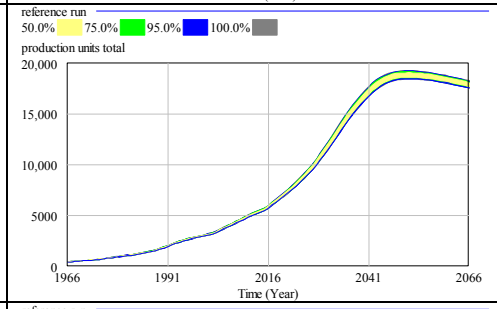
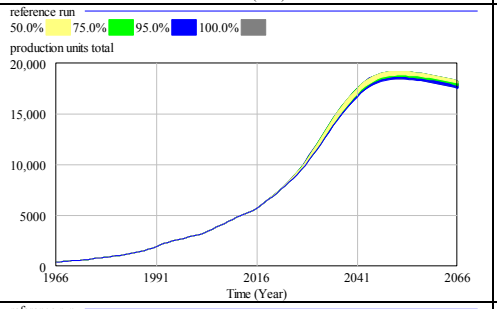
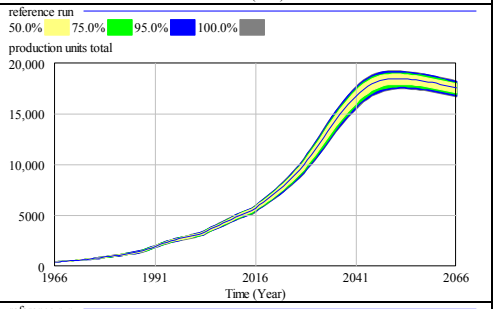
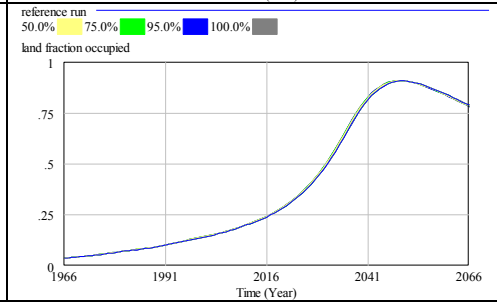
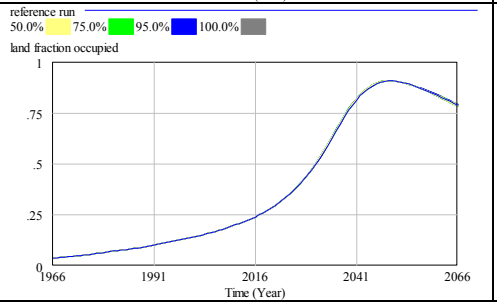
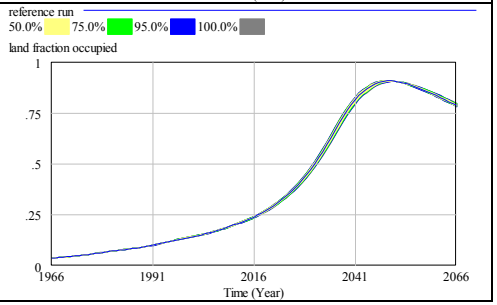
Parameter	initial throughput	fraction managers of total port employment	fraction labor of total port employment
Units	kton/year	-	-
Nominal value	1940	0.088	0.912
Minimum plausible	0	0.044	0.824
Maximum plausible	1940*2	0.176	0.956
Sensitivity plot: New Enterprise			

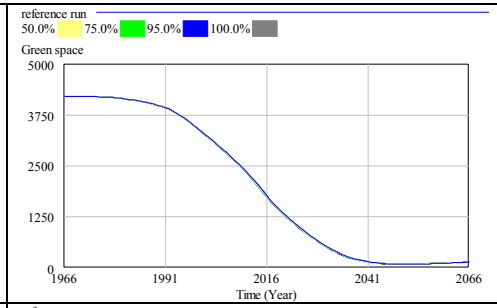
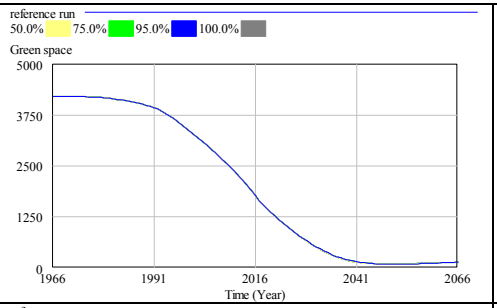
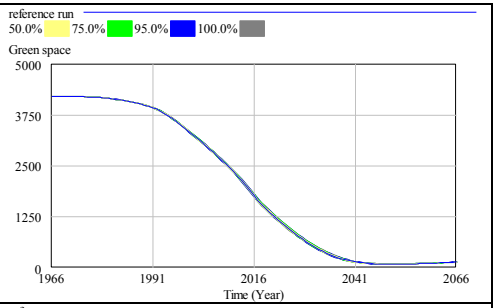
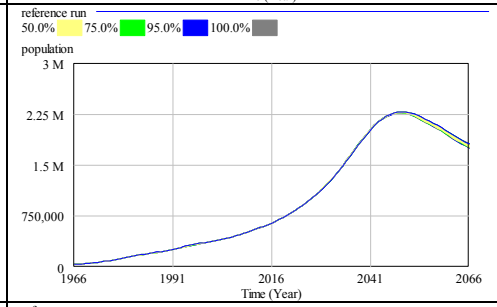
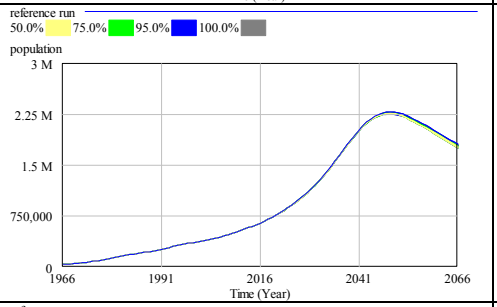
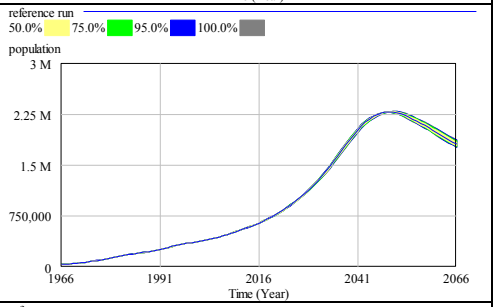
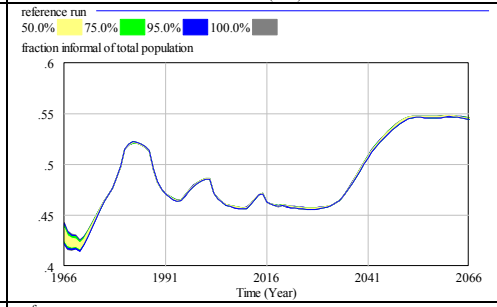
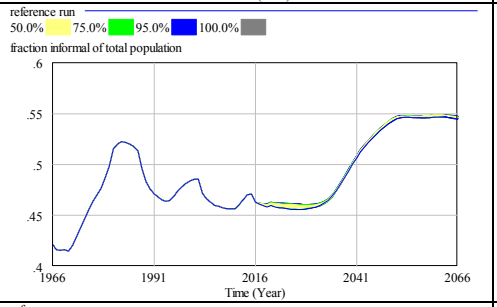
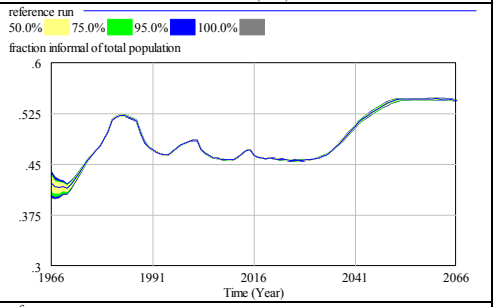
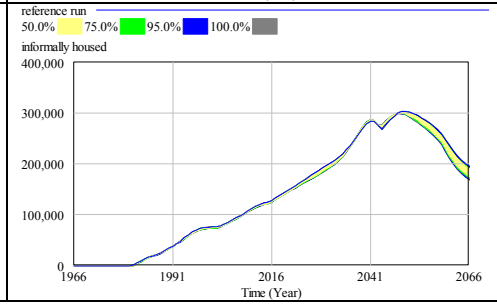
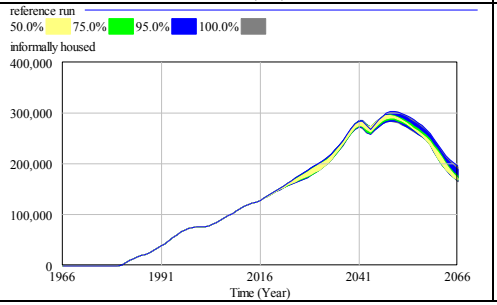
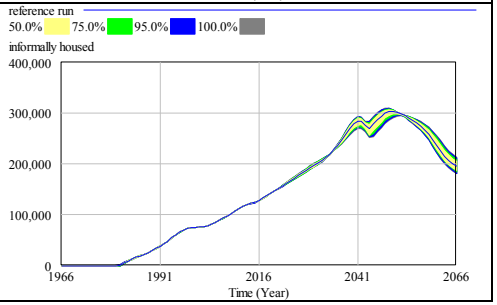
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

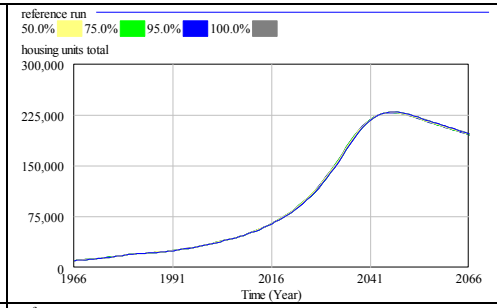
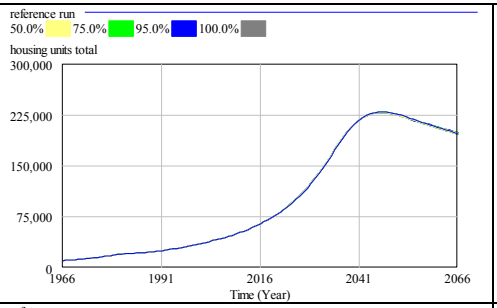
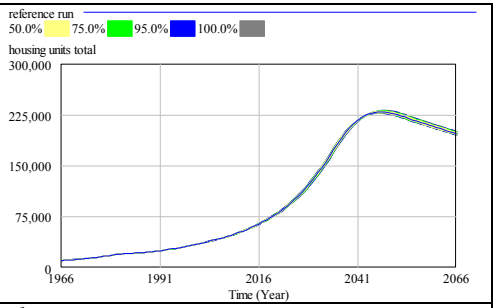
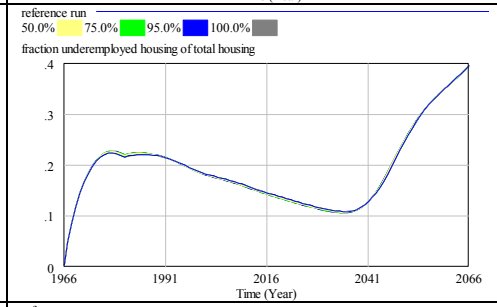
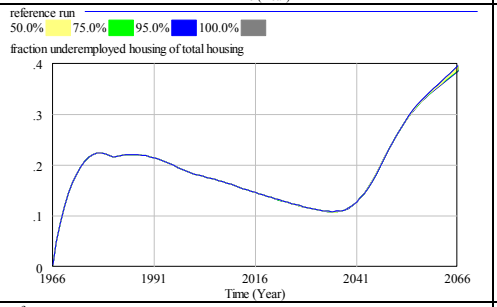
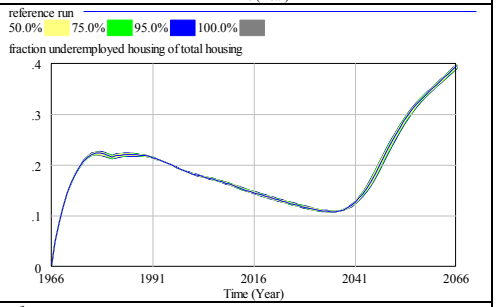
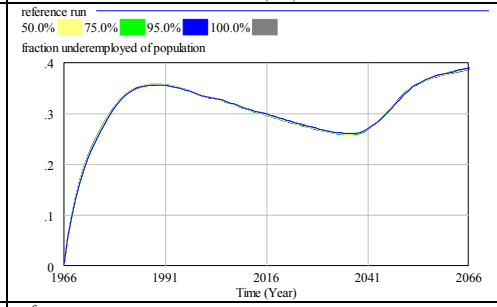
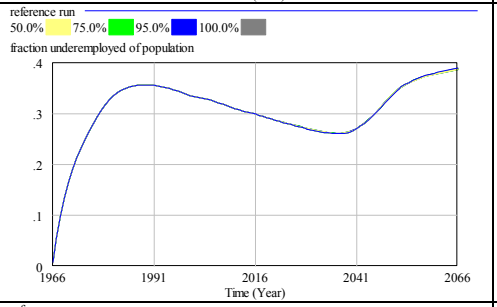
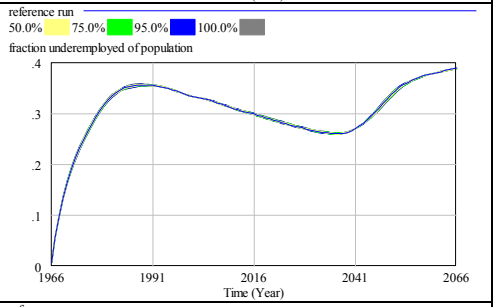
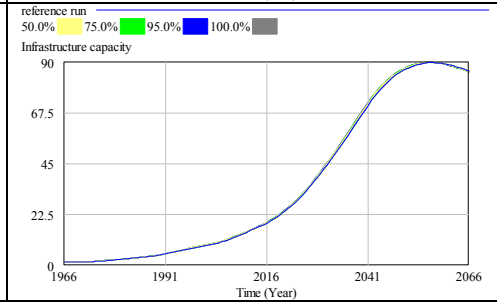
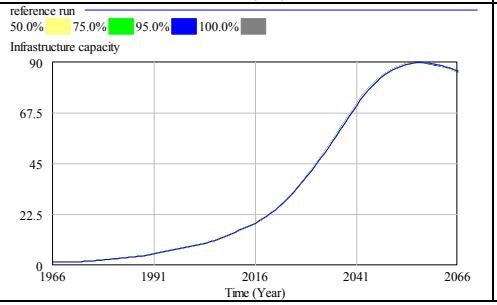
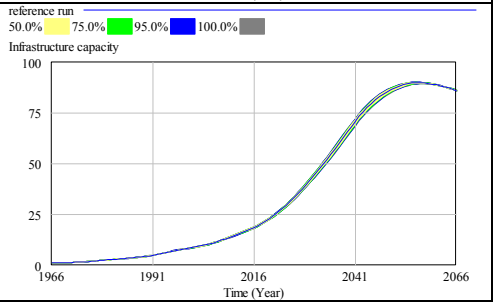
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

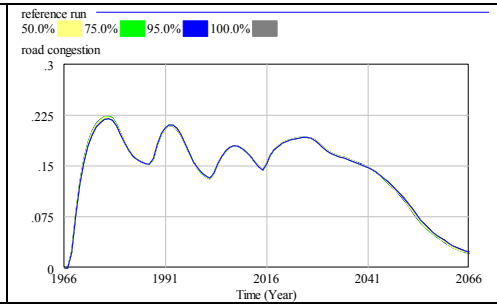
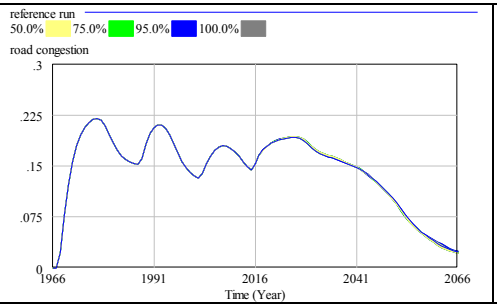
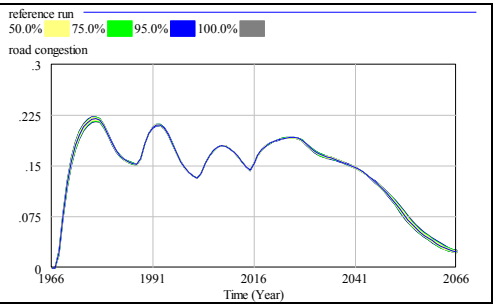
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

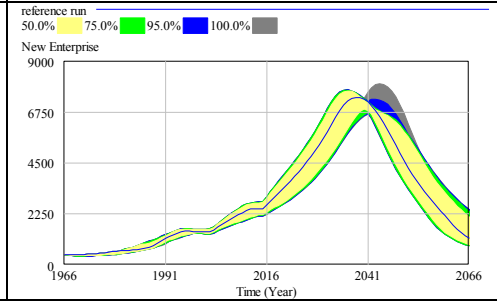
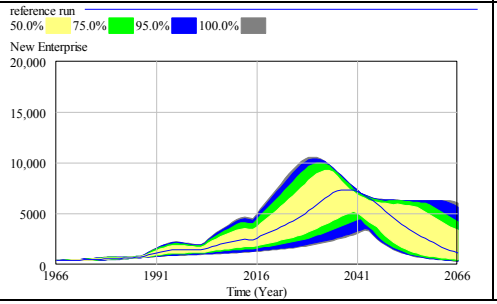
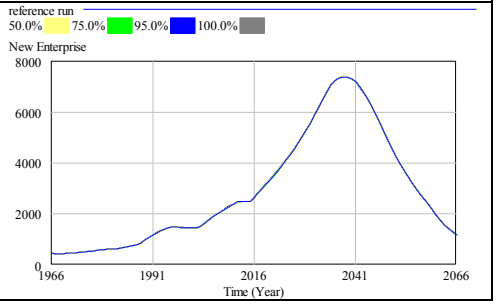
Parameter	level of port automation (steady value)	level of port automation (ramped introduction)	port employment per throughput
Units	-	-	worker/(kton/year)
Nominal value	0.05	0.05	0.5
Minimum plausible	0	0	0.1

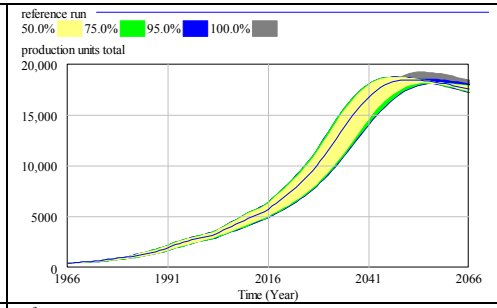
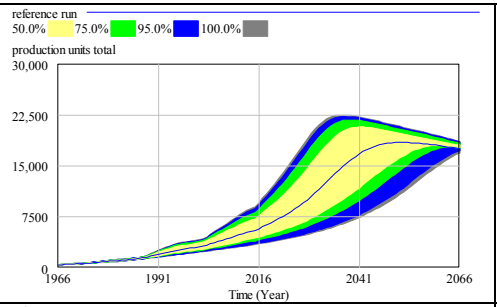
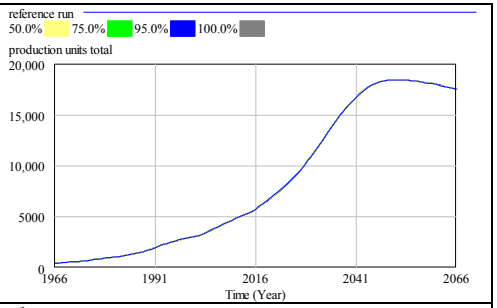
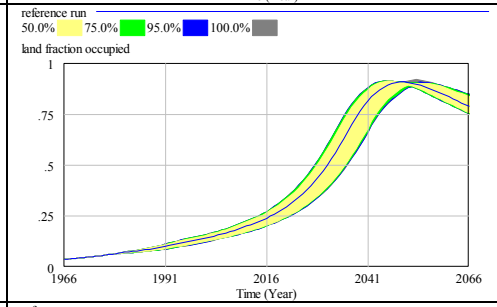
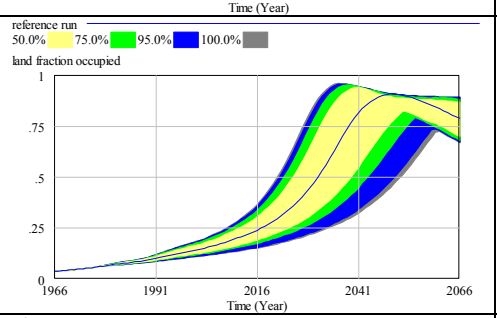
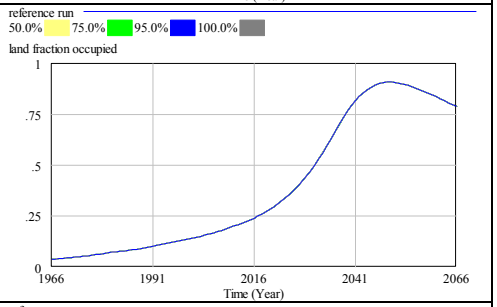
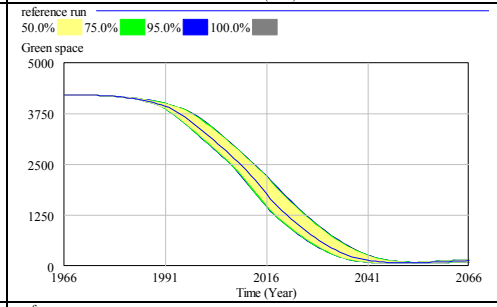
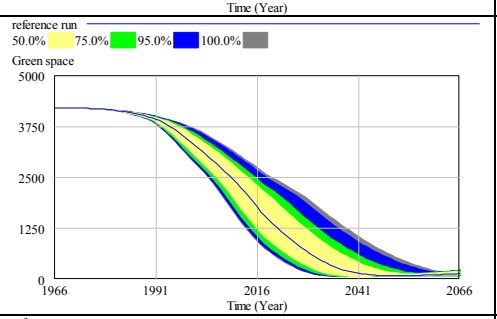
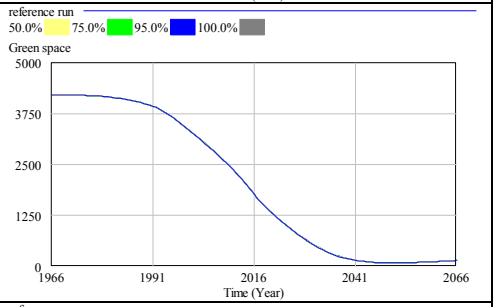
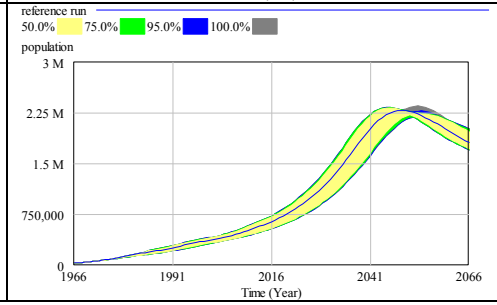
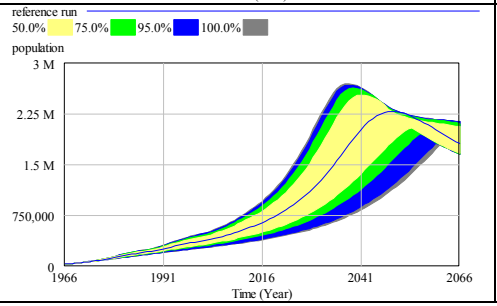
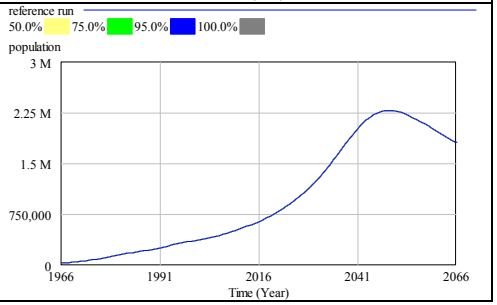
Maximum plausible	1	Full automation within 10 years starting from 2016 (automation rate = 0.1)	1
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			

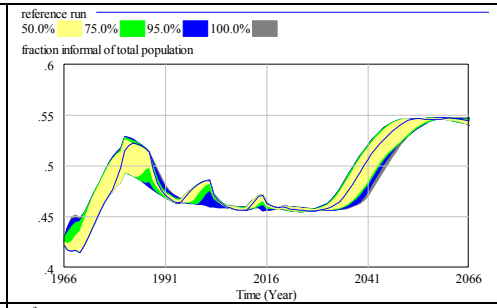
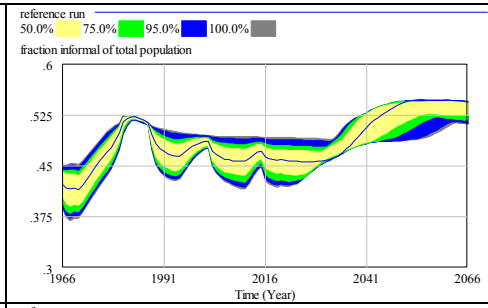
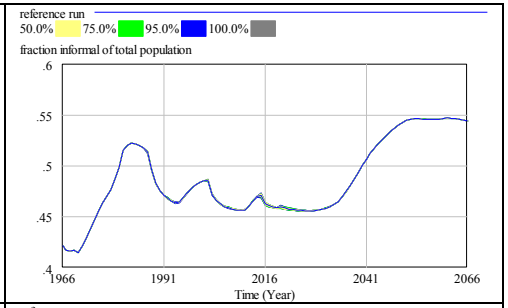
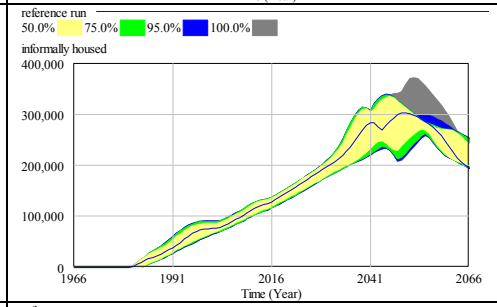
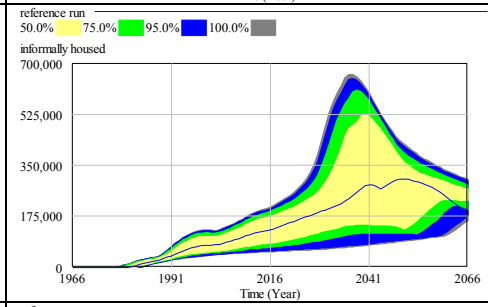
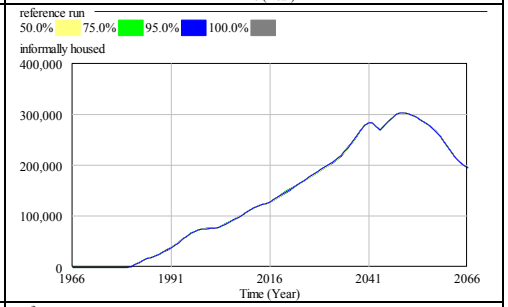
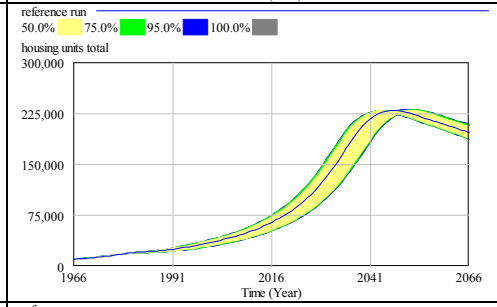
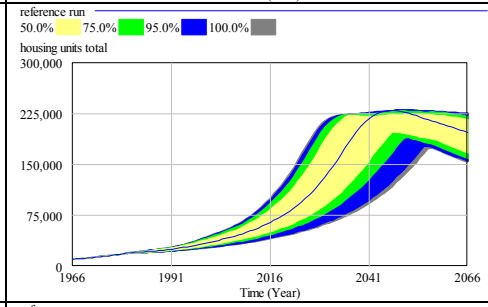
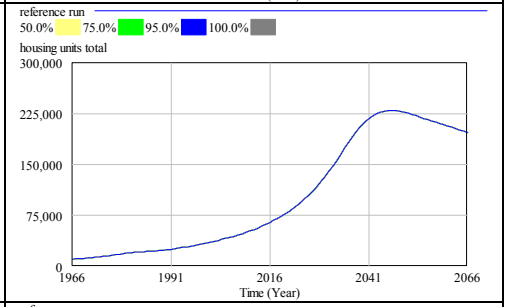
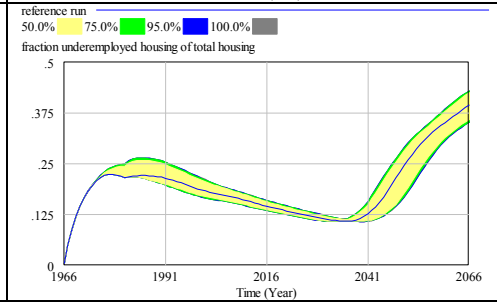
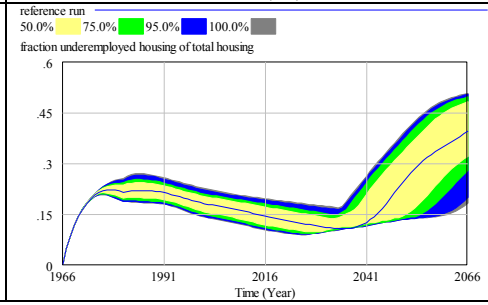
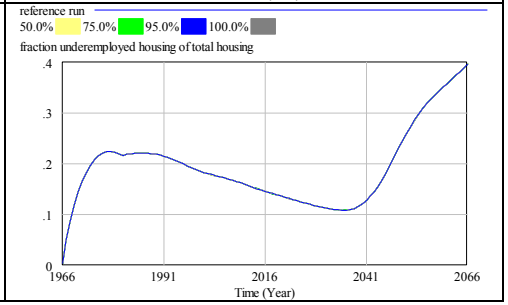
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			

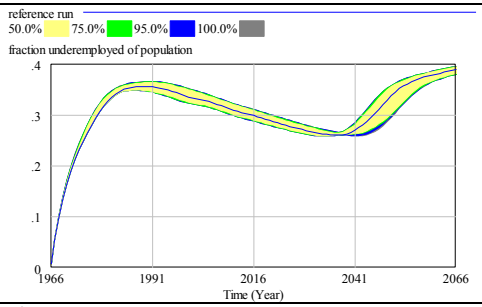
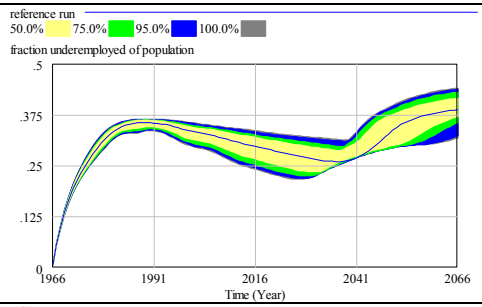
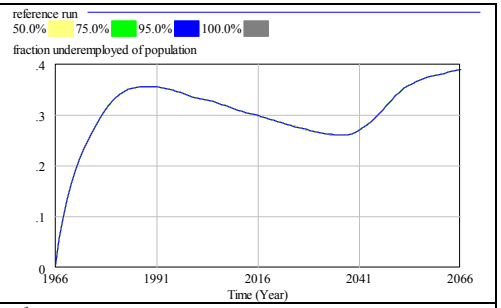
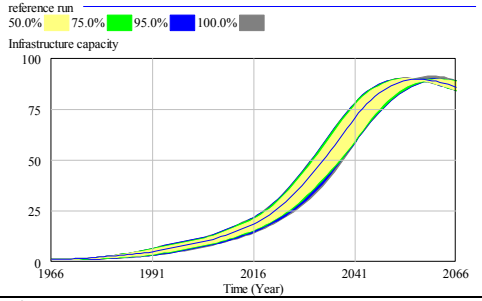
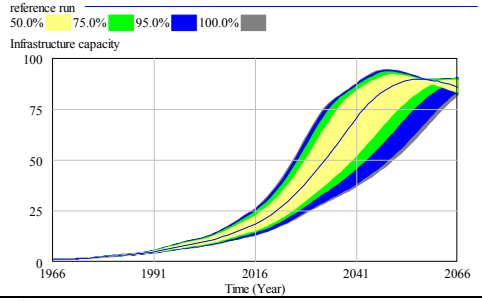
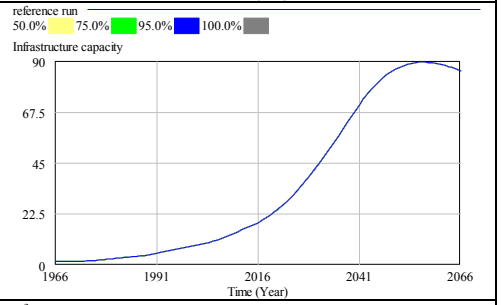
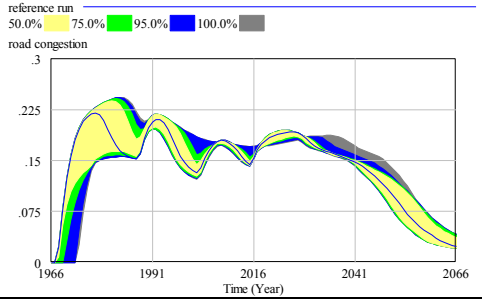
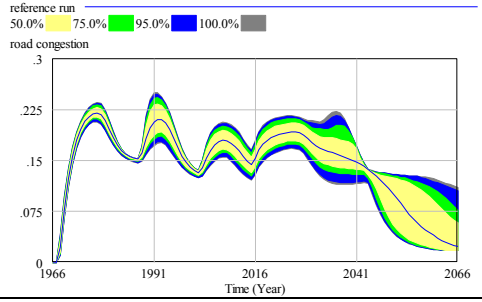
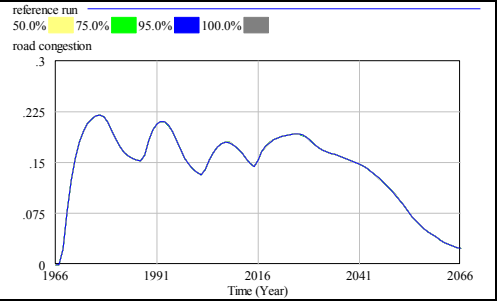
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			

Sensitivity plot: road congestion			

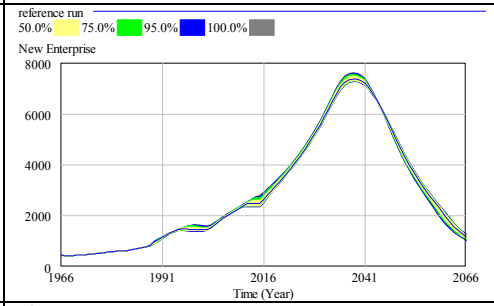
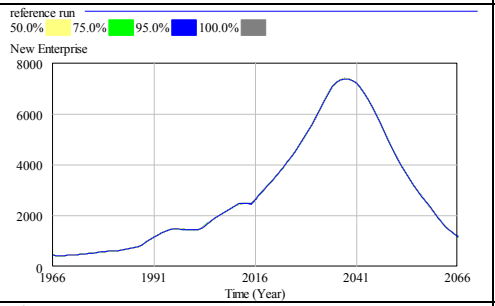
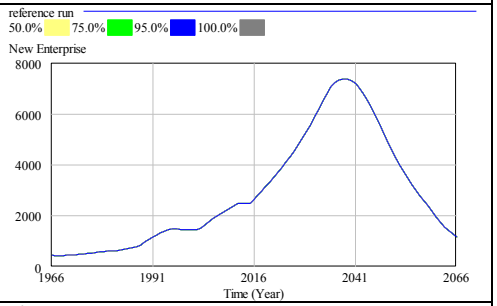
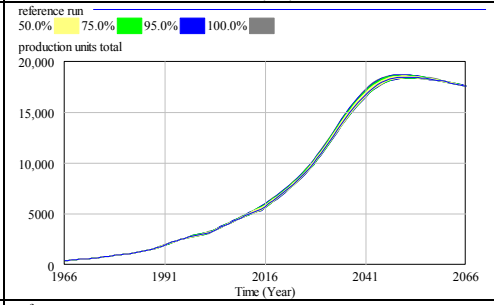
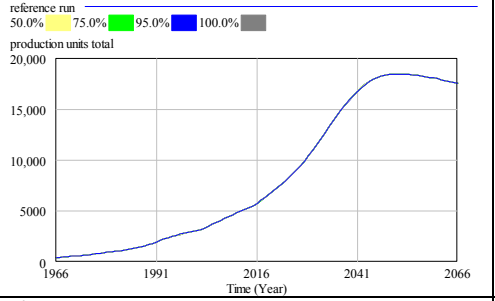
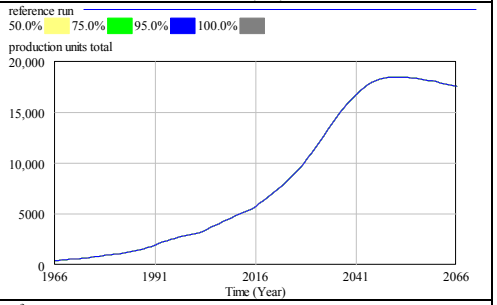
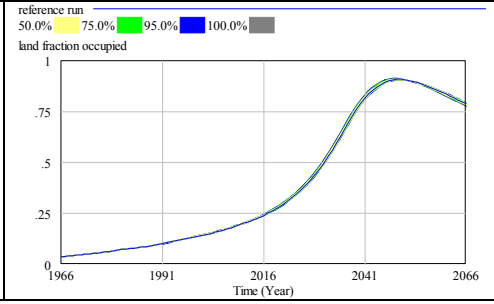
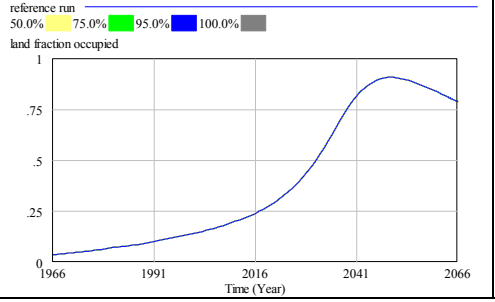
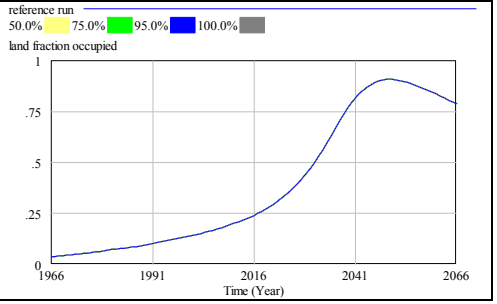
Parameter	initial port capacity	port effect on city factor	labor per port construction
Units	kton/year	-	worker/((kton/Year)/ Year)
Nominal value	5476	1	0.25
Minimum plausible	547.6	0 (no port effects)	0 (zero local employment)
Maximum plausible	10952 (about the cap. of Accra in the 60's)	2 (doubled port effects)	0.5 (double local employment)
Sensitivity plot: New Enterprise			

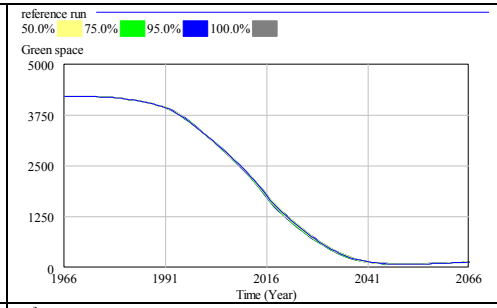
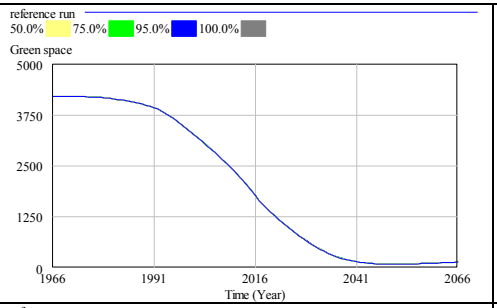
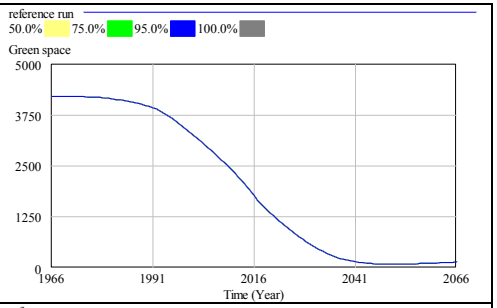
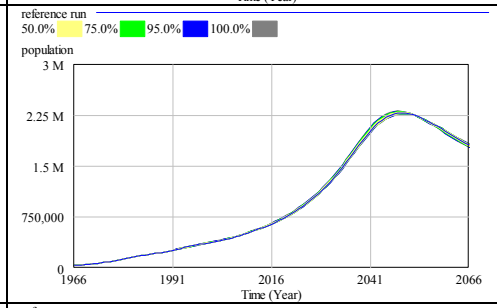
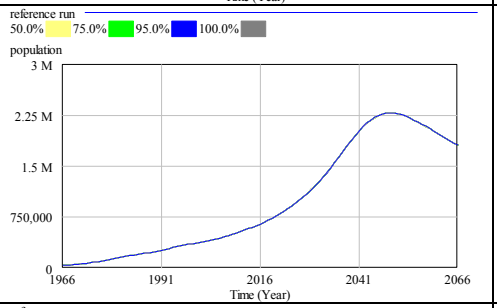
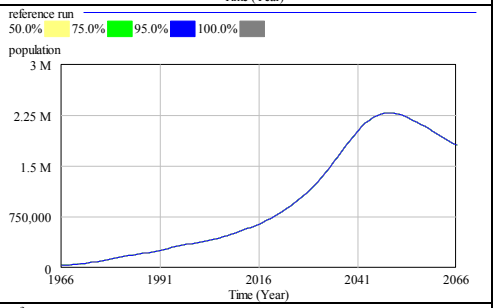
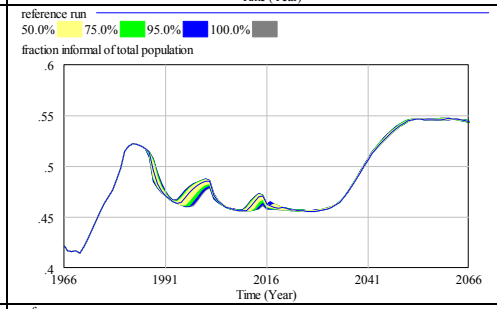
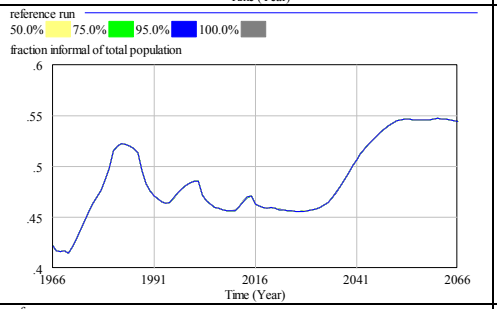
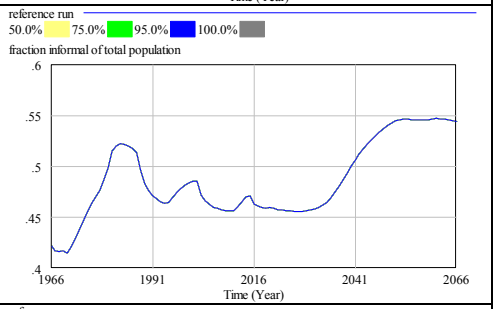
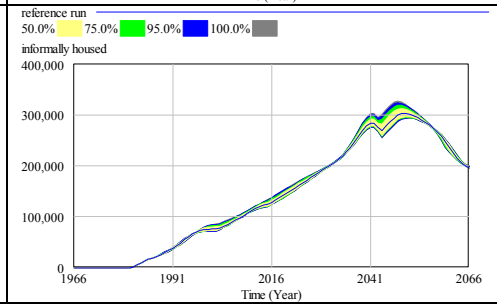
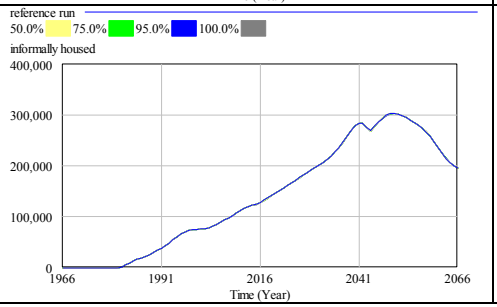
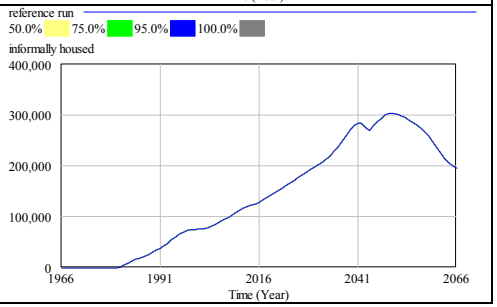
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

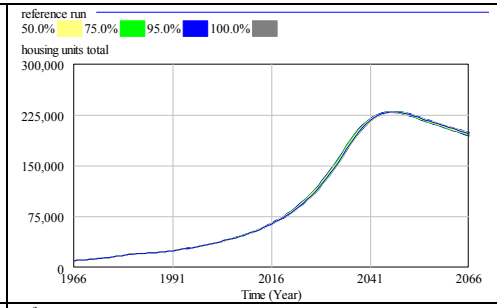
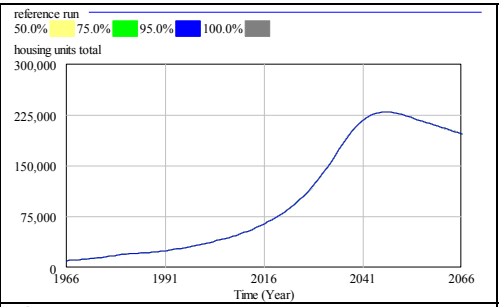
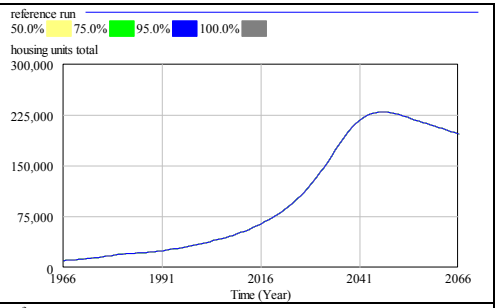
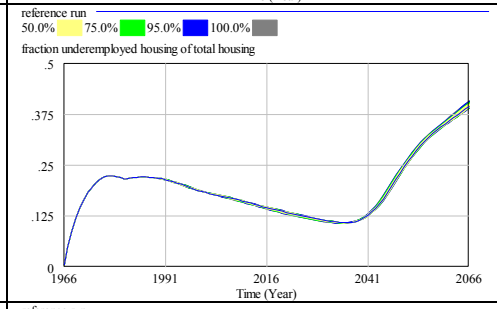
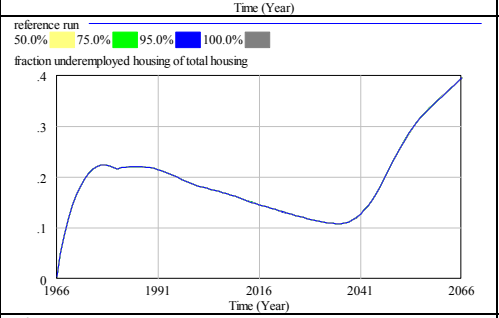
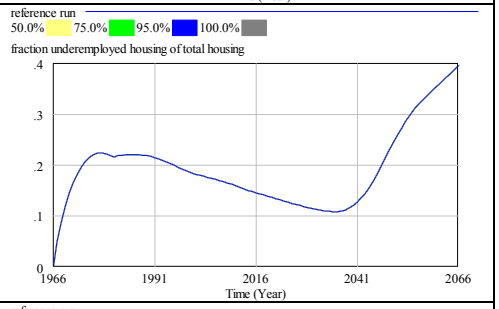
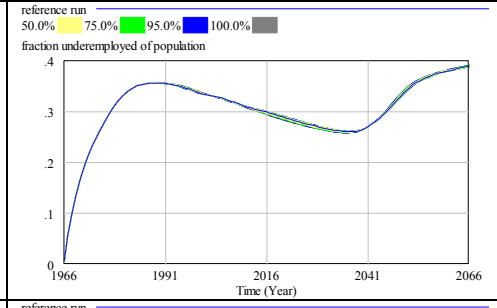
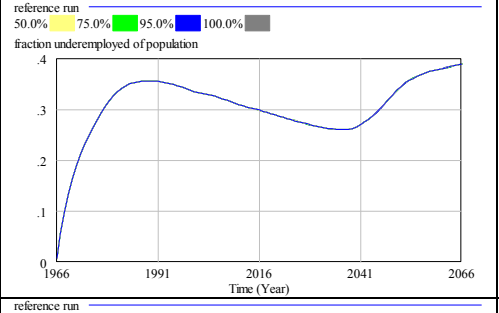
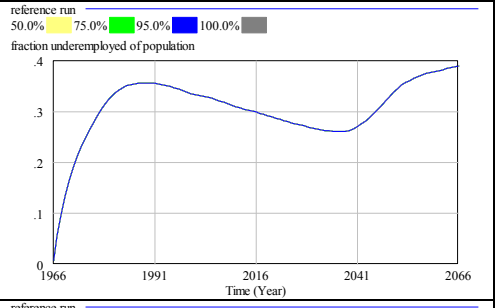
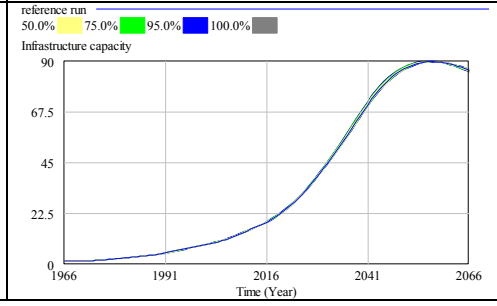
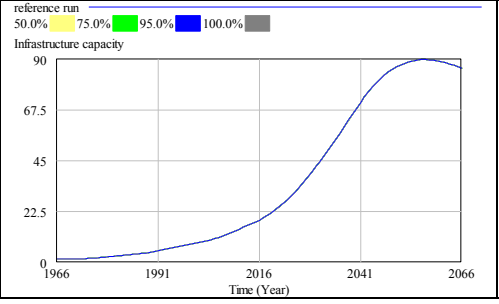
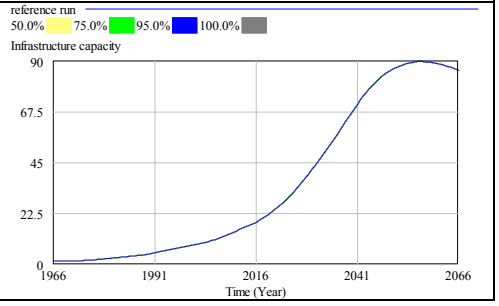
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

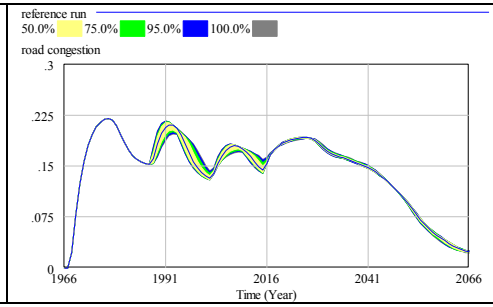
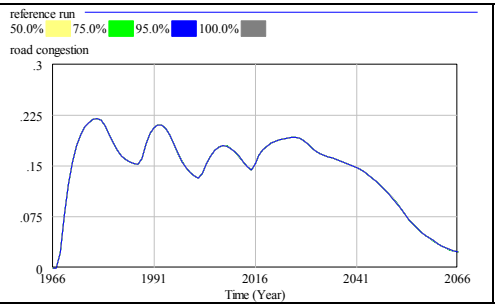
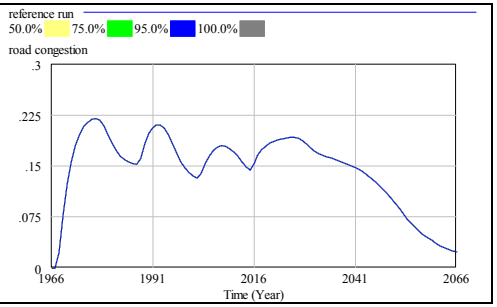
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

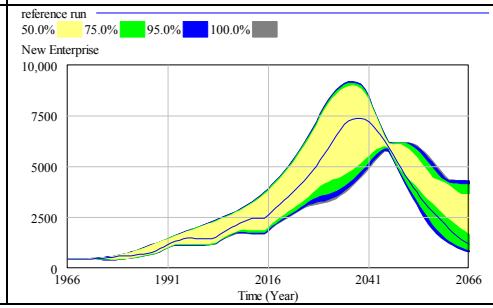
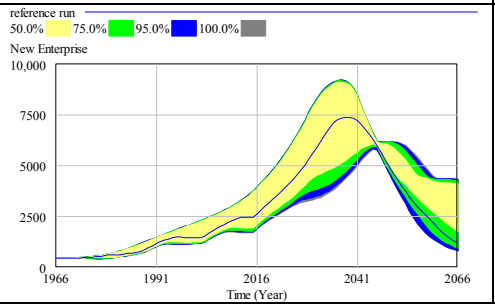
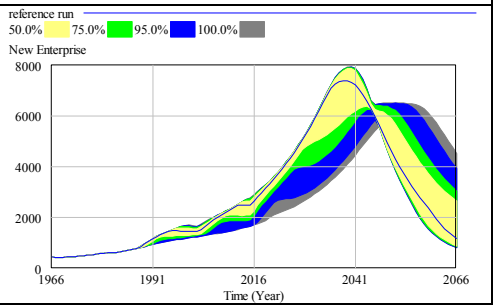
Parameter	port construction delay	port capacity effect on national GDP delay	initial GDP
Units	Year	Year	US Dollar/year
Nominal value	5	5	2.1263e+009
Minimum plausible	1	1	2.1263e+008

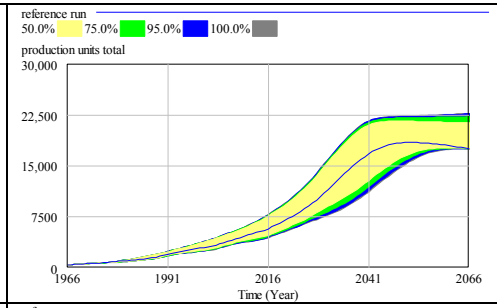
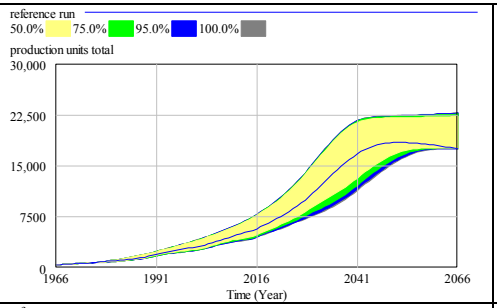
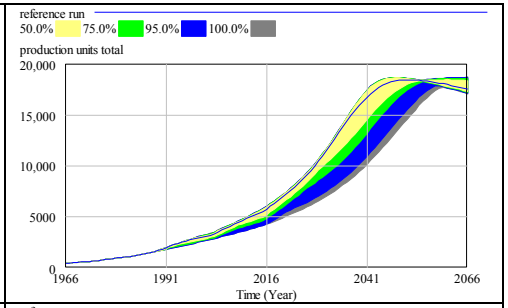
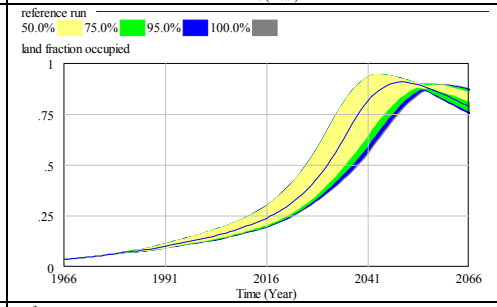
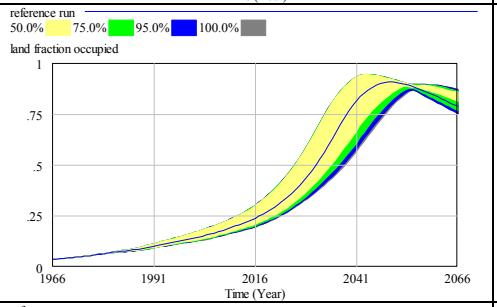
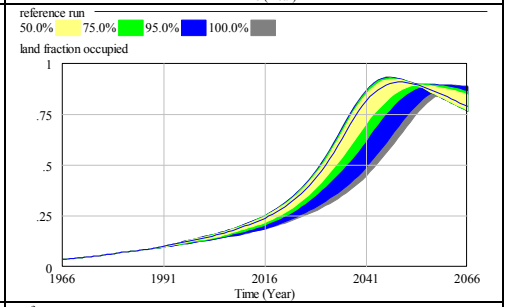
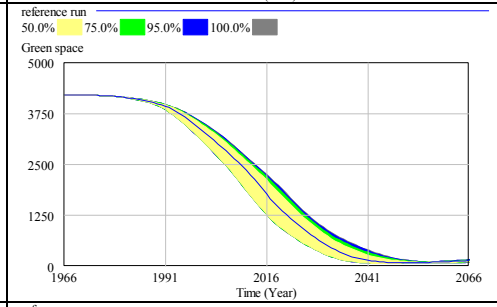
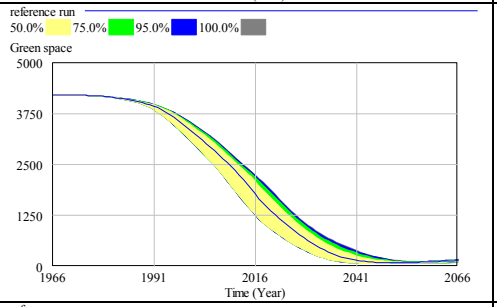
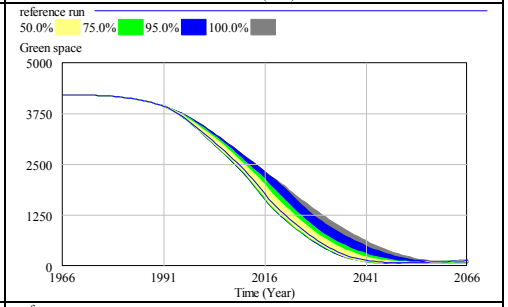
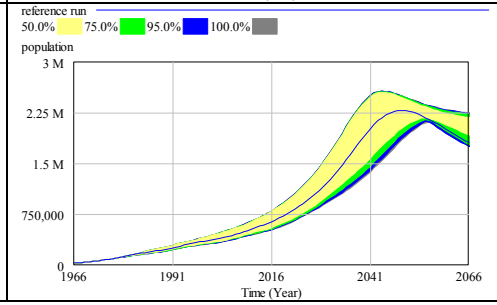
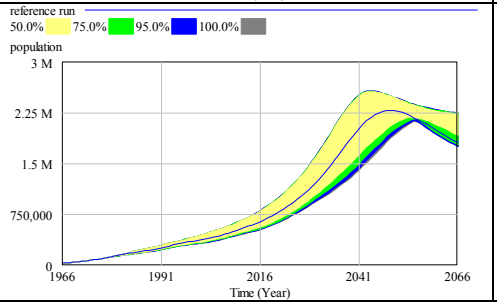
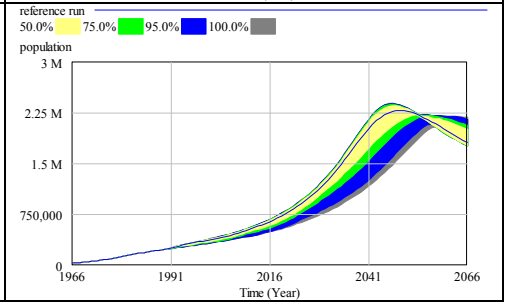
Maximum plausible	10	10	2.1263e+010
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			

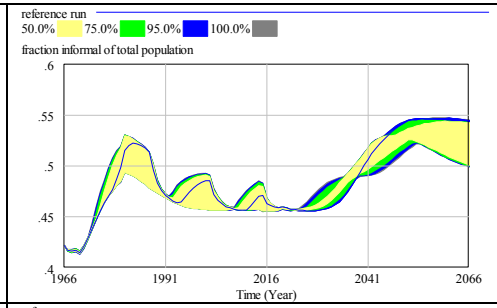
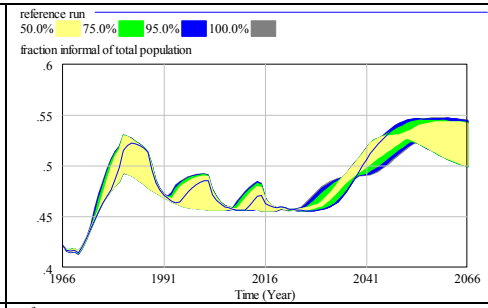
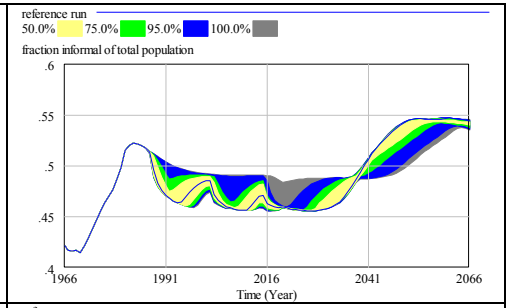
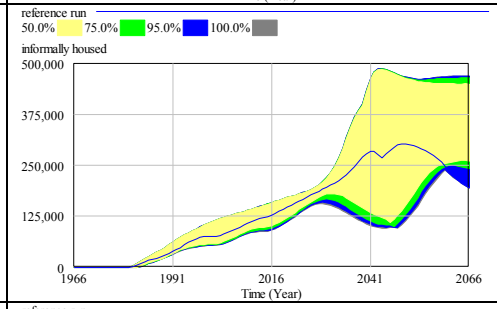
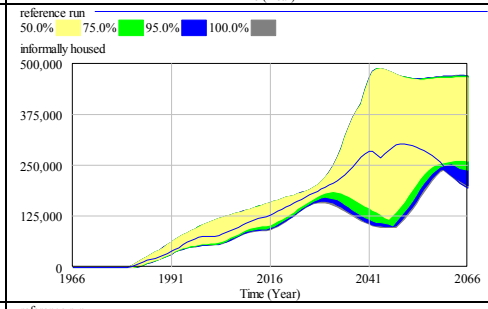
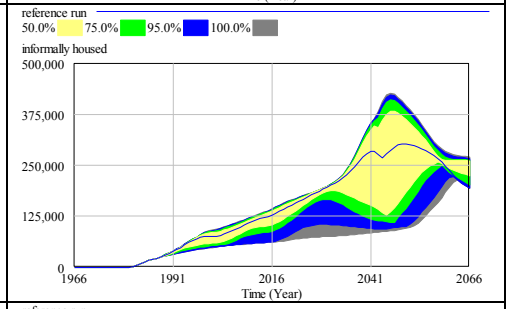
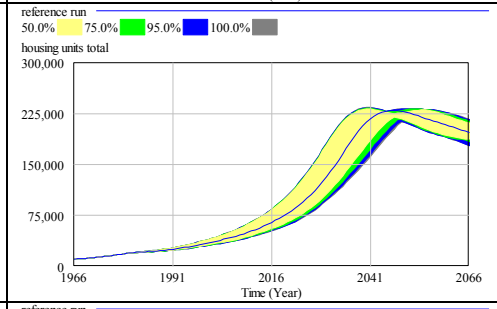
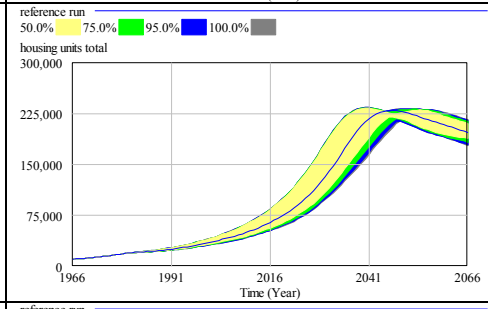
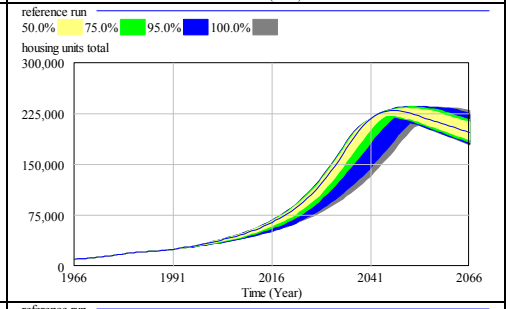
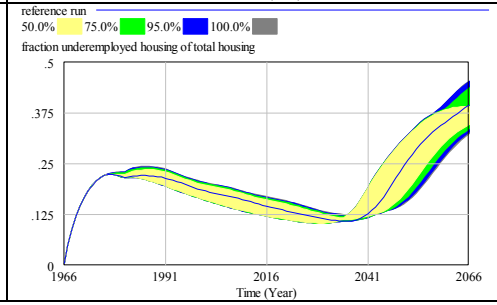
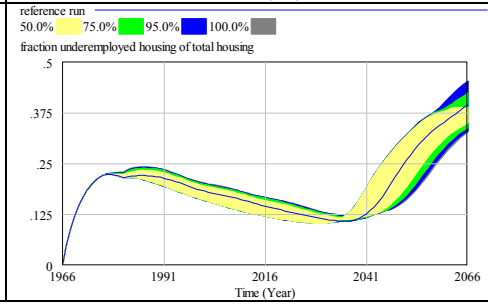
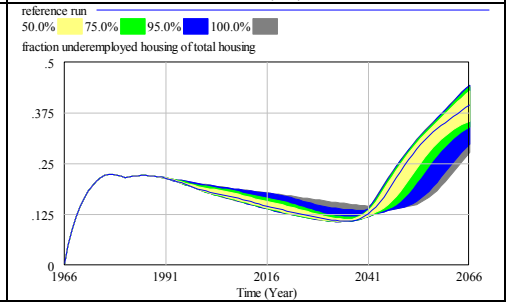
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			

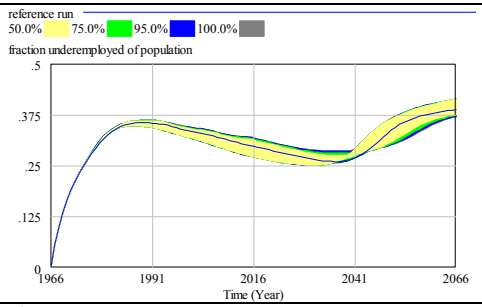
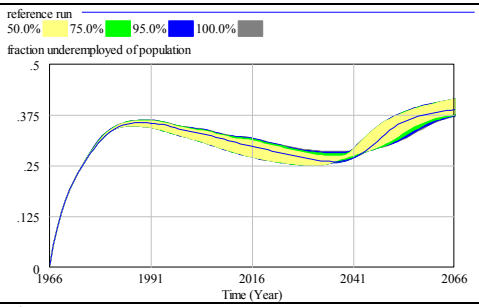
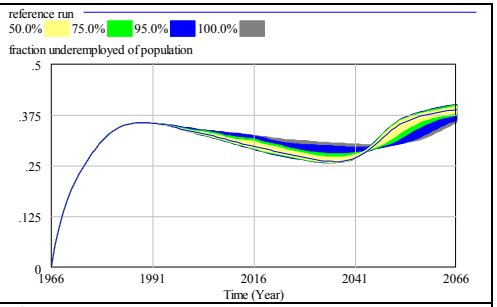
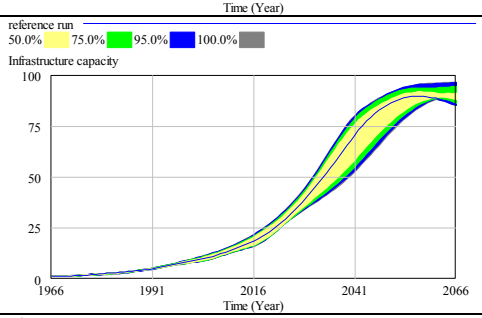
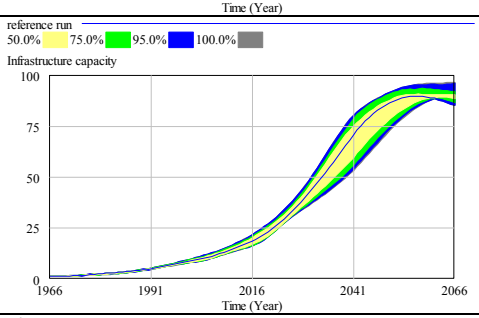
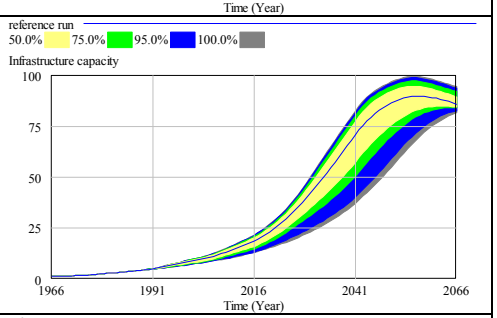
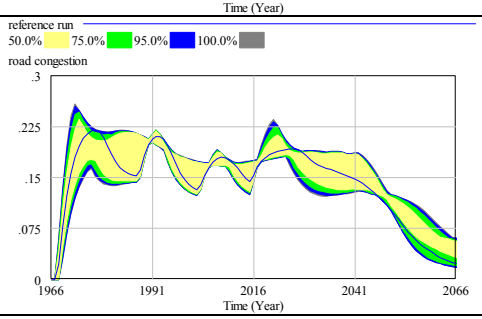
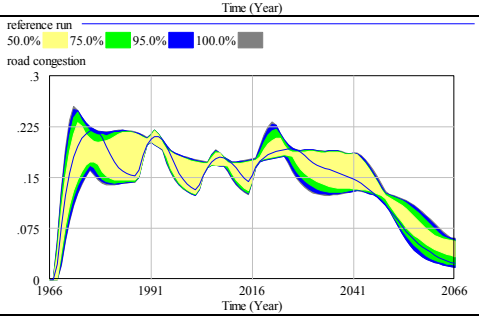
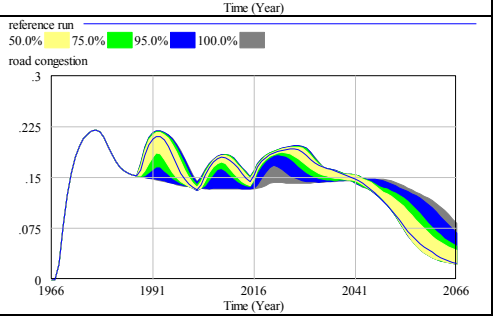
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			

Sensitivity plot: road congestion			

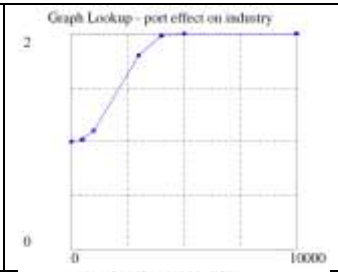
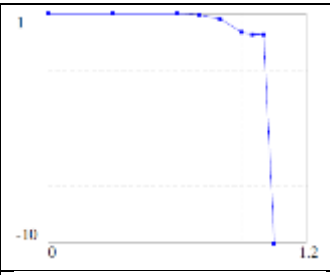
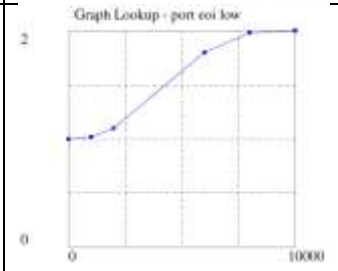
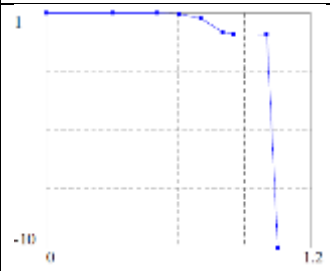
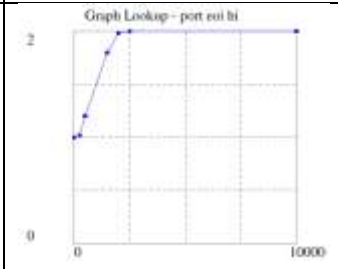
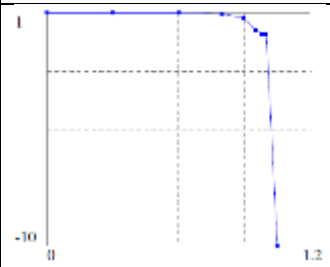
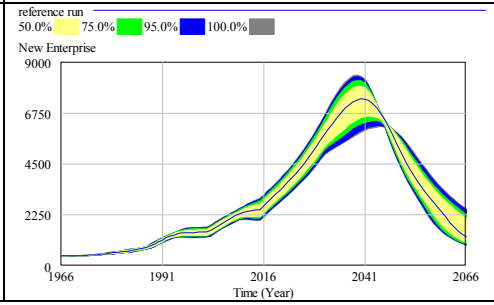
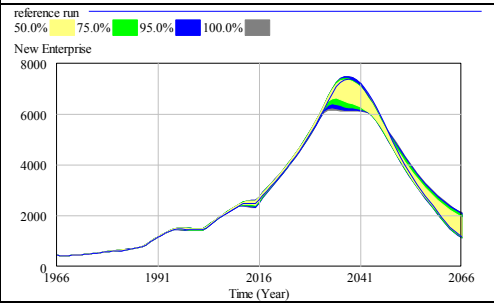
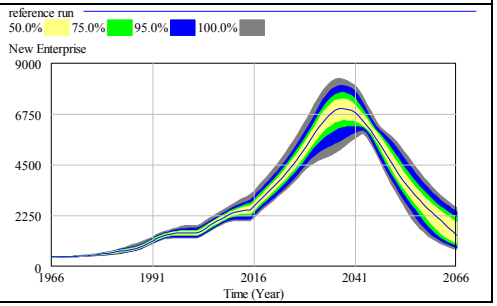
Parameter	normal GDP growth rate	throughput growth rate factor	port capacity growth
Units	1/Year	-	(kton/year)/year
Nominal value	0.06946	1	3286 (1987) + 6050 (2002) + 27500 (2015)
Minimum plausible	0	-0.2	0
Maximum plausible	0.13892	2	double the nominal values (port expansion factor = 2)
Sensitivity plot: New Enterprise			

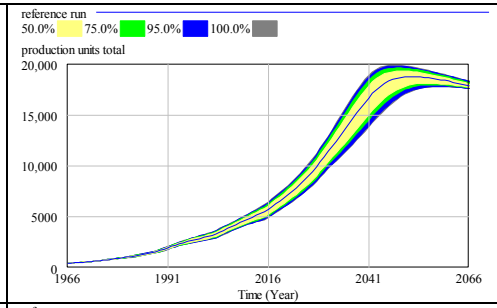
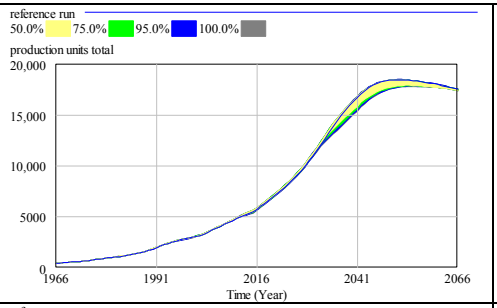
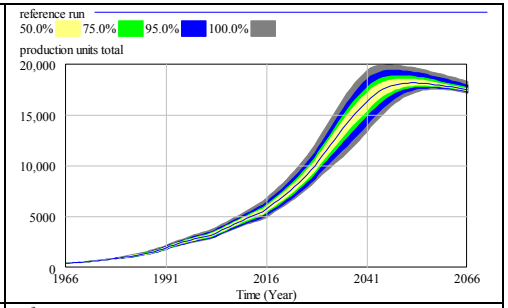
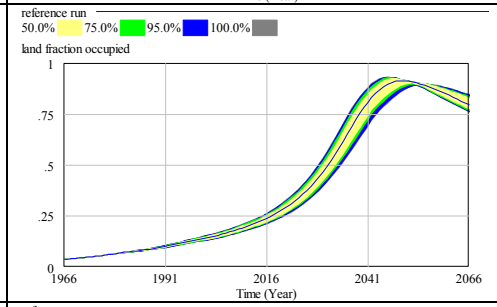
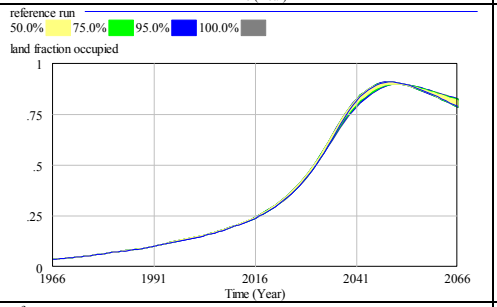
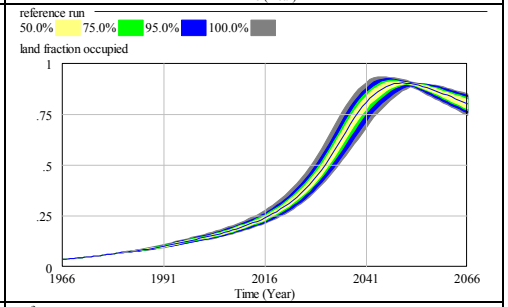
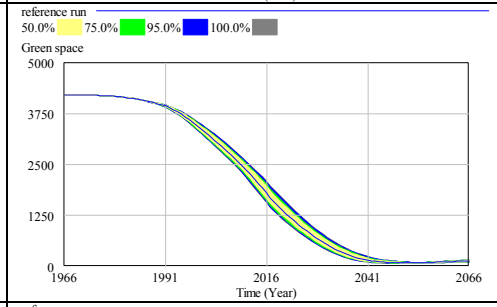
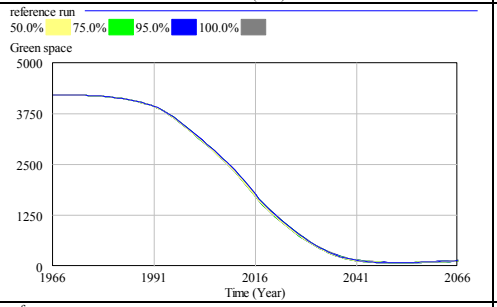
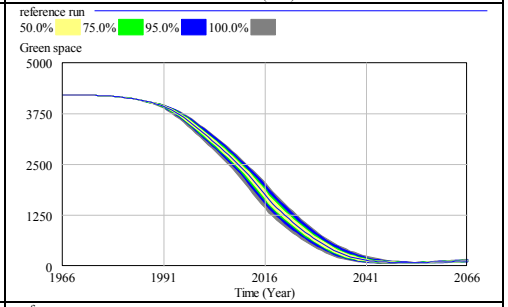
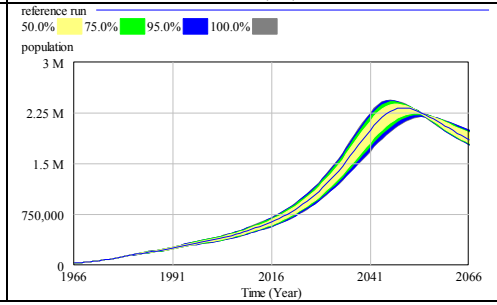
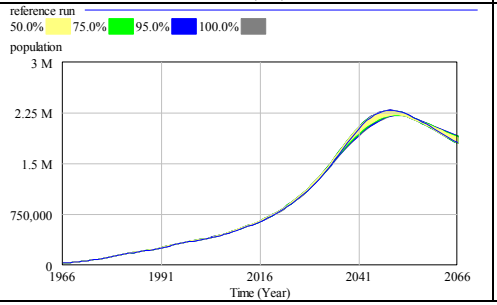
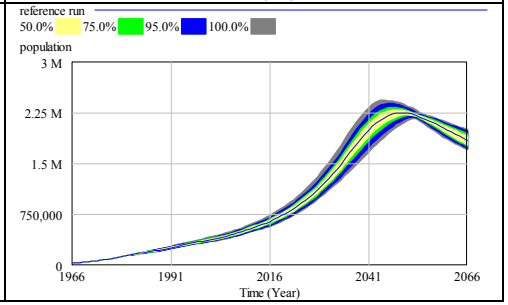
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

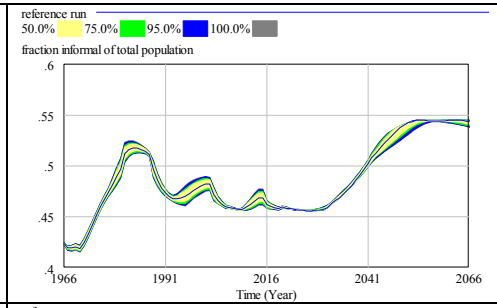
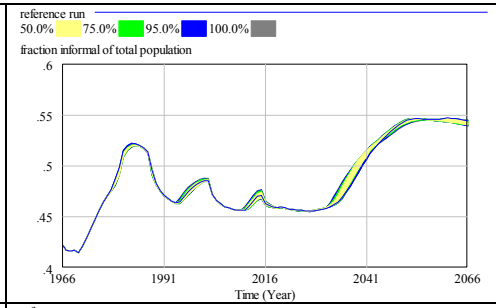
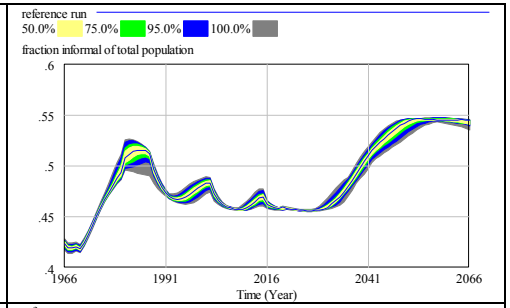
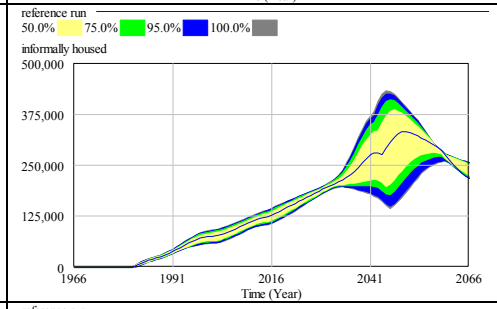
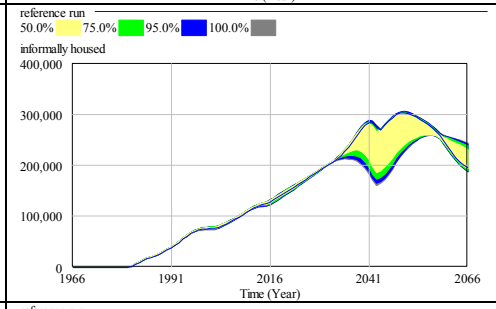
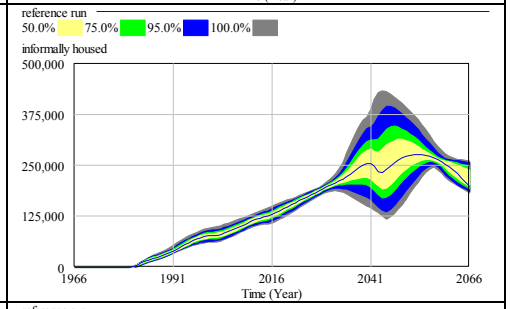
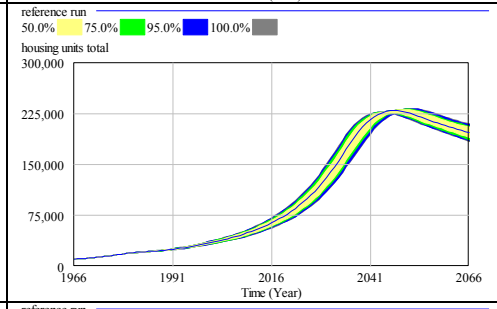
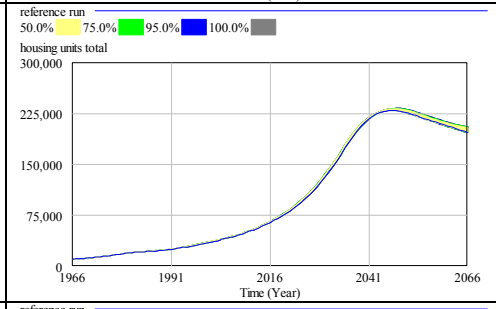
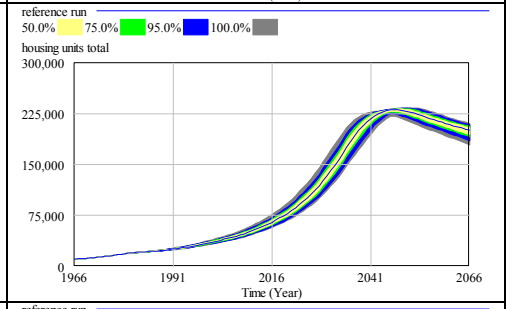
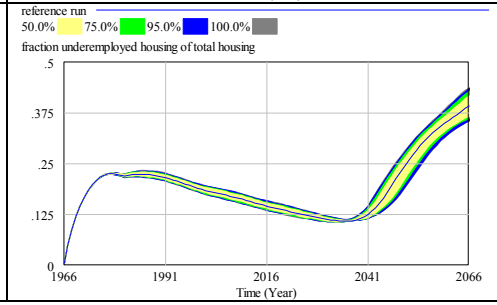
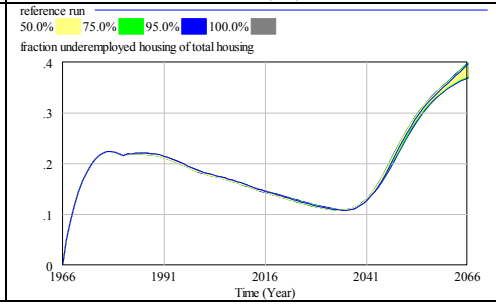
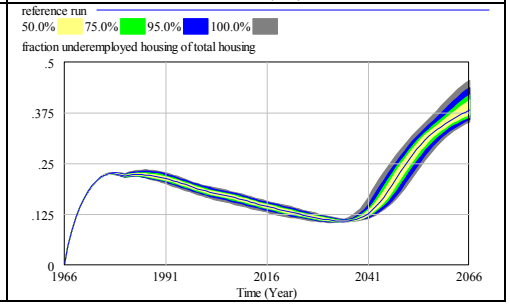
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

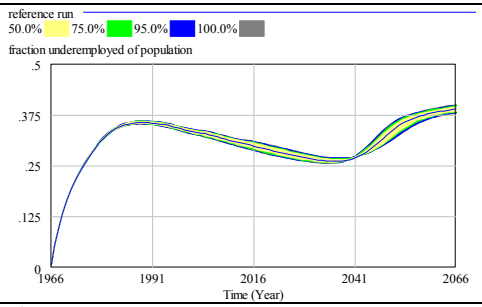
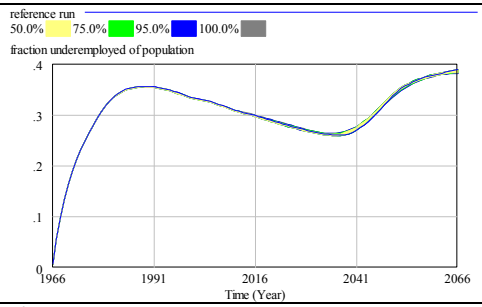
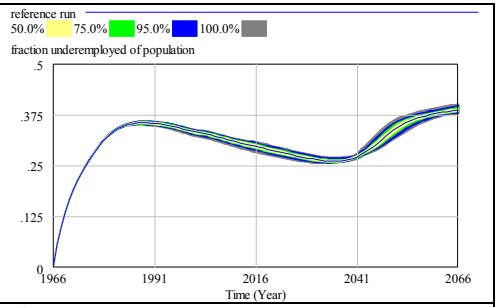
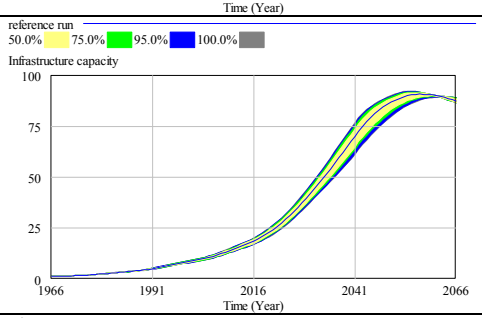
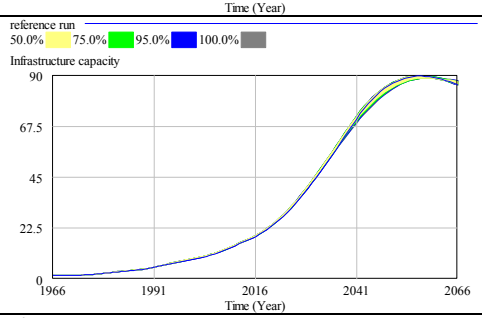
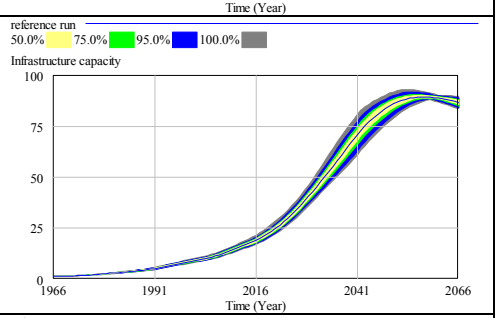
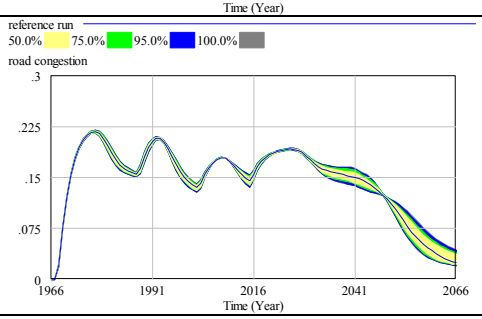
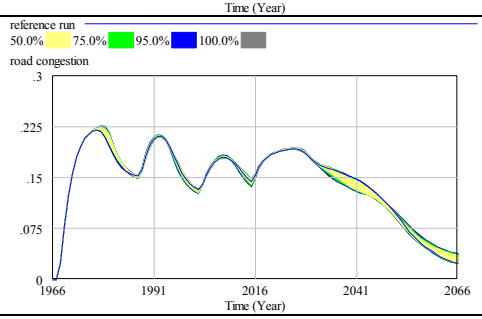
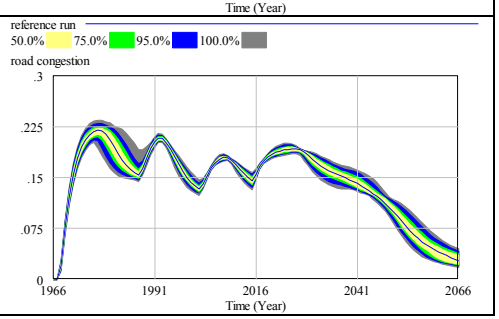
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

Parameter	port effect on industry (lookup)	port congestion effect on throughput growth (lookup)	Multivariate, all parameters and lookups except port expansion
Units	-	-	-

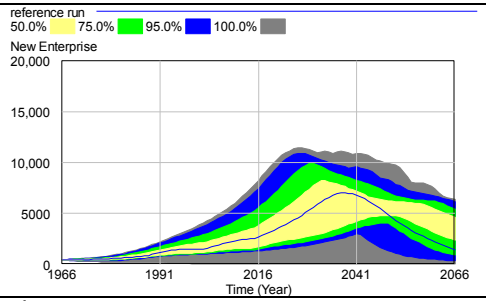
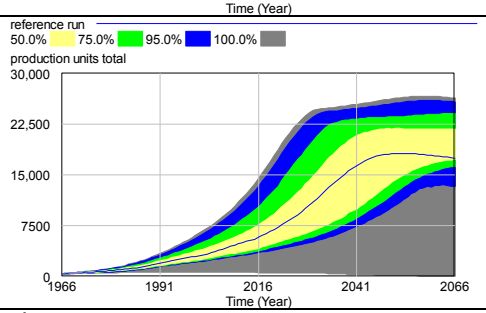
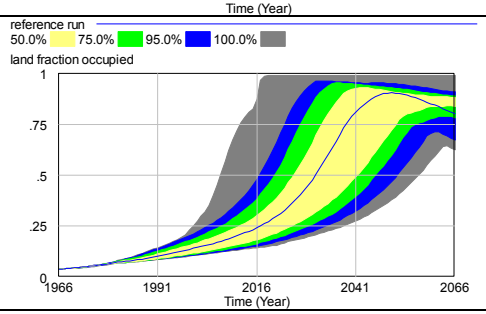
Nominal value			-
Minimum plausible			-10%
Maximum plausible			+10%
Sensitivity plot: New Enterprise			

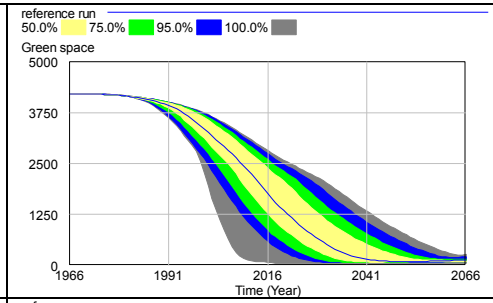
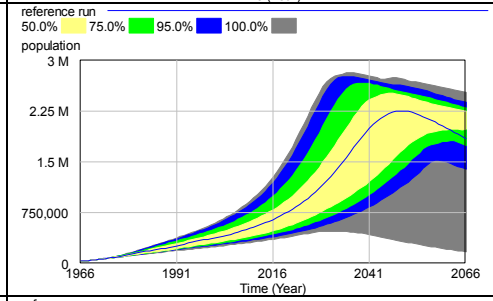
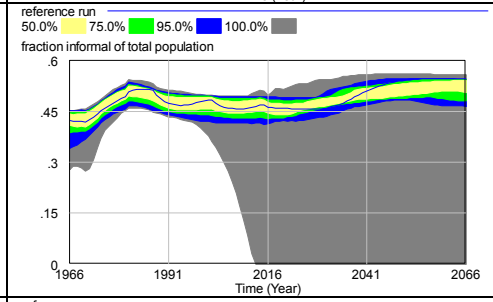
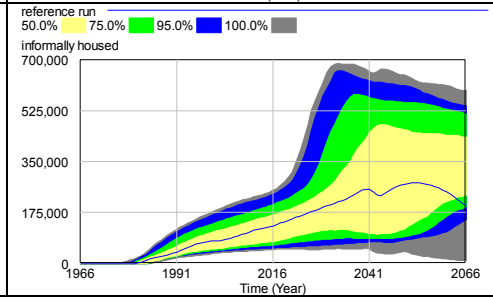
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

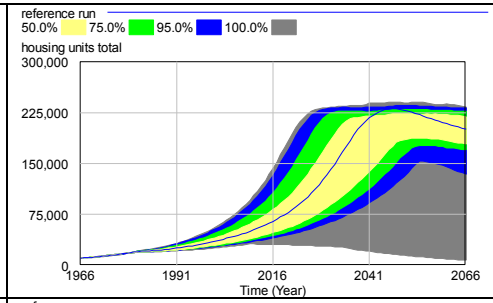
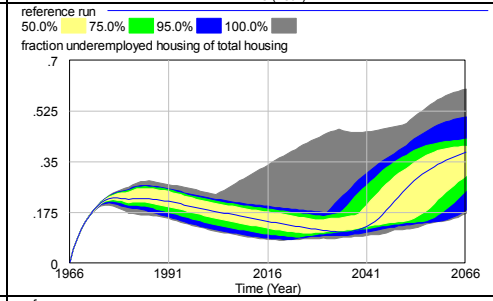
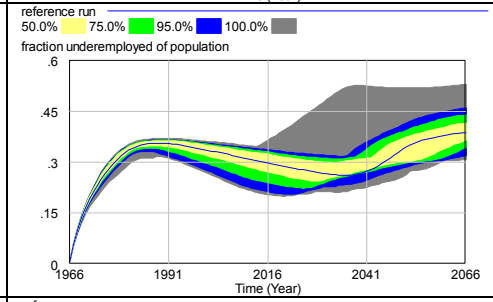
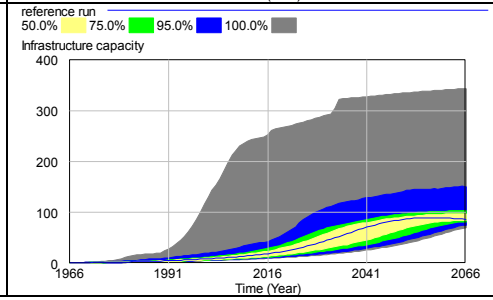
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

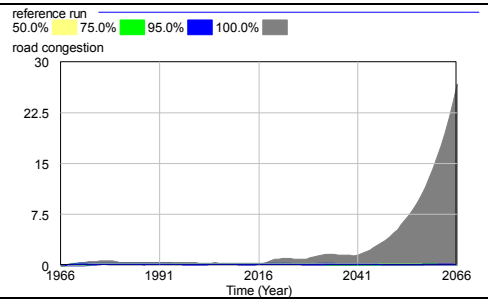
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

Parameter	Multivariate, all parameters		
Units	-		
Nominal value	-		
Minimum plausible	Respective minimum values		

Maximum plausible	Respective maximum values		
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			

Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			

Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			

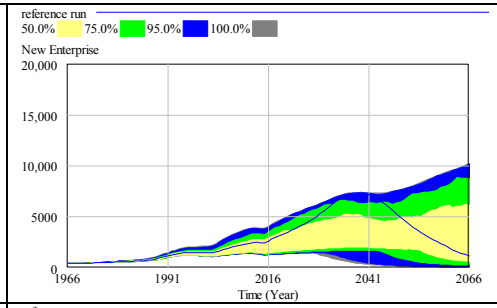
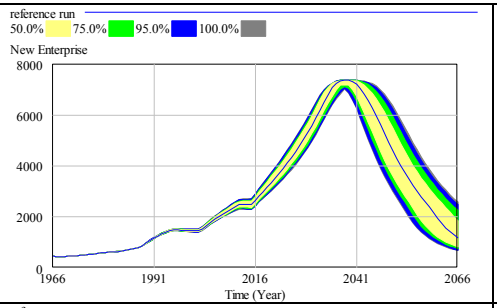
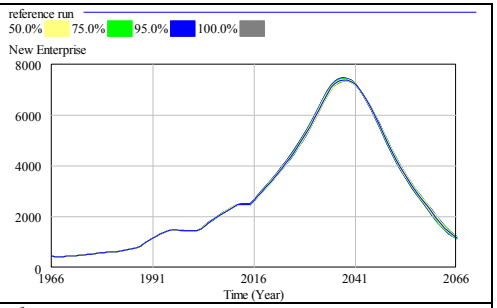
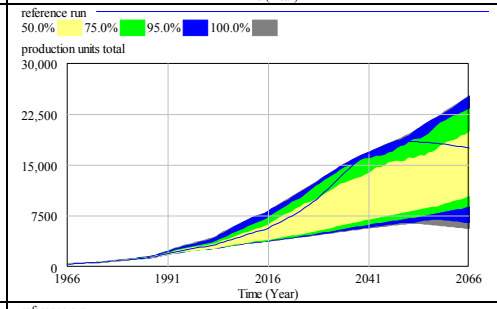
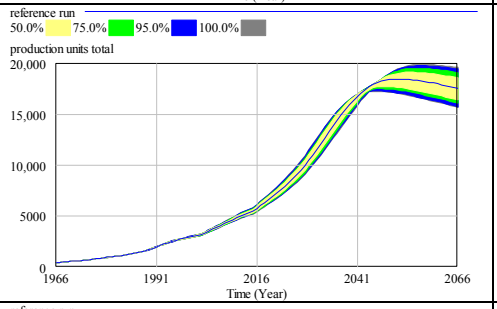
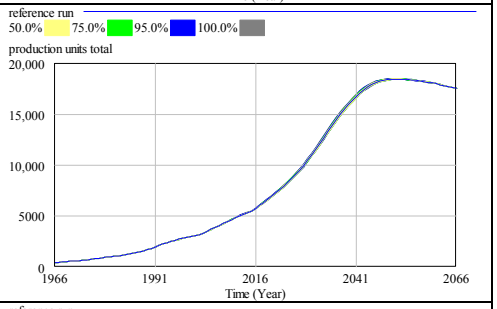
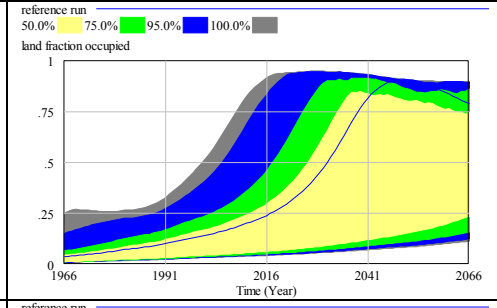
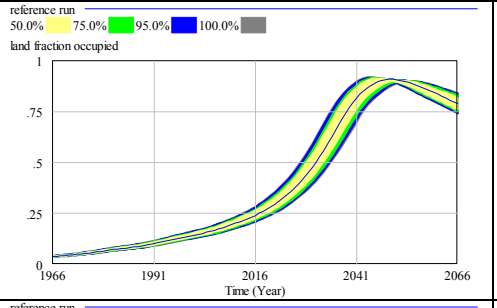
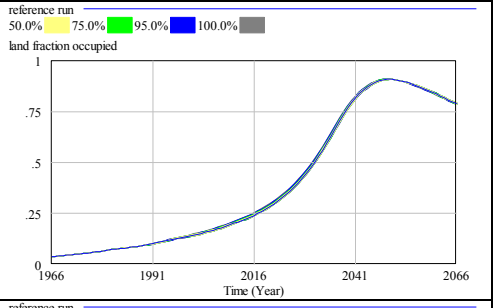
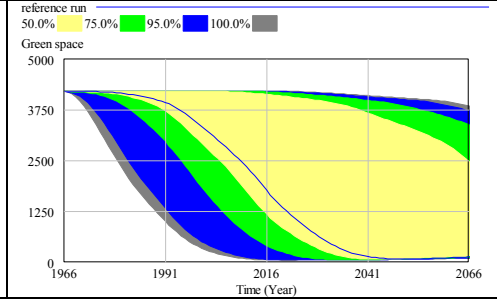
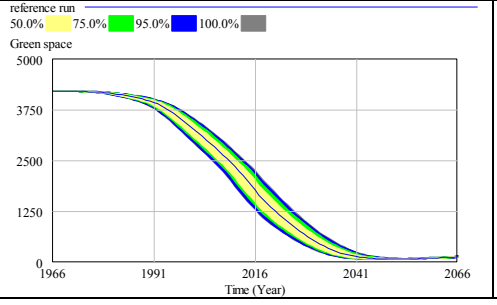
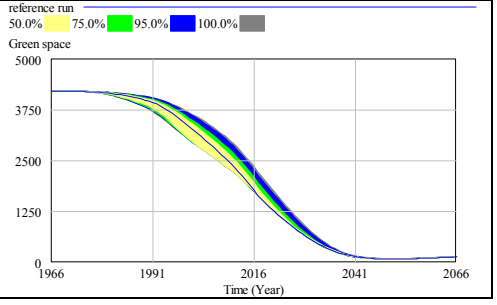
Sensitivity plot: road congestion			

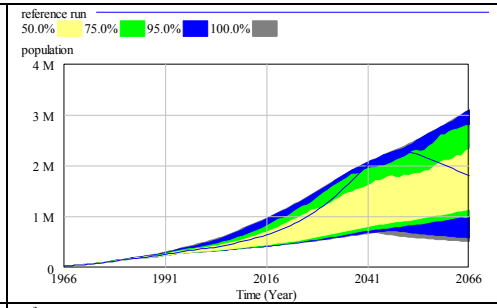
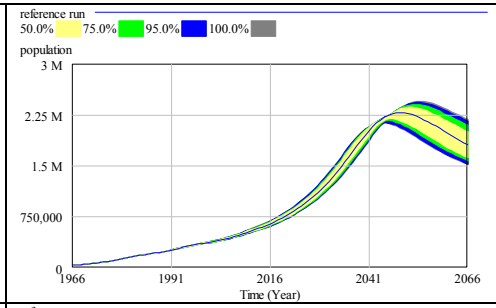
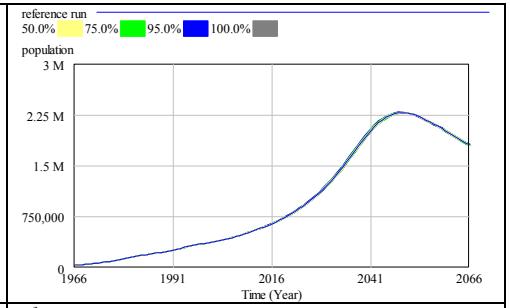
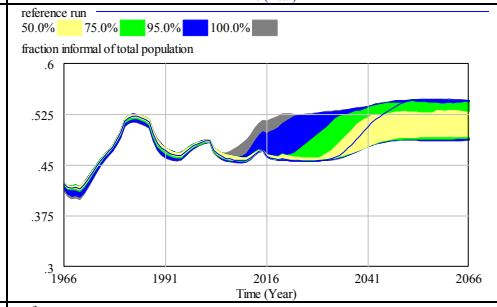
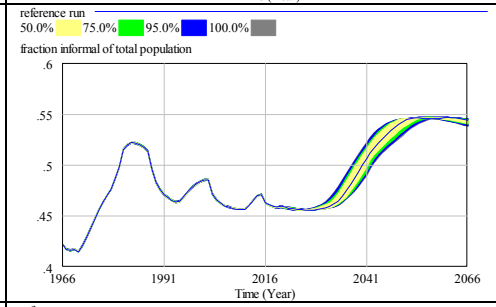
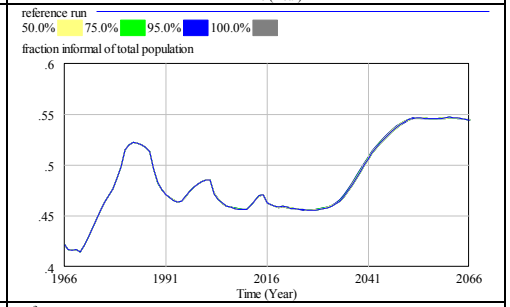
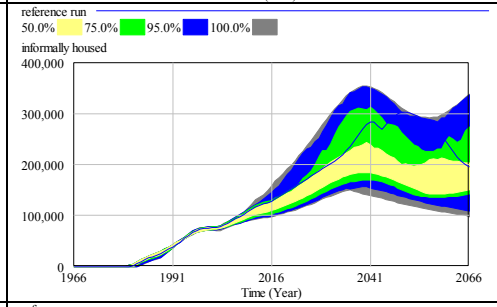
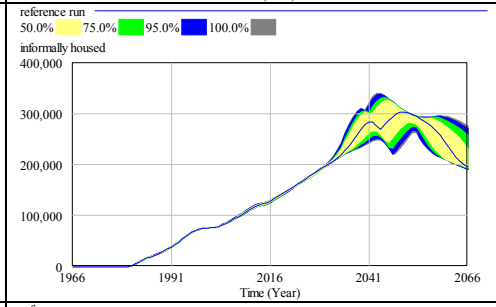
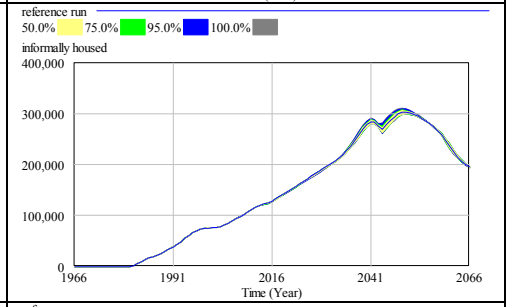
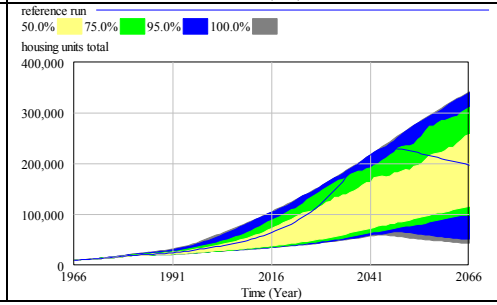
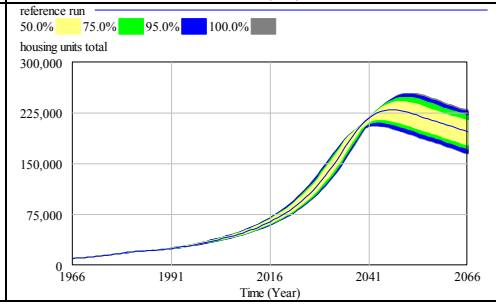
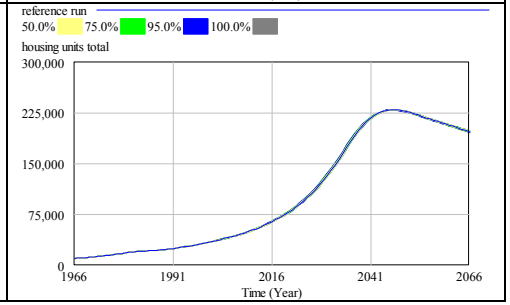
4.2 Land section sensitivity

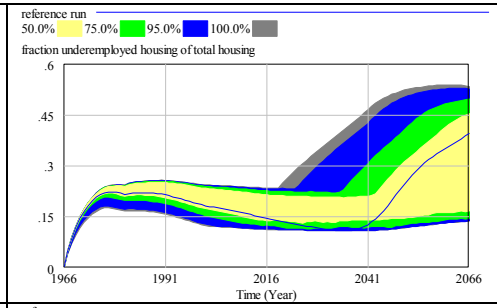
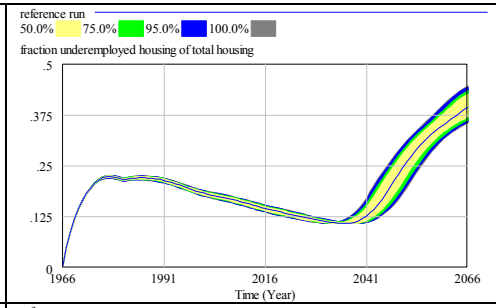
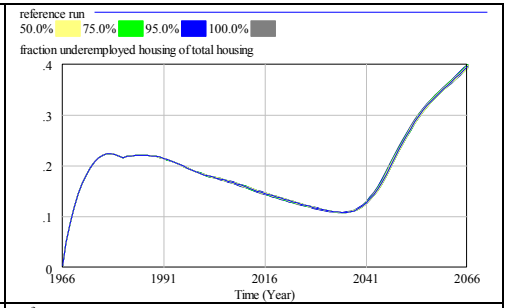
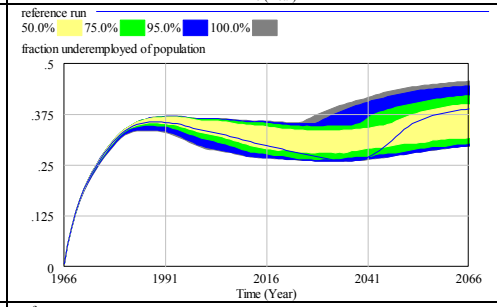
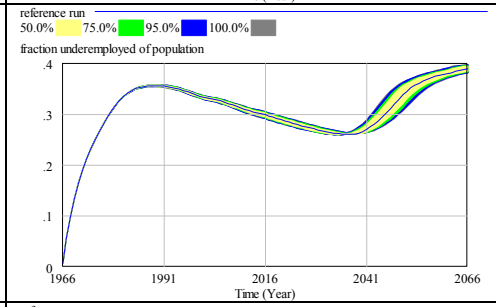
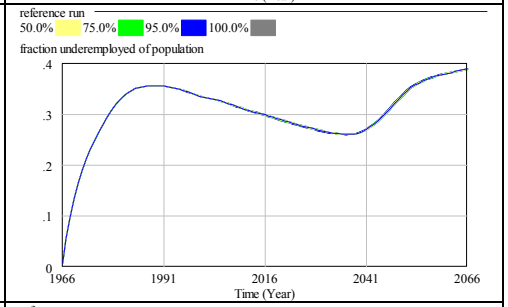
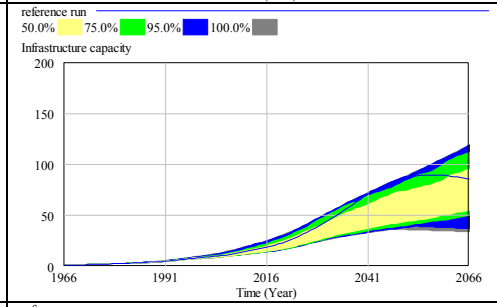
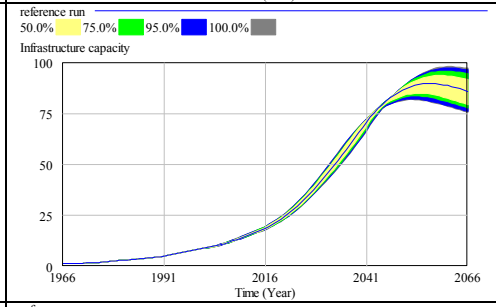
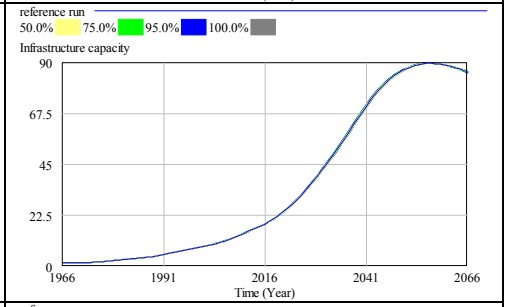
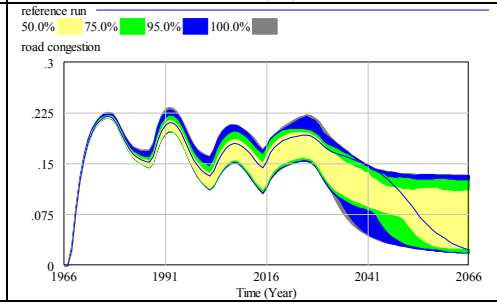
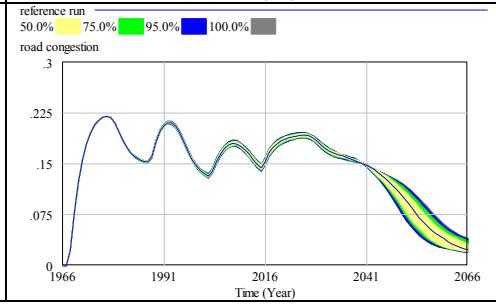
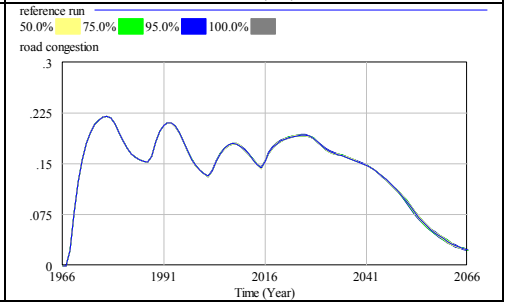
Parameters and lookups to check:

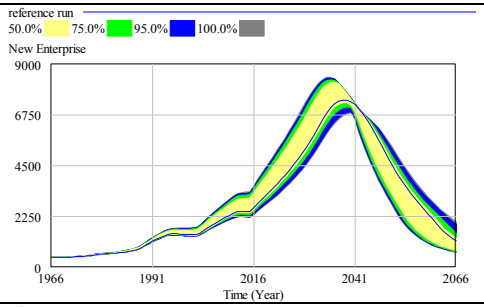
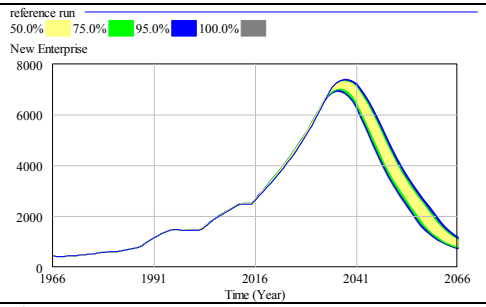
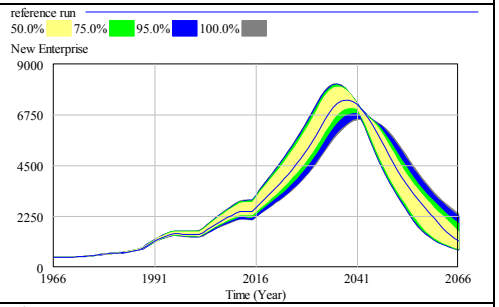
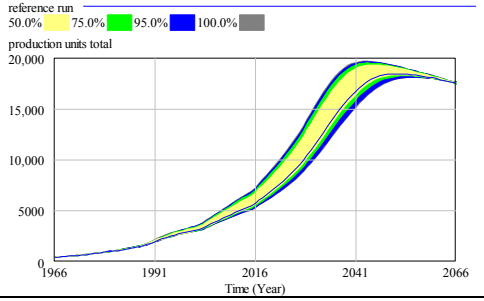
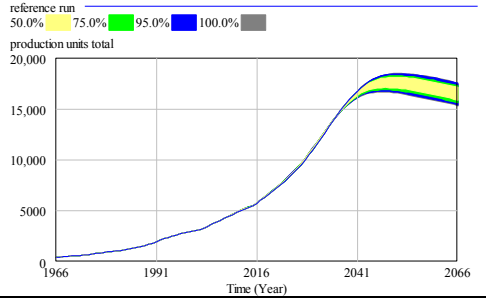
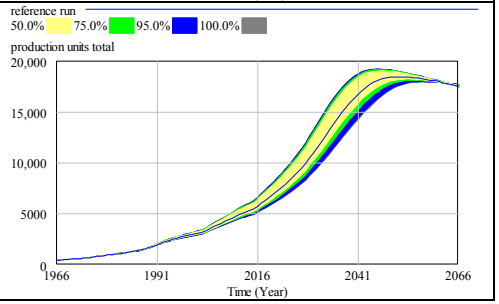
- land area
- societal willingness to settle green space
- green space settlement factor
- min green space area
- initial green space
- unused land to green space delay
- max green space area
- land per production unit
- land per house
- housing area zoned
- industrial area zoned
- land availability effect on green space settlement (lookup)
- zoning effect on housing multiplier (lookup)
- zoning effect on industry multiplier (lookup)

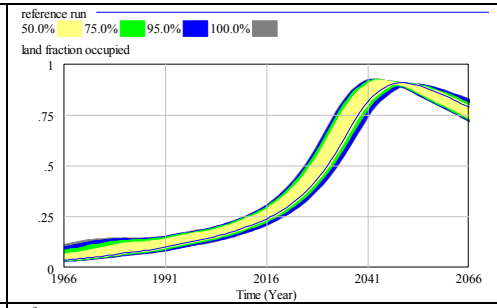
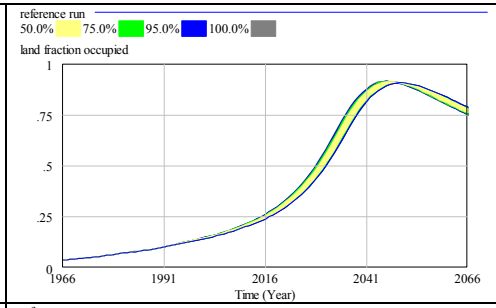
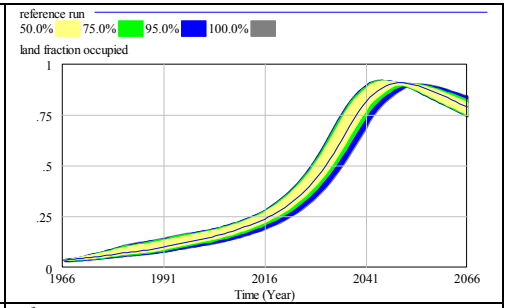
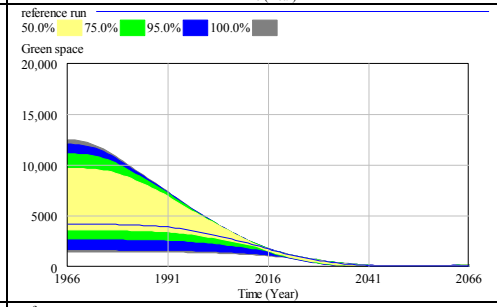
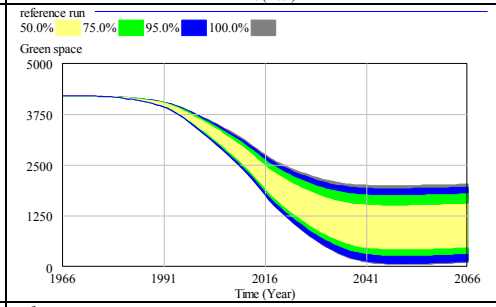
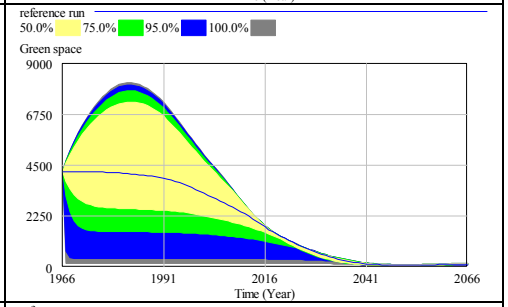
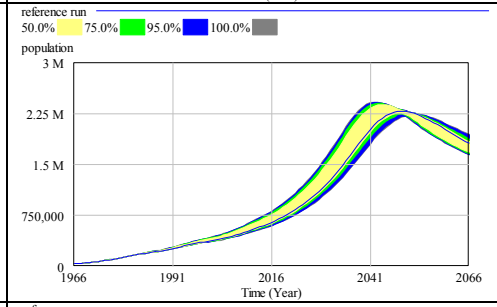
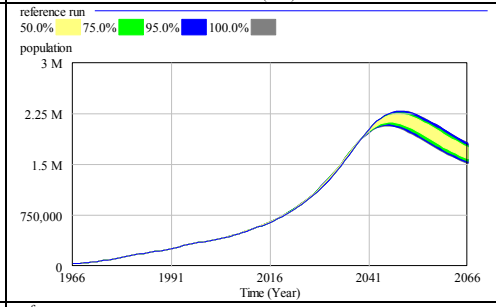
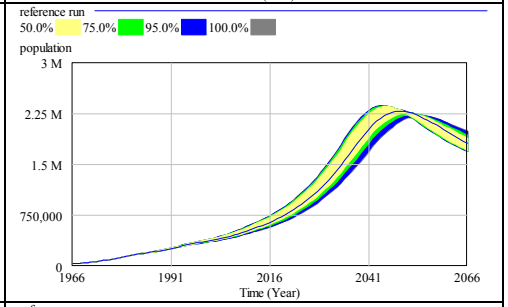
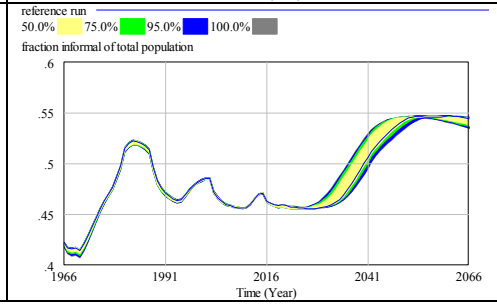
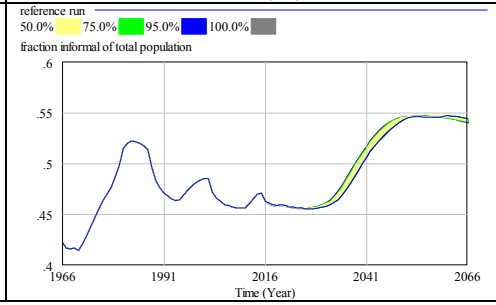
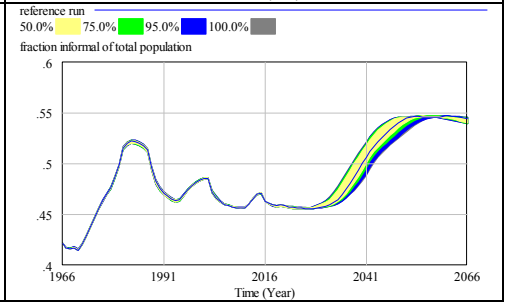
Parameter	land area	land area	societal willingness to settle green space
Units	Ha	Ha	-
Nominal value	16700	16700	From zero to full willingness in 50 years (0.02 slope)
Minimum plausible	5567 (1/3 times Tema)	15030 (-10%)	From zero to full willingness in 100 years (0.01 slope)
Maximum plausible	50100 (3 times Tema)	18370 (+10%)	From zero to full willingness in 25 years (0.04 slope)

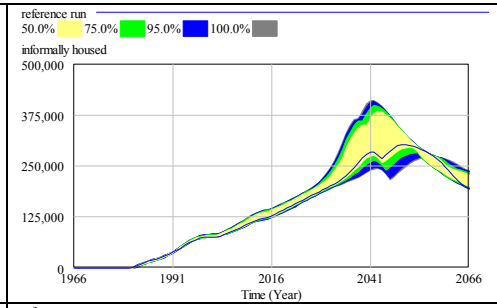
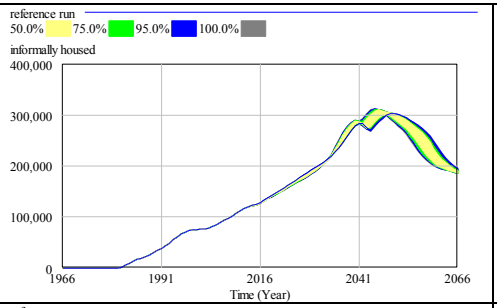
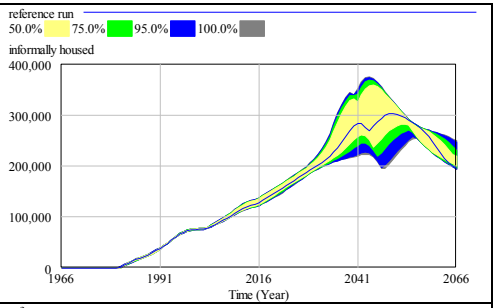
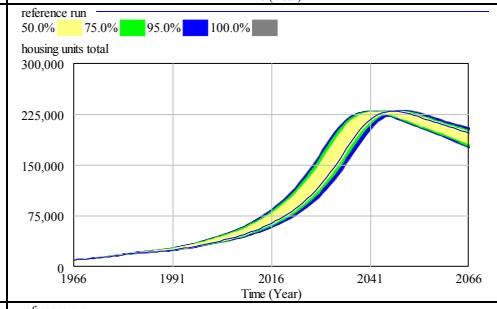
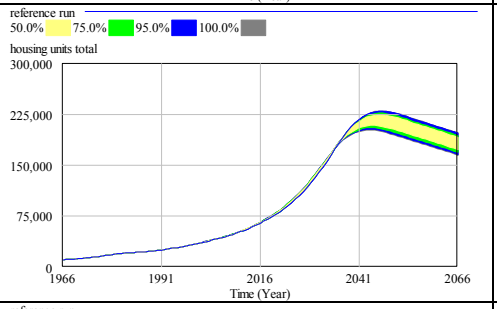
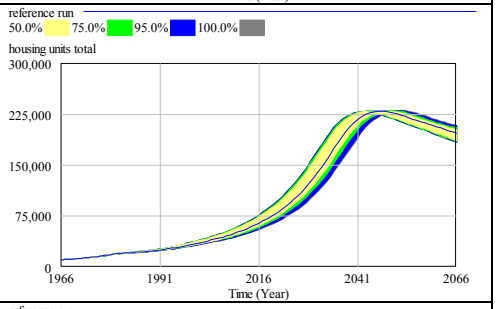
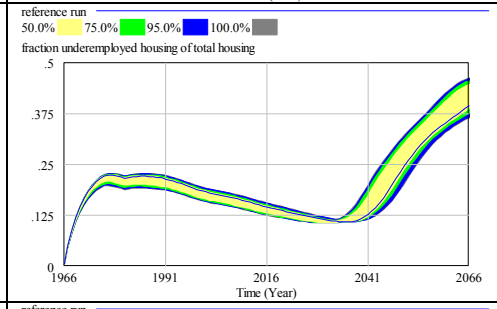
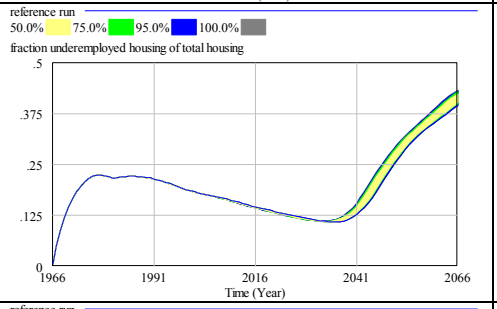
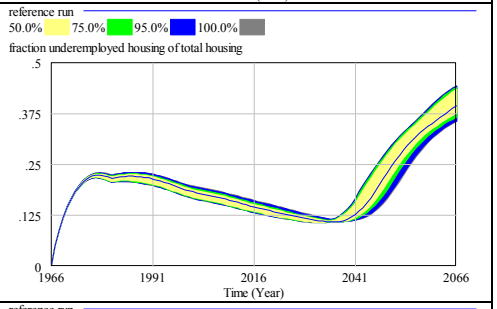
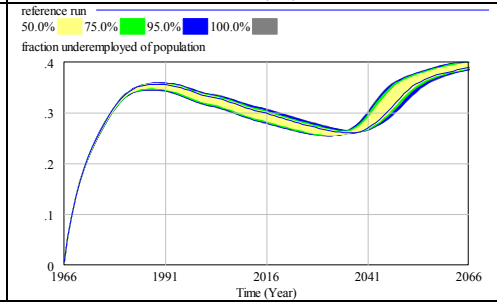
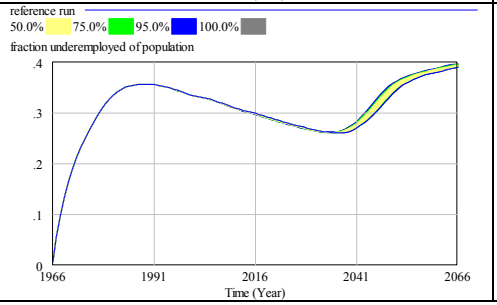
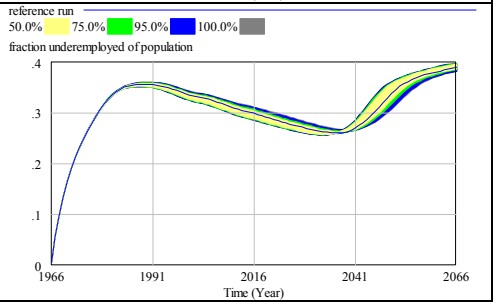
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

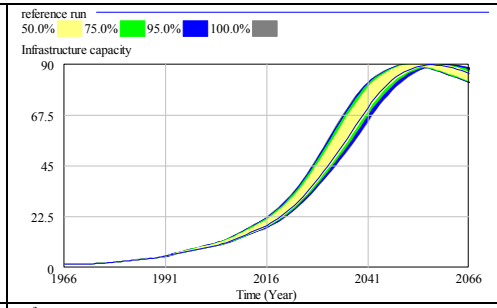
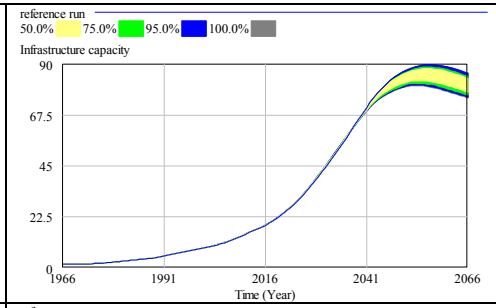
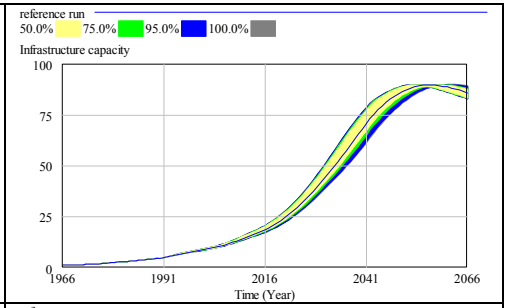
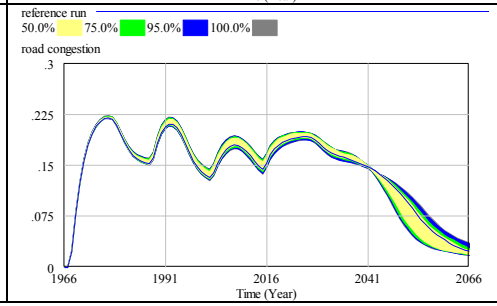
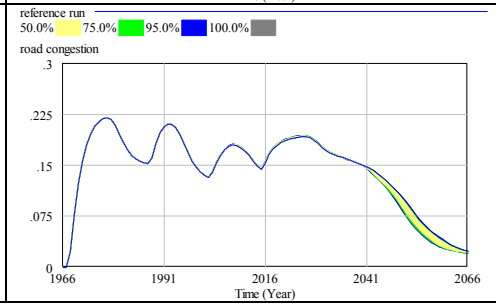
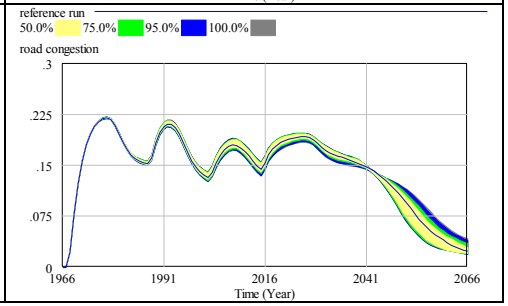
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

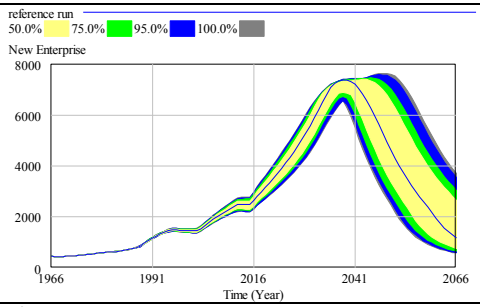
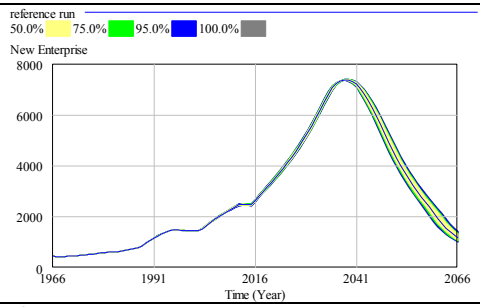
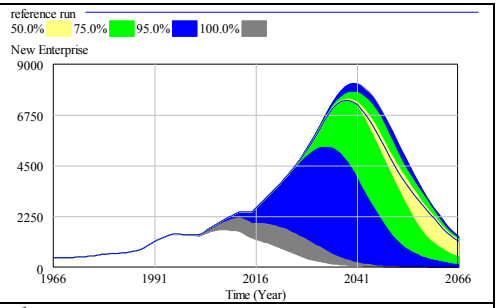
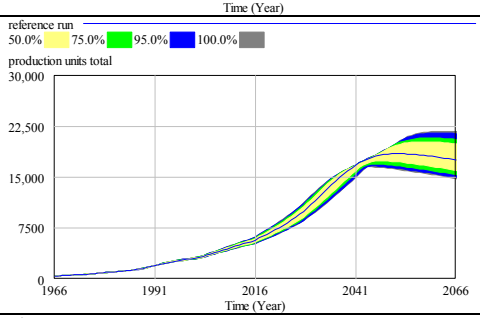
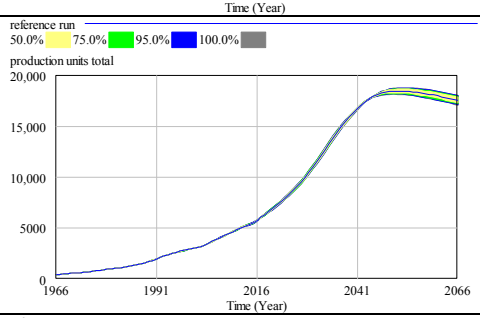
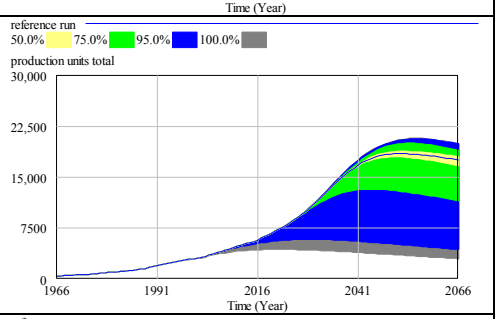
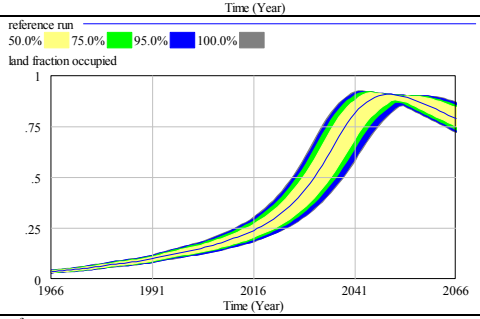
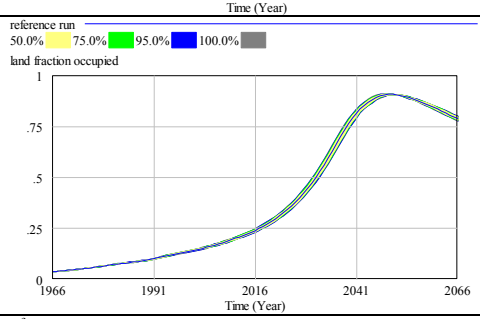
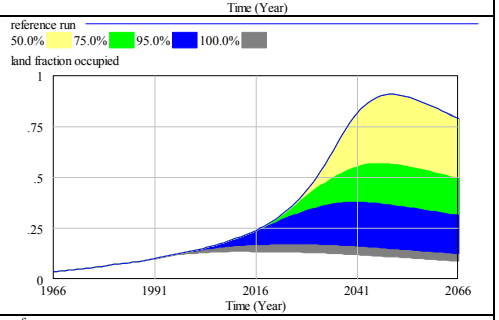
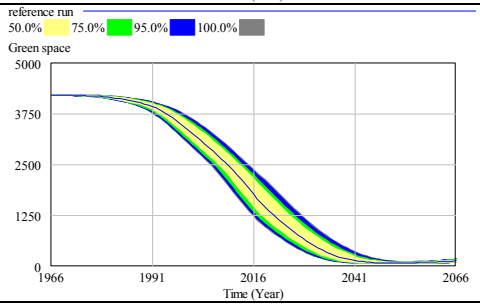
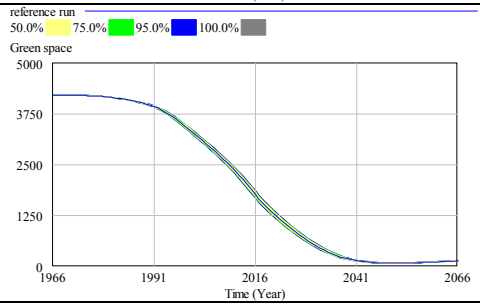
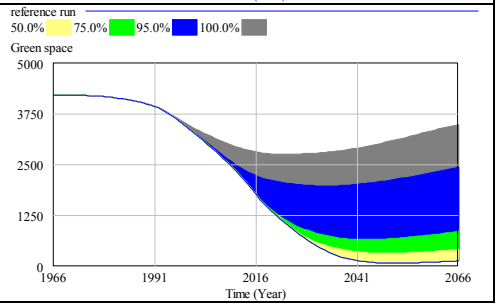
Parameter	initial green space	min green space	max green space
Units	Ha	Ha	Ha
Nominal value	4199	50	4199
Minimum plausible	1340 (1/3 times actual)	0	0
Maximum plausible	12597 (3 times actual) (**max green space* set to *initial green space*)	2000 (protect an area almost twice the Sakumo ramsar site)	12597 (3 times actual 1966 value)
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			

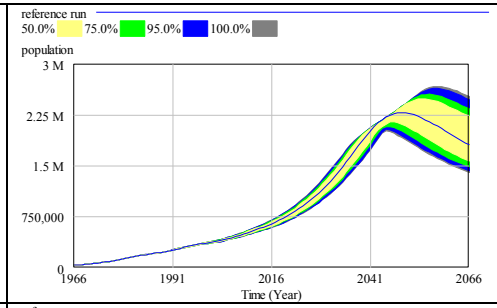
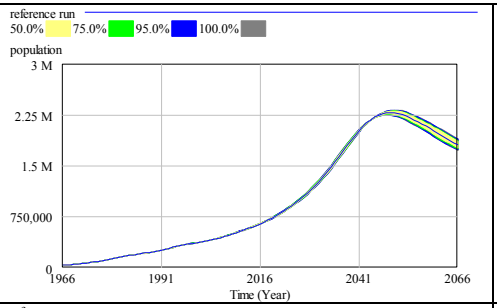
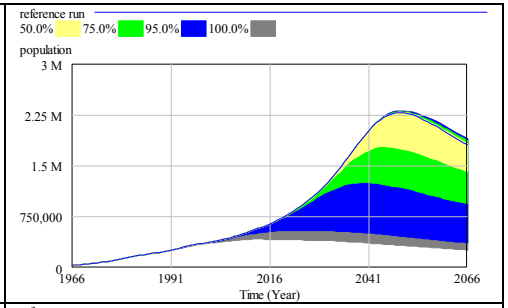
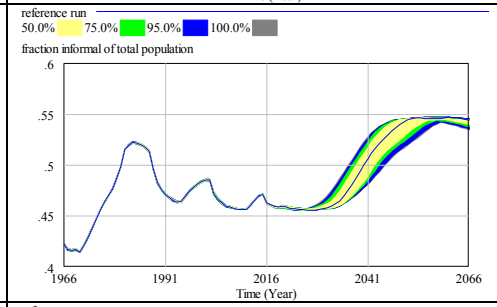
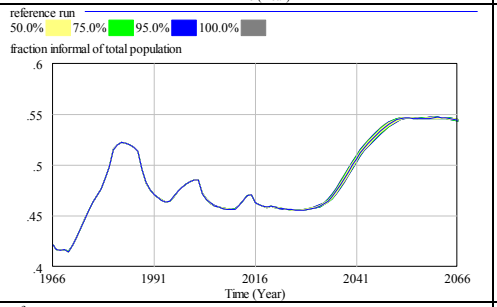
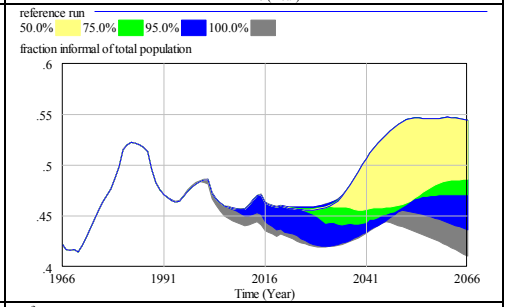
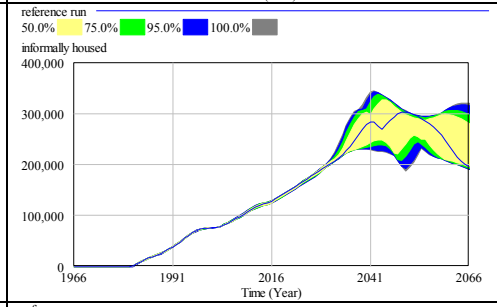
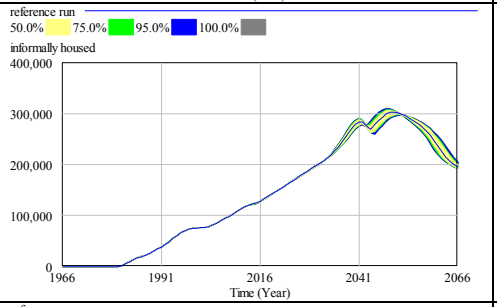
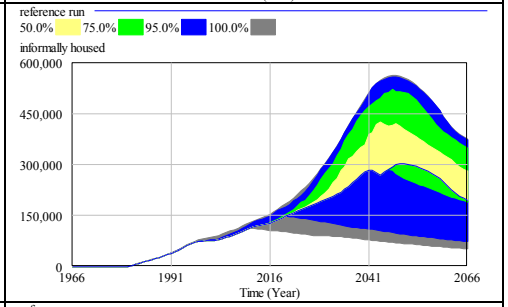
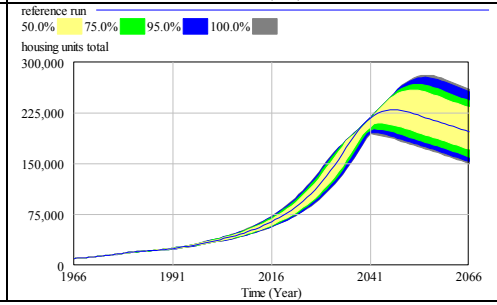
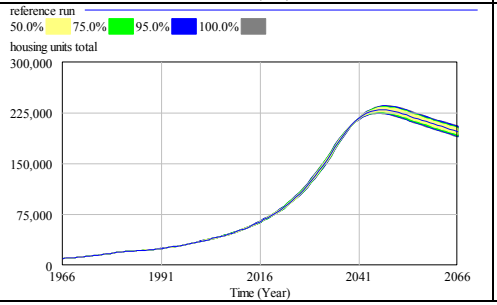
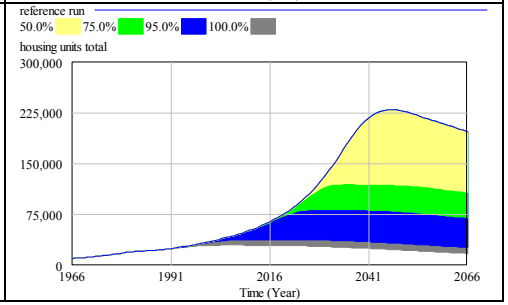
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			

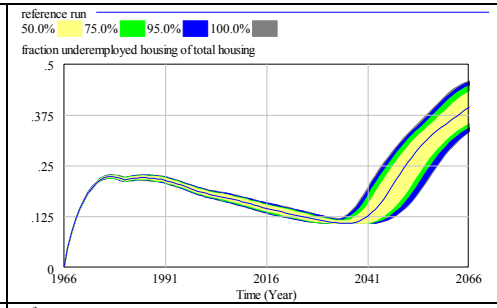
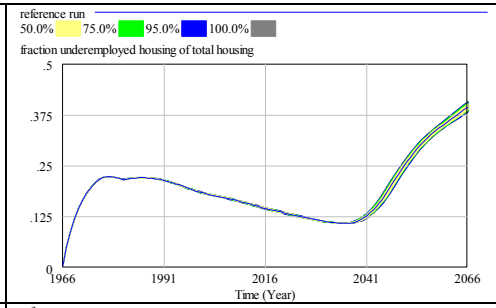
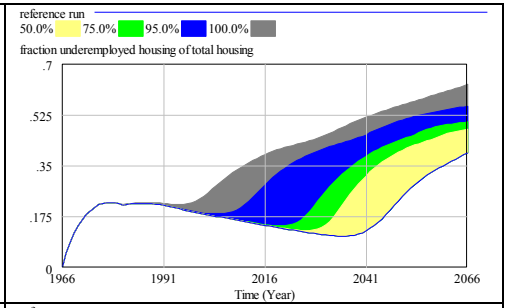
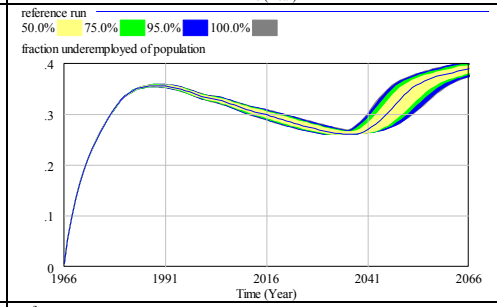
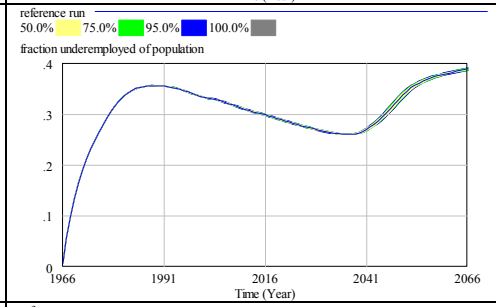
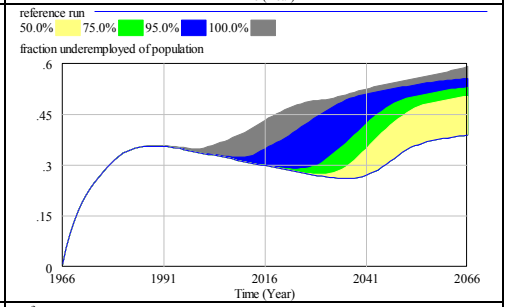
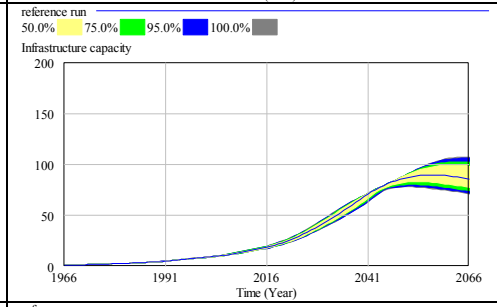
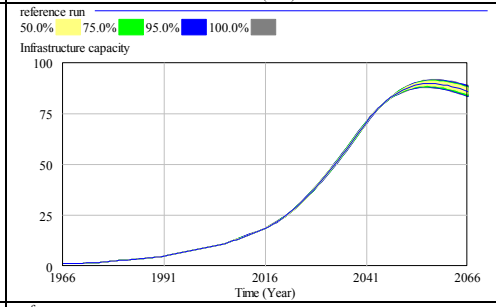
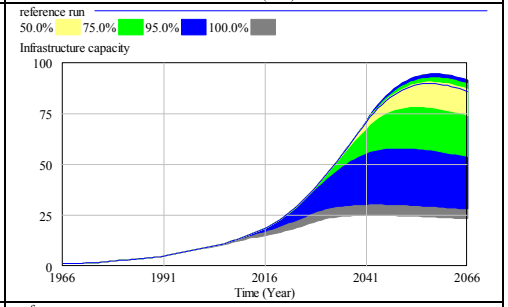
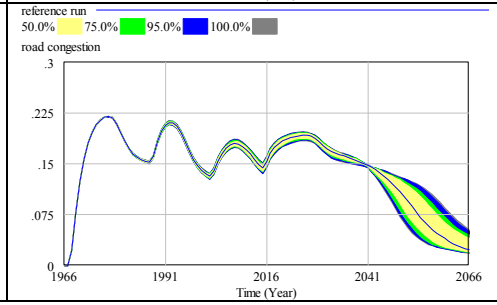
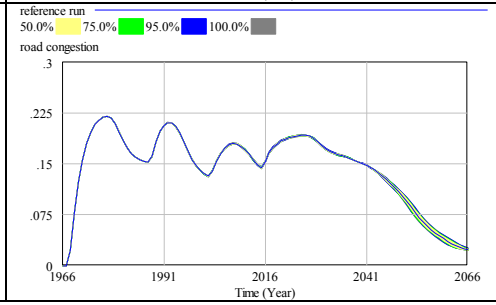
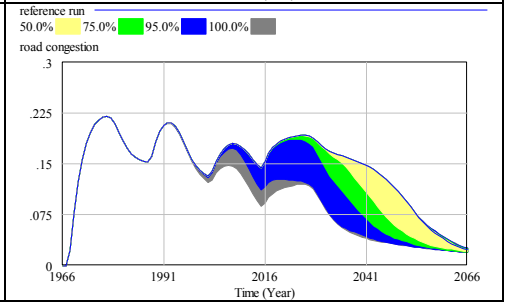
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			

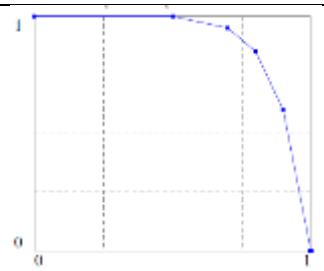
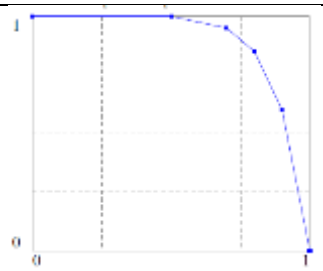
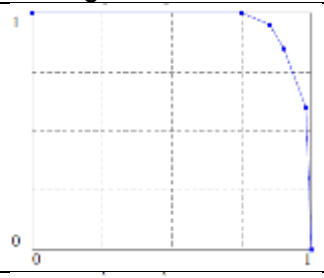
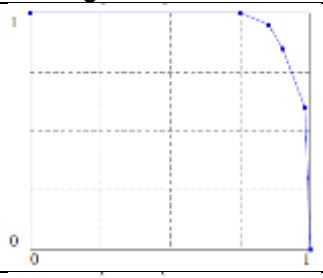
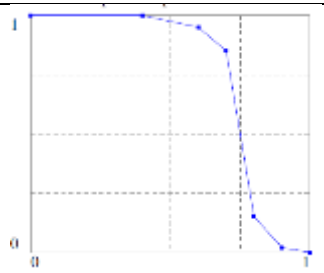
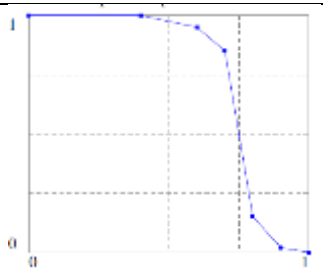
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

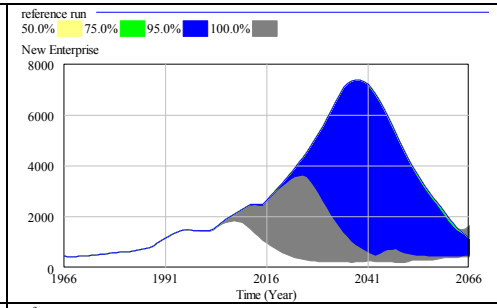
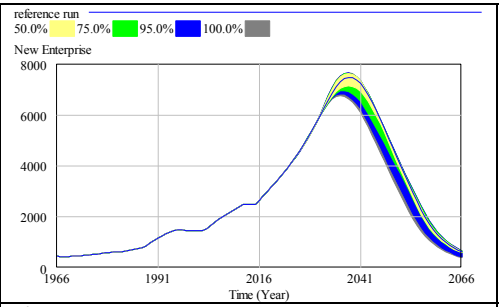
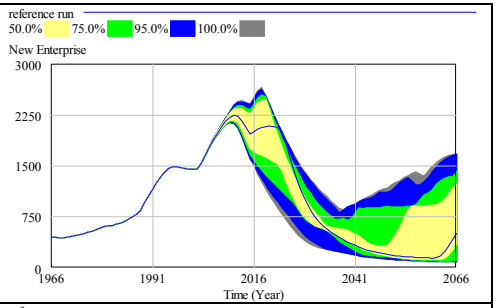
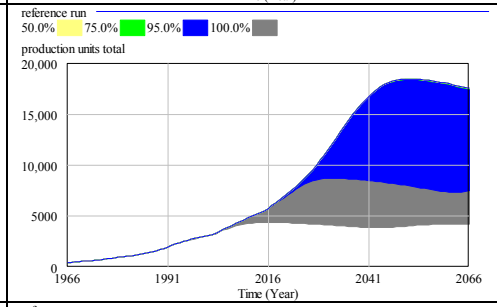
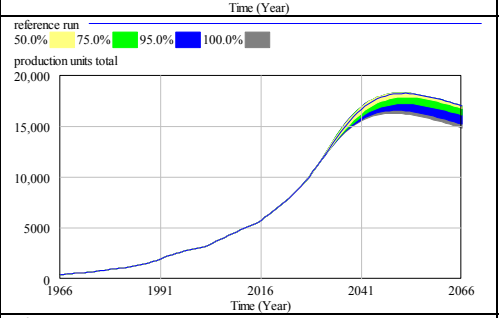
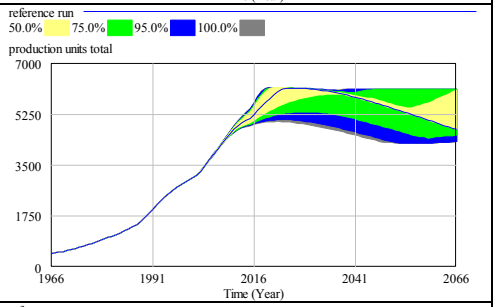
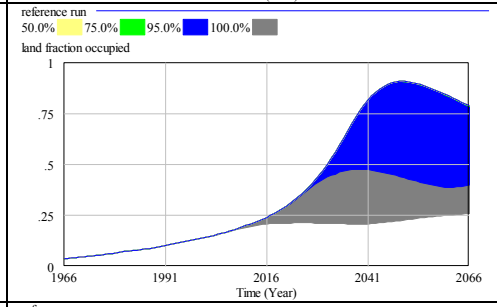
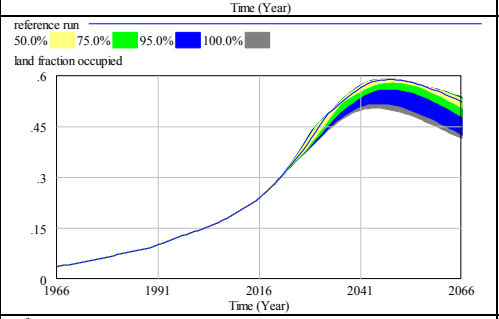
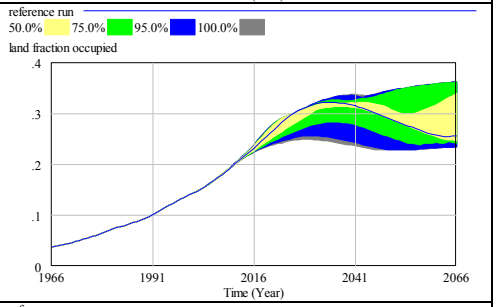
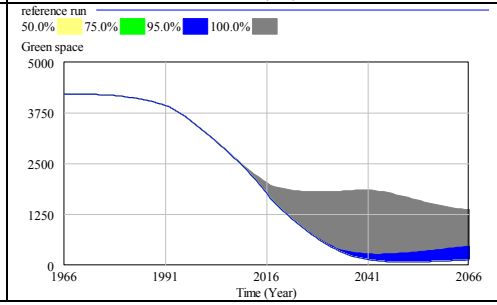
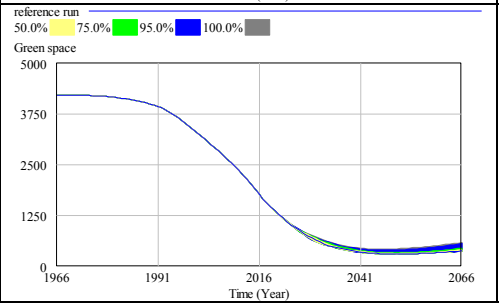
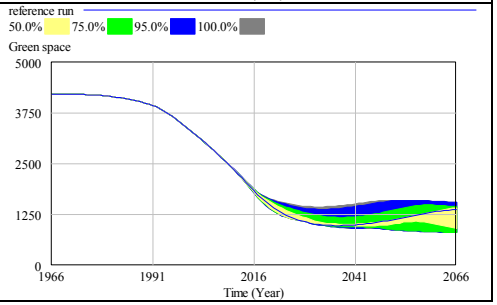
Parameter	land per house	land per production unit	housing area zoned
Units	Ha/housing unit	Ha/productive unit	Ha
Nominal value	0.0405	0.080937	16700*1.2
Minimum plausible	0,0324 (-20%)	0,0647496 (-20%)	1000
Maximum plausible	0,0486 (+20%)	0,0971244 (+20%)	16700*1.2

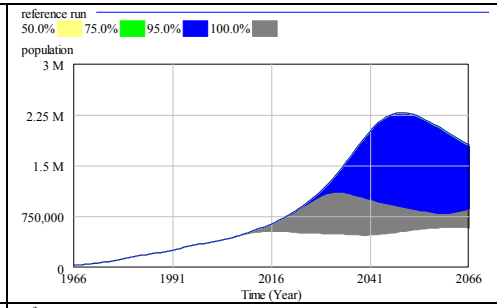
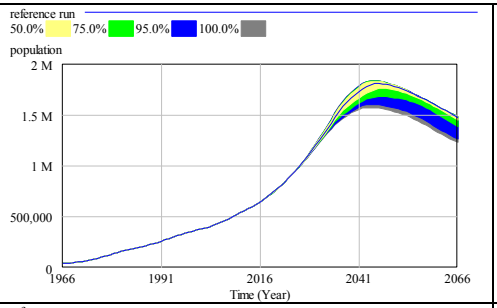
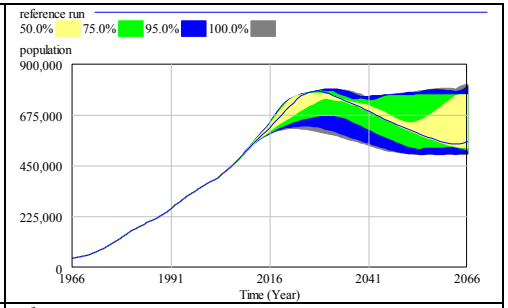
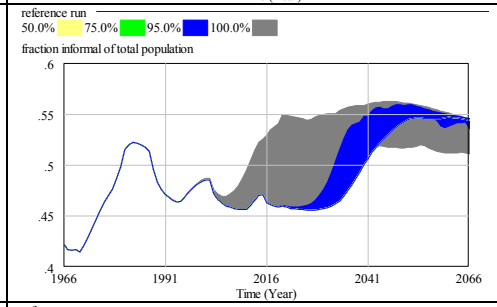
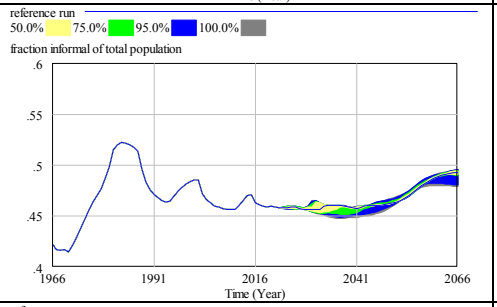
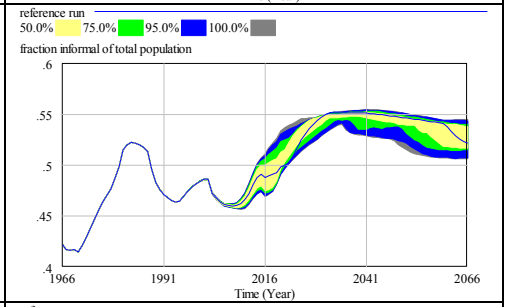
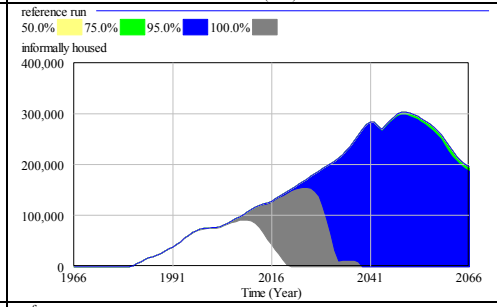
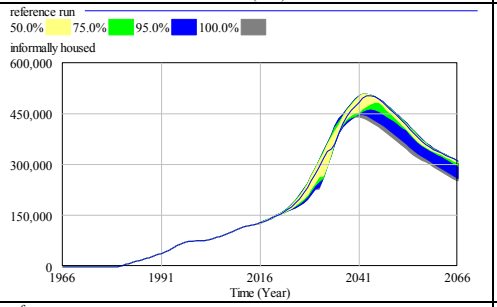
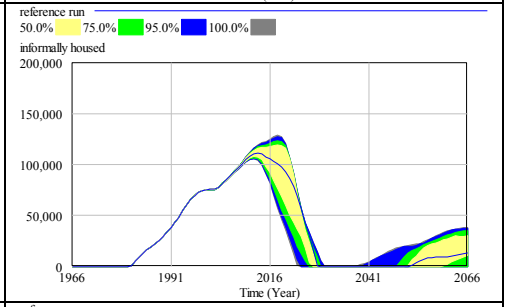
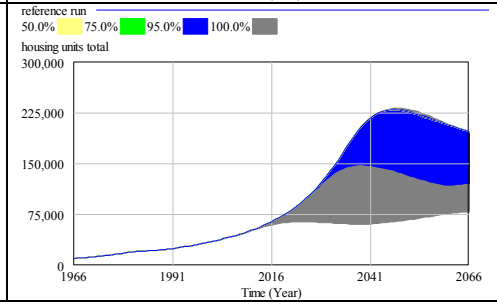
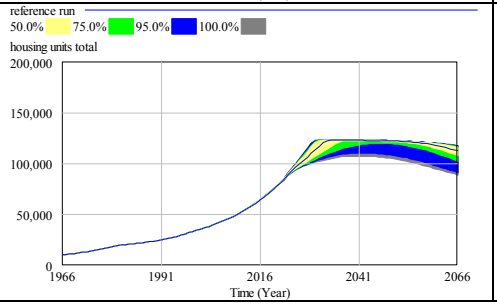
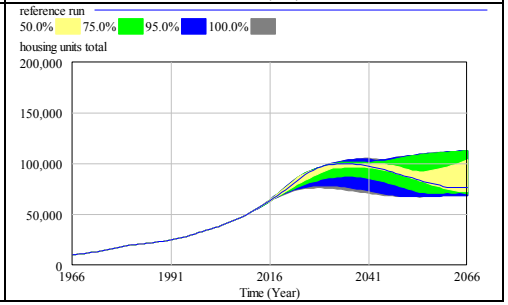
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

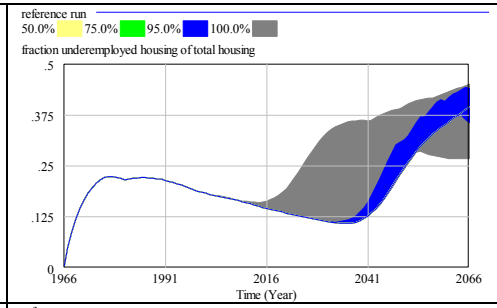
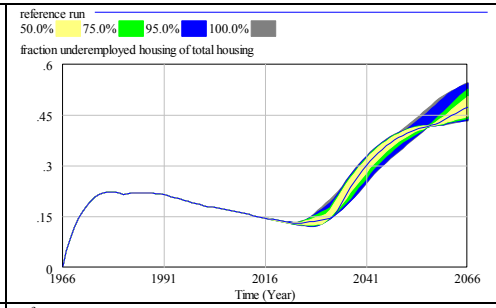
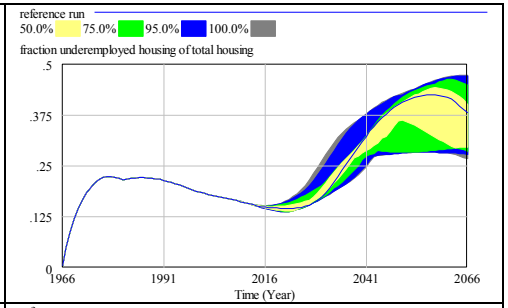
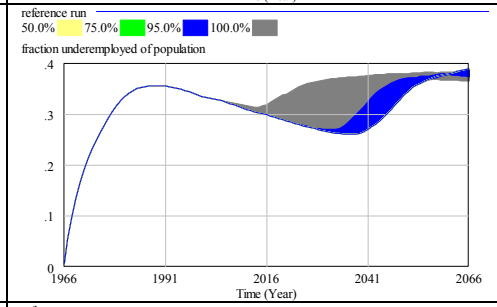
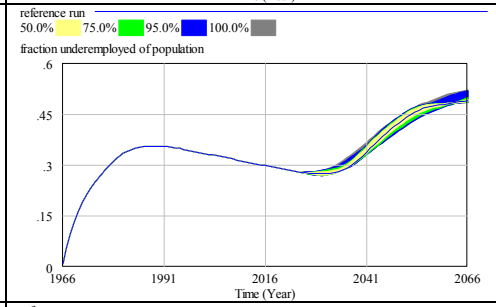
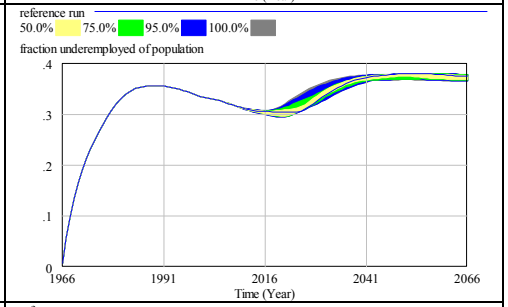
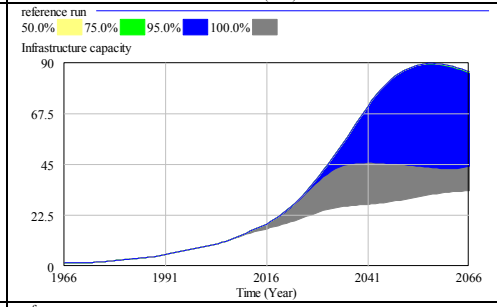
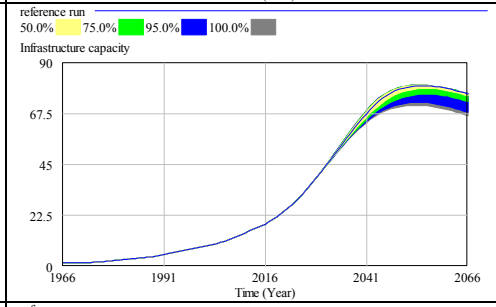
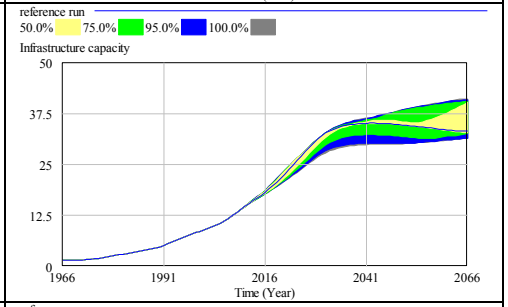
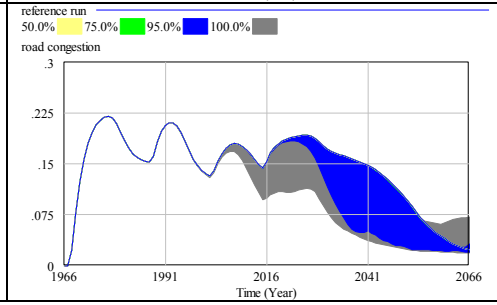
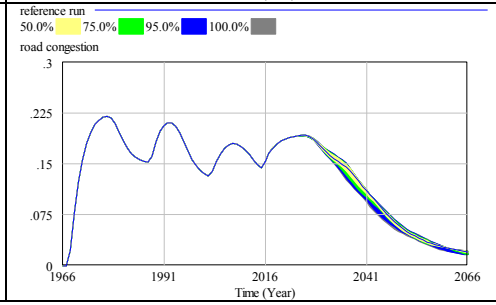
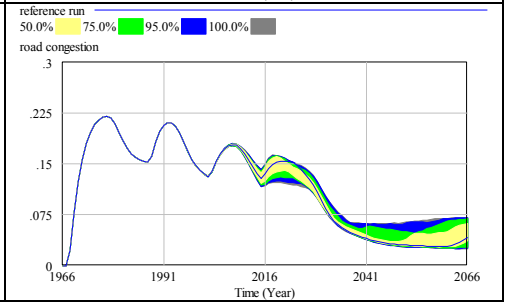
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

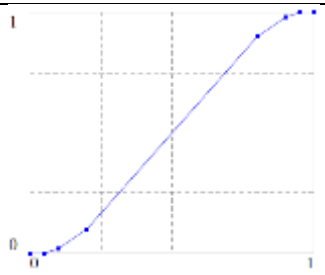
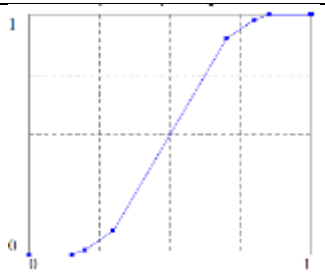
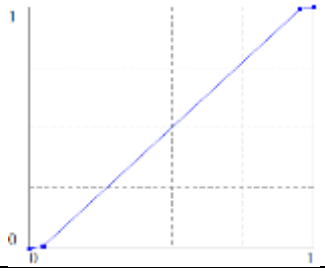
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

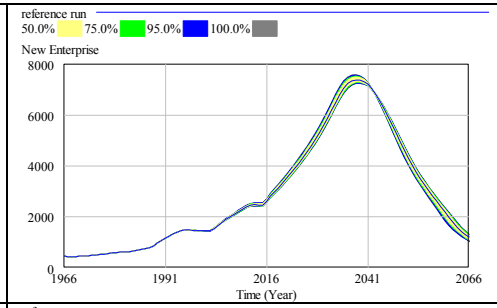
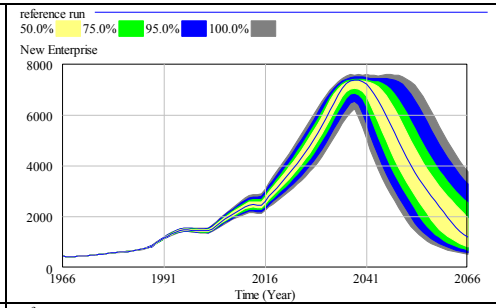
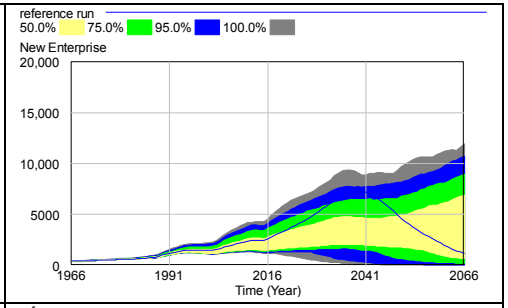
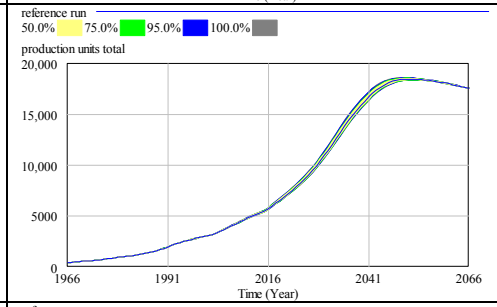
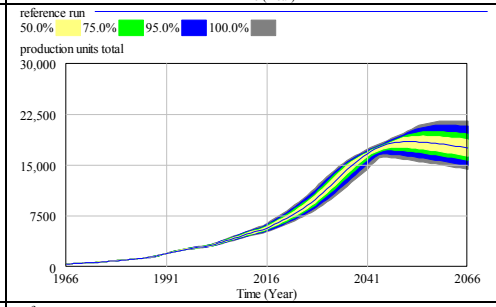
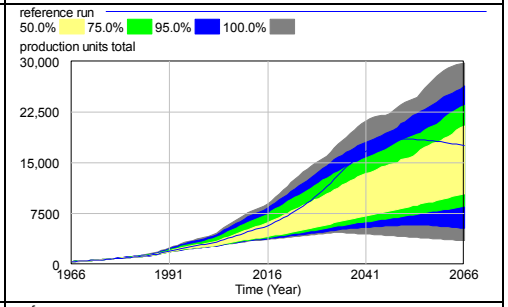
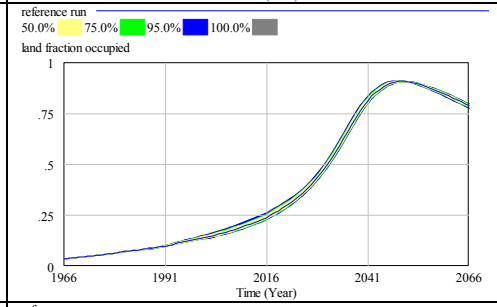
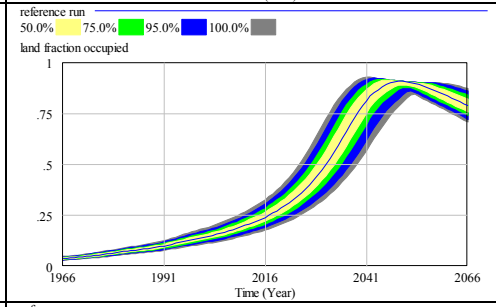
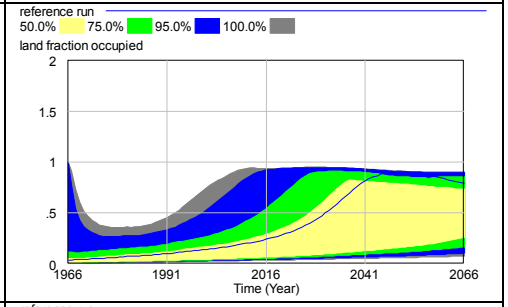
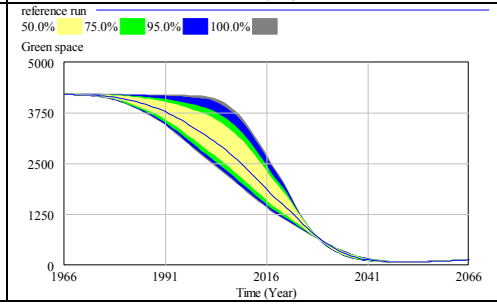
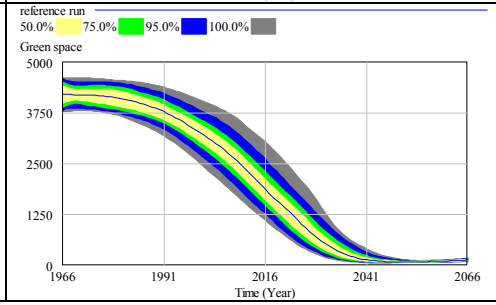
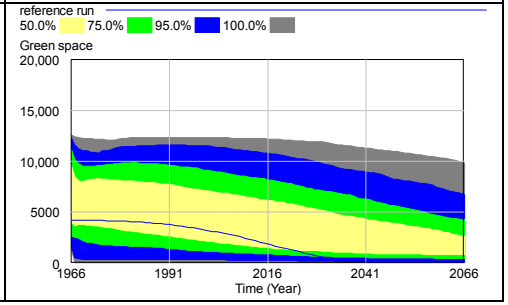
Parameter	industrial area zoned	zoning effect on housing multiplier (lookup)	zoning effect on industry multiplier (lookup)
Units	Ha	-	-
Nominal value	20040	 Zoning limit: 5000	 Zoning limit: 500
Minimum plausible	100		
Maximum plausible	20040		

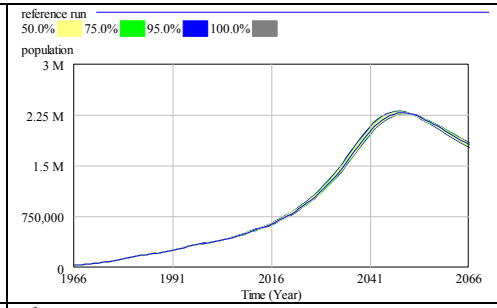
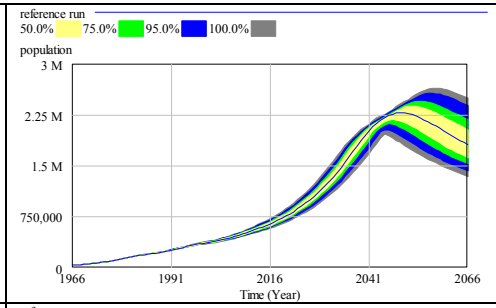
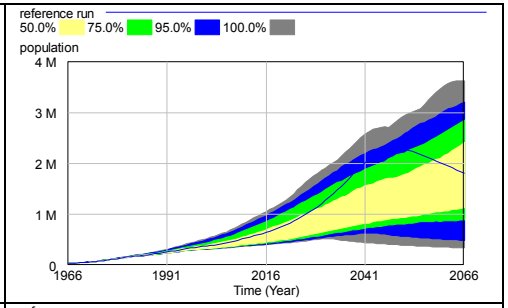
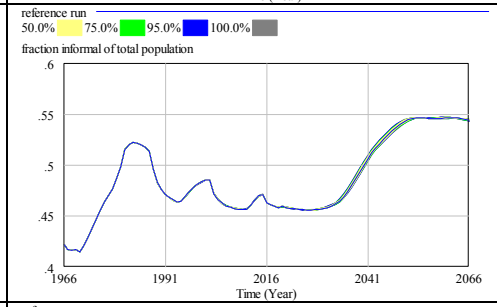
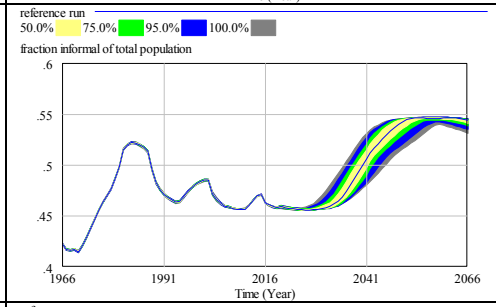
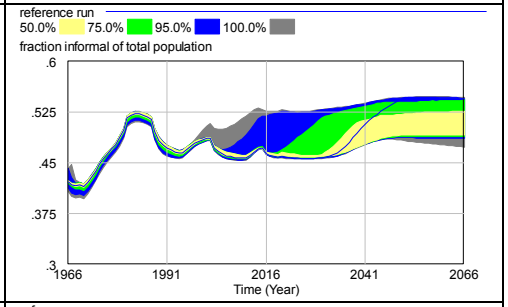
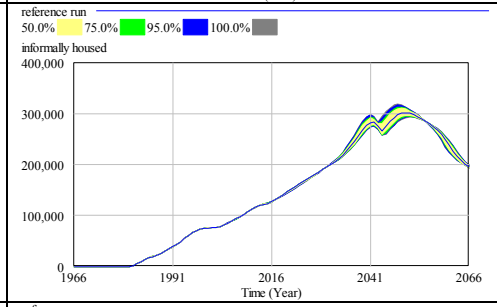
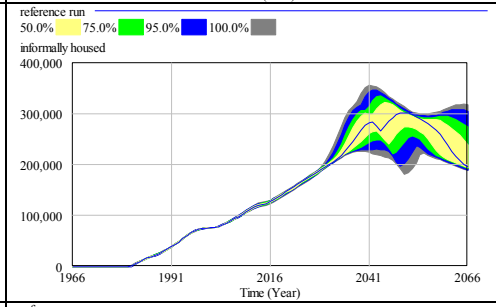
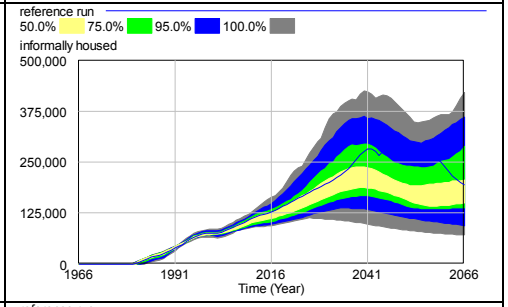
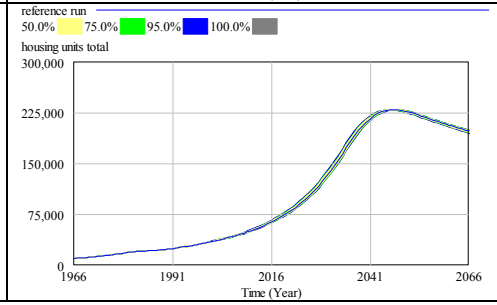
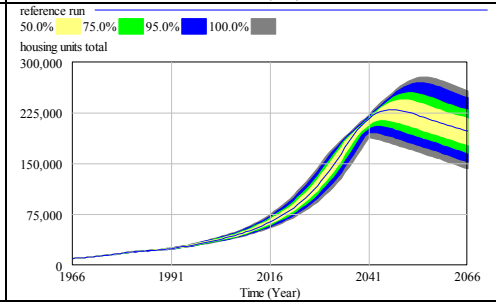
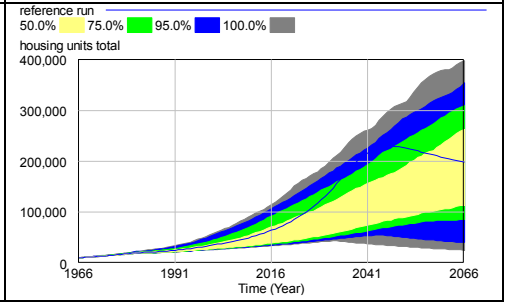
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

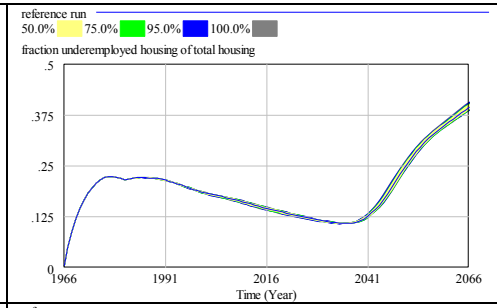
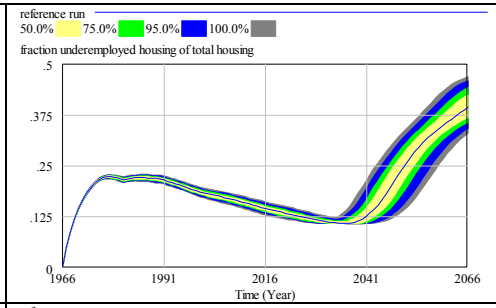
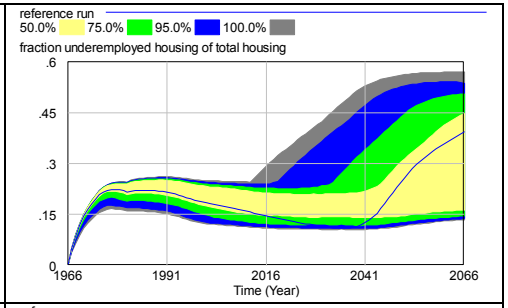
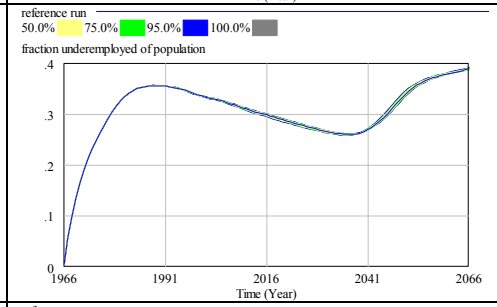
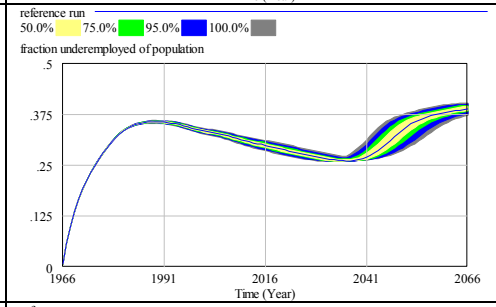
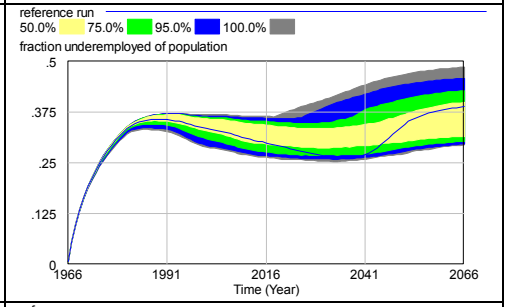
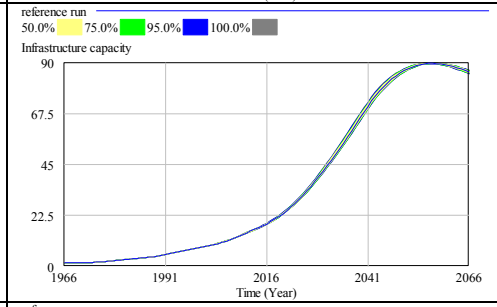
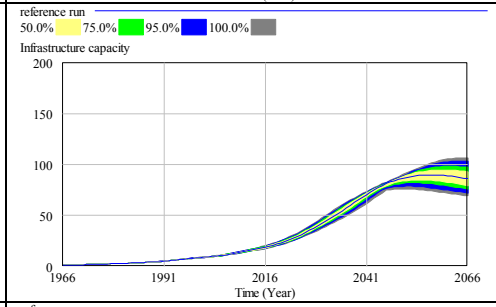
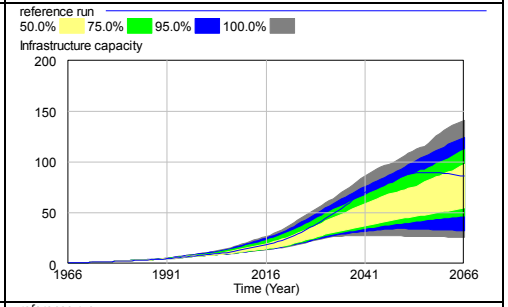
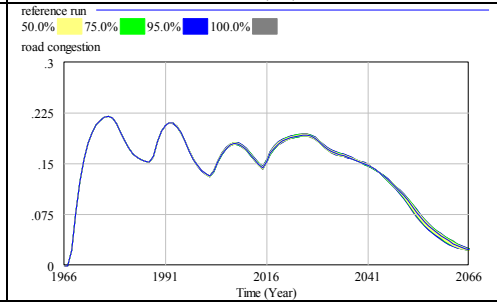
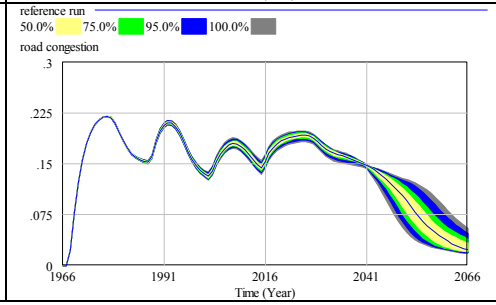
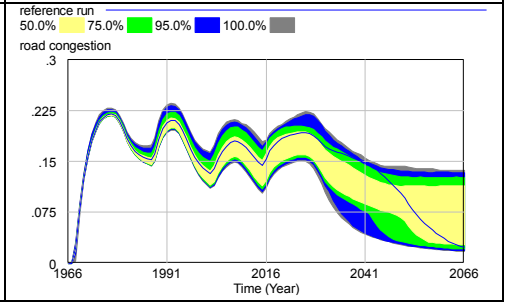
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

Parameter	land availability effect on green space settlement (lookup)	Multivariate, all parameters except zoning	Multivariate, all parameters except zoning
Units	-	-	-
Nominal value		-	-
Minimum plausible		-10%	Respective minimum values per variable *(except correction for min green space to be equal to or below max green space)*
Maximum plausible		+10%	Respective maximum values per variable

Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

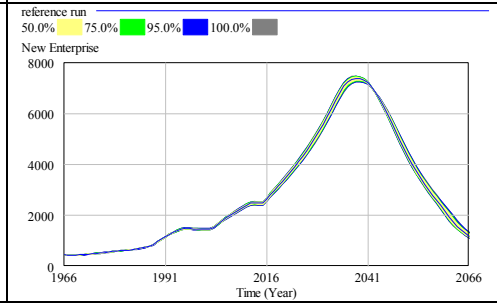
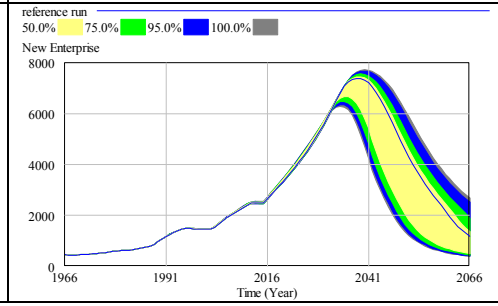
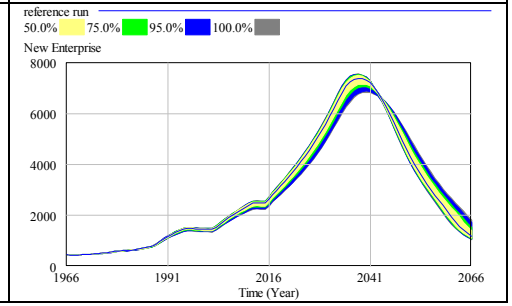
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

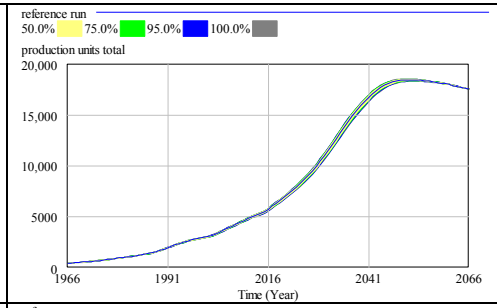
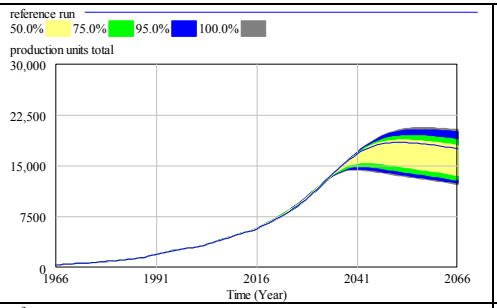
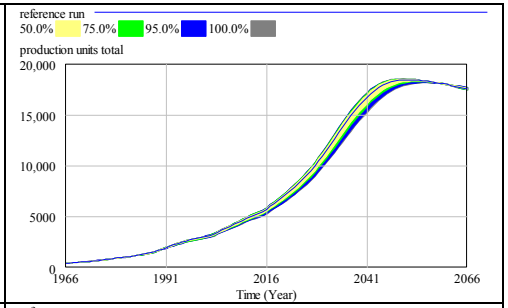
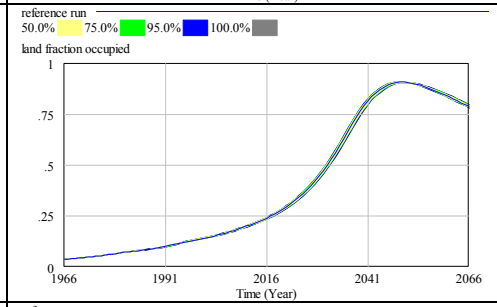
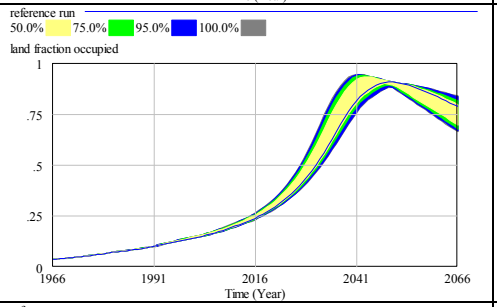
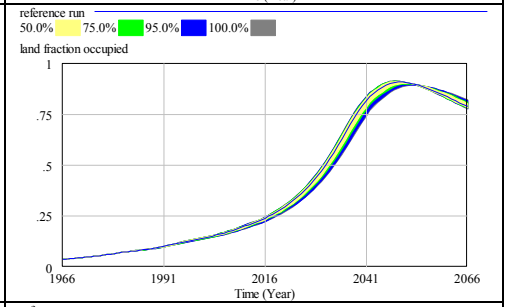
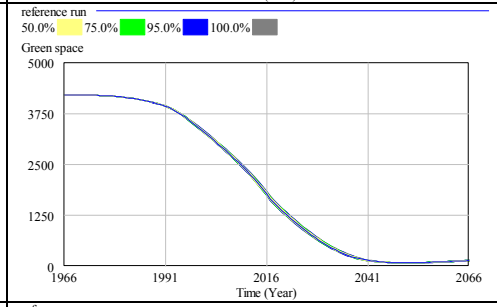
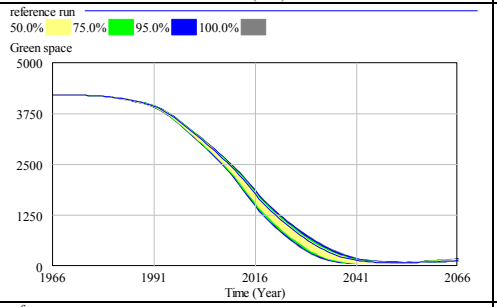
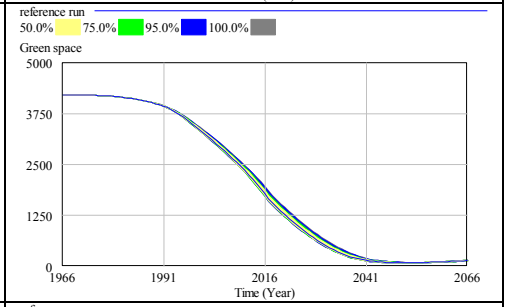
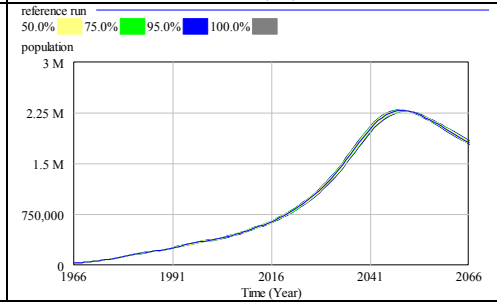
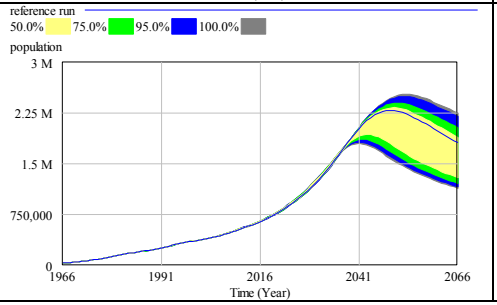
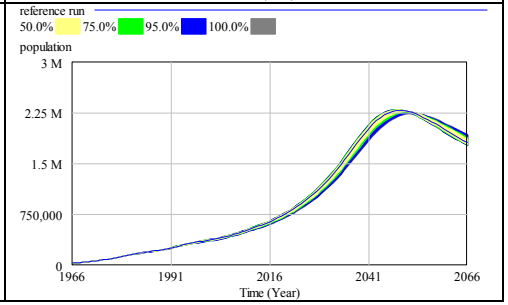
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

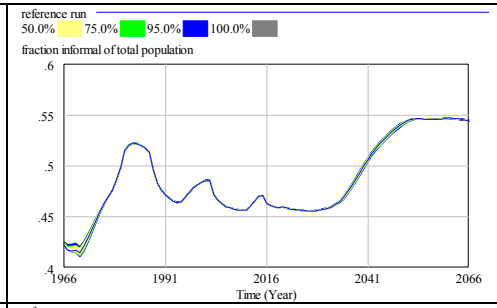
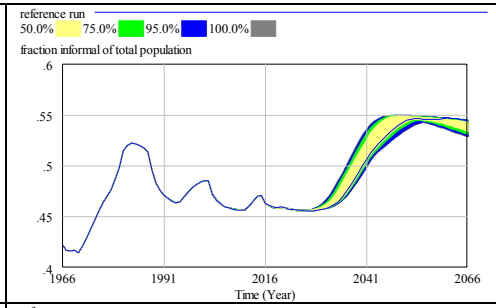
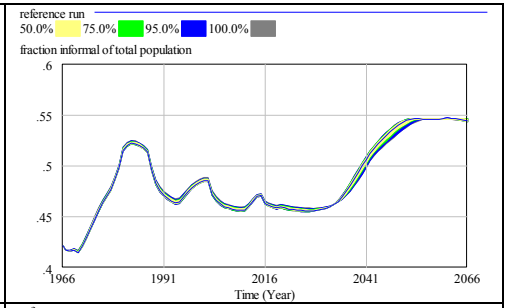
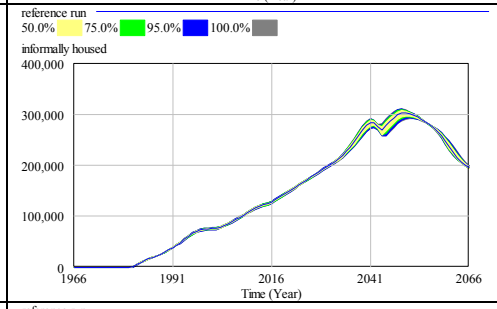
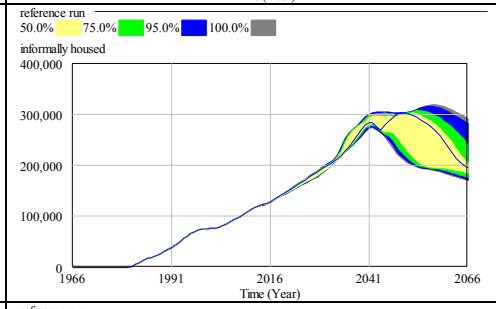
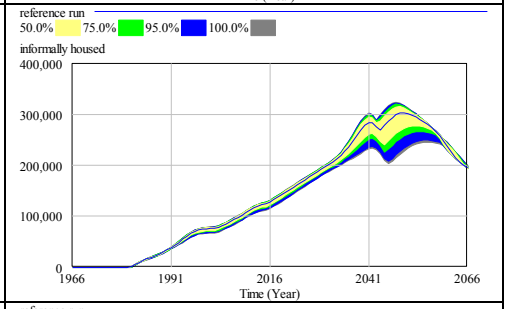
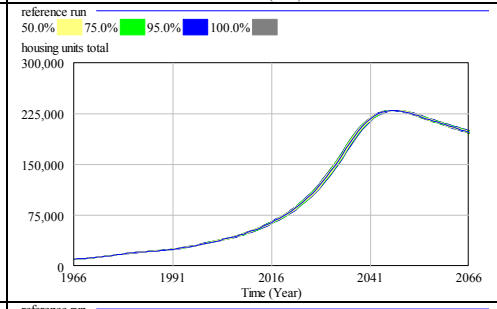
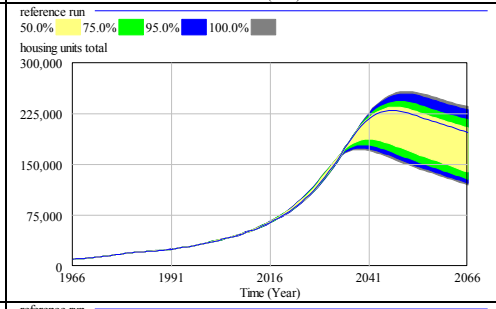
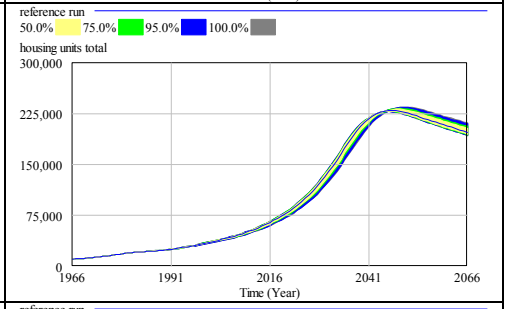
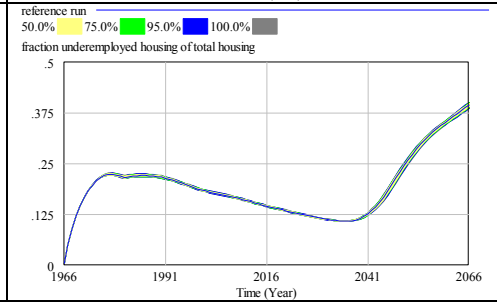
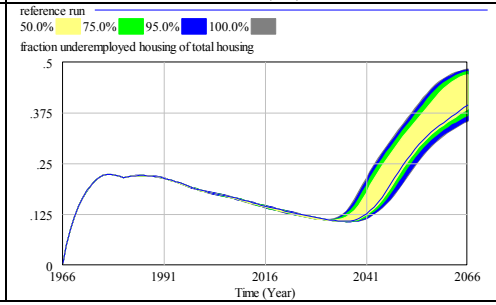
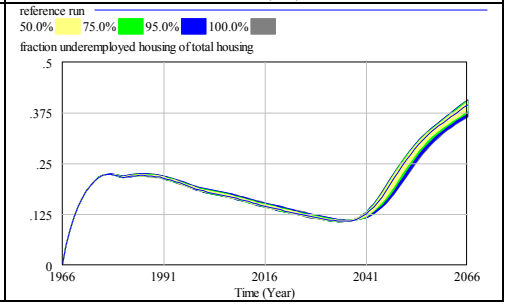
4.3 Transport sub-model sensitivity

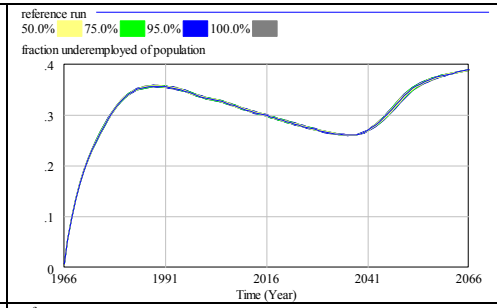
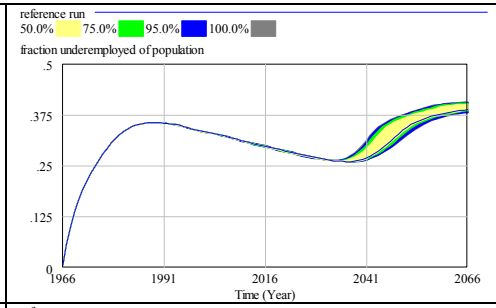
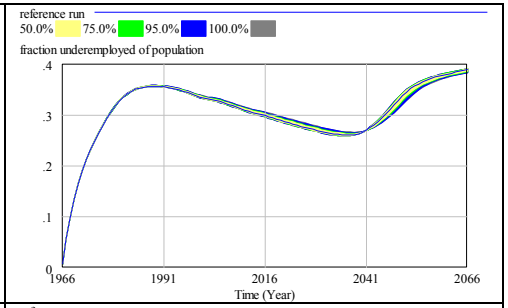
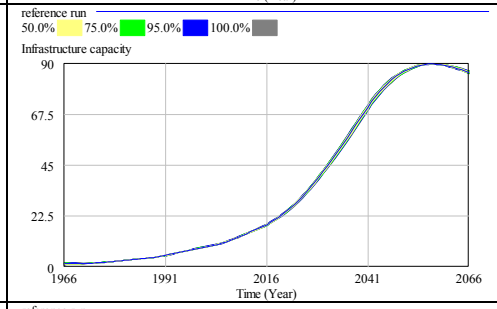
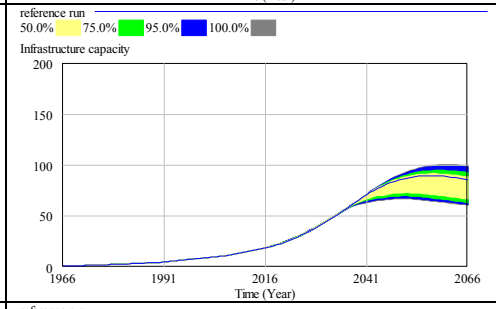
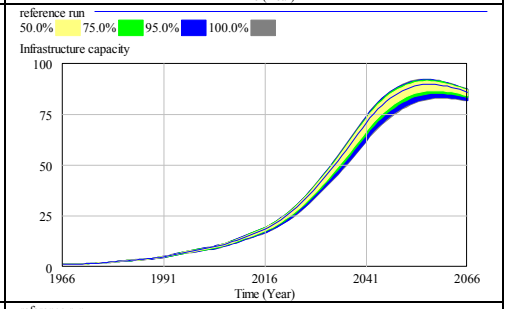
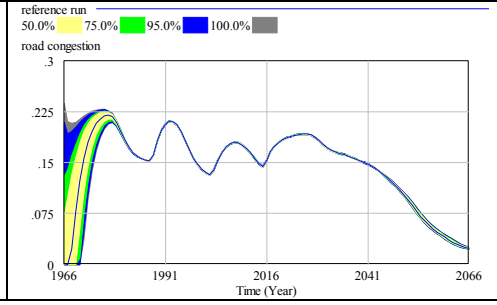
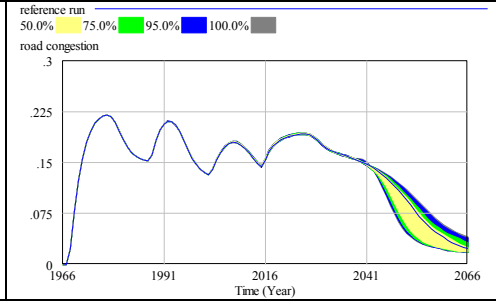
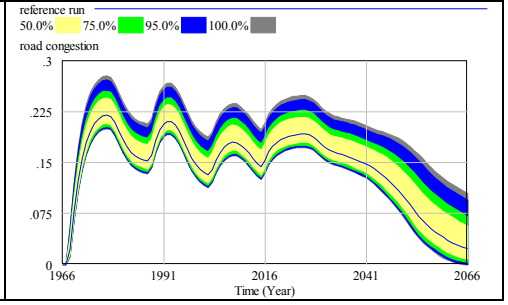
Parameters and lookups to check:

- initial infrastructure capacity
- infrastructure fraction of initial area
- infrastructure decay time
- infrastructure construction delay
- transport investment factor
- transport effects on city
- infrastructure saturation capacity
- freight transshipment ratio
- fraction of port freight by road
- fraction port transport of total transport
- fraction population transport of total transport
- fraction industry transport of total transport
- pc transport demand growth rate
- max pc transport demand
- transport congestion multiplier (lookup)
- land availability effect on transport construction (lookup)

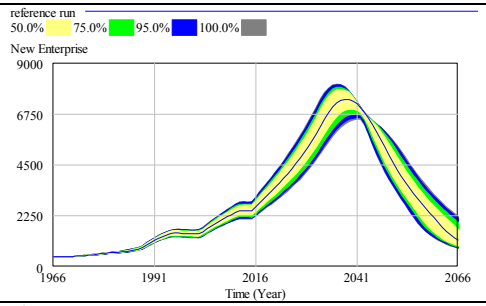
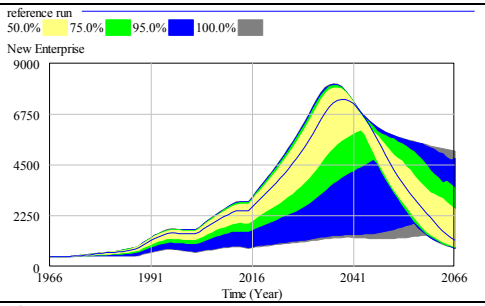
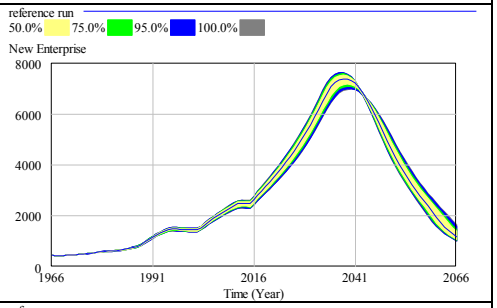
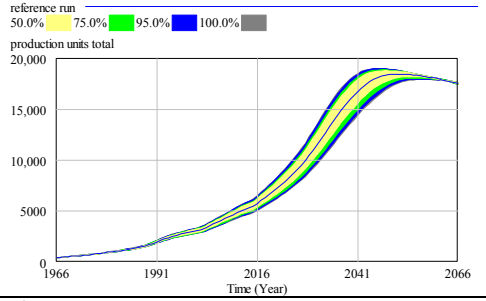
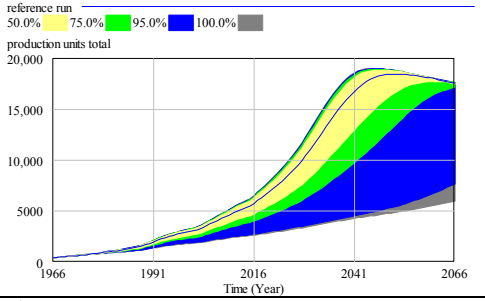
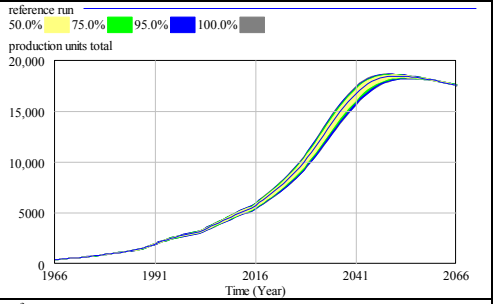
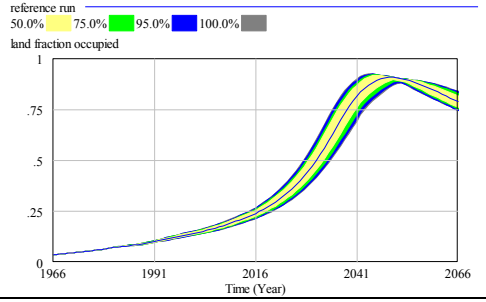
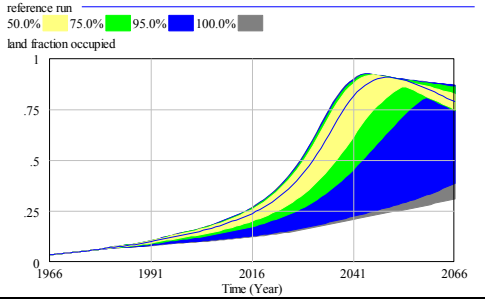
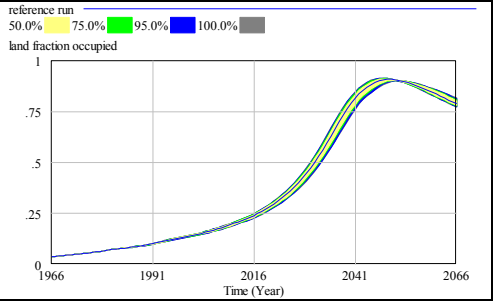
Parameter	initial infrastructure capacity	infrastructure fraction of initial area	infrastructure decay time
Units	-	-	Year
Nominal value	1.5	0.1	40
Minimum plausible	1	0.05	20
Maximum plausible	2	0.25	60
Sensitivity plot: New Enterprise			

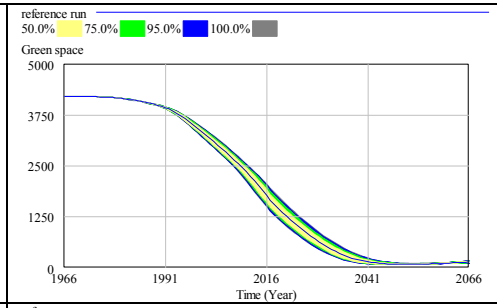
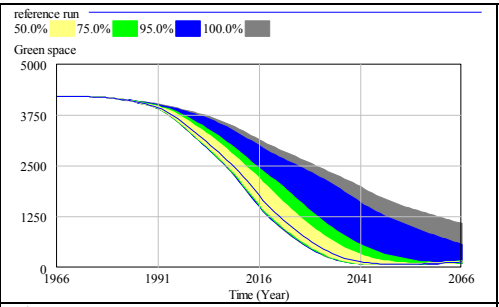
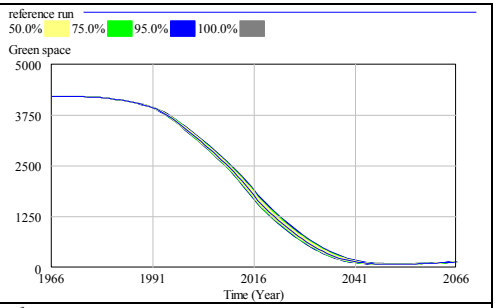
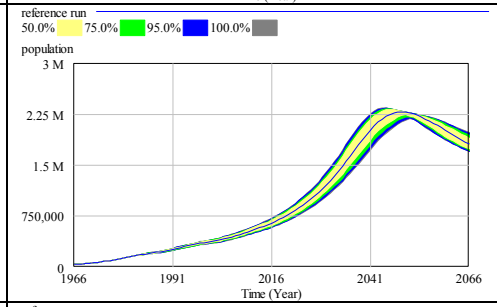
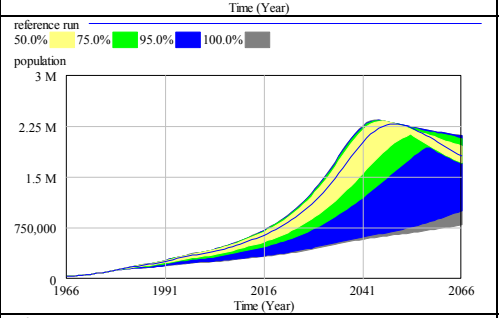
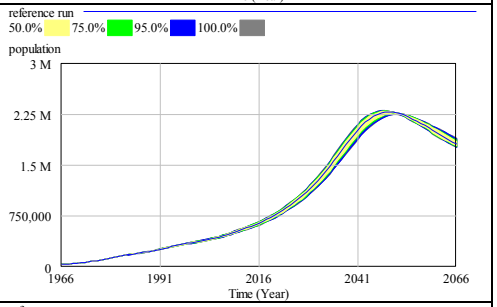
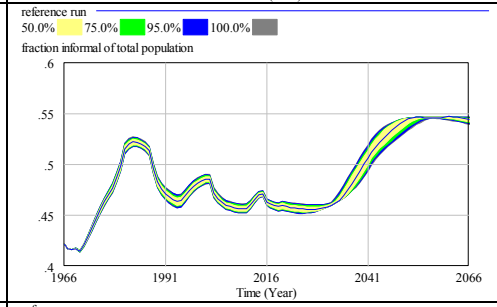
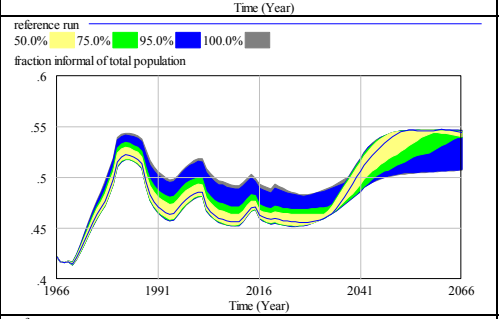
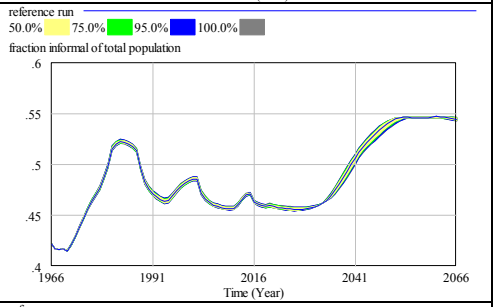
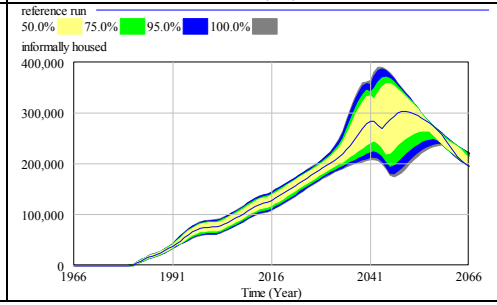
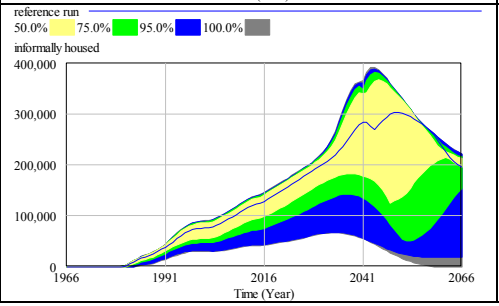
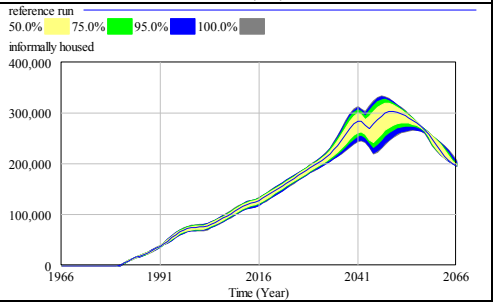
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

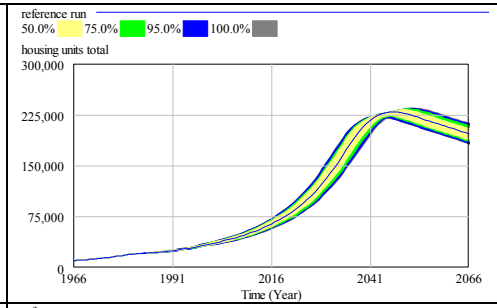
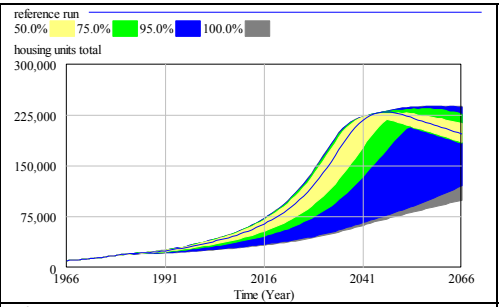
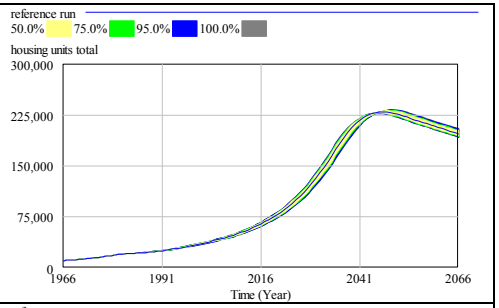
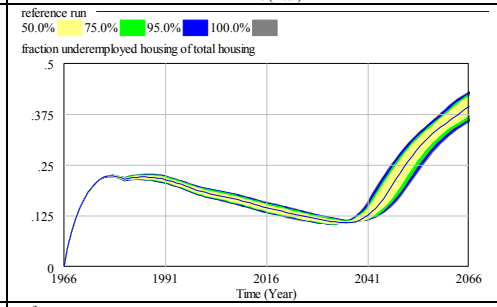
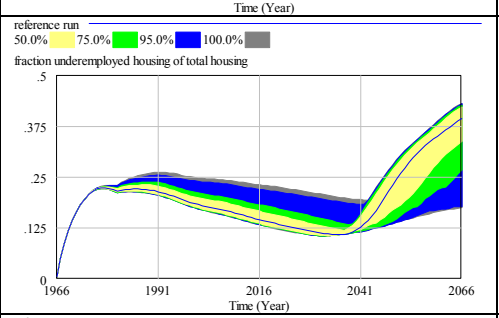
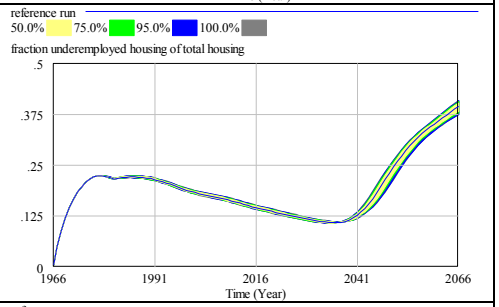
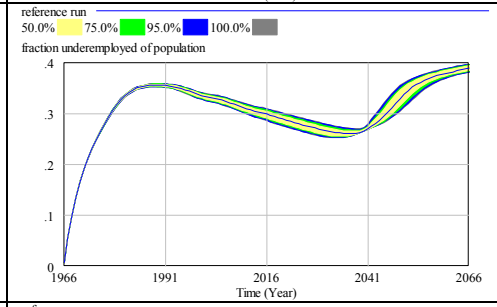
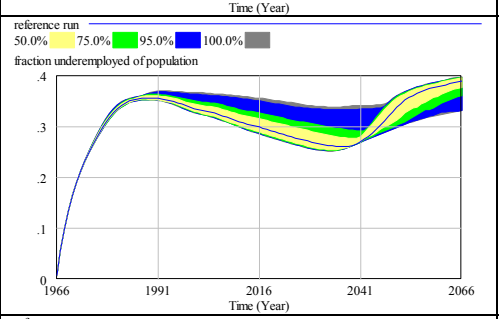
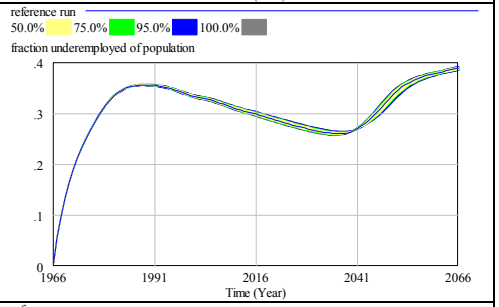
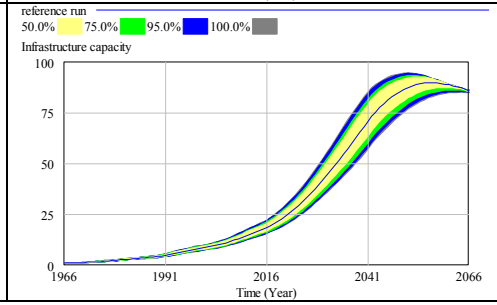
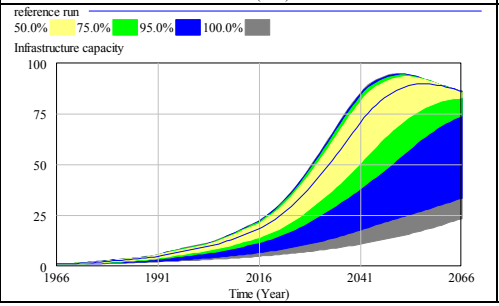
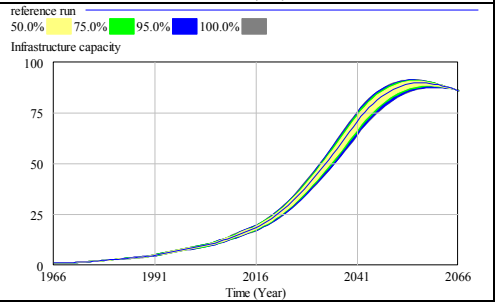
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

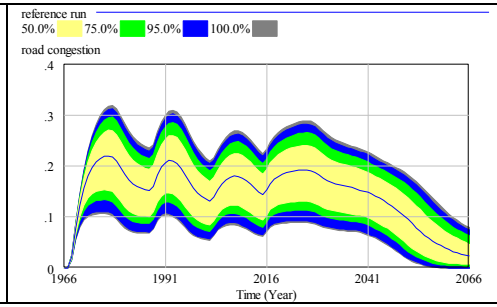
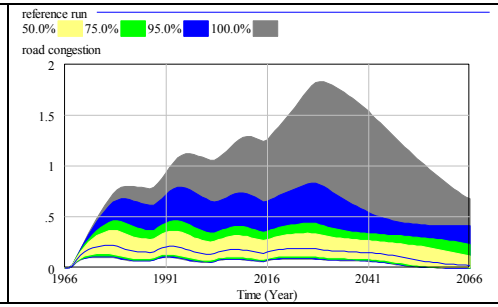
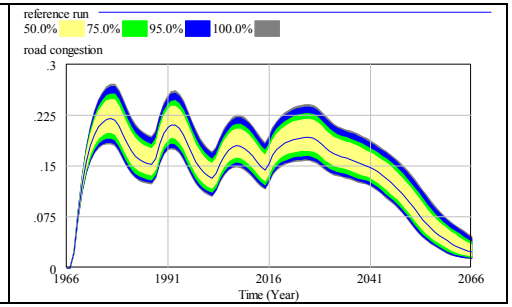
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

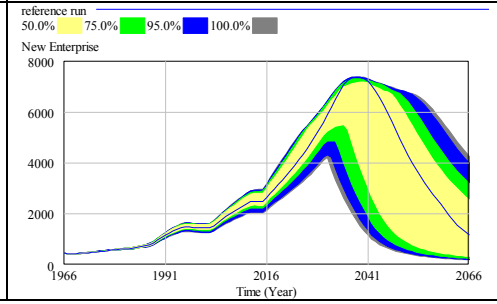
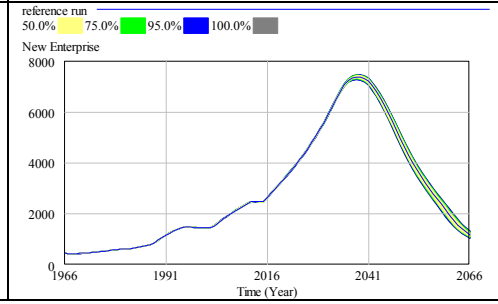
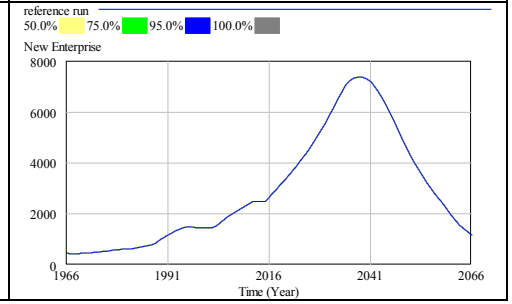
Parameter	infrastructure construction delay	transport investment factor	transport investment factor
Units	Year	-	-
Nominal value	10	5	5
Minimum plausible	5	1	4 (-20%)

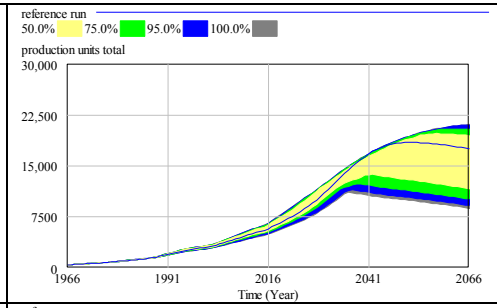
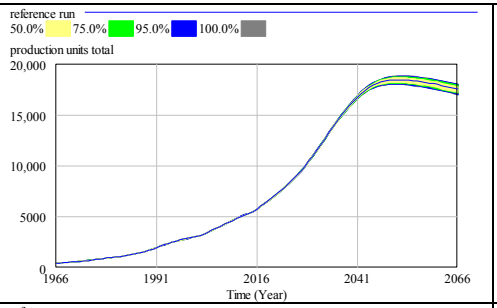
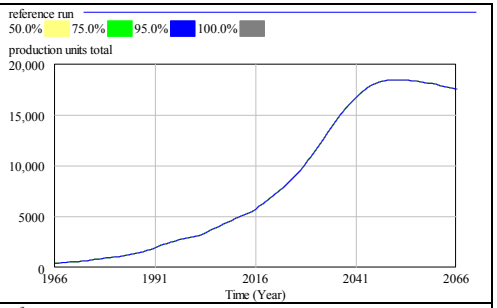
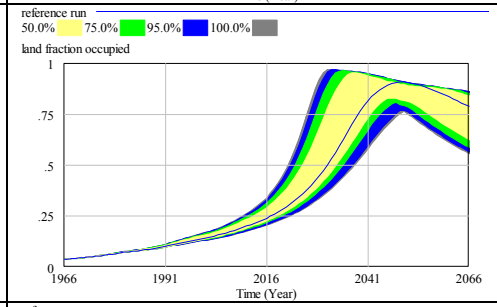
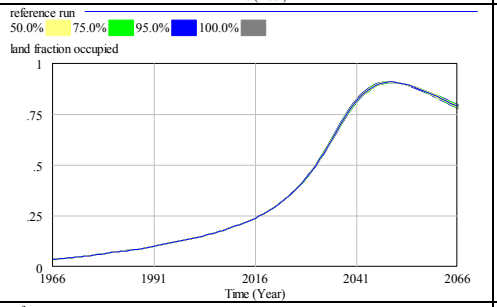
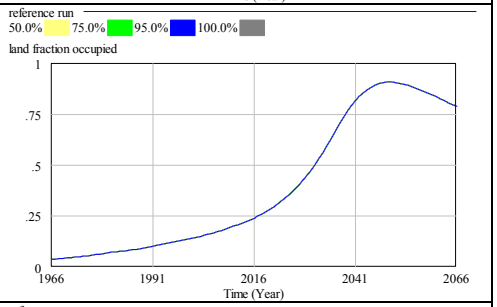
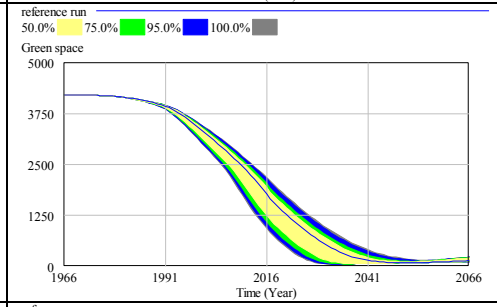
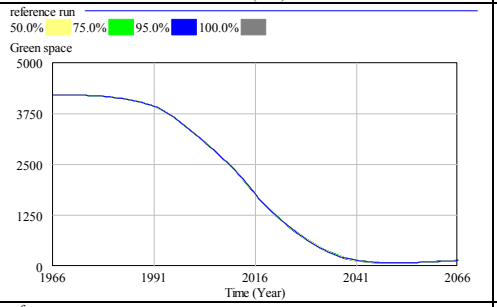
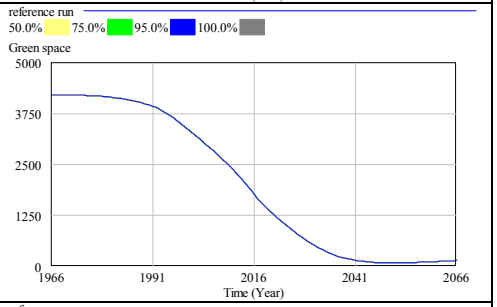
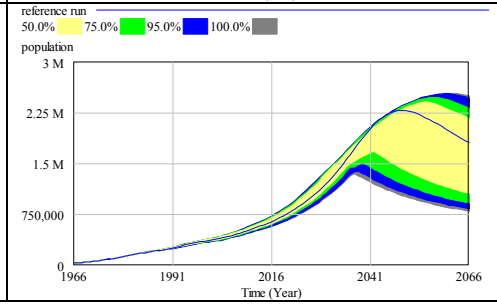
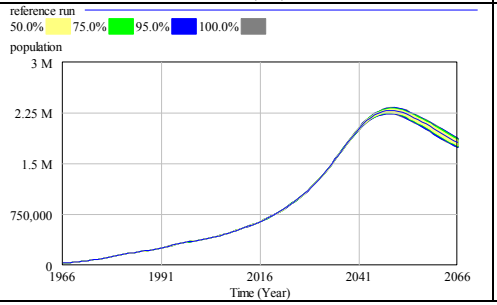
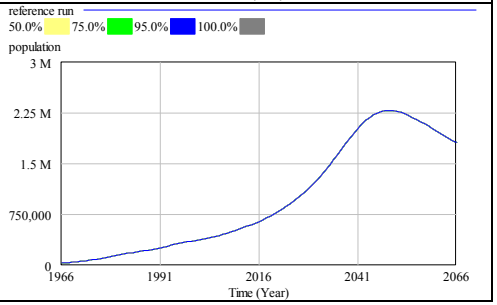
Maximum plausible	15	10	6 (+20%)
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			

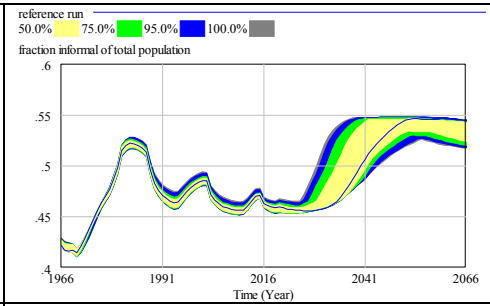
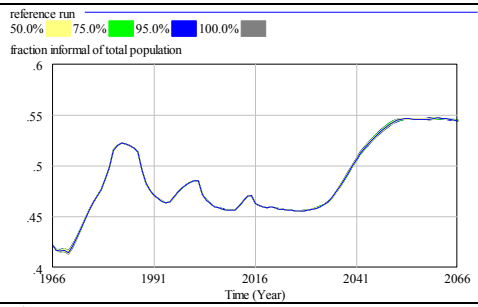
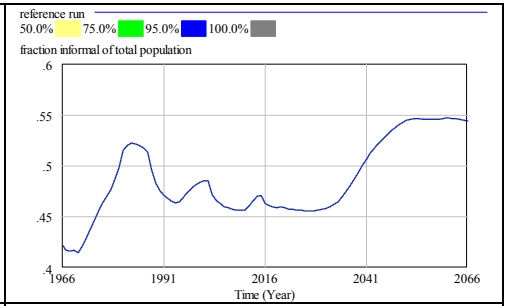
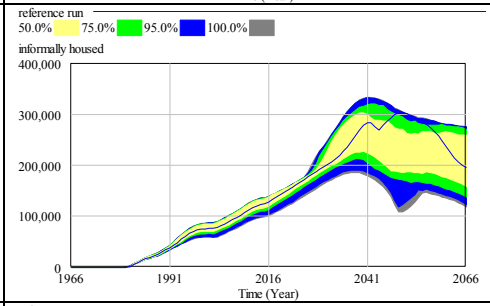
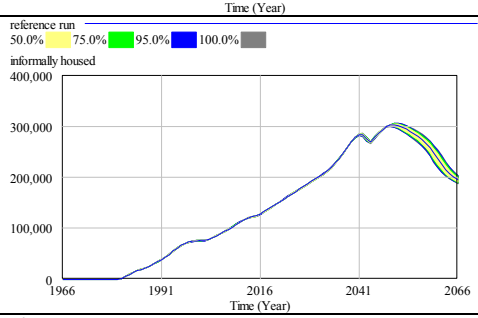
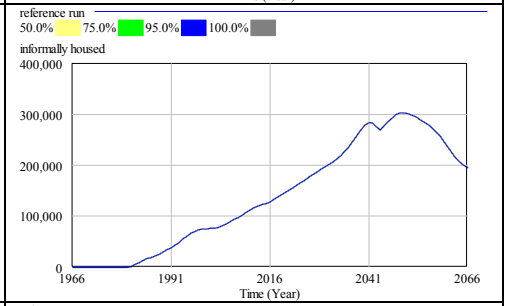
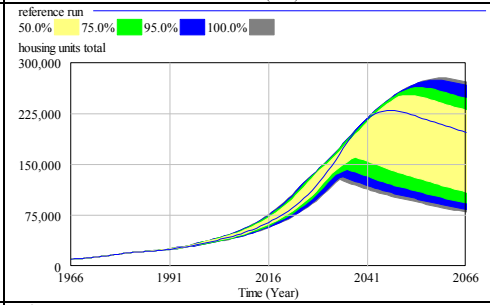
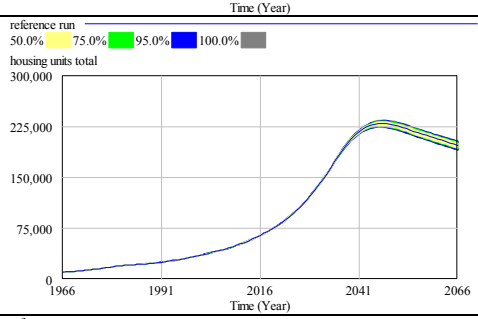
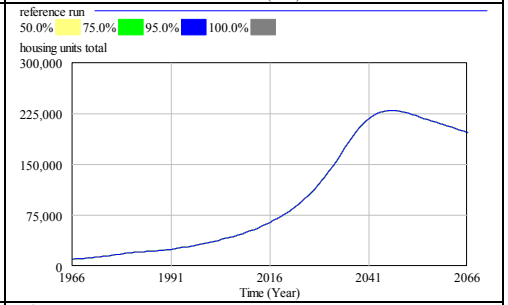
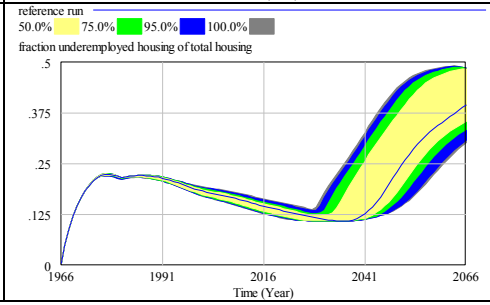
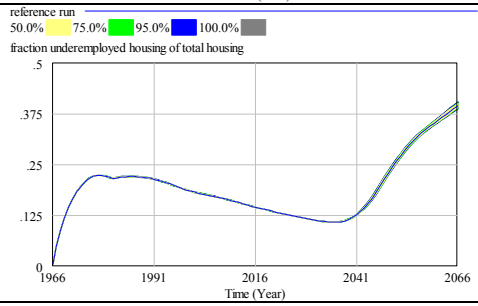
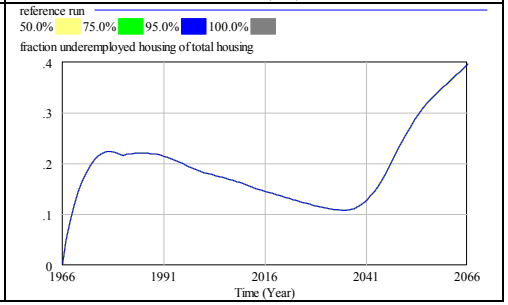
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			

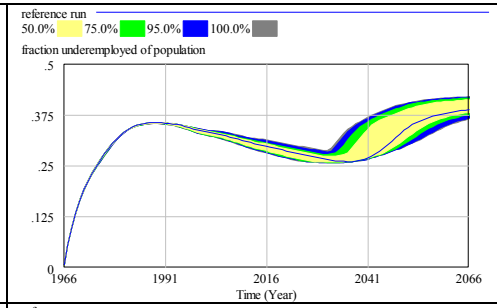
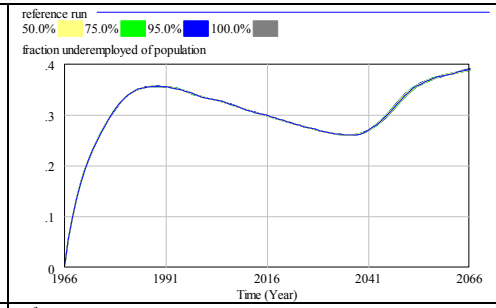
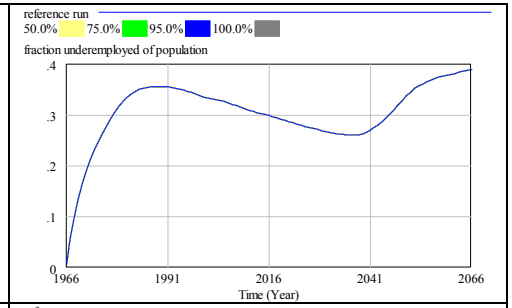
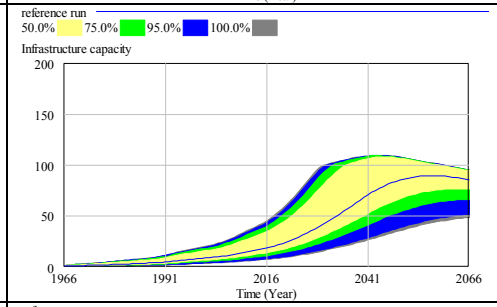
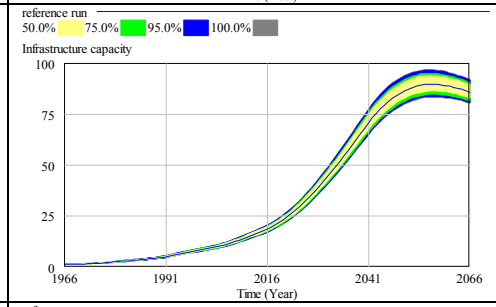
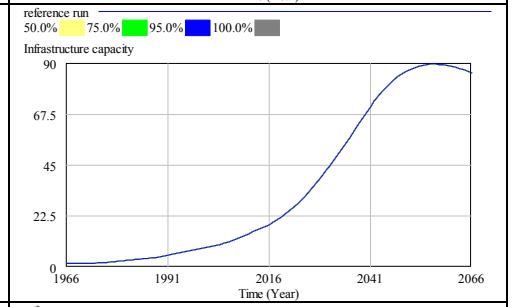
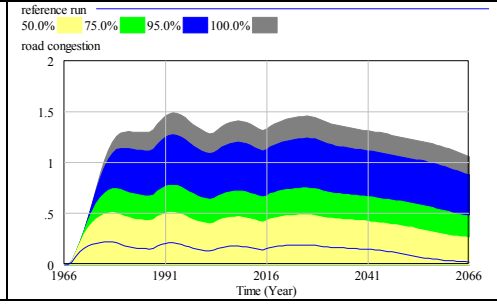
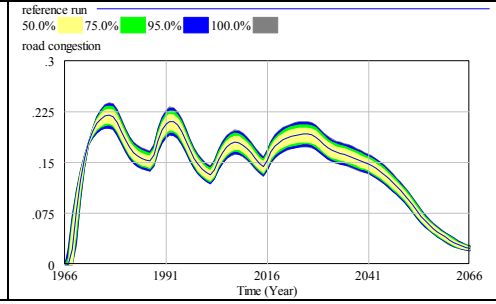
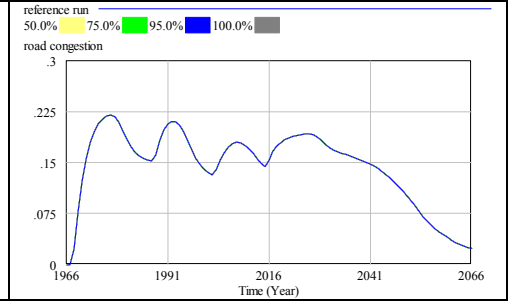
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			

Sensitivity plot: road congestion			

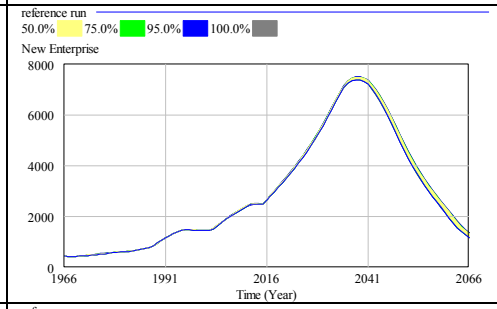
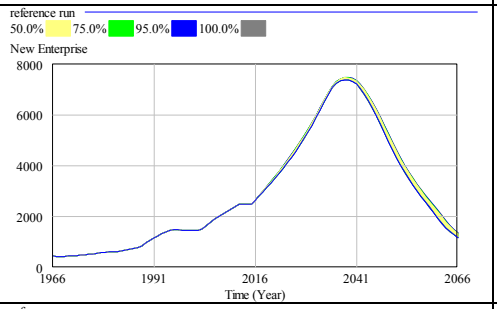
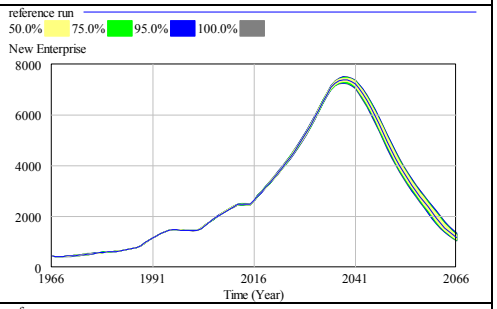
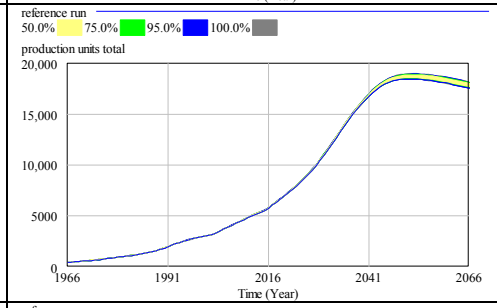
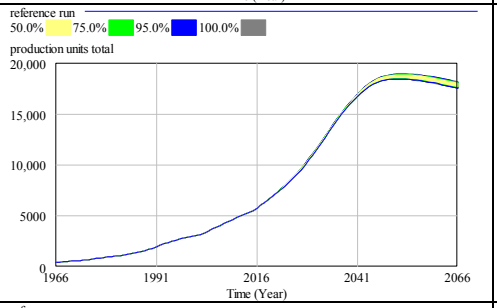
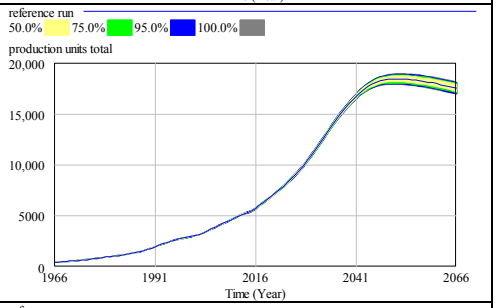
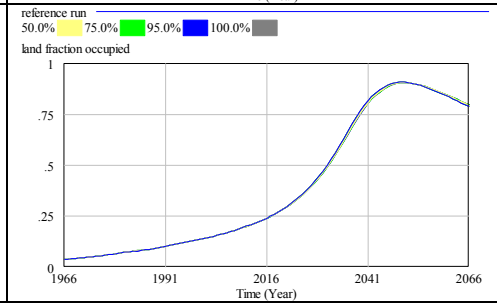
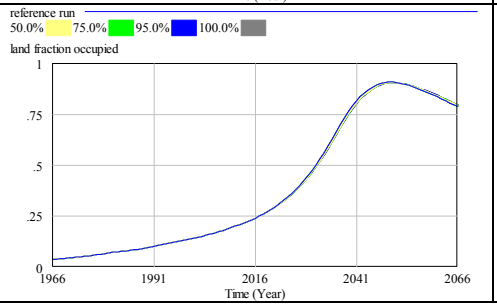
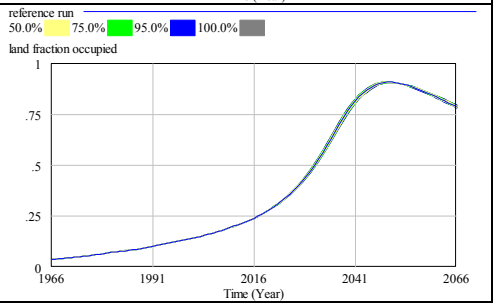
Parameter	transport effects on city	infrastructure saturation capacity	freight transshipment ratio
Units	-	-	-
Nominal value	1 (note that this cannot actually be scaled well below zero)	0.8	0.015
Minimum plausible	0.5	0.72 (-10%)	0
Maximum plausible	2	0.88 (+10%)	0.10
Sensitivity plot: New Enterprise			

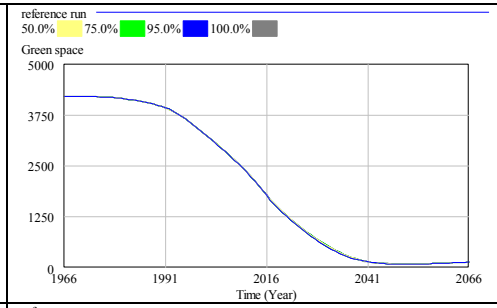
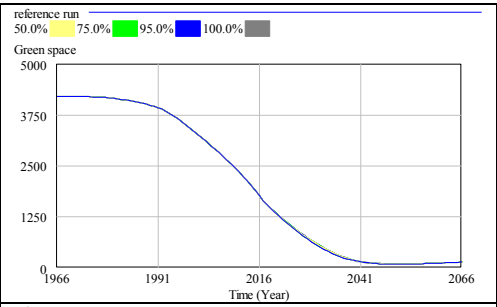
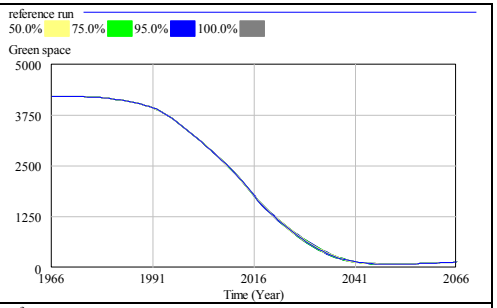
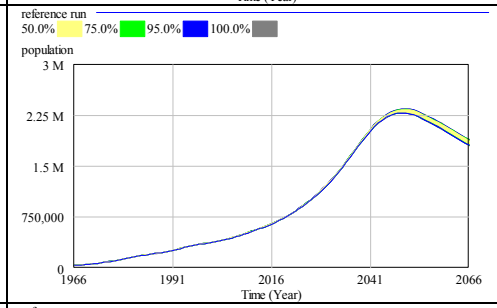
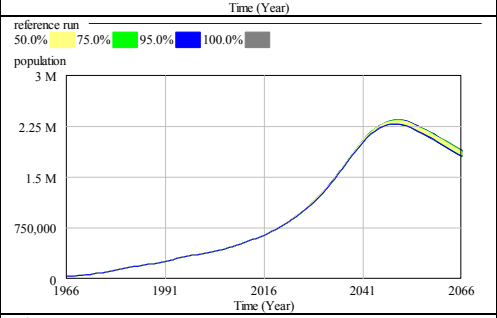
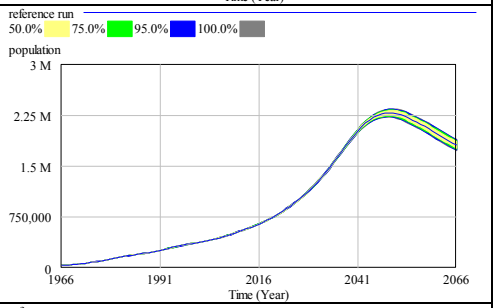
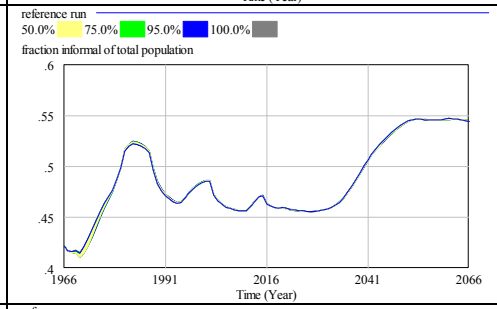
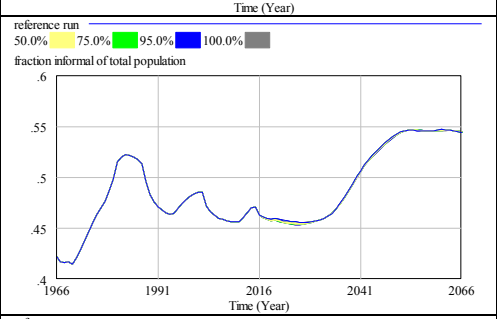
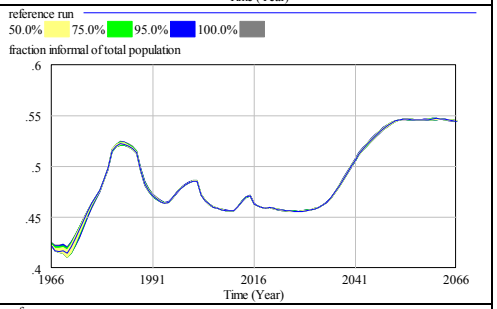
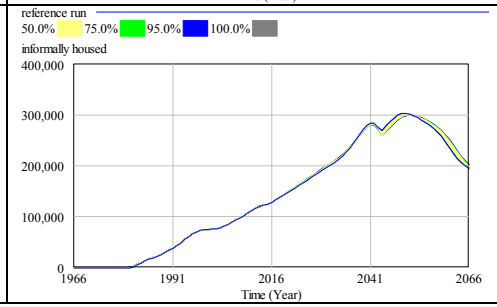
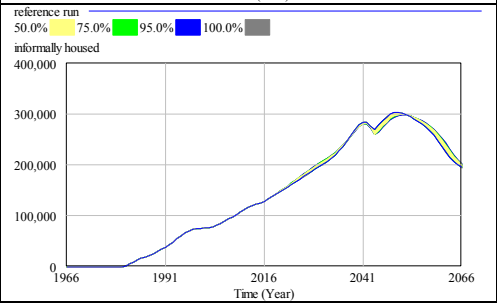
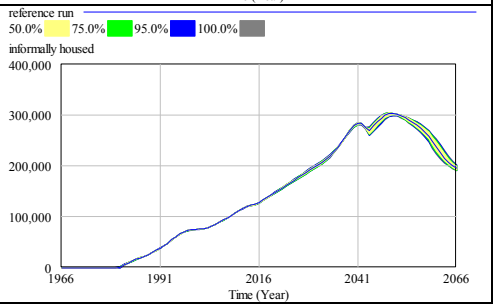
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

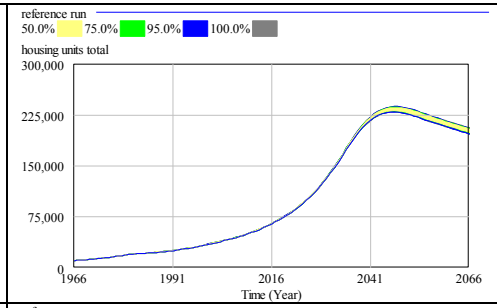
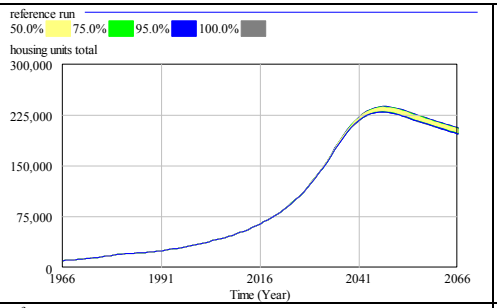
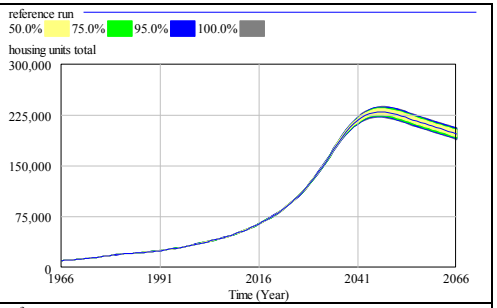
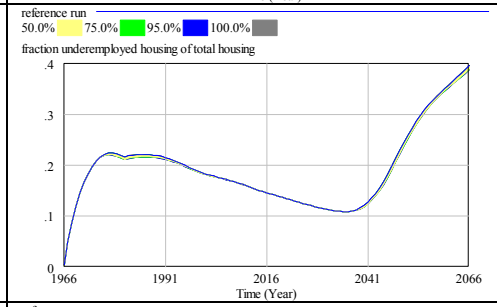
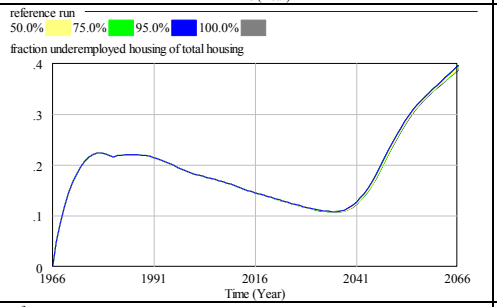
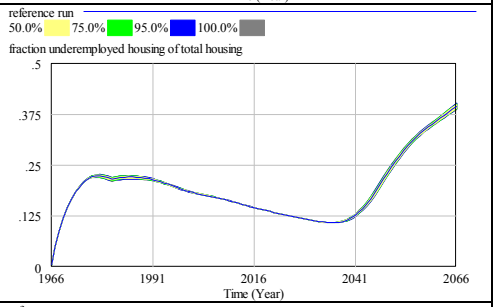
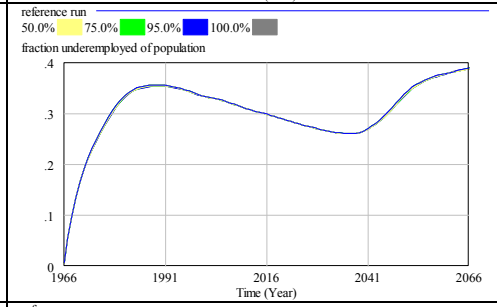
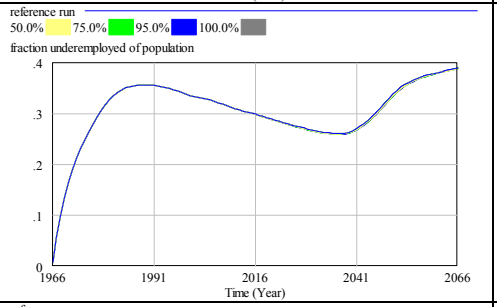
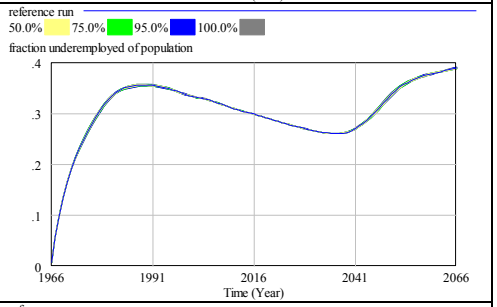
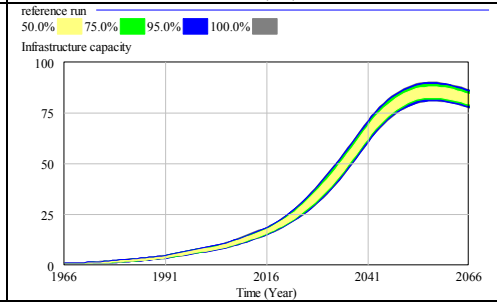
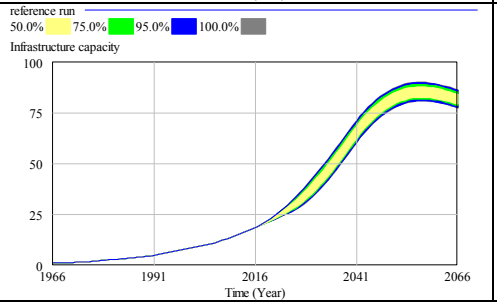
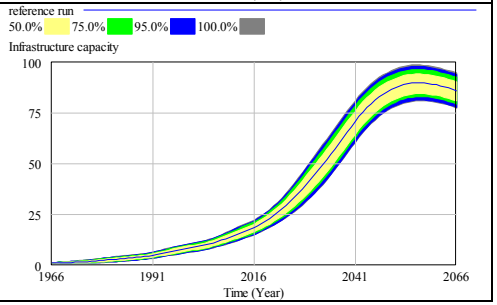
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

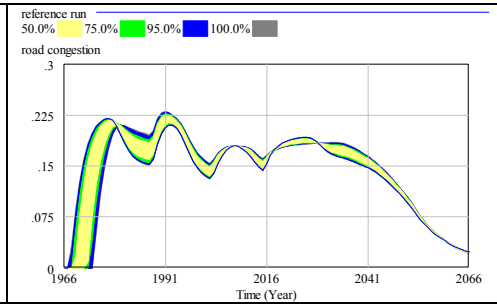
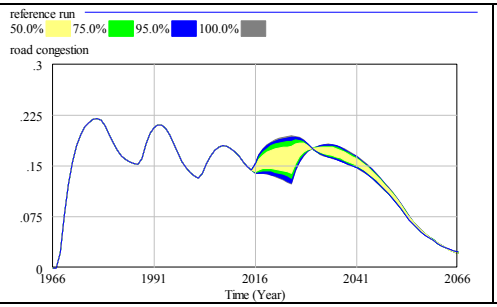
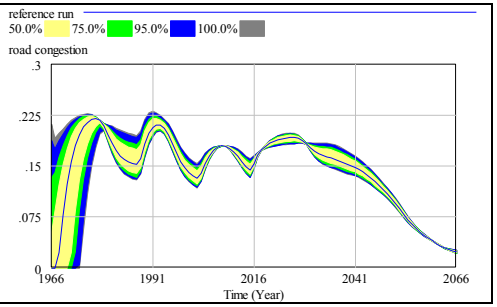
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

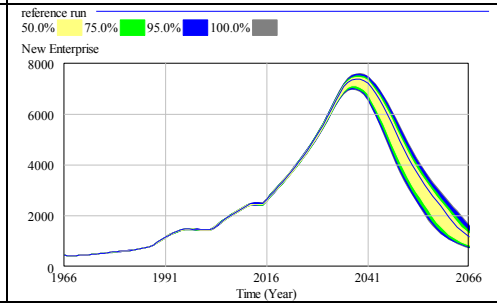
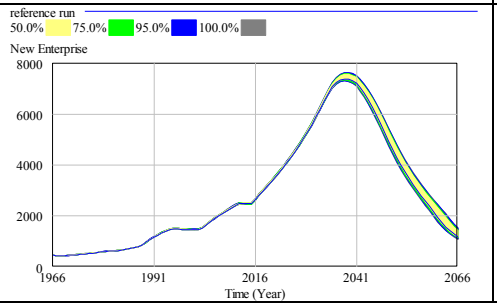
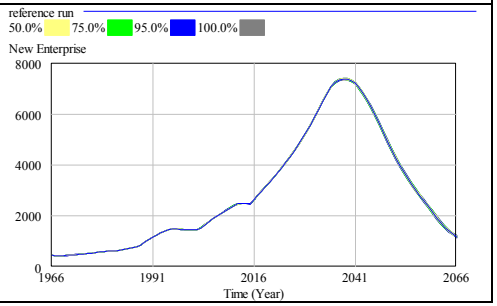
Parameter	fraction of port freight by road	fraction of port freight by road	fraction port transport of total transport
Units	-	-	-
Nominal value	0.95	0.95	0.25

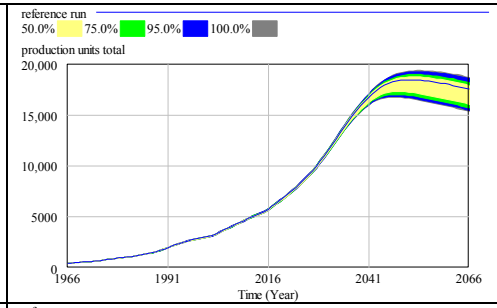
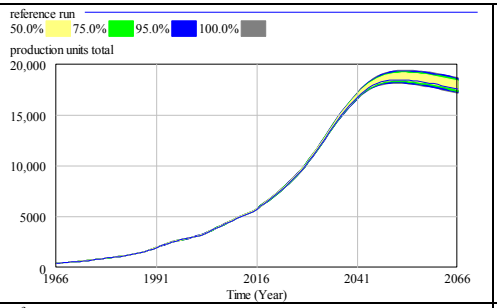
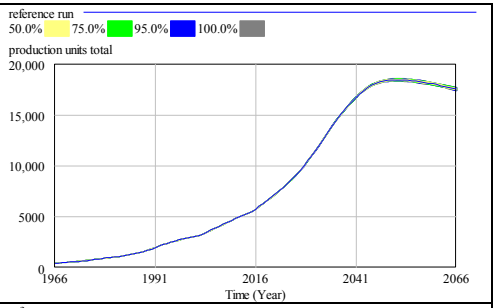
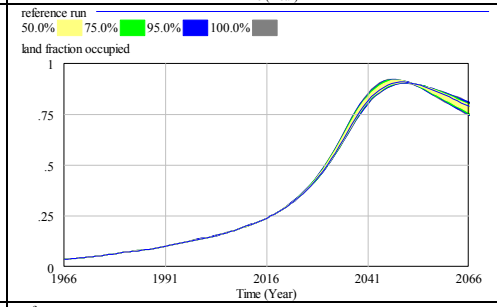
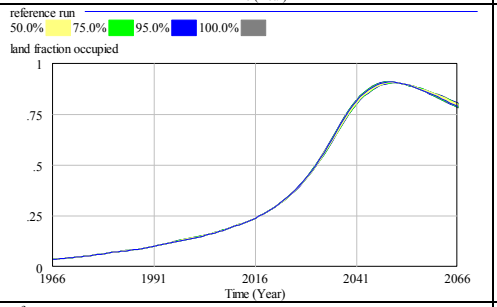
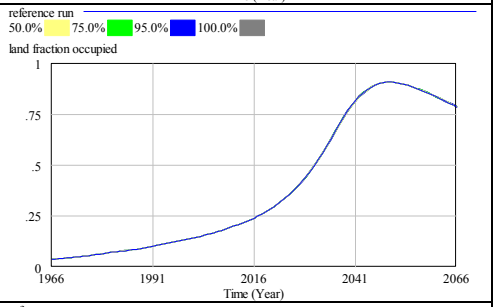
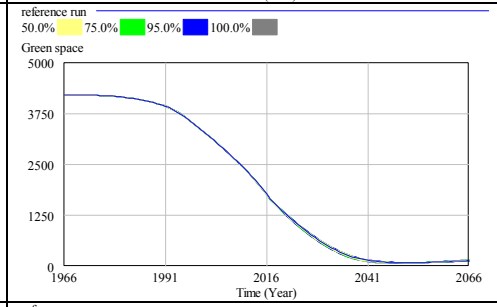
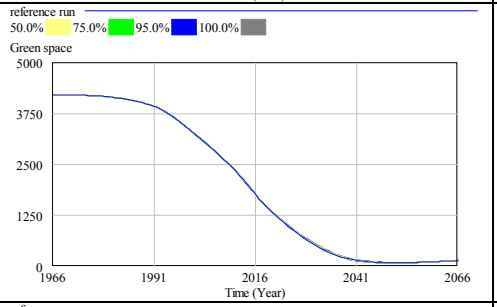
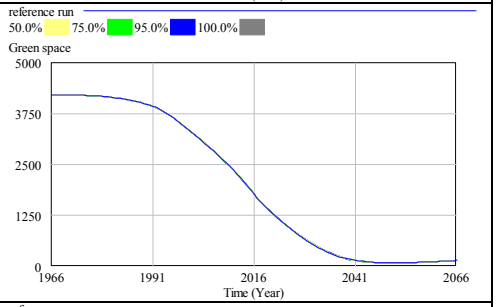
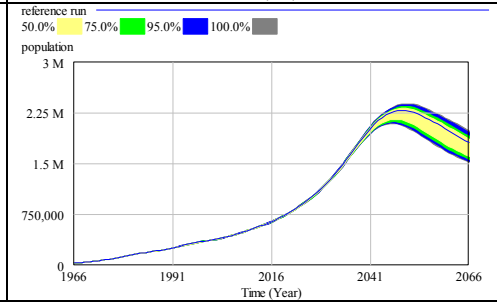
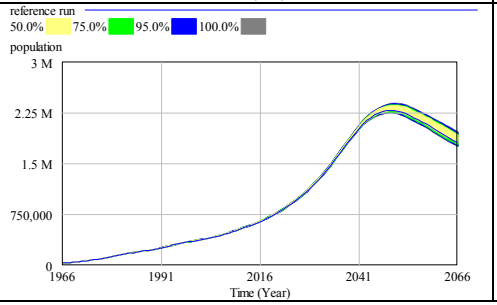
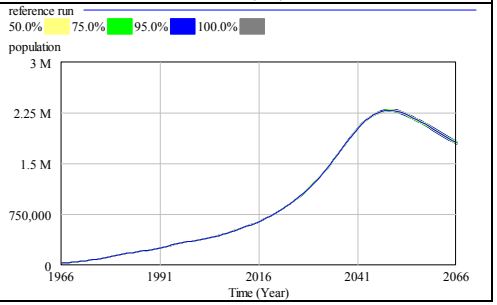
Minimum plausible	0.0	0.0 (changed from nominal 2015-2025)	0.0
Maximum plausible	1.00	1 (changed from nominal 2015-2025)	0.5 (ceteris paribus)
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			

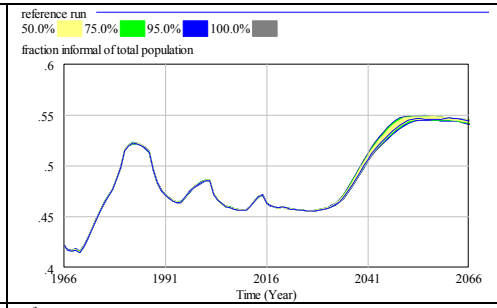
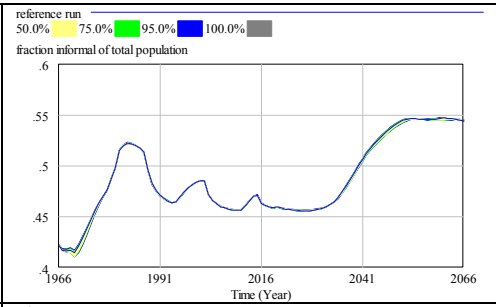
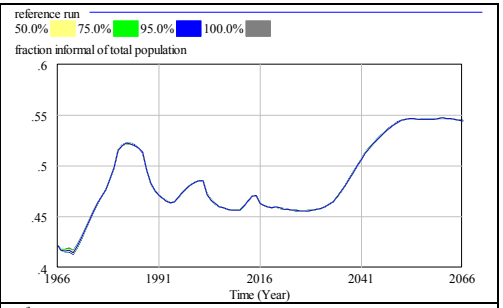
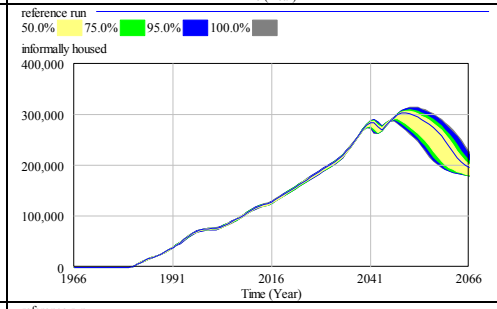
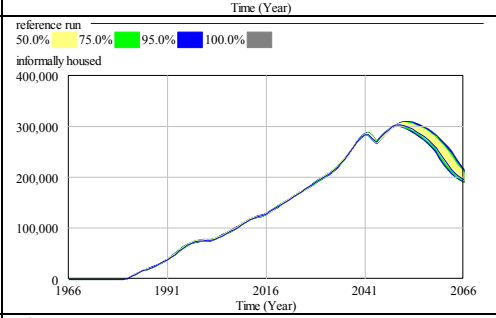
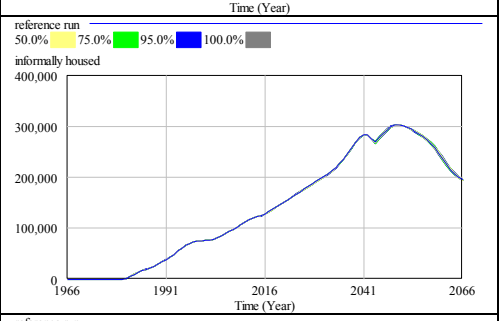
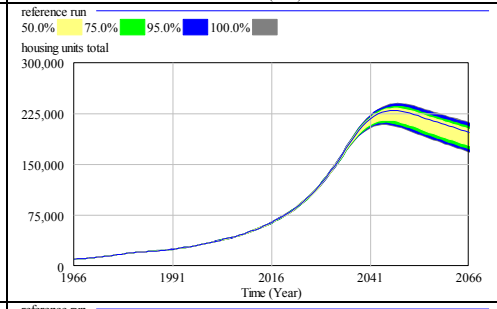
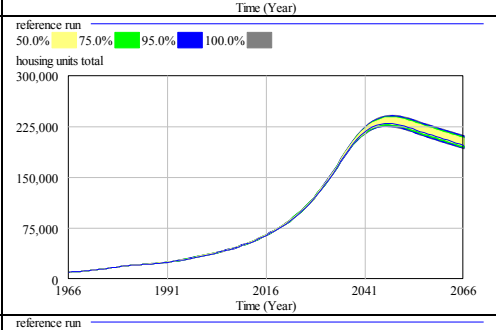
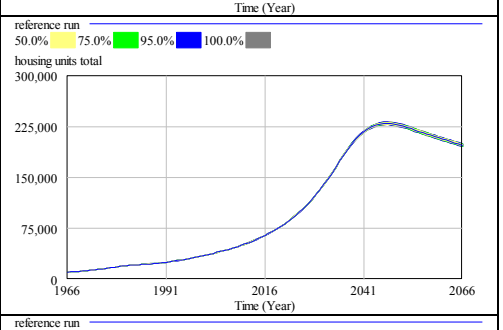
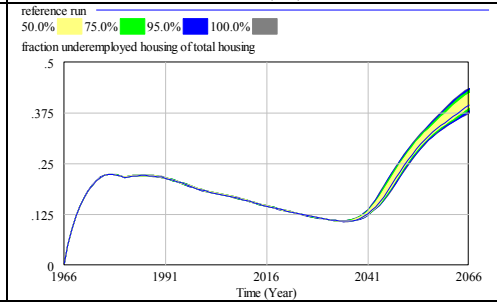
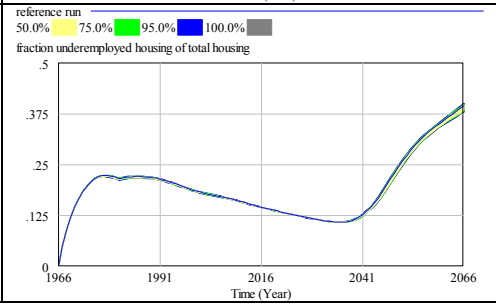
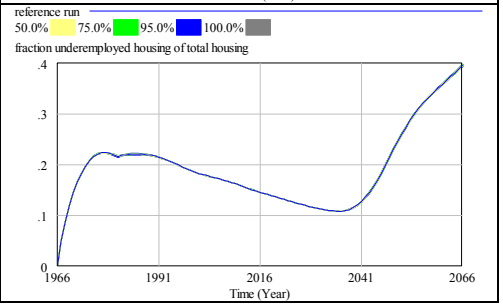
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			

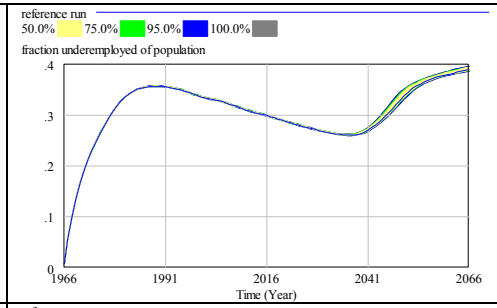
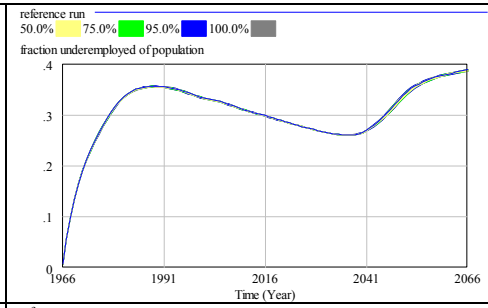
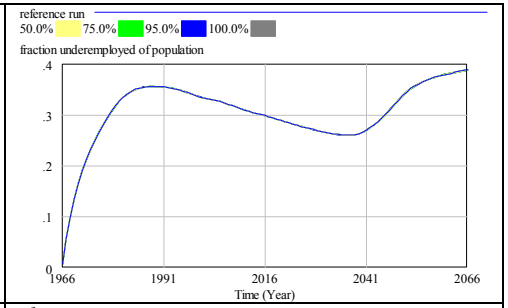
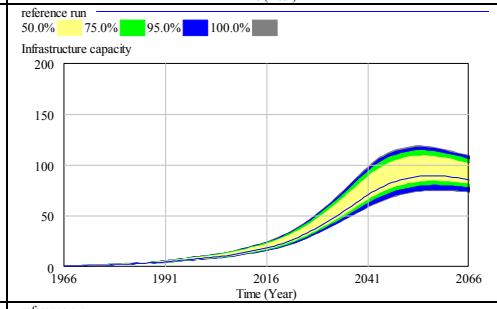
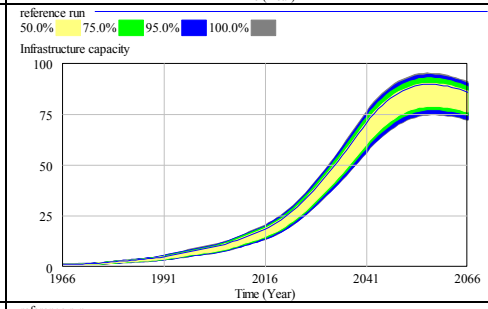
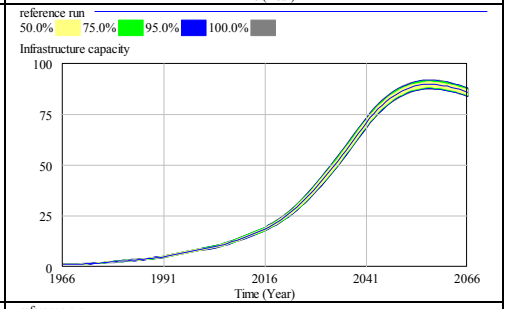
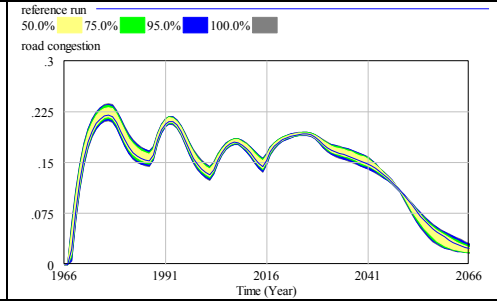
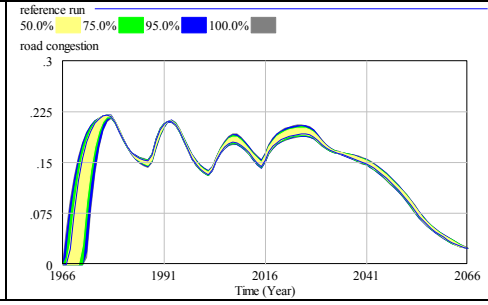
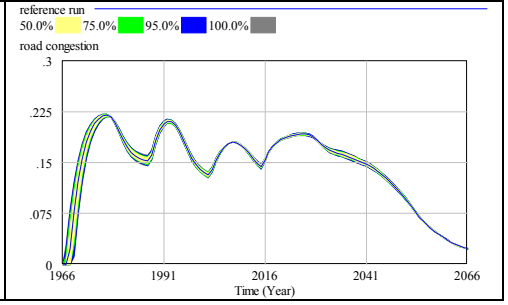
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			

Sensitivity plot: road congestion			

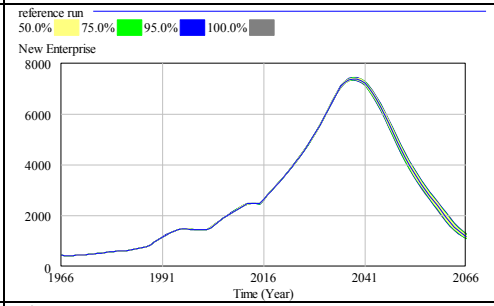
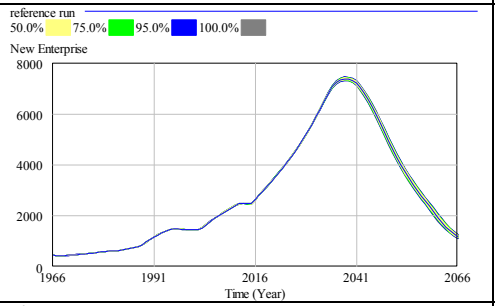
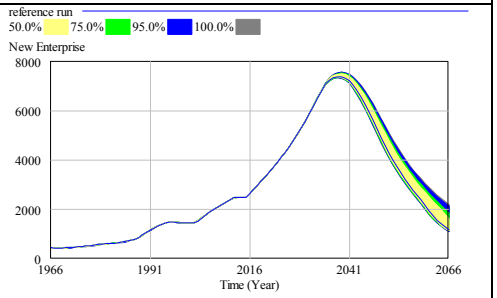
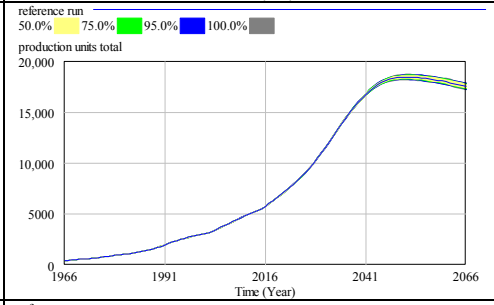
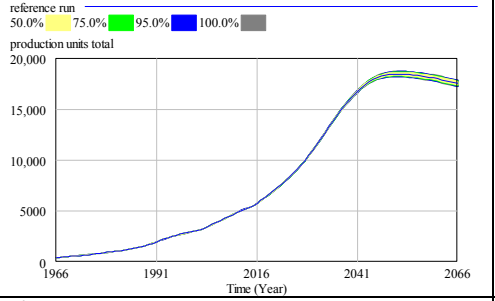
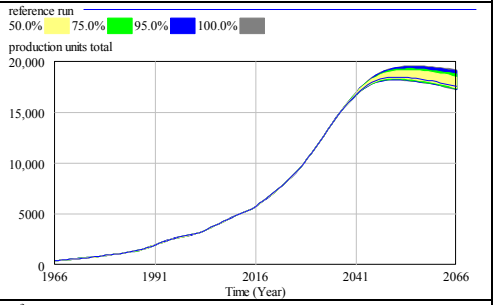
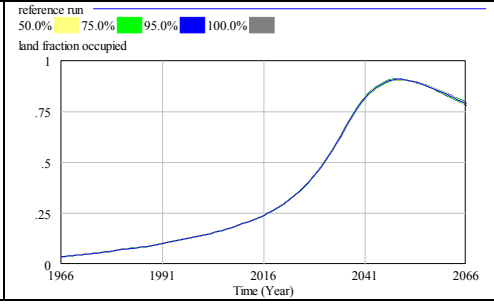
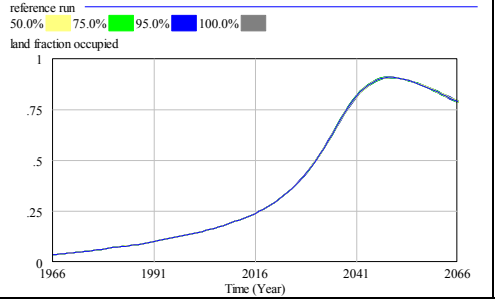
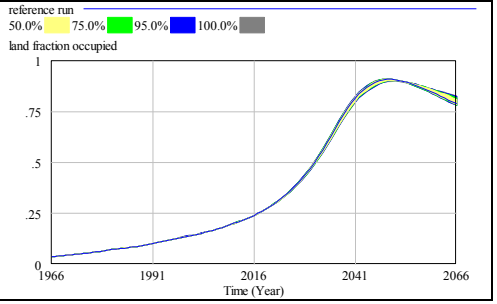
Parameter	fraction population transport of total transport	fraction industry transport of total transport	relative impact of port transport
Units	-	-	-
Nominal value	0.5	0.25	2
Minimum plausible	0.33	0.05	1.5
Maximum plausible	0.9	0.33	2.5
Sensitivity plot: New Enterprise			

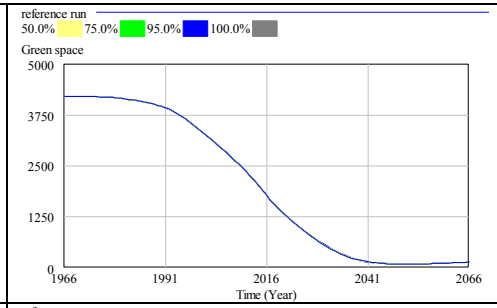
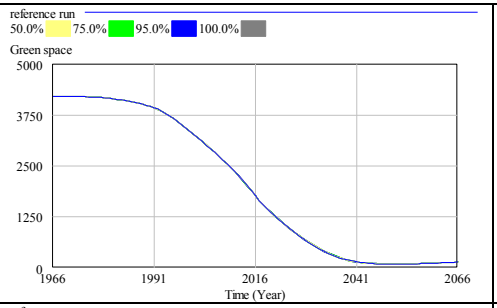
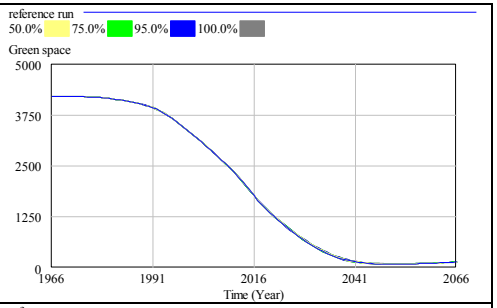
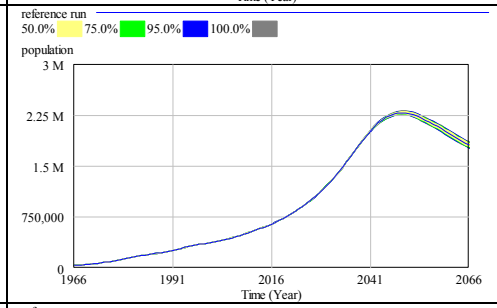
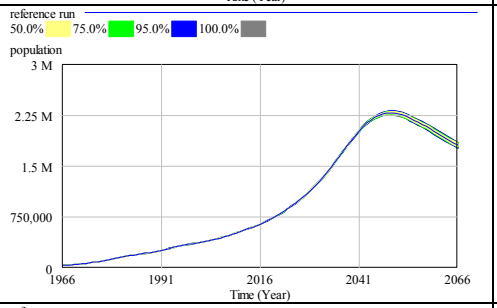
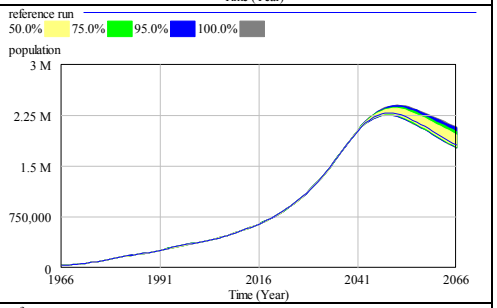
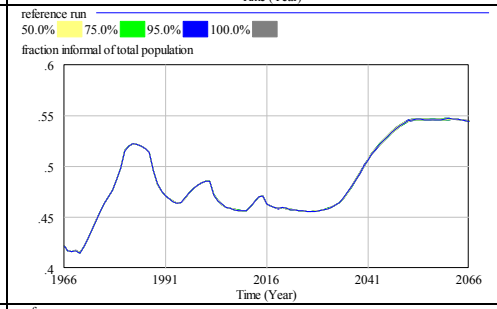
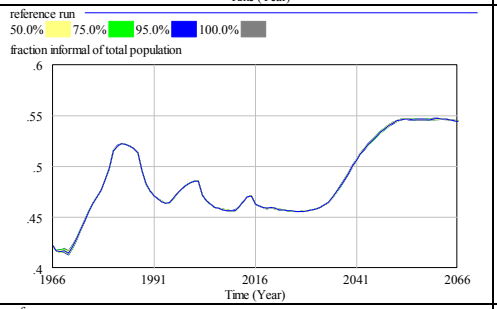
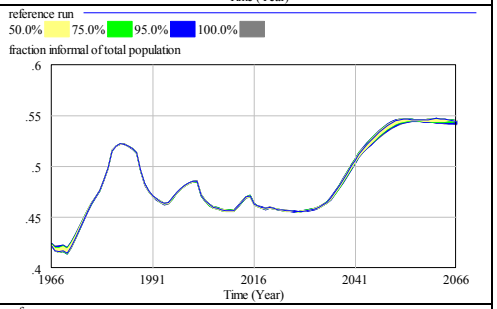
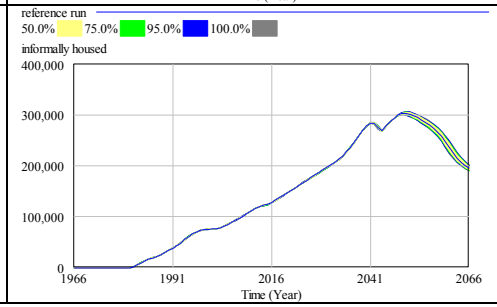
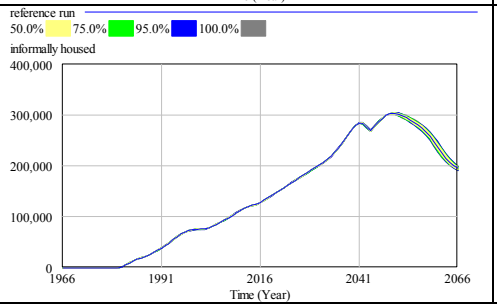
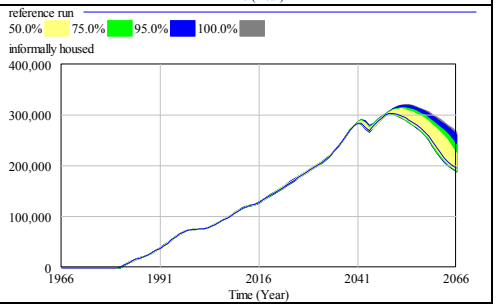
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

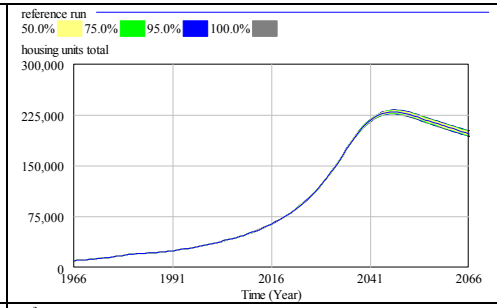
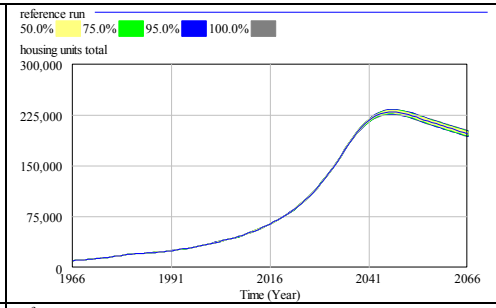
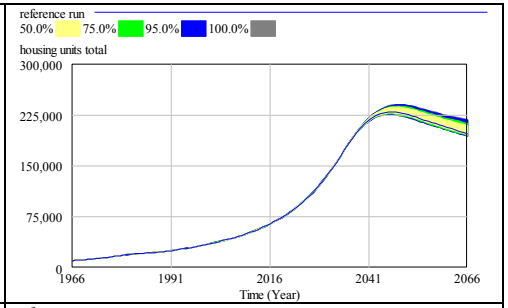
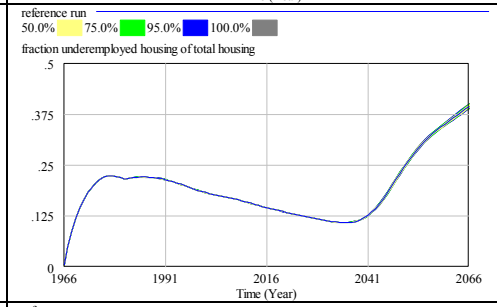
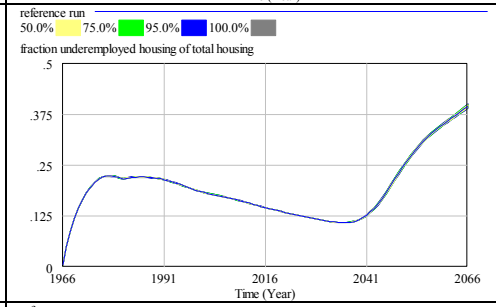
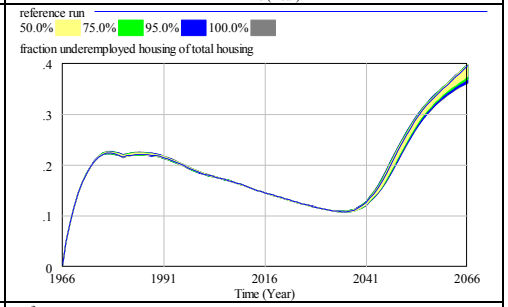
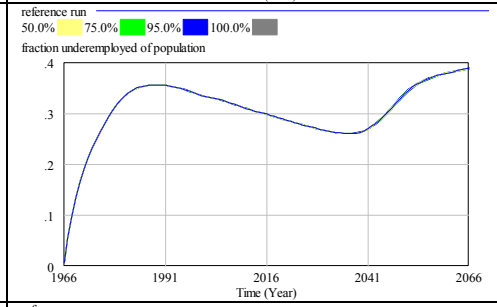
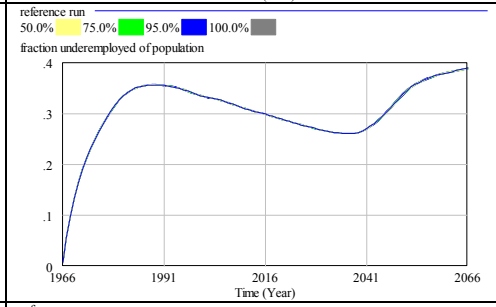
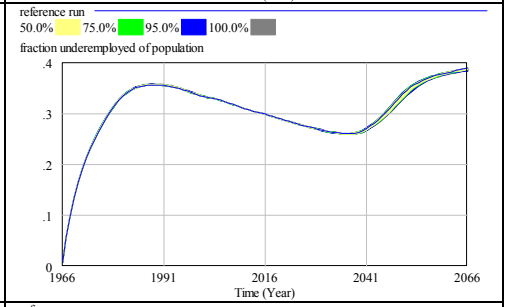
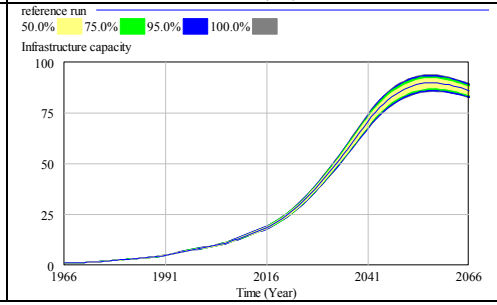
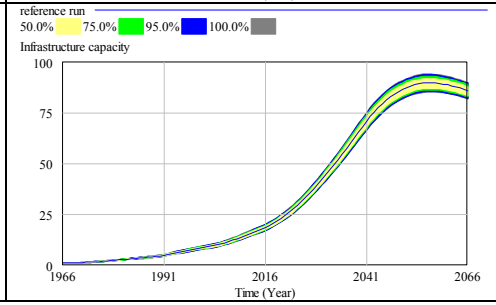
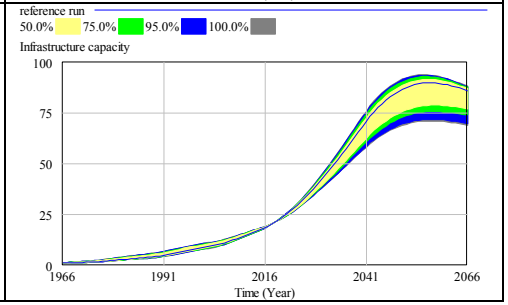
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

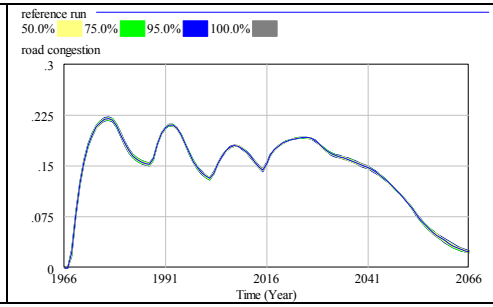
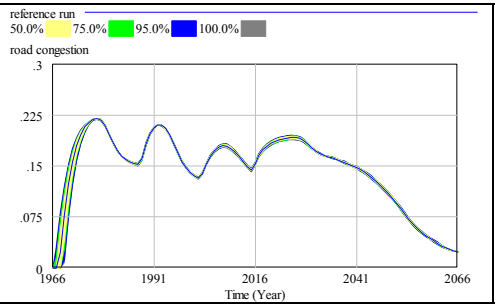
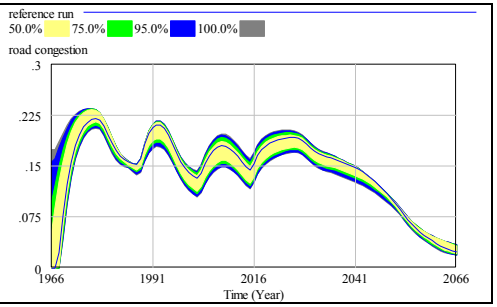
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

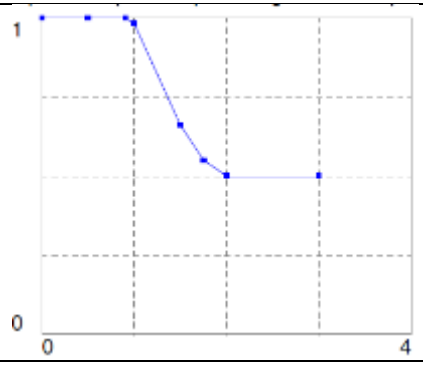
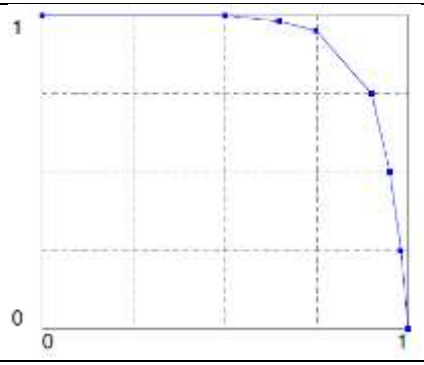
Parameter	relative impact of population transport	relative impact of industry transport	pc transport demand growth rate
Units	-	-	-
Nominal value	1	2	0.05
Minimum plausible	0.9	1.5	0.00

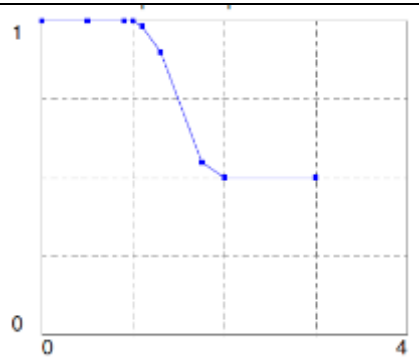
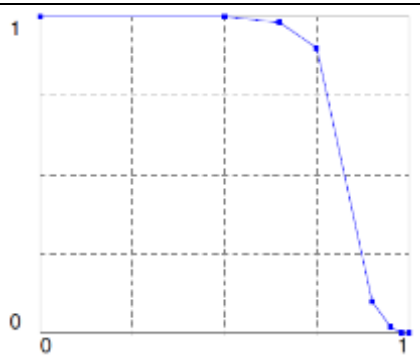
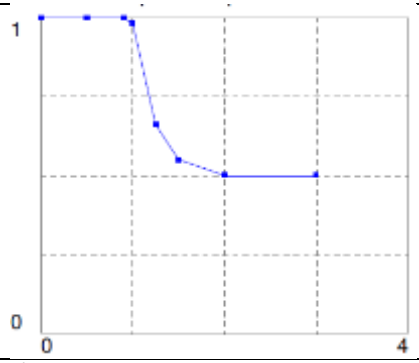
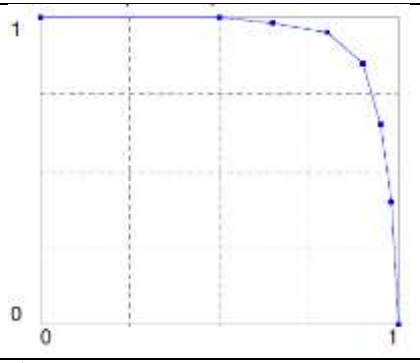
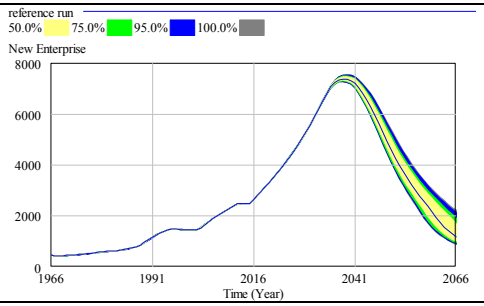
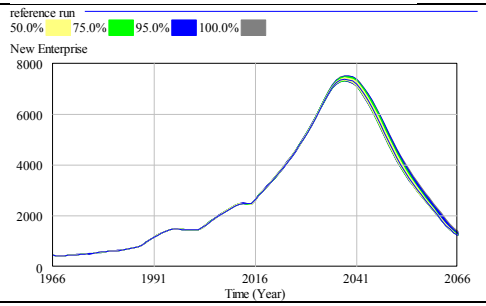
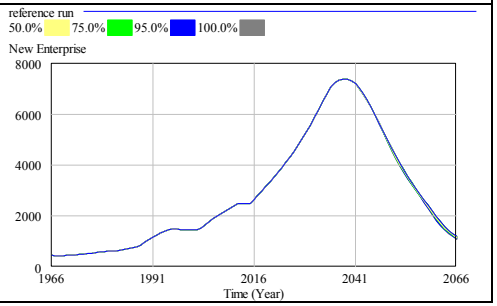
Maximum plausible	1.1	2.5	0.08
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			

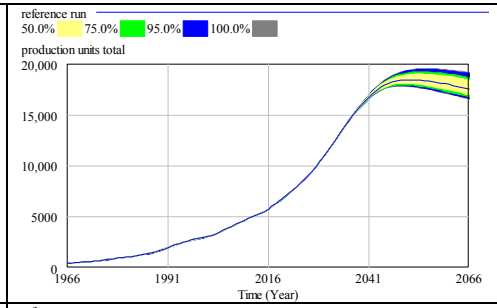
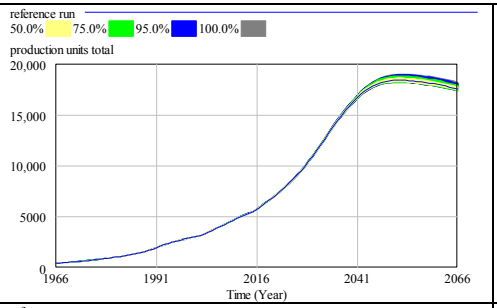
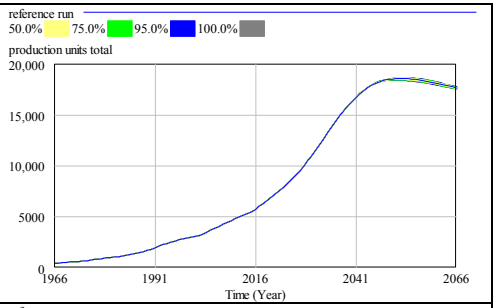
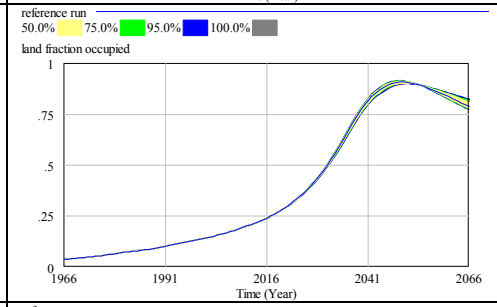
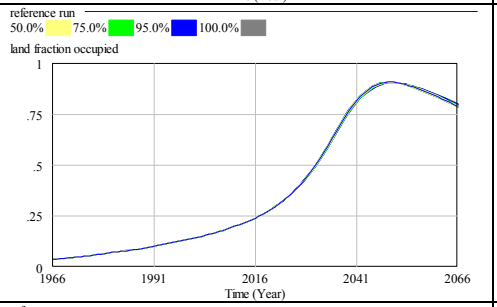
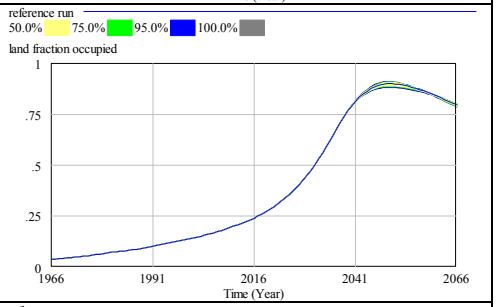
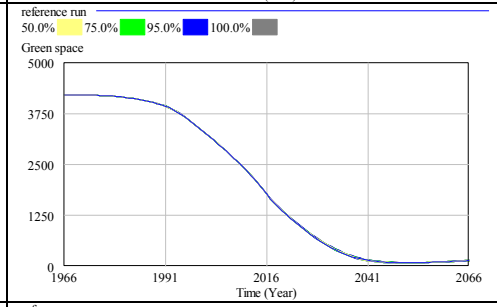
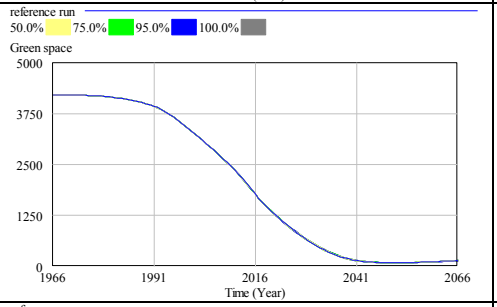
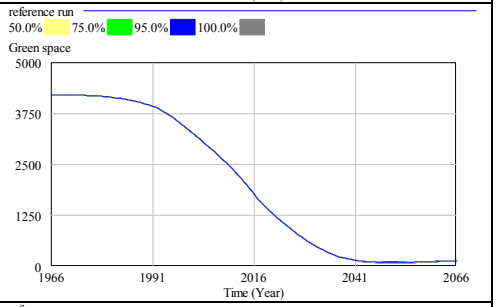
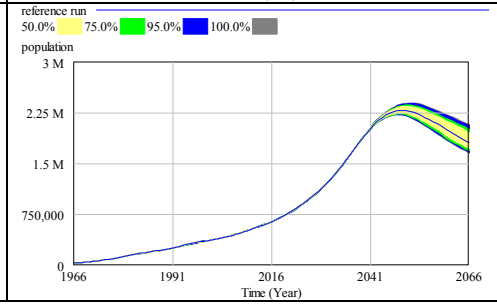
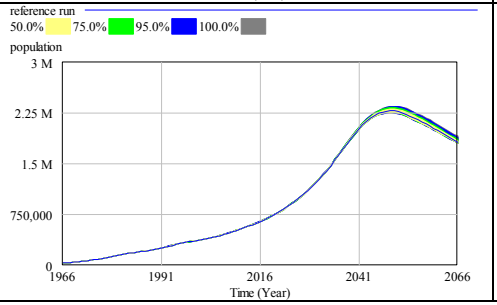
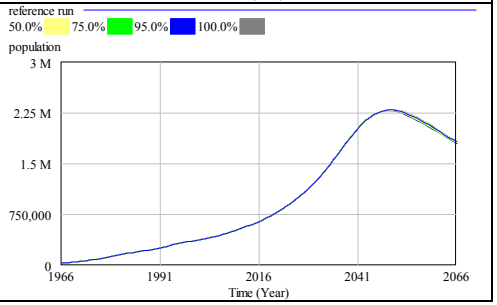
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			

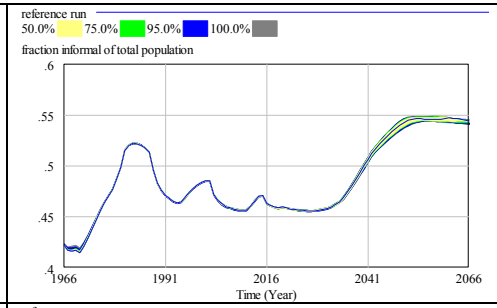
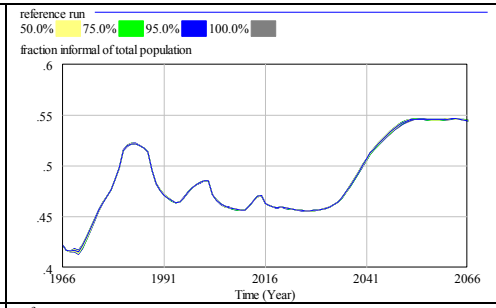
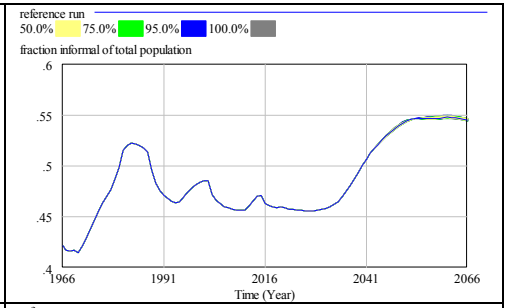
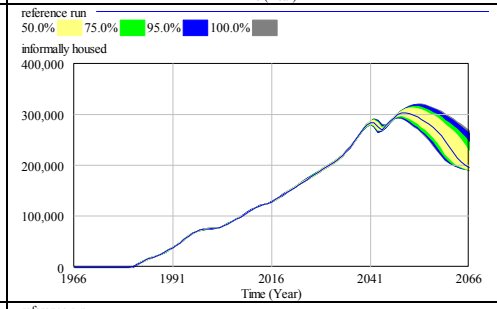
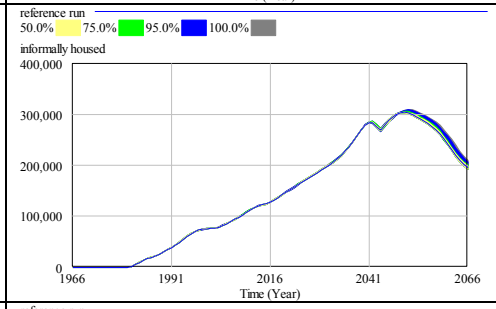
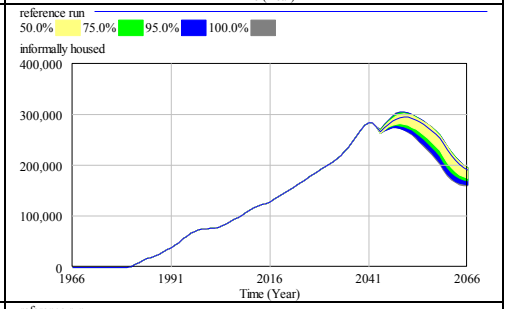
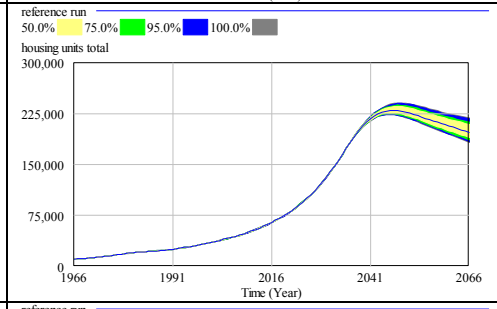
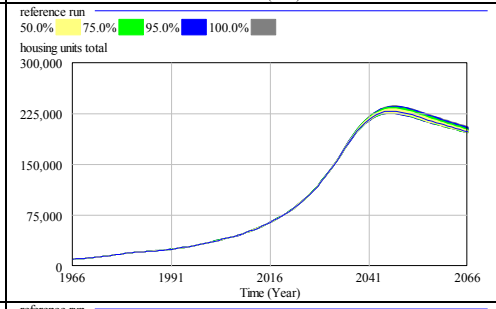
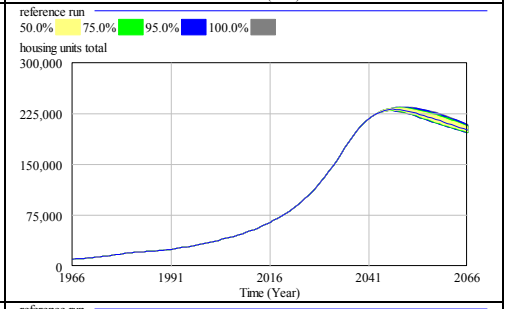
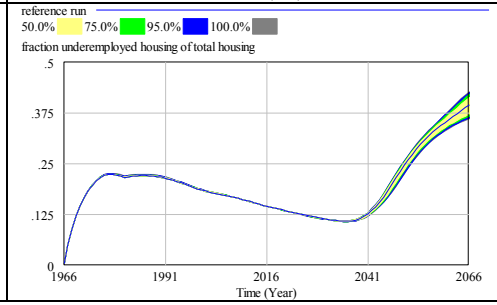
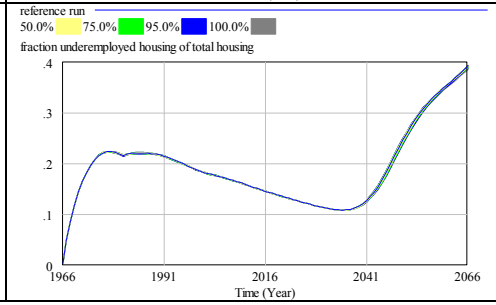
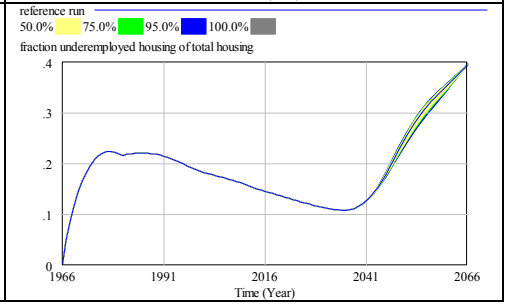
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			

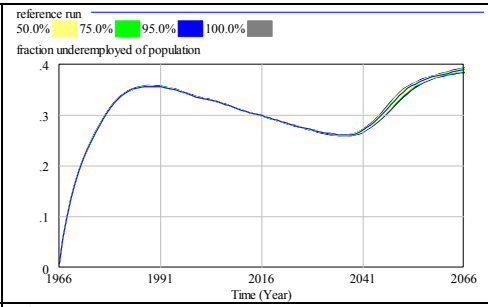
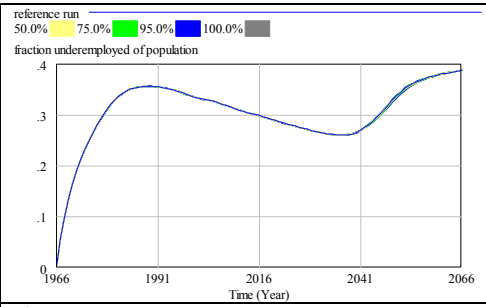
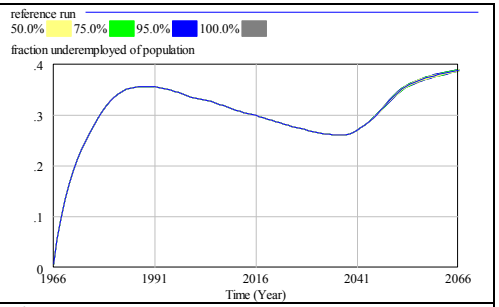
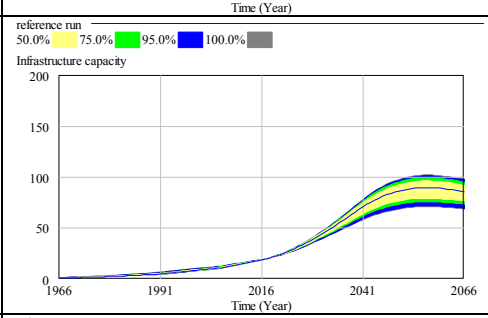
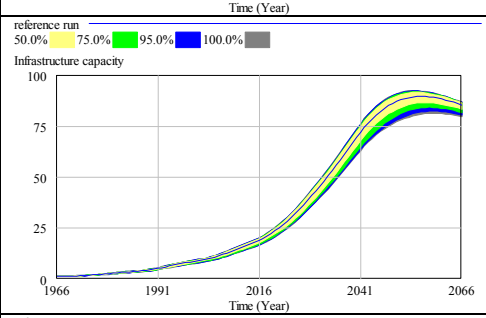
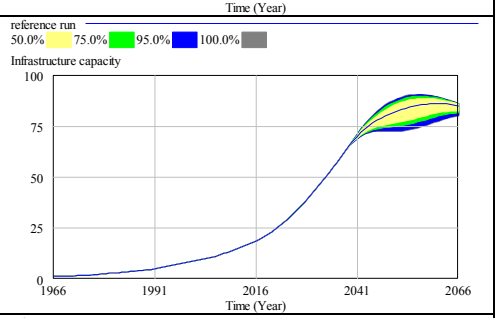
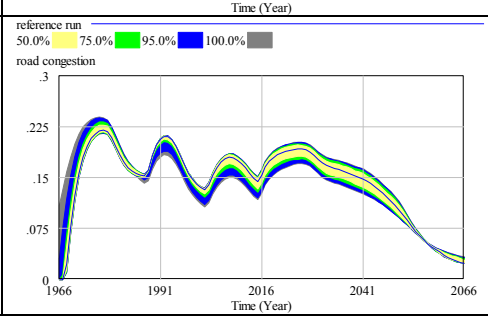
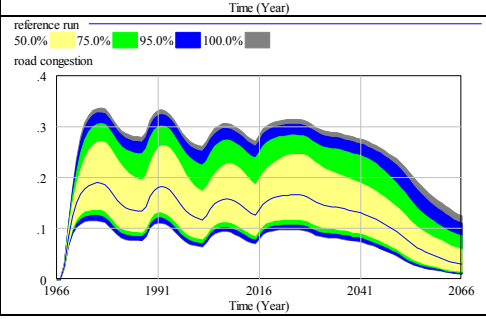
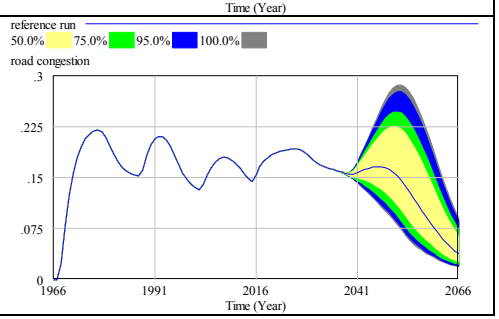
Sensitivity plot: road congestion			

Parameter	max per capita transport demand	transport congestion multiplier (lookup)	land availability effect on transport construction (lookup)
Units	-	-	-
Nominal value	2		

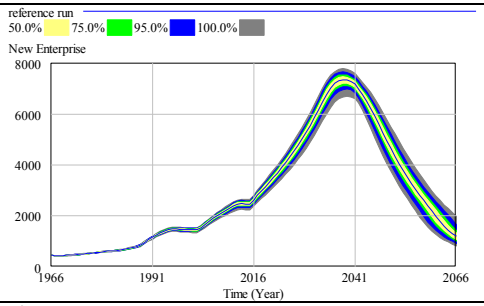
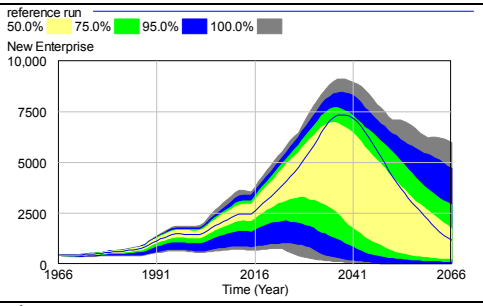
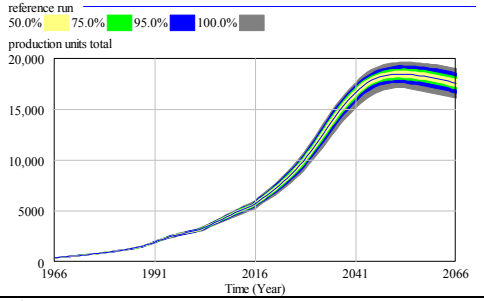
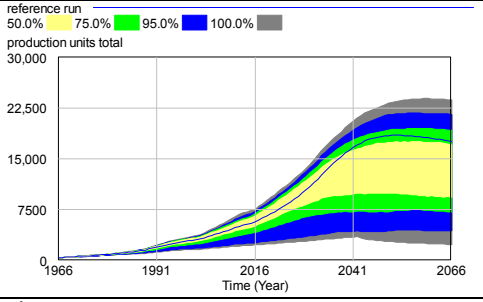
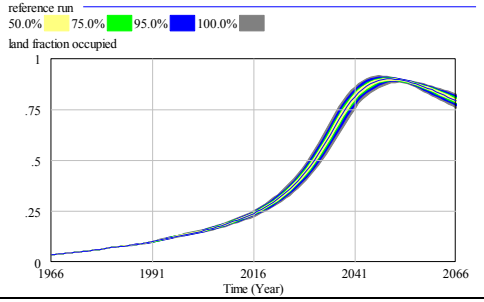
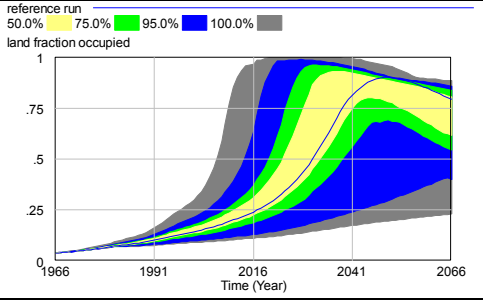
Minimum plausible	1 (same as in 2016)		
Maximum plausible	3 (three times 2016 pc demand)		
Sensitivity plot: New Enterprise			

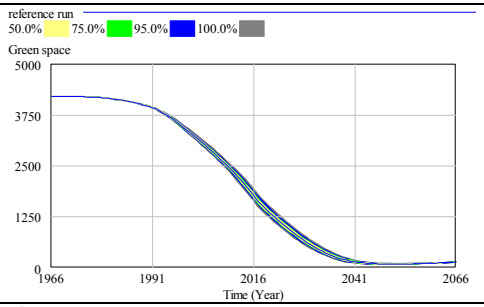
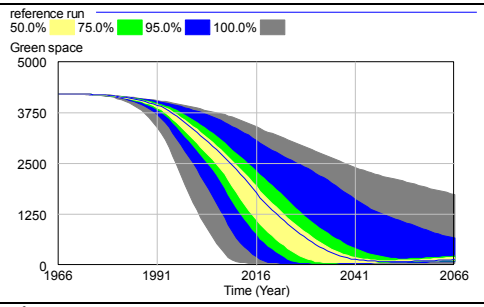
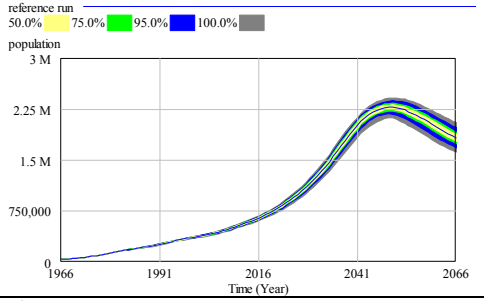
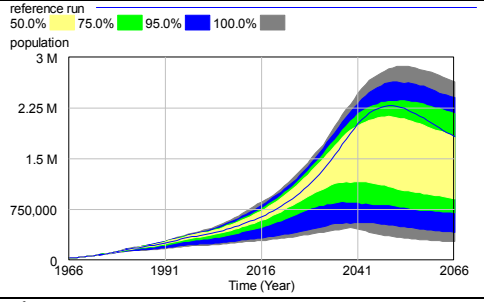
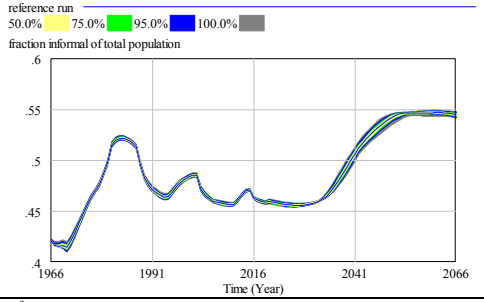
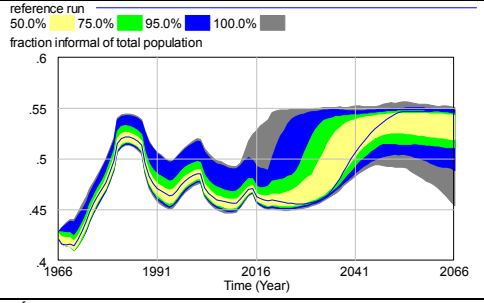
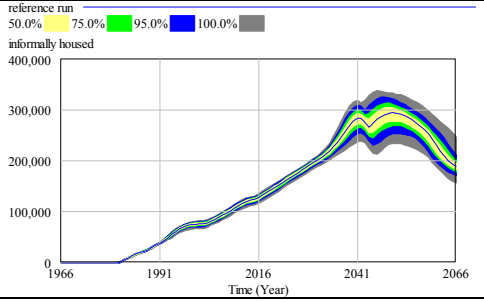
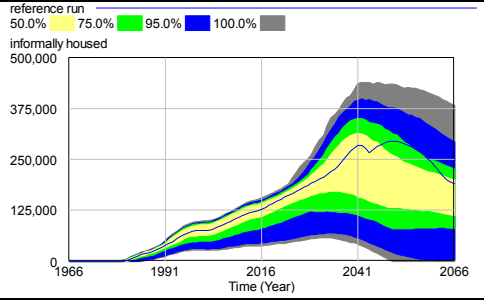
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

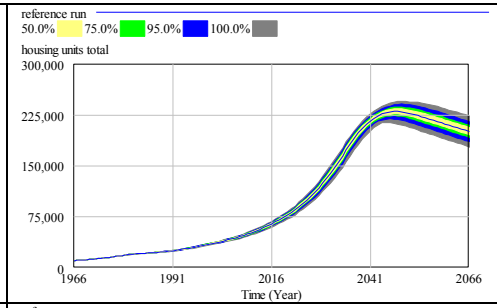
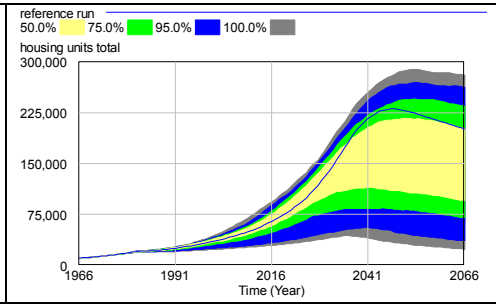
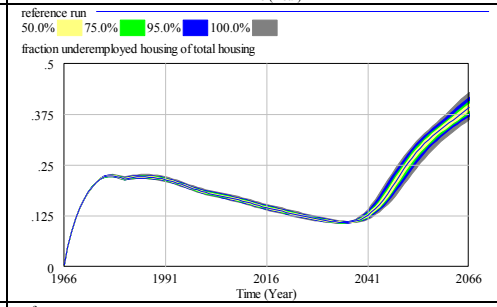
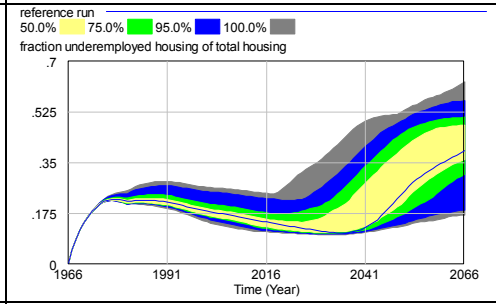
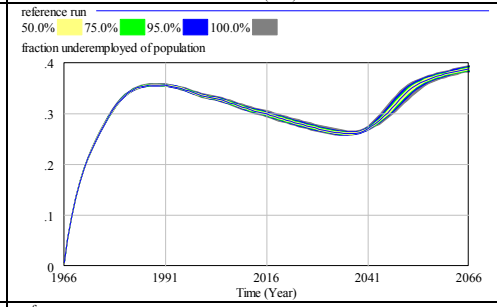
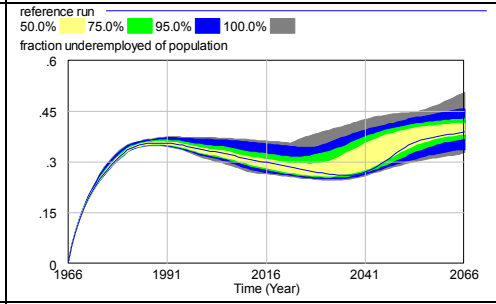
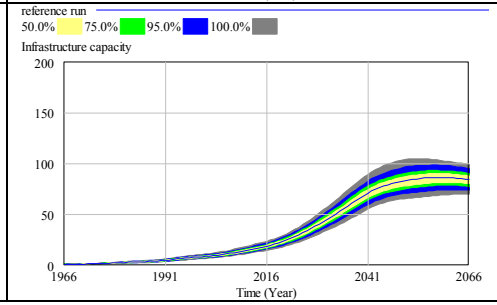
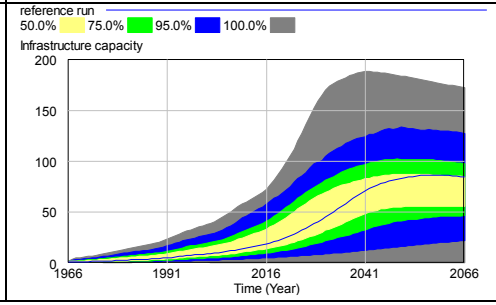
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

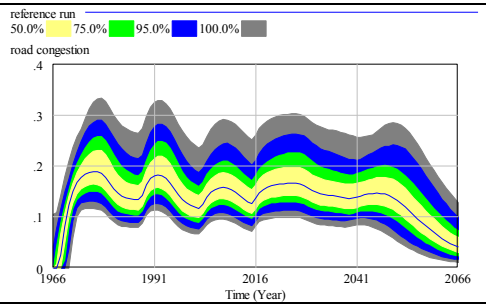
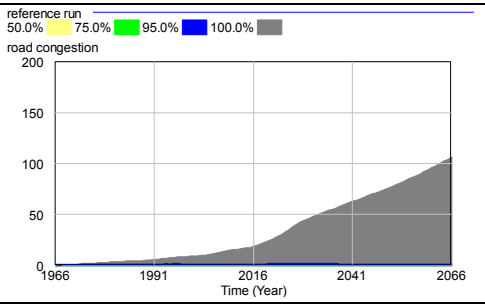
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

Parameter	Multivariate, all variables except *transport effects on city* and *road length*	Multivariate, all variables except *road length*	
Units	-	-	
Nominal value	-	-	
Minimum plausible	-10%	Respective minimum values per variable	

Maximum plausible	+10%	Respective maximum variables per variable	
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			

Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			

Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			

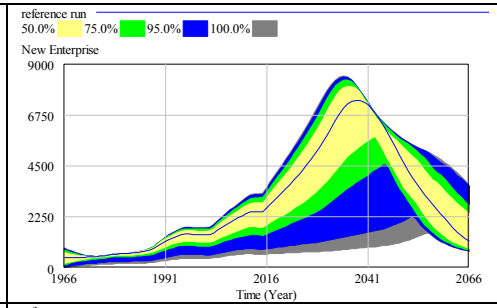
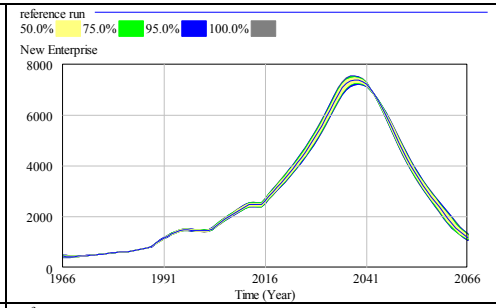
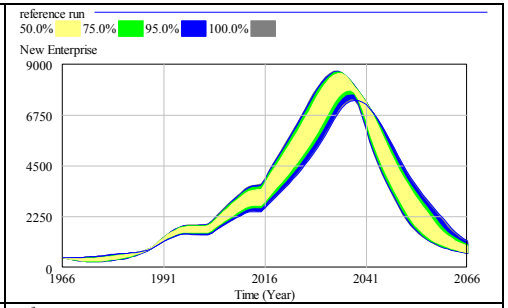
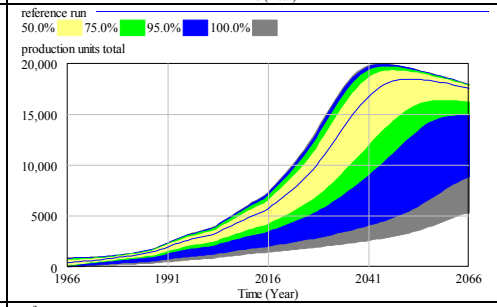
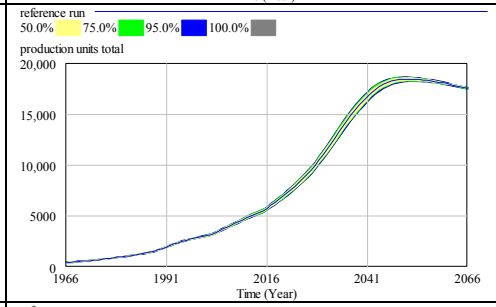
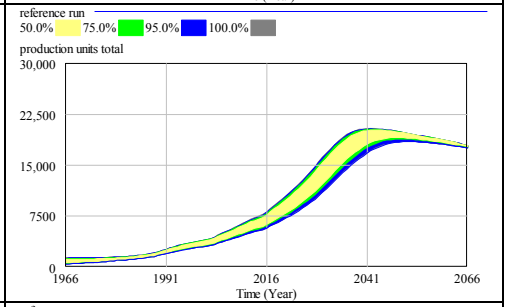
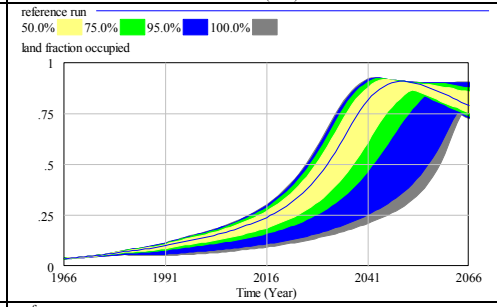
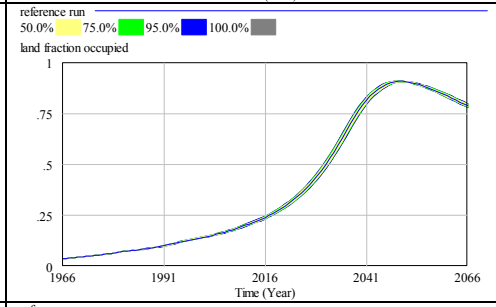
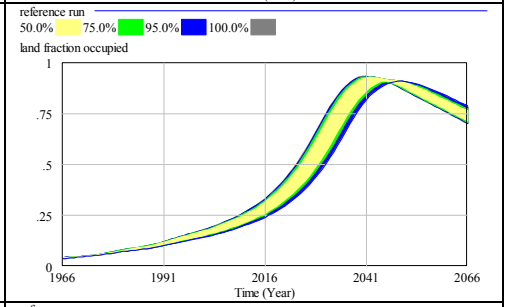
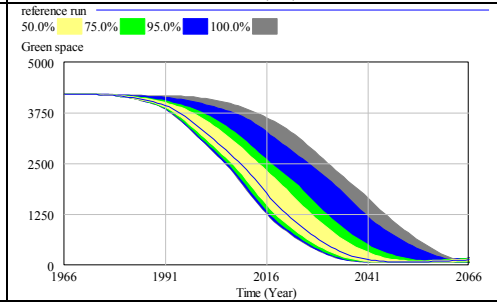
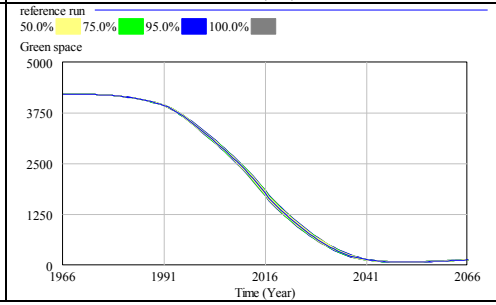
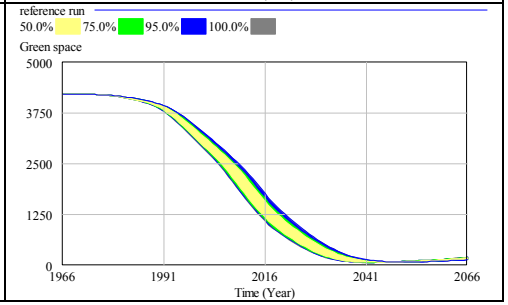
Sensitivity plot: road congestion			

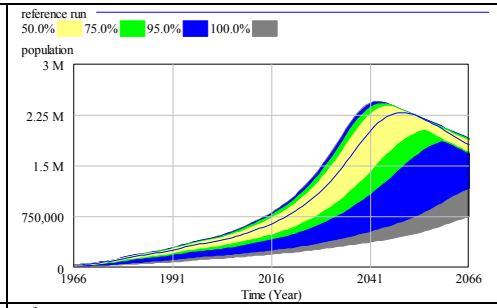
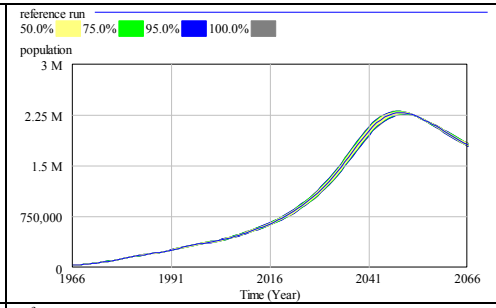
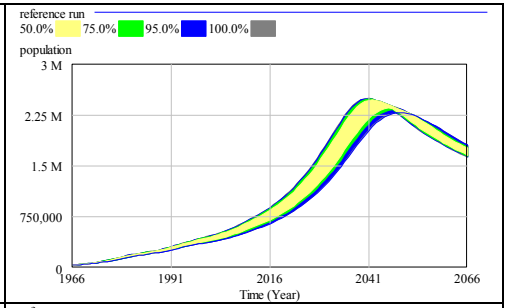
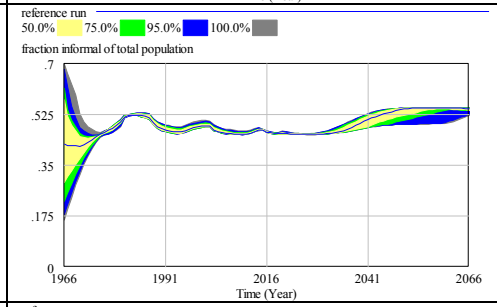
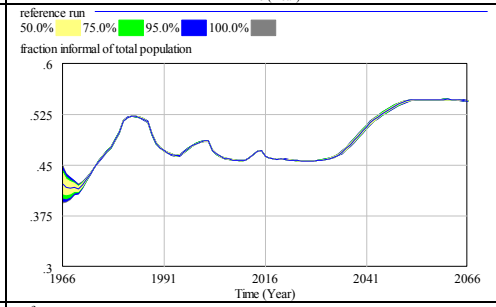
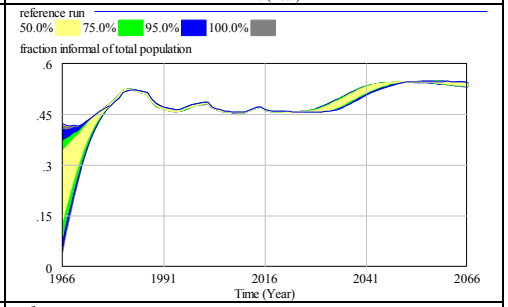
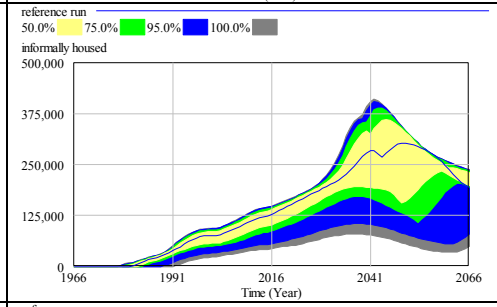
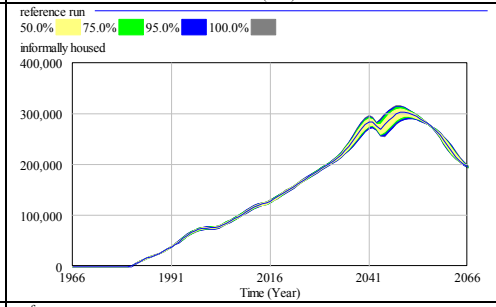
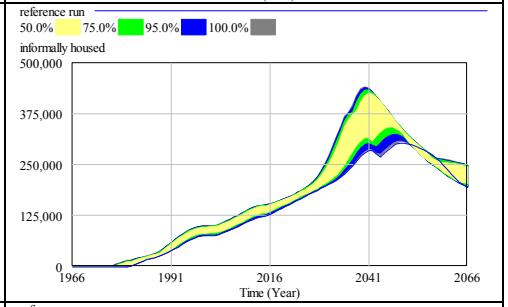
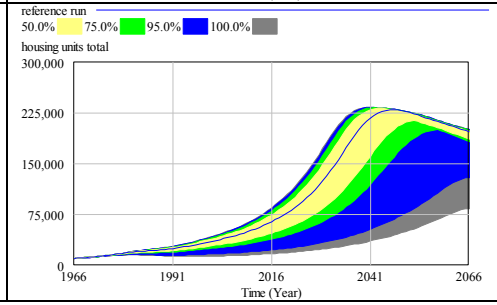
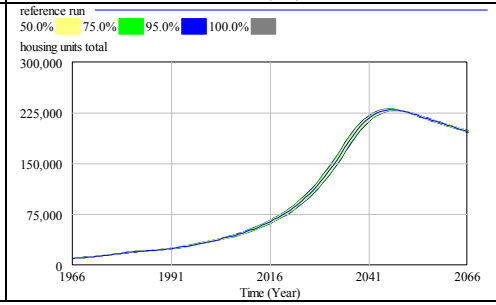
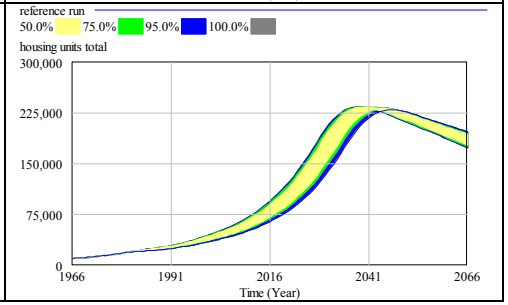
4.4 Industry Chain sensitivity

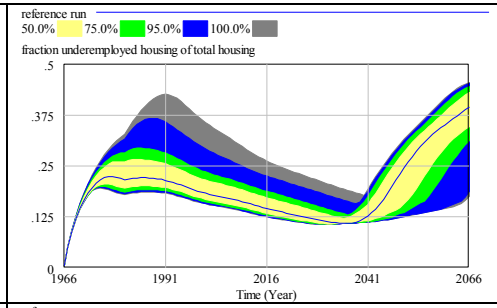
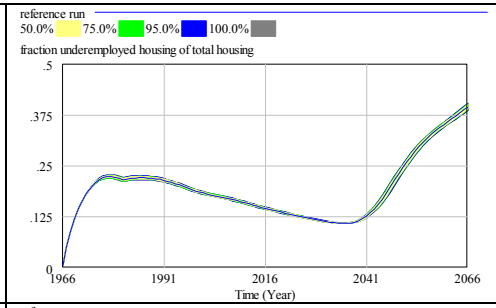
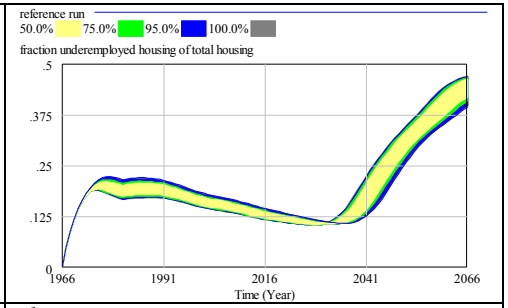
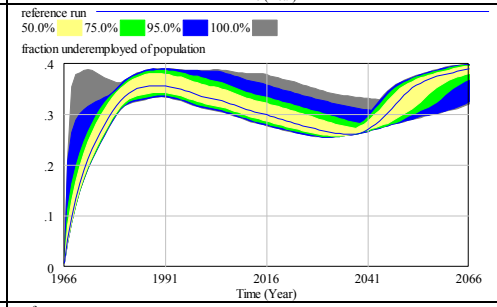
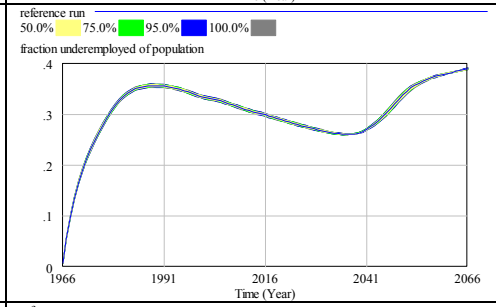
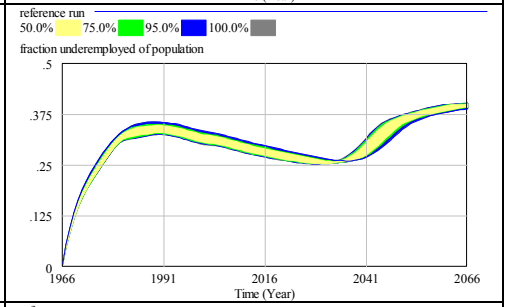
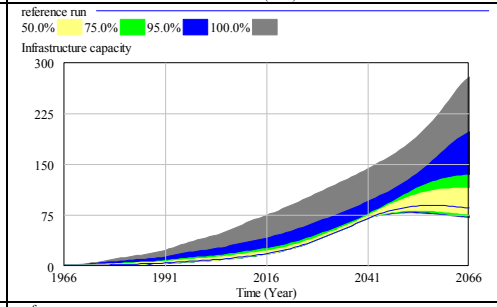
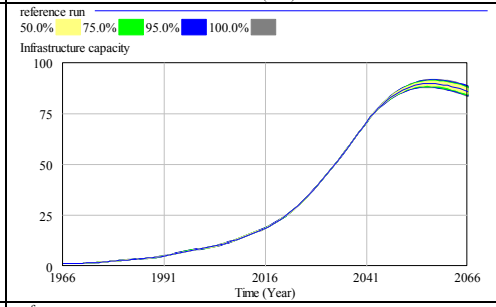
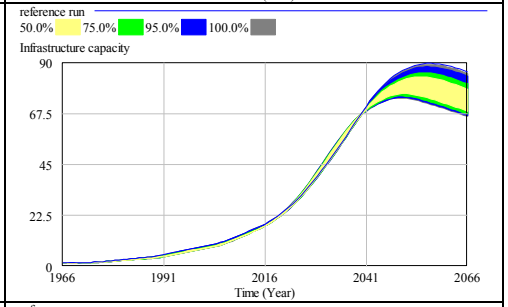
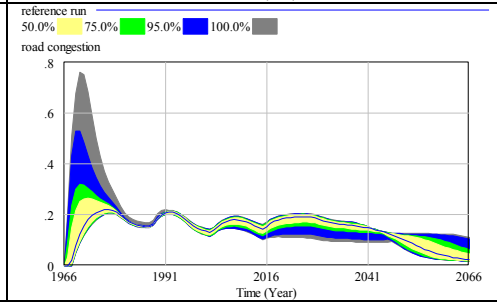
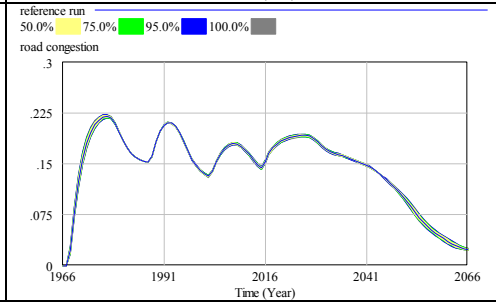
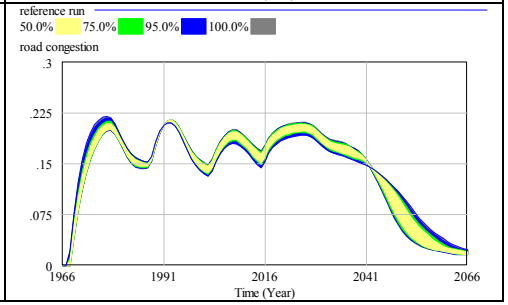
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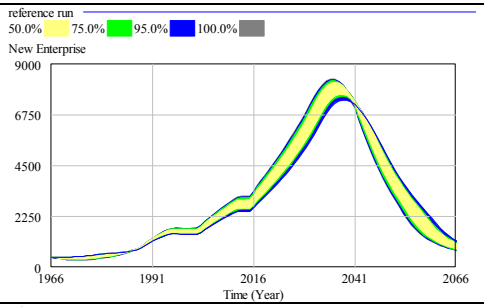
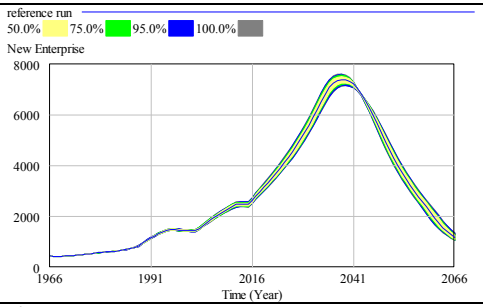
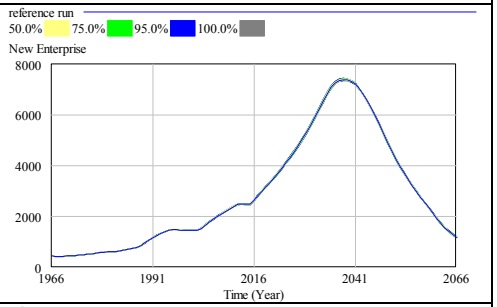
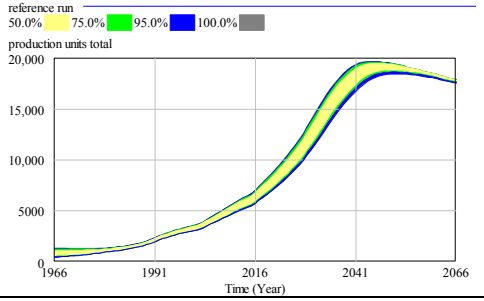
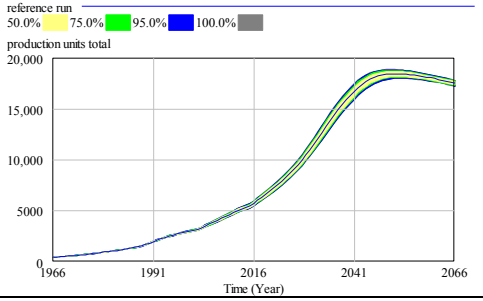
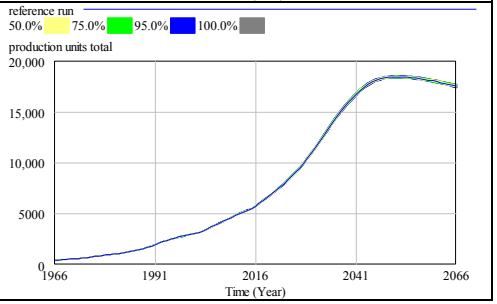
- New Enterprise initial value
- Mature Business initial value
- Declining industry initial value
- mature business construction factor
- declining industry construction factor
- enterprise factor
- new enterprise construction normal
- new enterprise construction factor
- new enterprise construction program
- new enterprise growth rate initial
- new enterprise decline normal
- new enterprise averaging time
- mature business decline normal
- declining industry demolition normal
- declining industry demolition program
- declining industry demolition factor
- enterprise manager/job multiplier (lookup)
- enterprise tax multiplier (lookup)
- enterprise labor/job multiplier (lookup)
- enterprise land multiplier (lookup)
- enterprise-growth multiplier (lookup)
- enterprise decline multiplier (lookup)
- business decline multiplier (lookup)
- declining enterprise land multiplier (lookup)
- declining-industry enterprise multiplier (lookup)

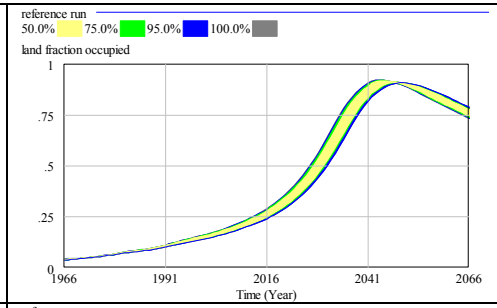
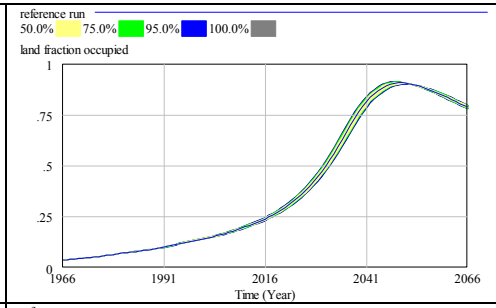
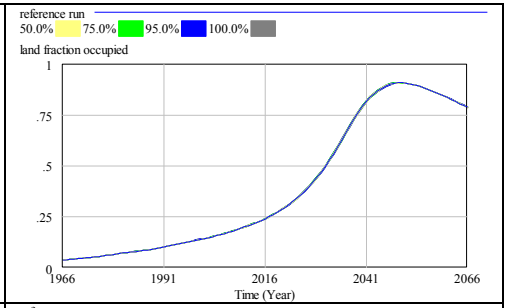
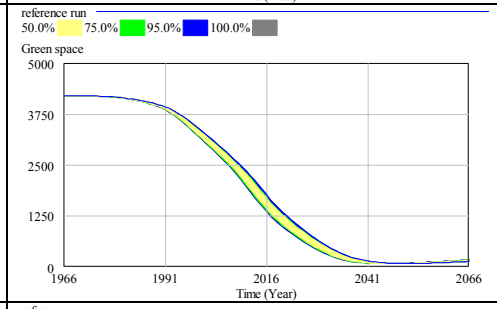
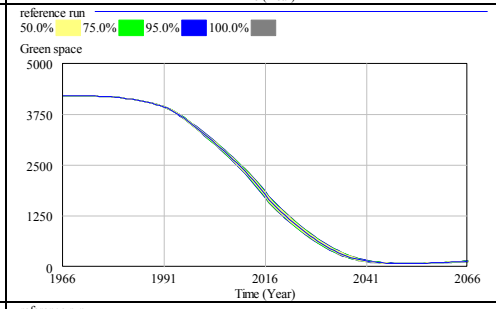
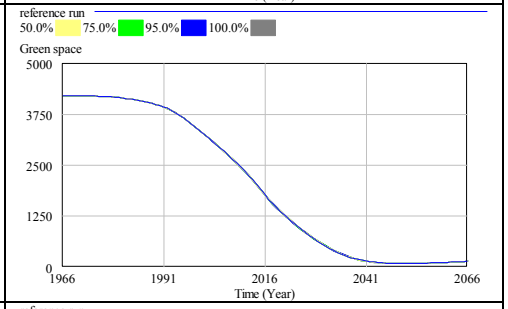
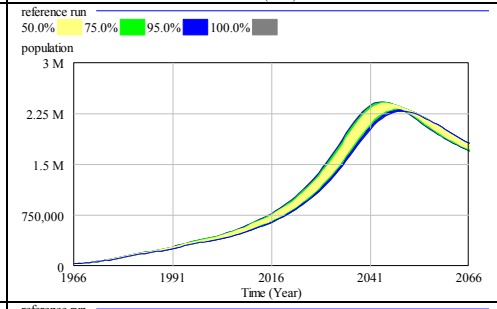
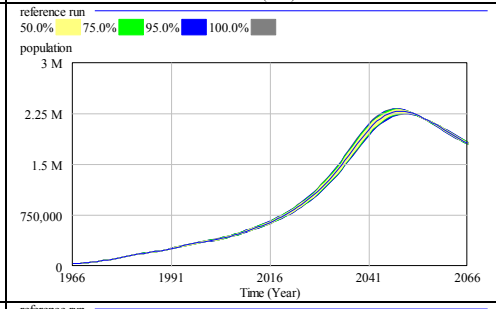
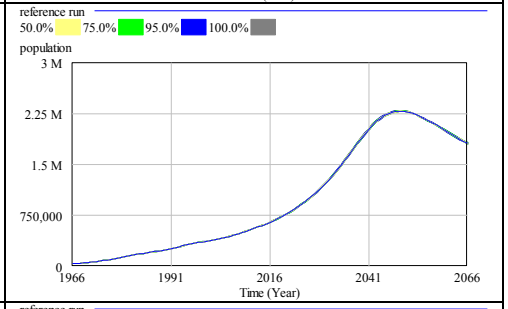
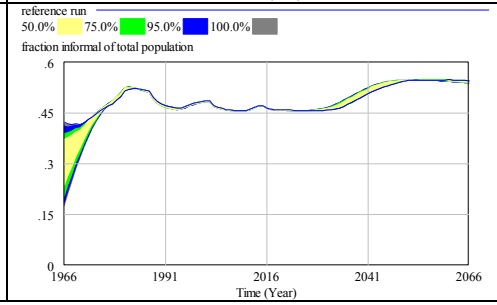
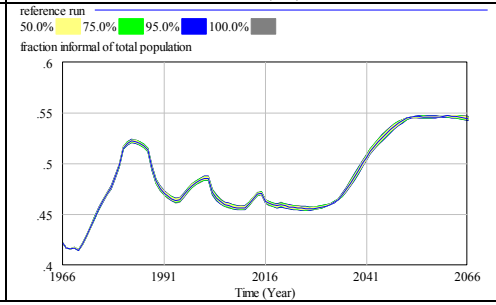
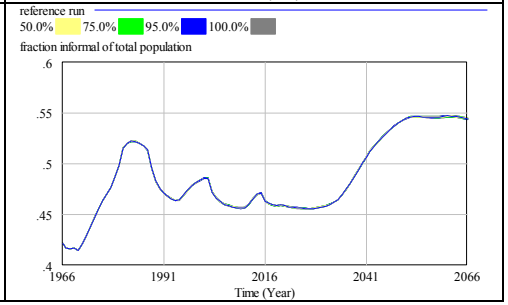
Parameter	New Enterprise initial value	New Enterprise initial value	Mature Business initial value
Units	productive unit	productive unit	productive unit
Nominal value	455	455	0
Minimum plausible	0	410 (-10%)	0
Maximum plausible	900	501 (+10%)	900

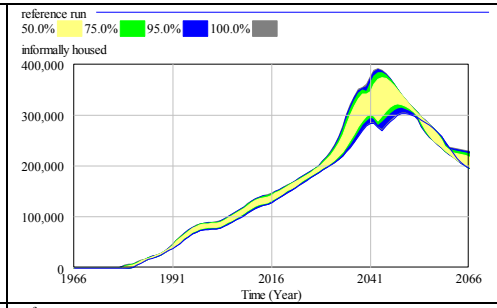
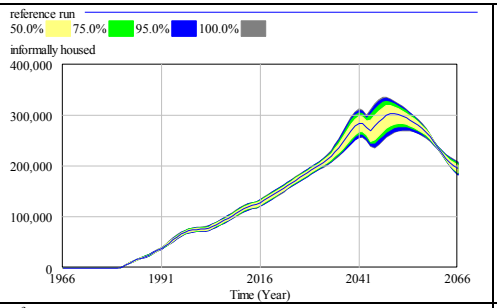
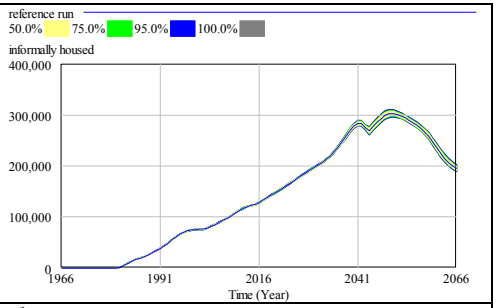
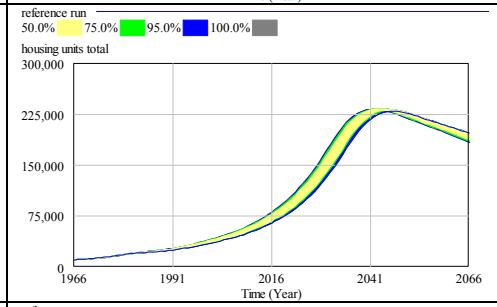
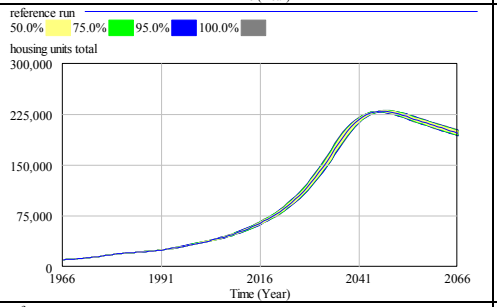
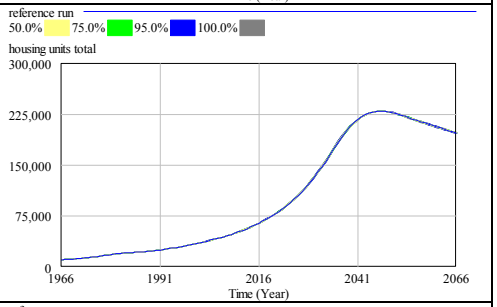
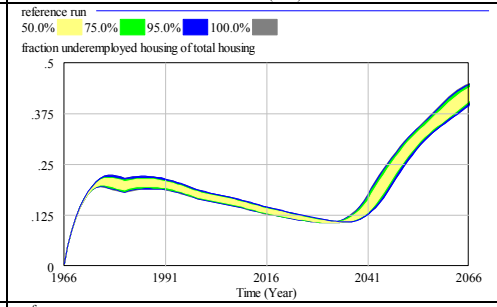
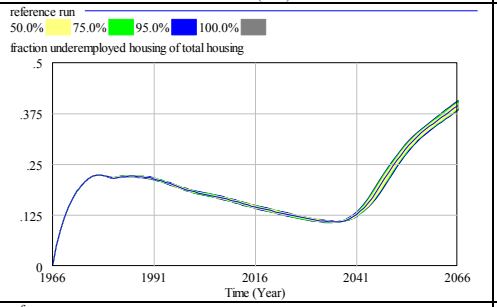
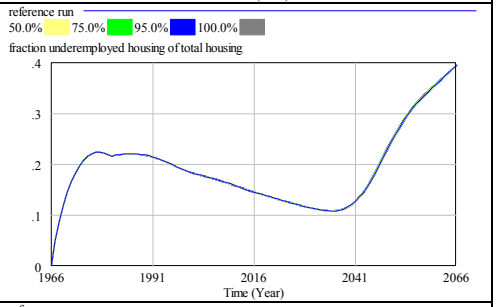
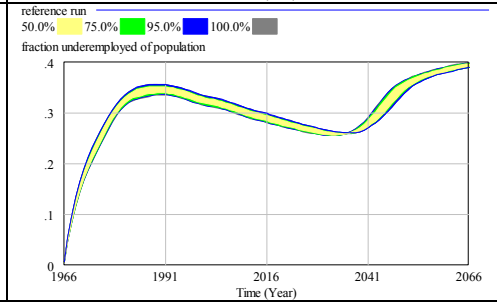
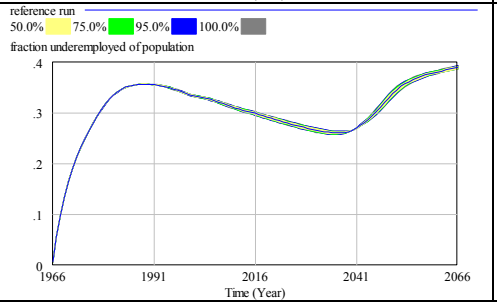
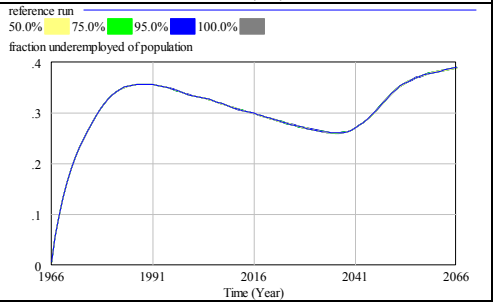
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

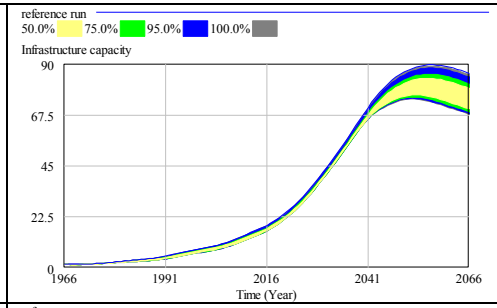
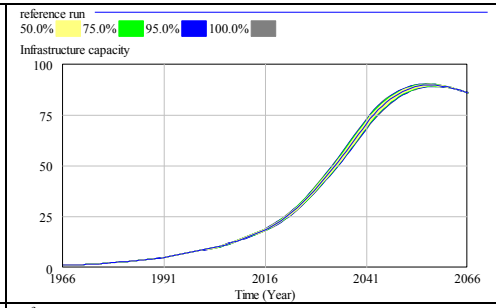
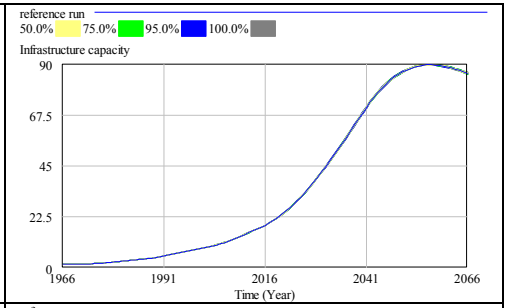
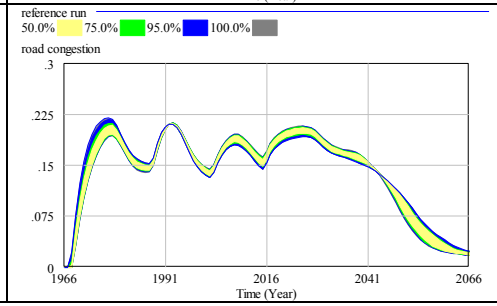
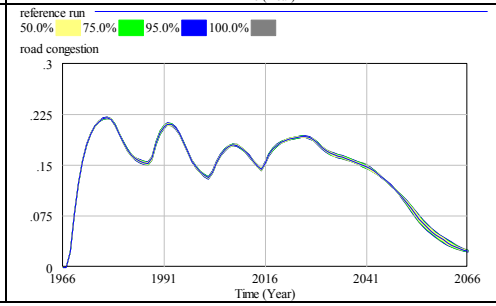
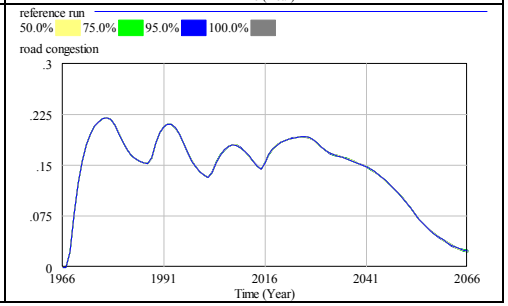
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

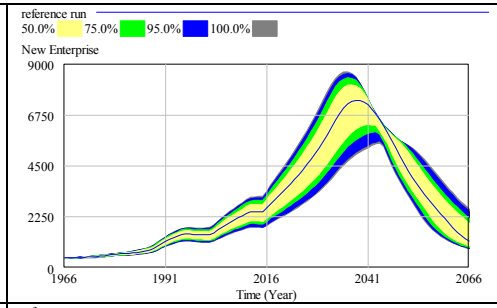
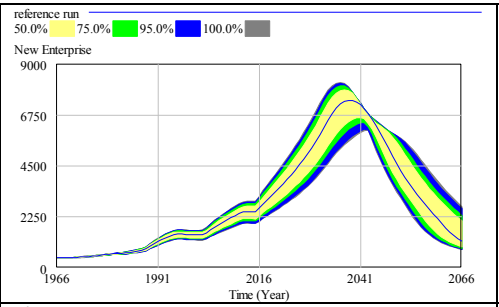
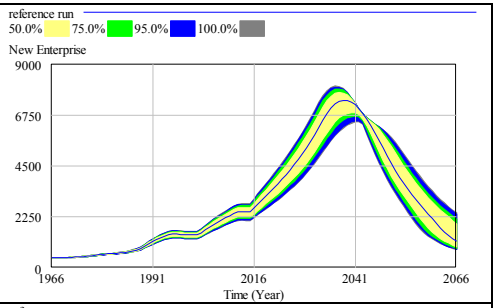
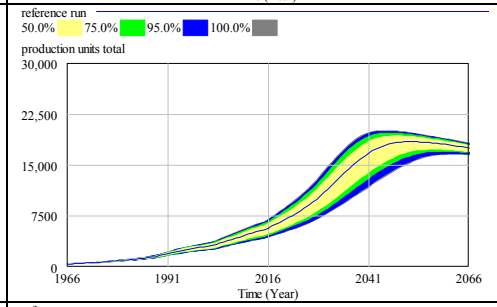
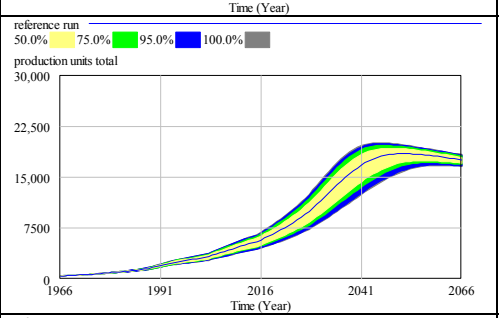
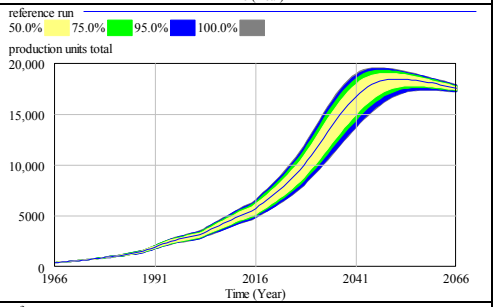
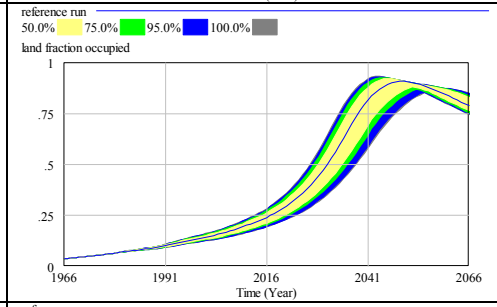
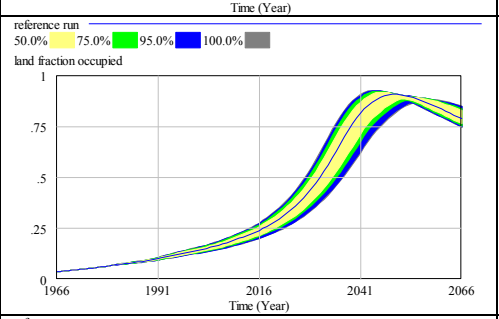
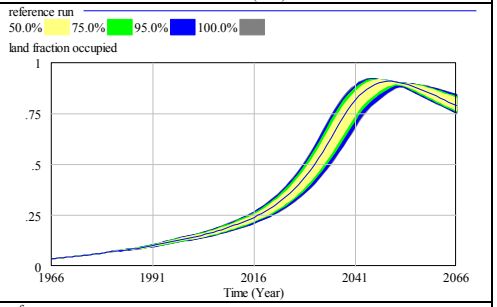
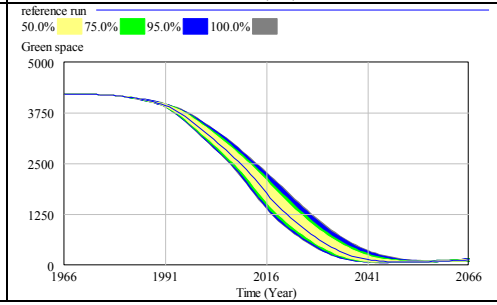
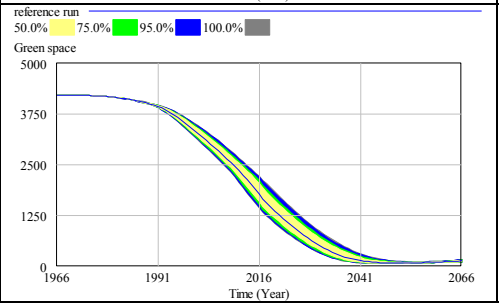
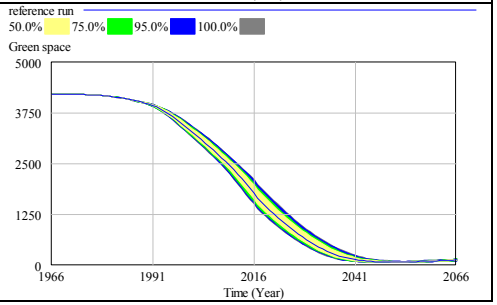
Parameter	Declining industry initial value	mature business construction factor	declining industry construction factor
Units	productive unit	-	-
Nominal value	0	0.5	0.3
Minimum plausible	0	0.4 (-20%)	0.24 (-20%)
Maximum plausible	900	0.6 (+20%)	0.36 (+20%)
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			

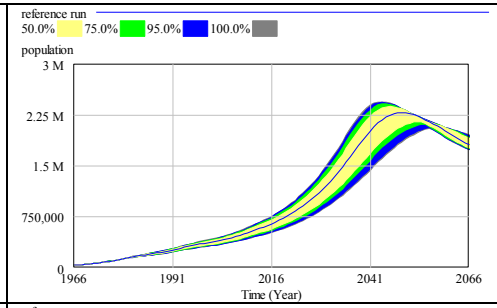
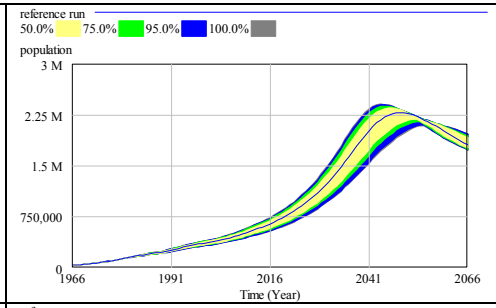
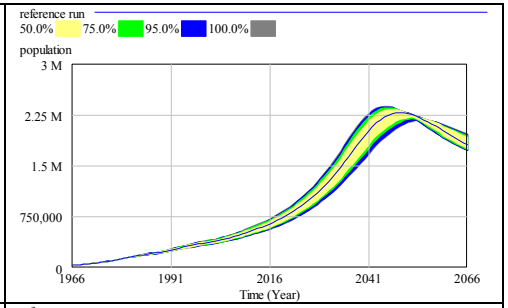
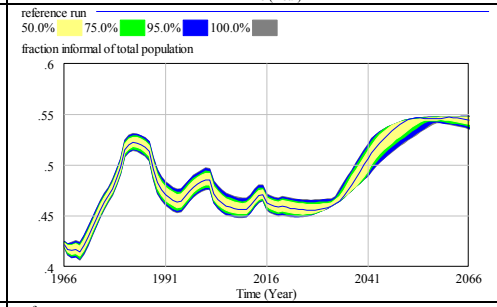
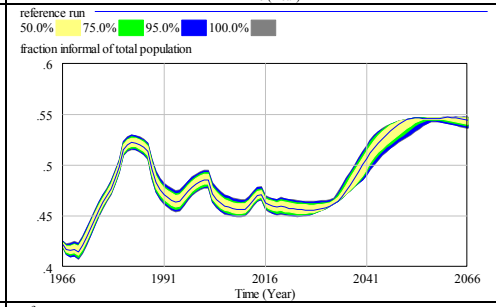
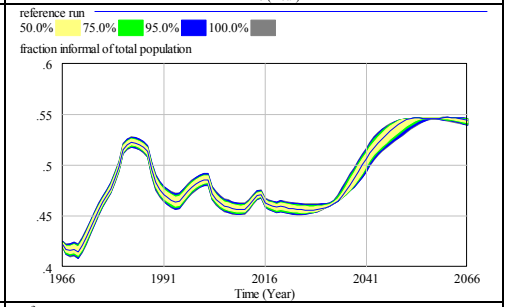
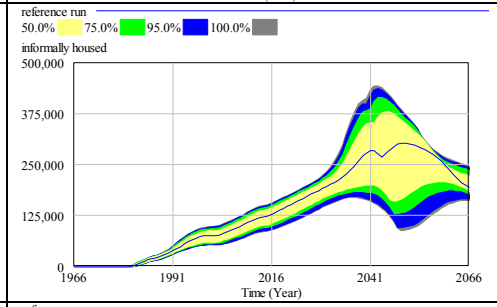
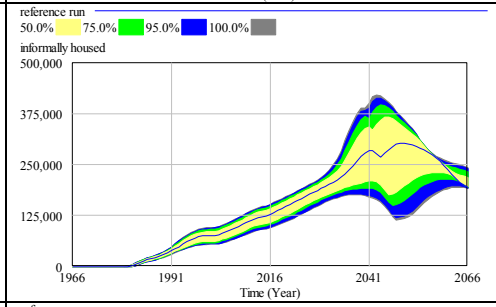
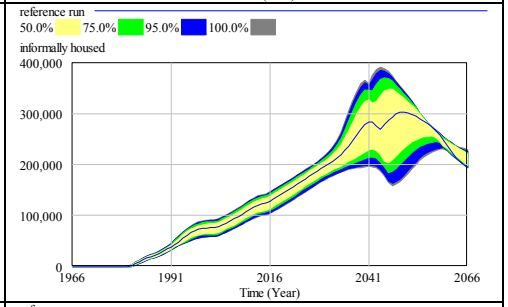
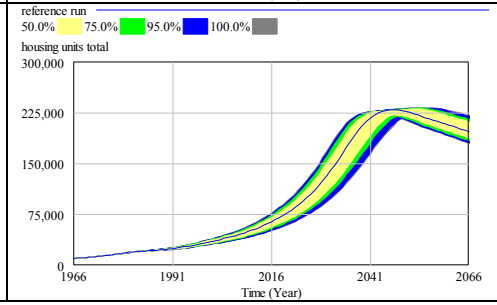
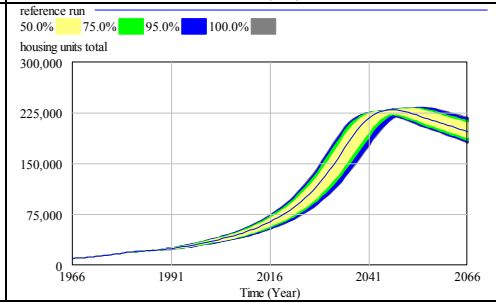
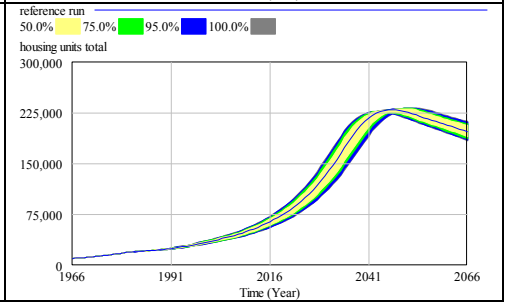
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			

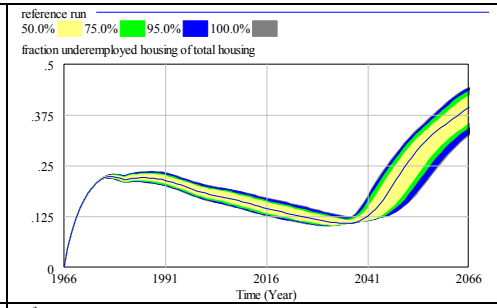
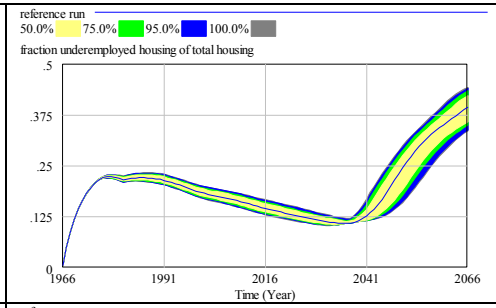
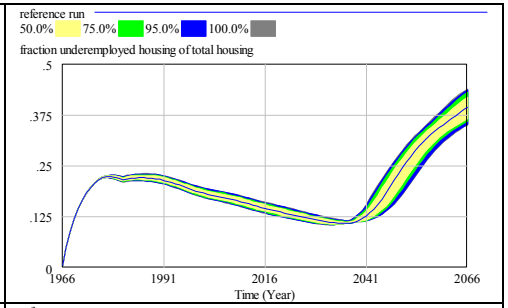
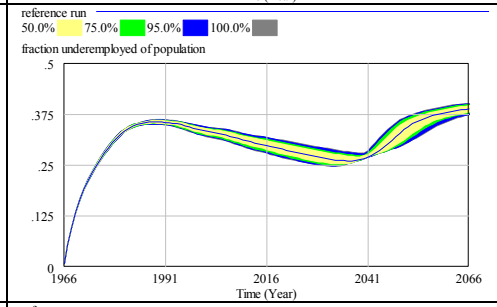
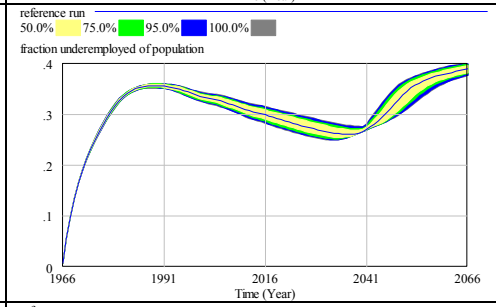
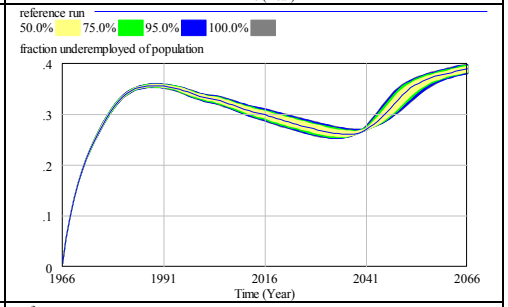
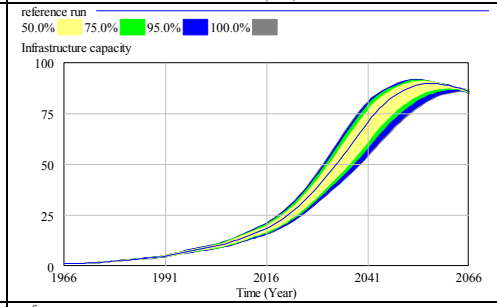
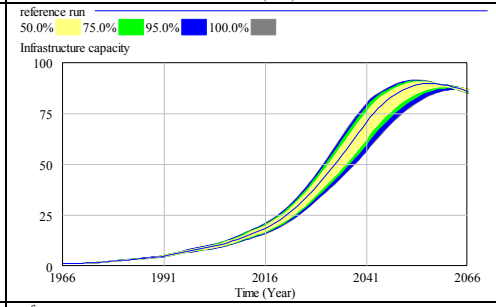
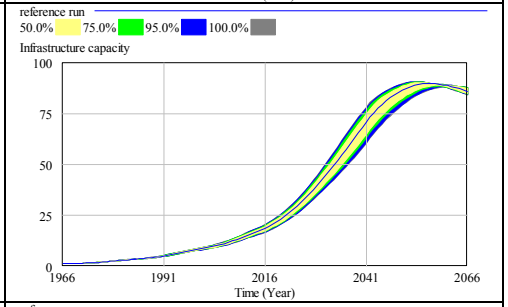
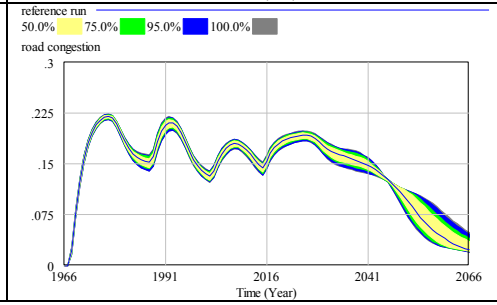
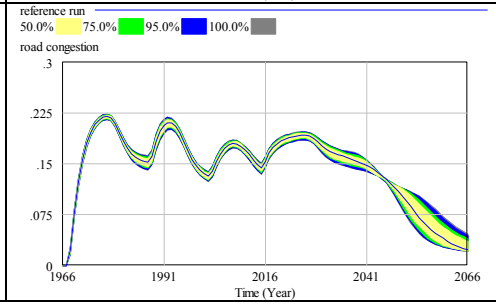
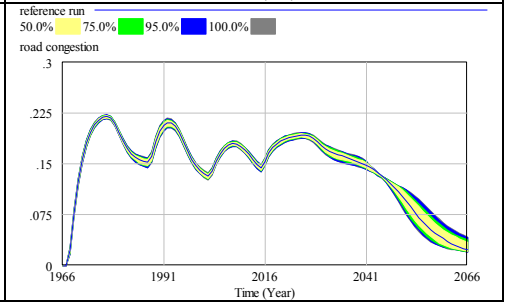
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			

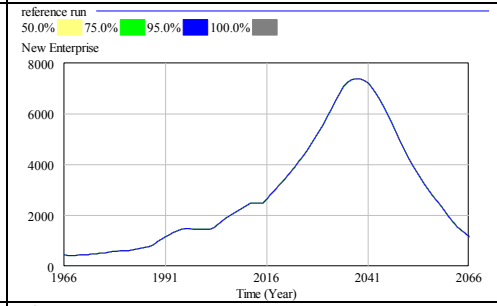
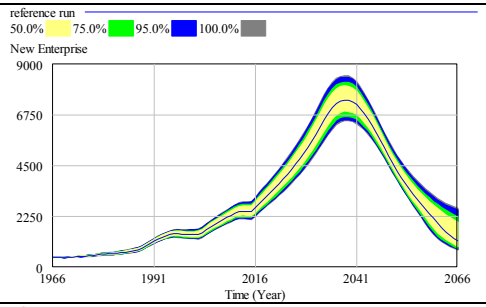
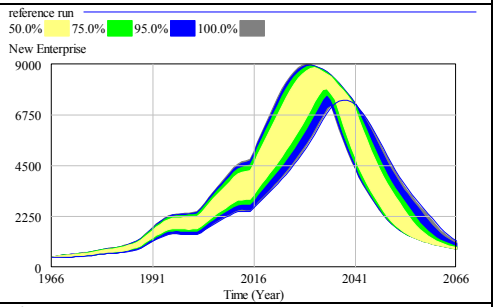
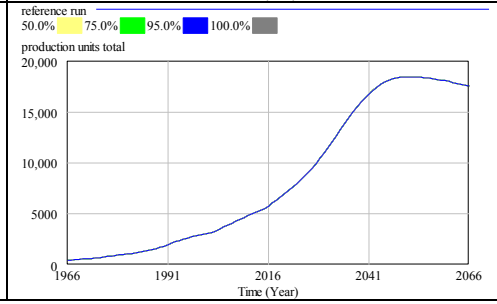
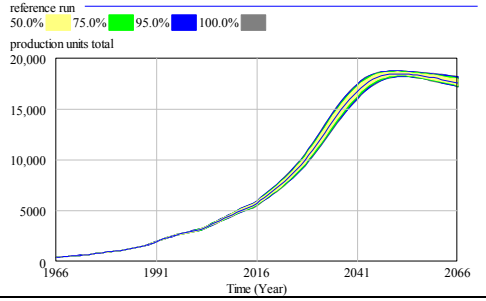
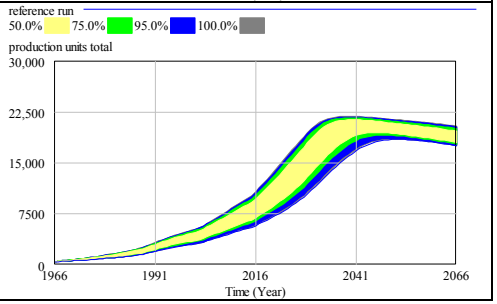
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

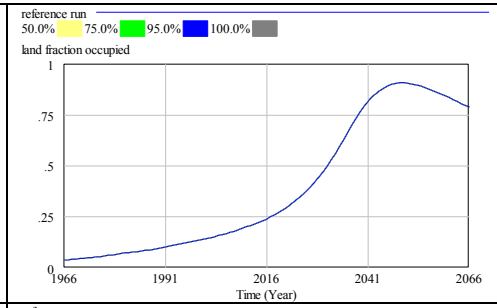
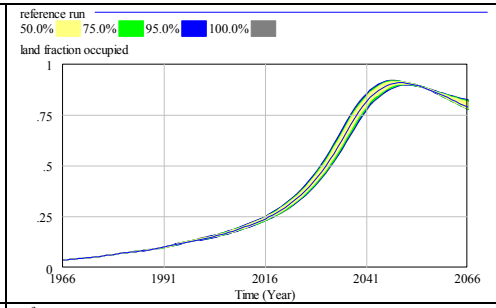
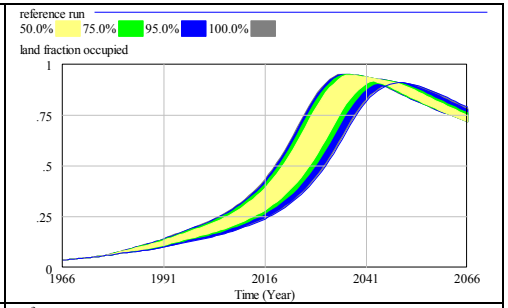
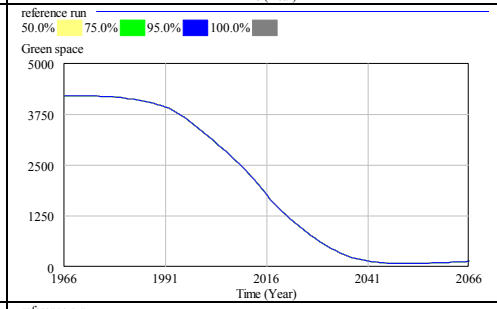
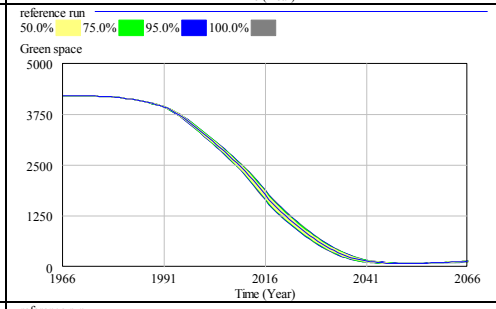
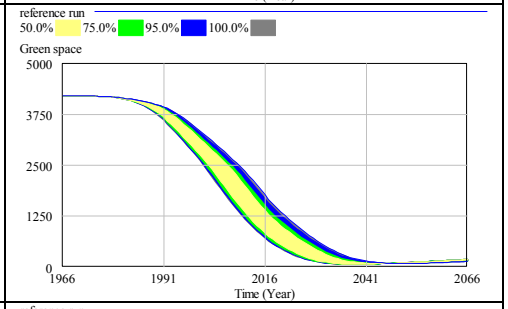
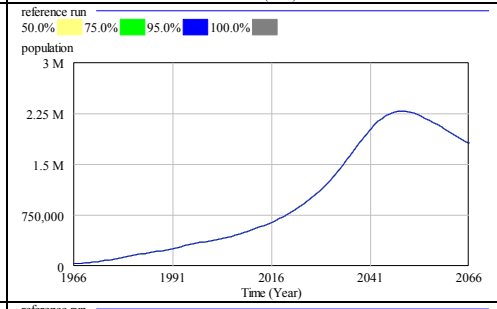
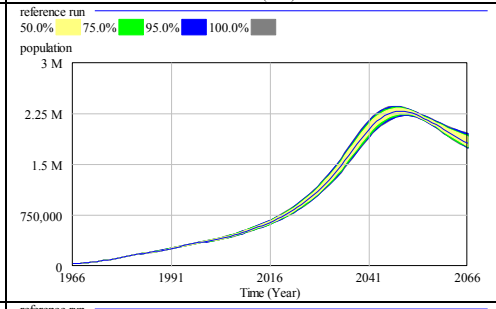
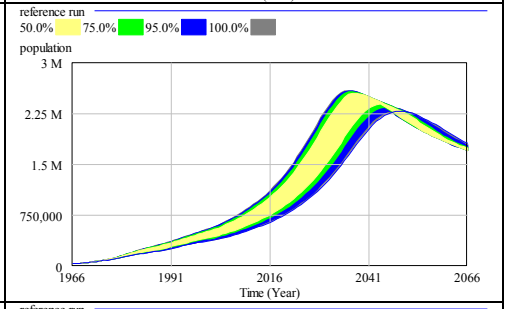
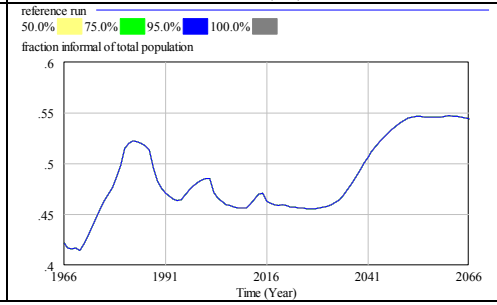
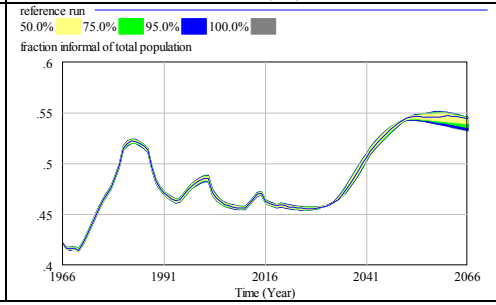
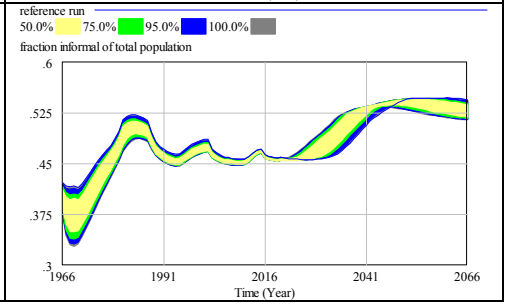
Parameter	enterprise factor	new enterprise construction normal	new enterprise construction factor
Units	-	-	-
Nominal value	1	0.05	1
Minimum plausible	0.8 (-20%)	0.04 (-20%)	0.8 (-20%)
Maximum plausible	1.2 (+20%)	0.06 (+20%)	1.2 (+20%)

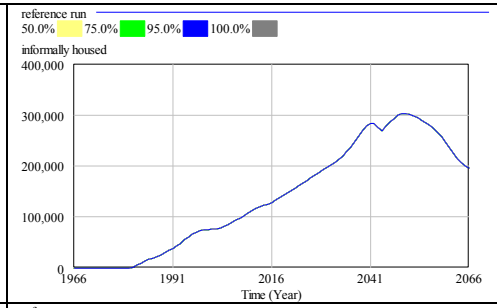
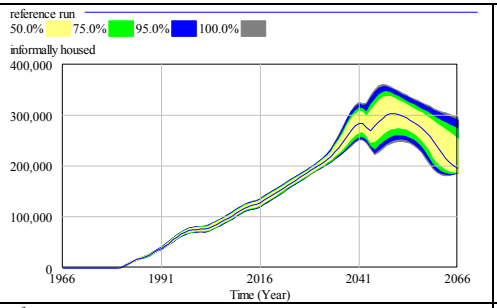
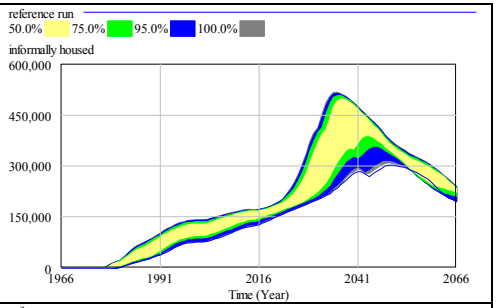
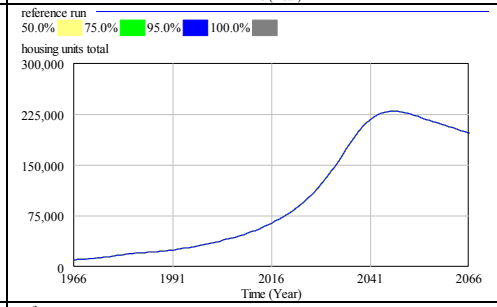
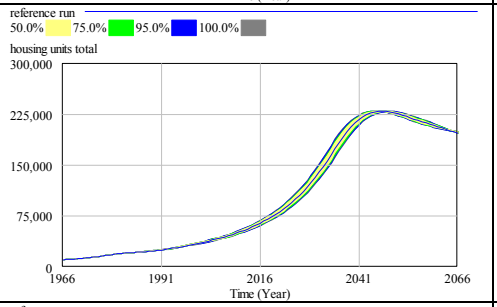
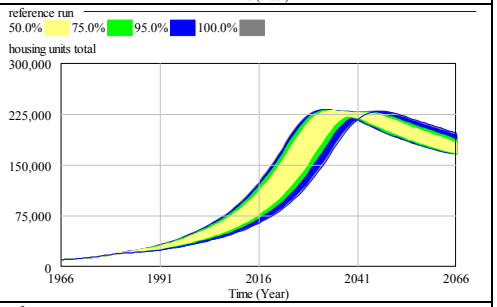
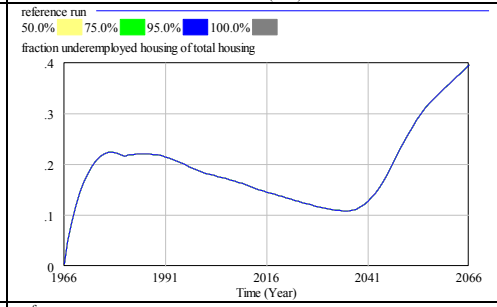
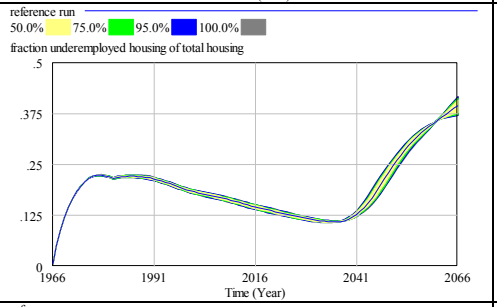
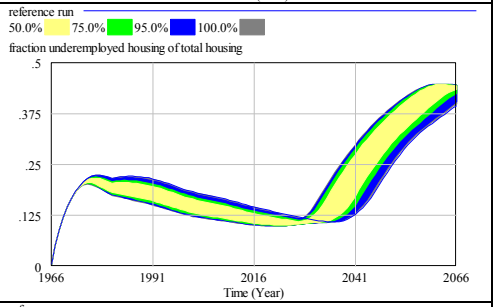
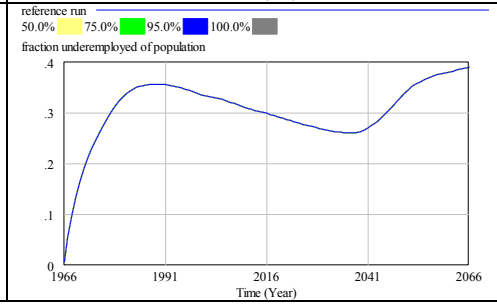
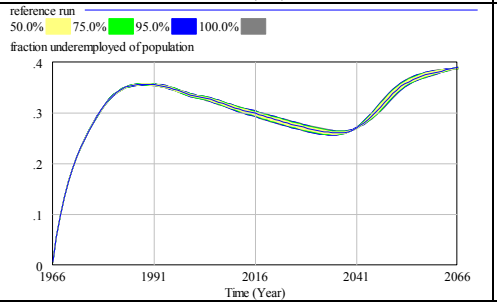
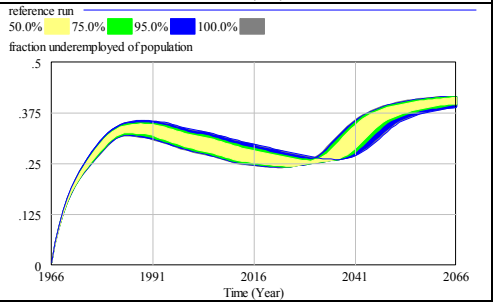
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

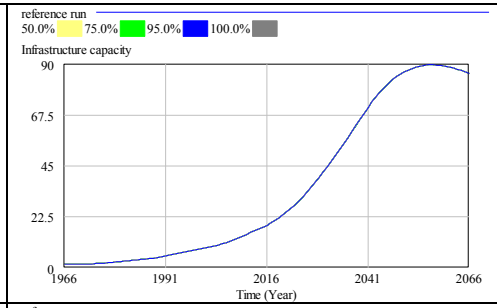
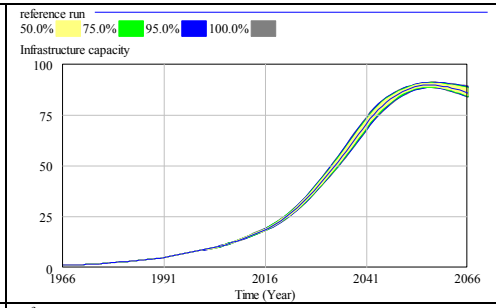
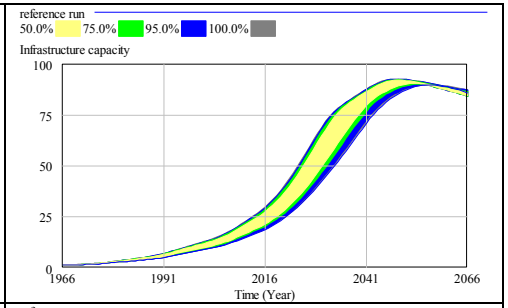
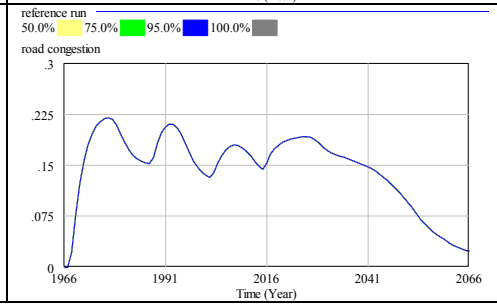
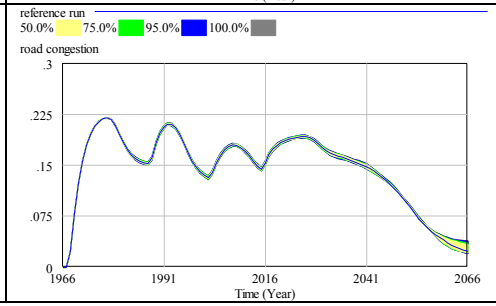
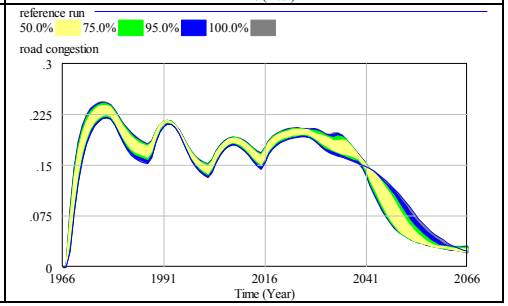
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

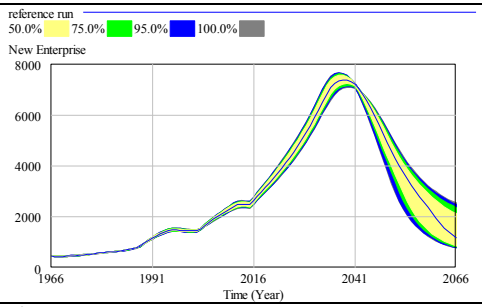
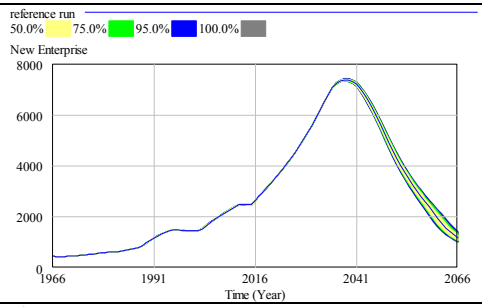
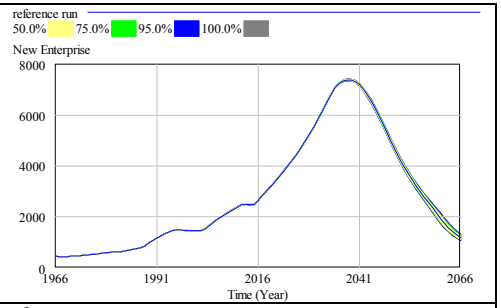
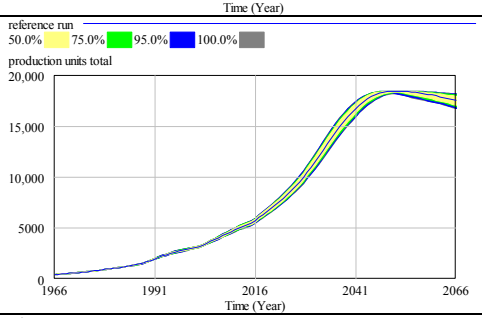
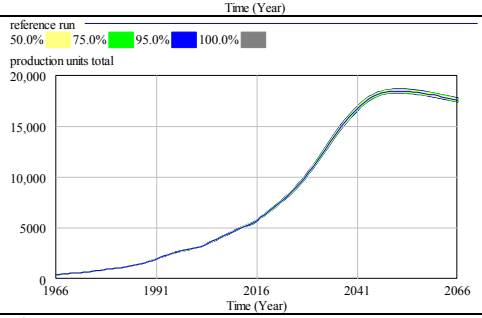
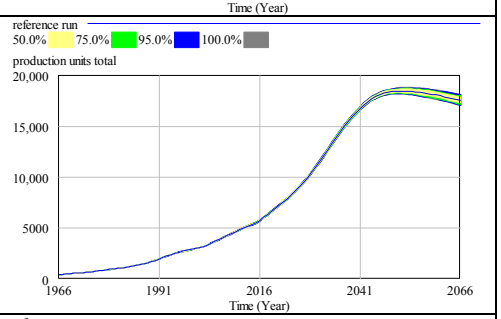
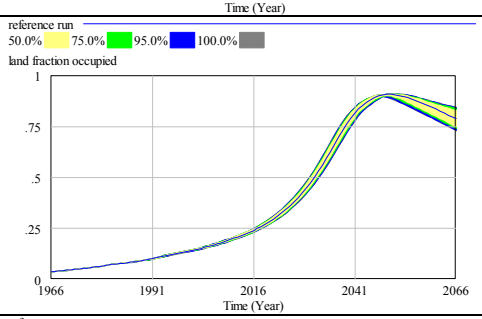
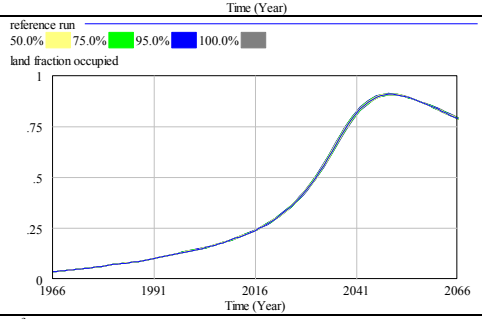
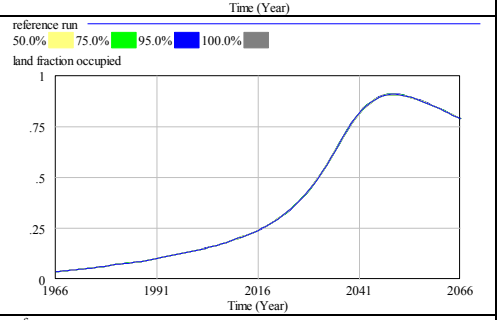
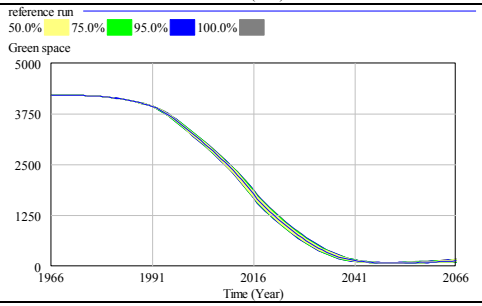
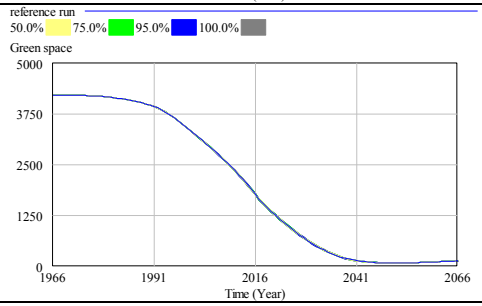
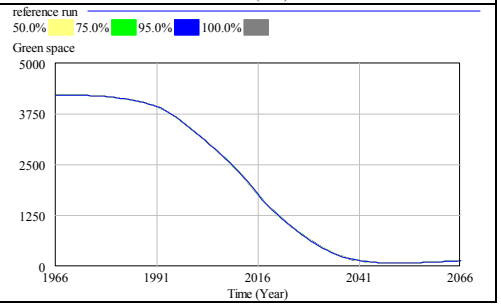
Parameter	new enterprise growth rate initial	new enterprise decline normal	new enterprise construction program
Units	1/year	1/year	productive units/year
Nominal value	0.03	0.08 (=12.5 years)	0
Minimum plausible	0.015 (-100%)	0.064 (-20%, =15.6 years)	0
Maximum plausible	0.045 (+100%)	0.096 (+20%, =10.4 years)	100
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			

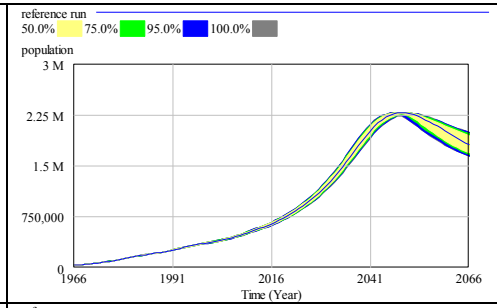
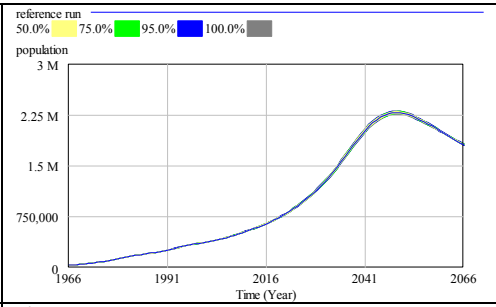
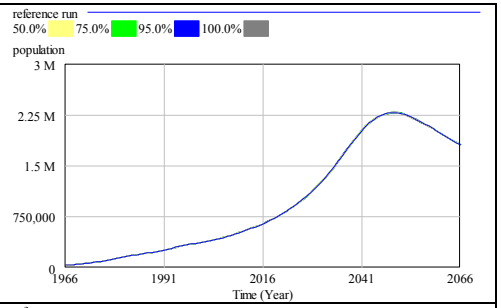
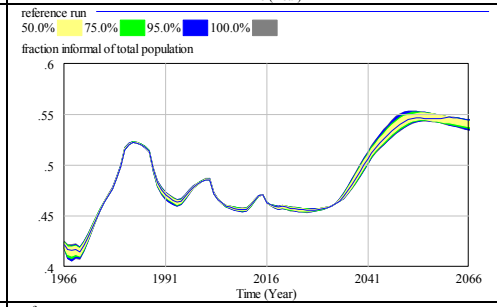
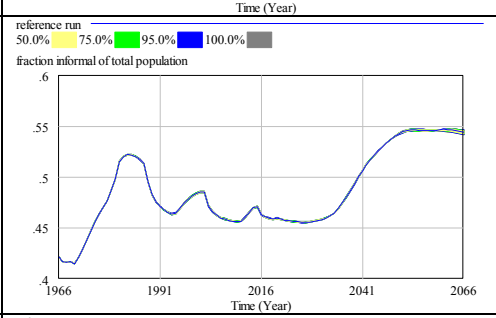
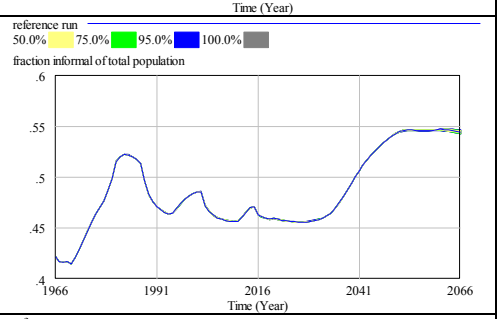
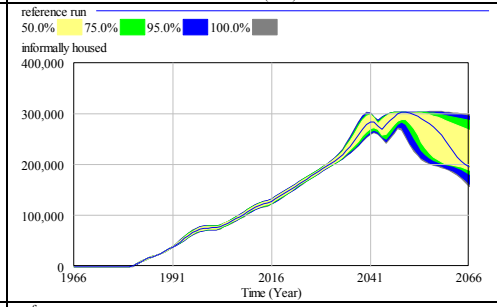
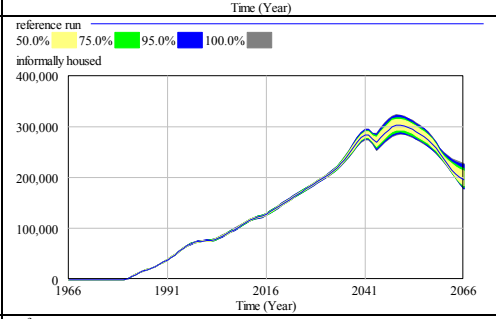
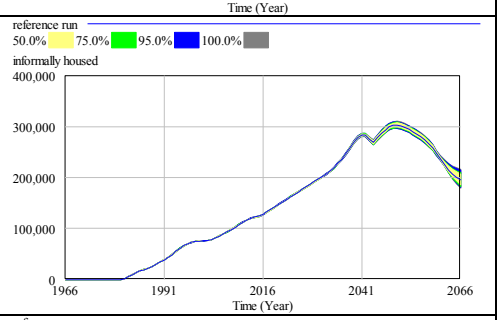
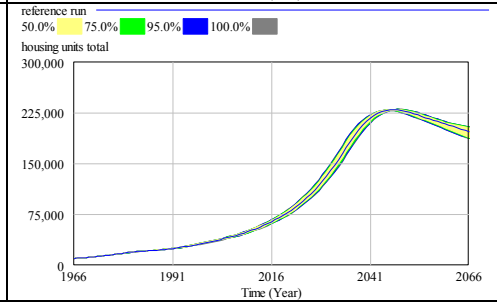
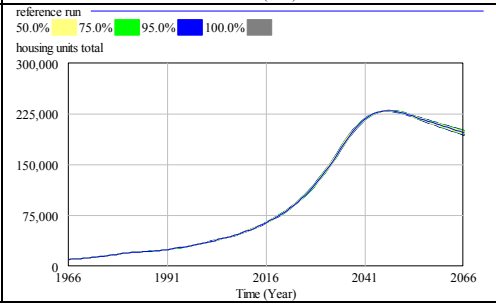
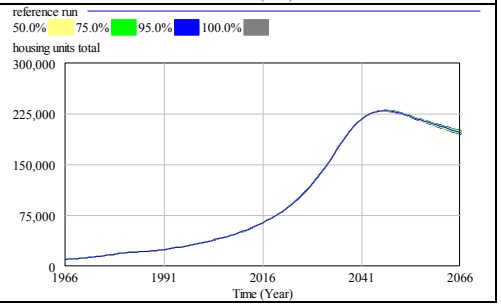
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			

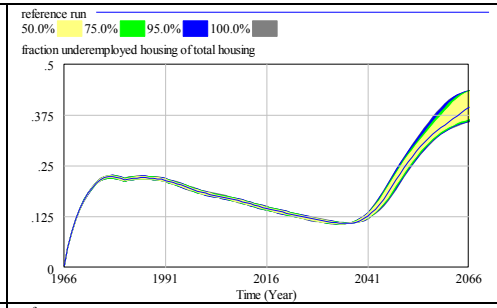
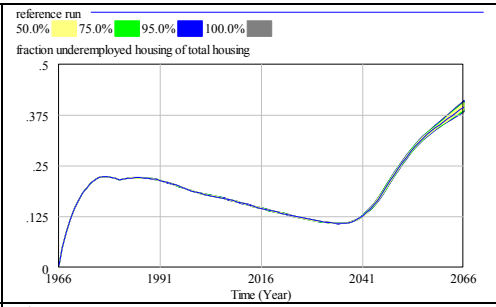
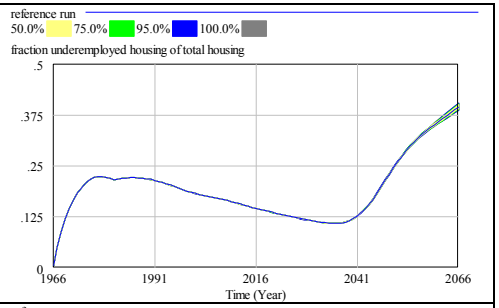
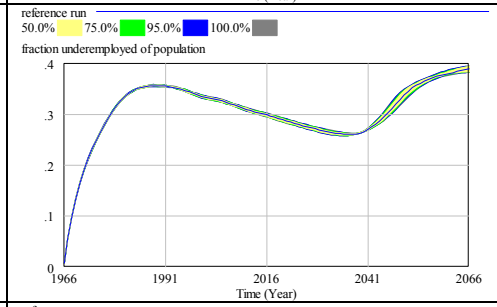
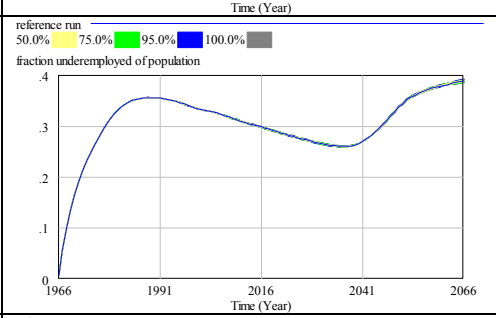
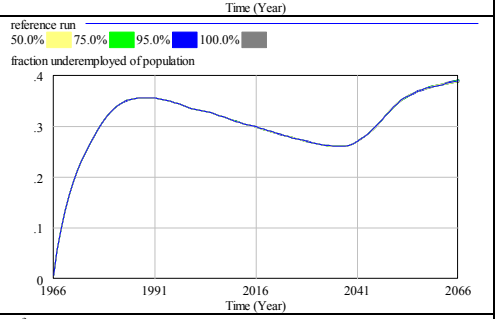
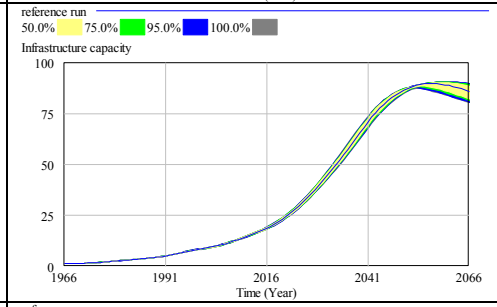
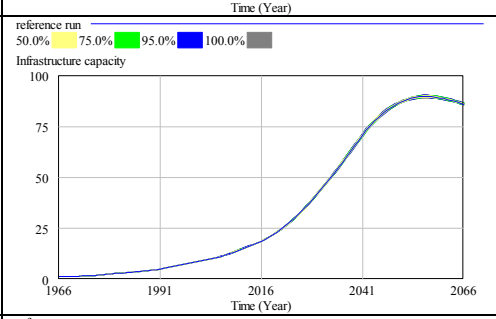
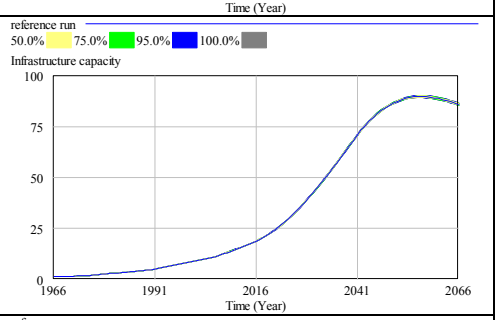
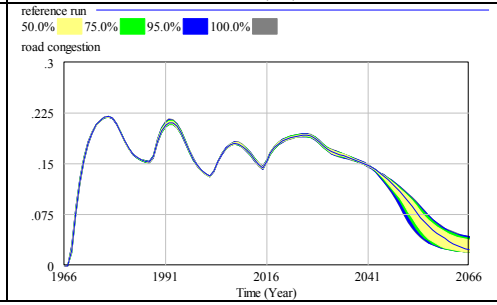
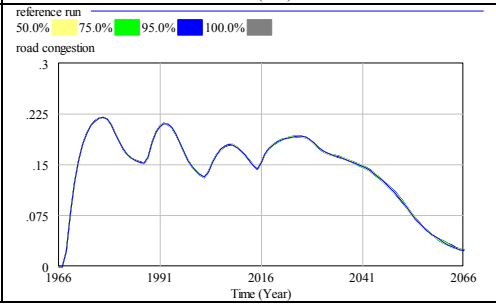
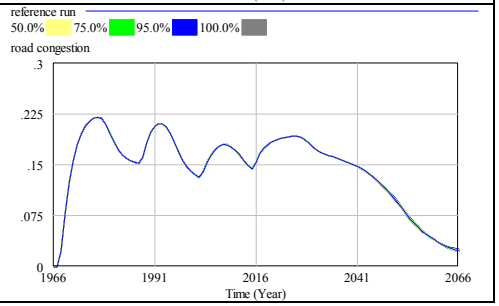
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			

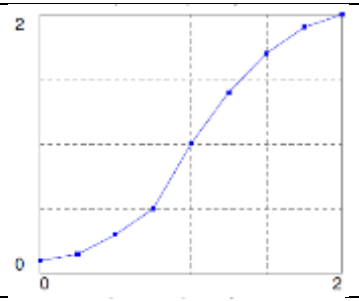
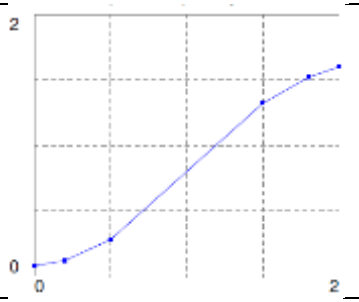
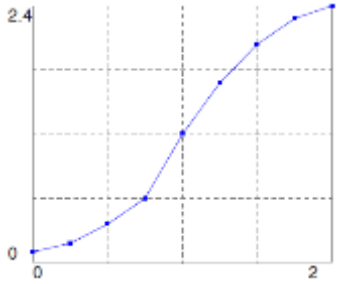
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

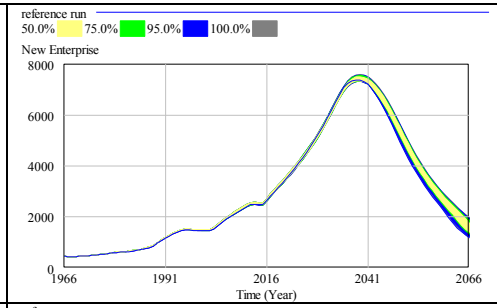
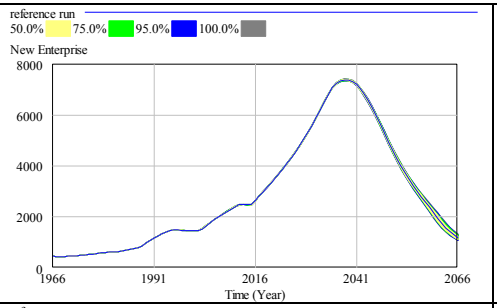
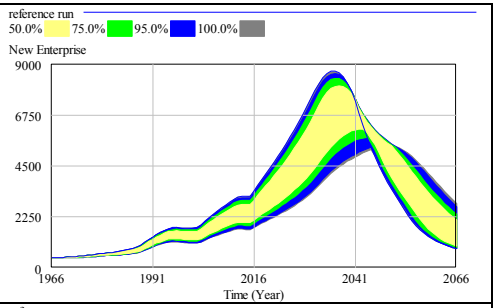
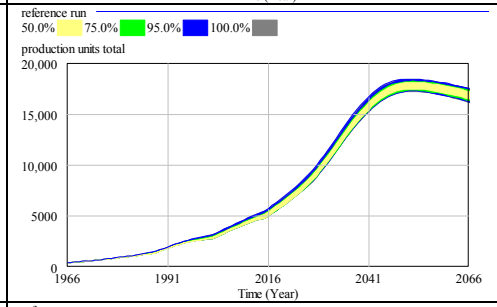
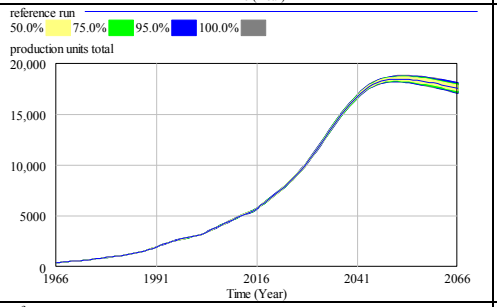
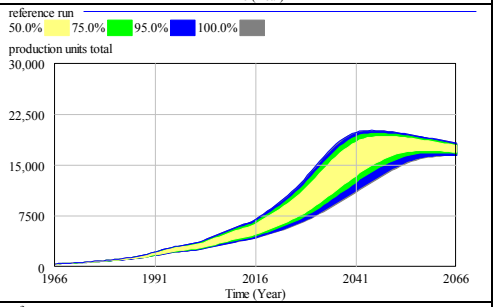
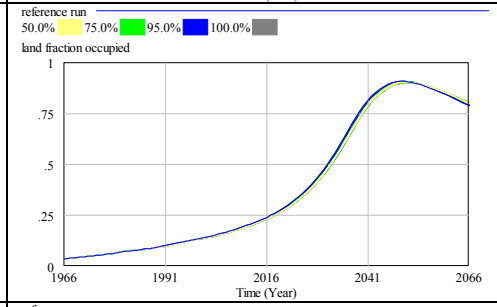
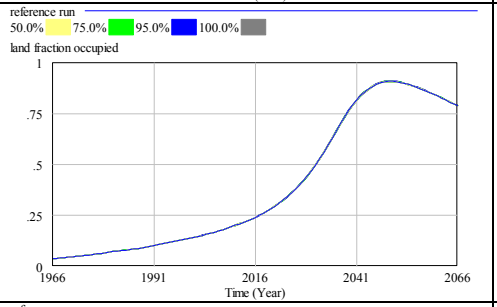
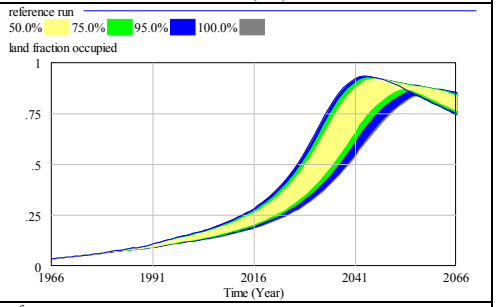
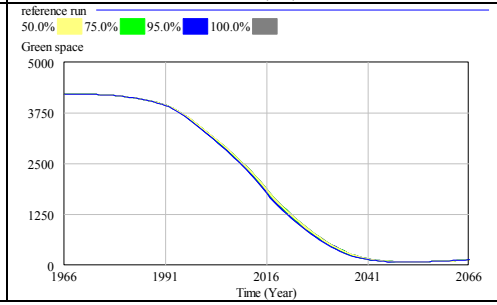
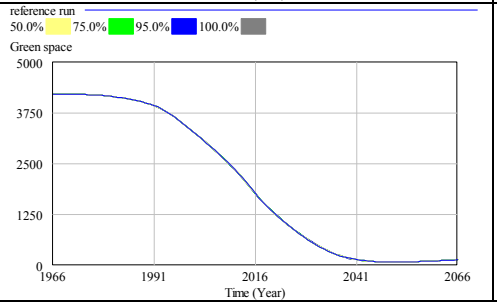
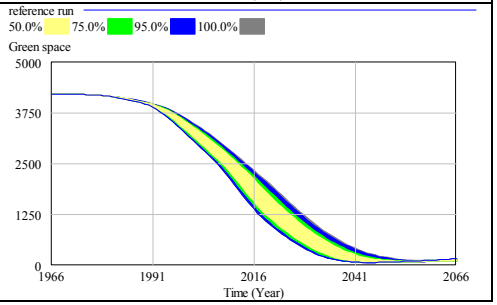
Parameter	new enterprise averaging time	mature business decline normal	declining industry demolition normal
Units	Year	1/year	1/Year
Nominal value	10	0.05 (20 years)	0.03 (= averagely 33 years after becoming declining business structure)
Minimum plausible	5 (-50%)	0.04 (-20%, =25 years)	0.024 (-20%, = 42 years)
Maximum plausible	15 (+50%)	0.06 (+20%, =16.6 years)	0.036 (+20%, = 27 years)

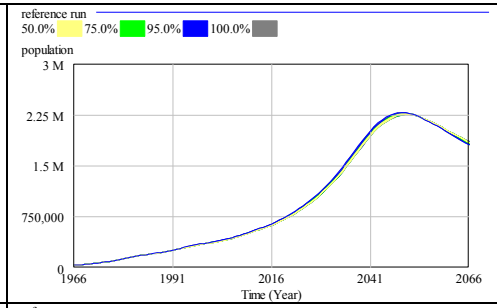
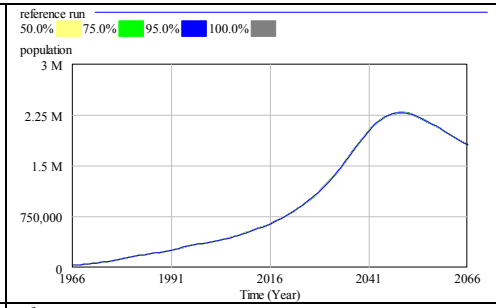
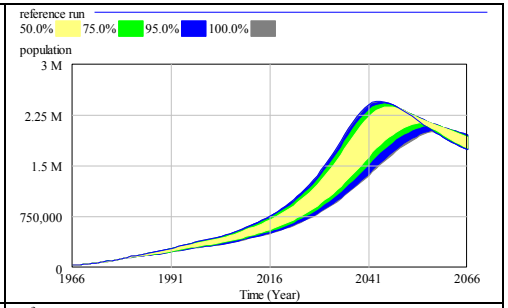
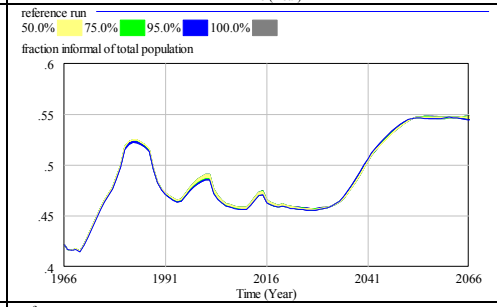
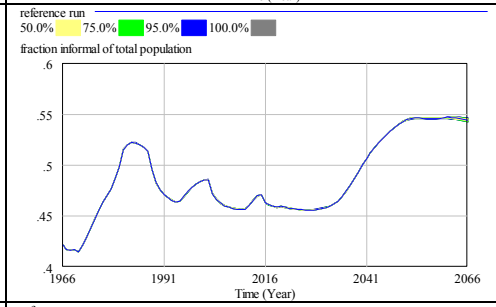
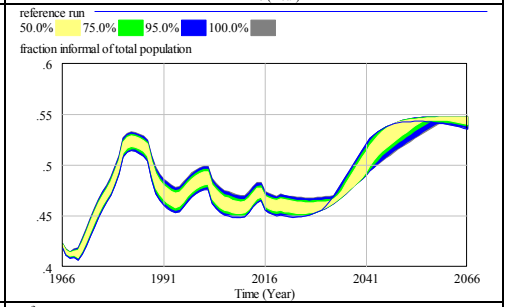
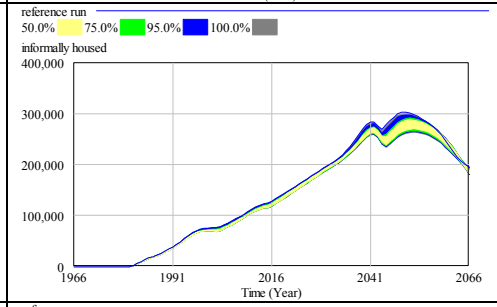
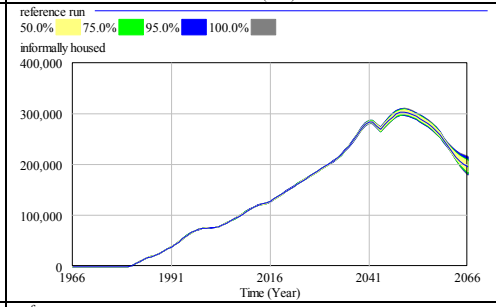
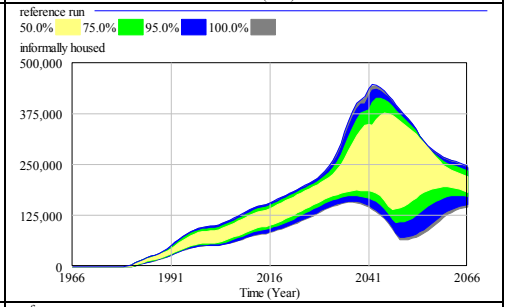
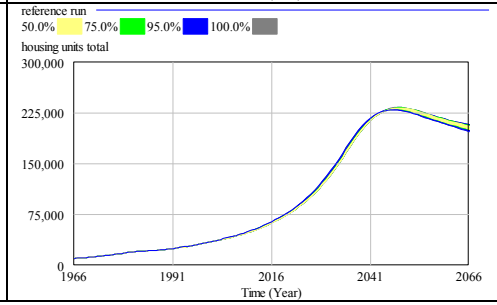
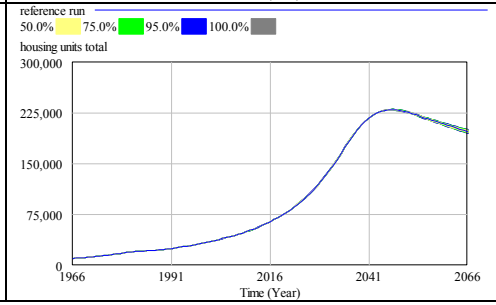
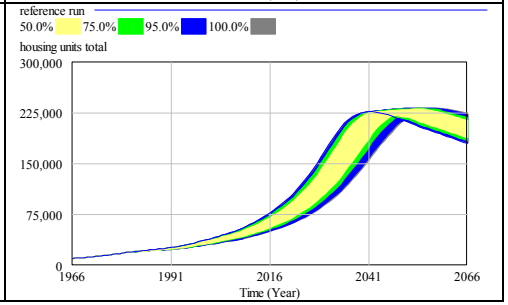
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

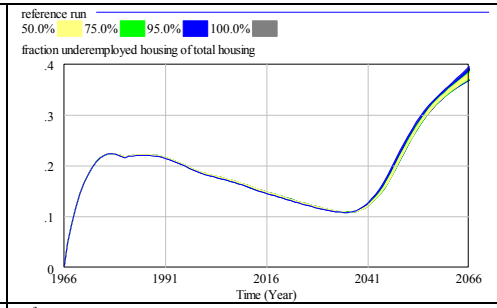
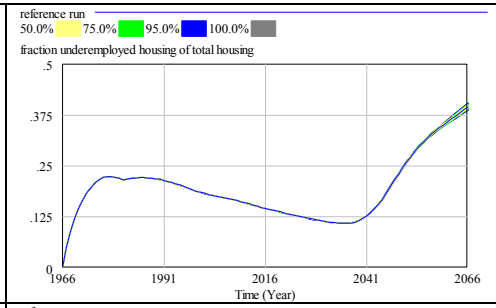
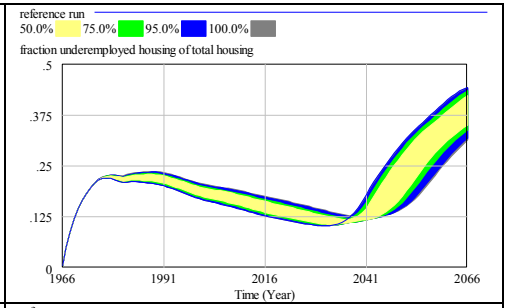
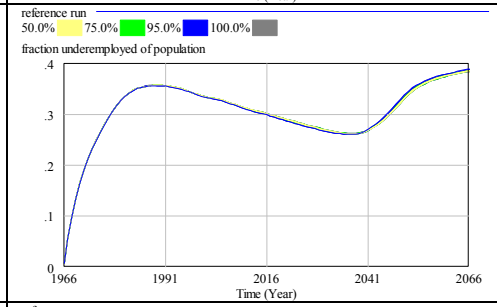
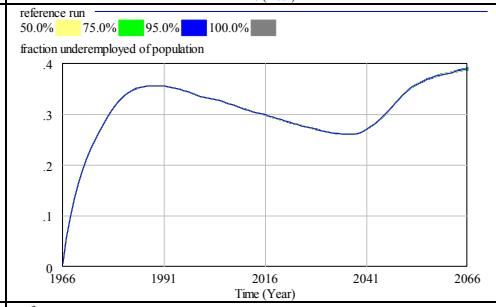
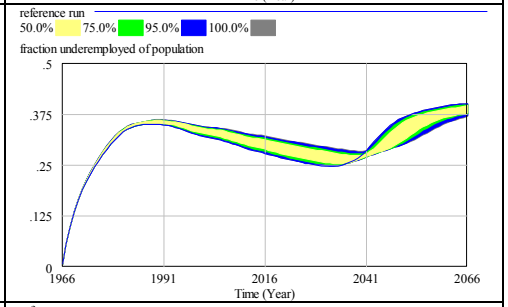
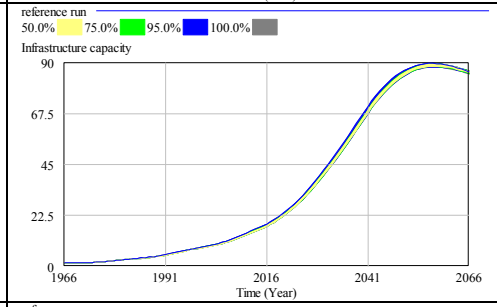
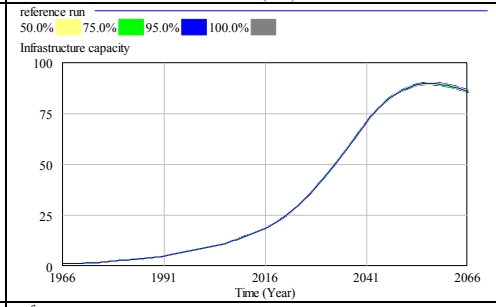
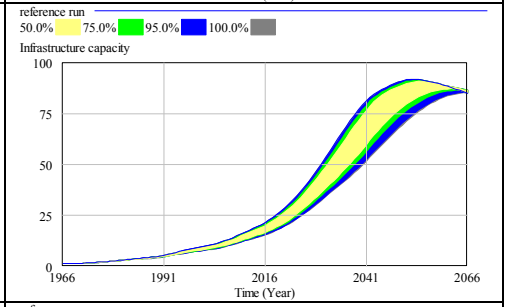
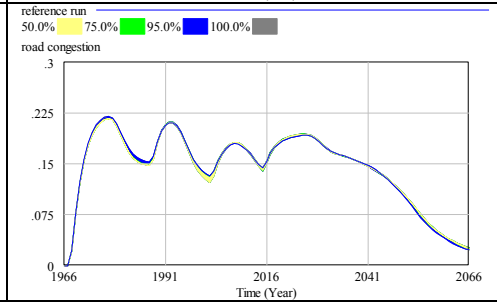
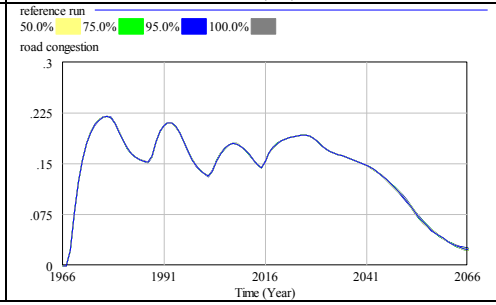
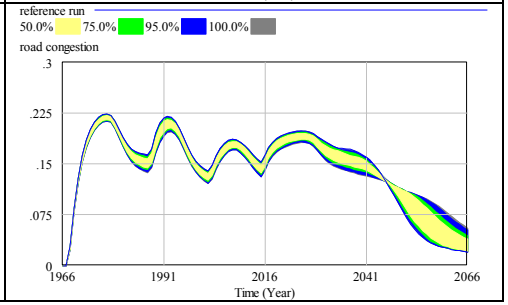
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

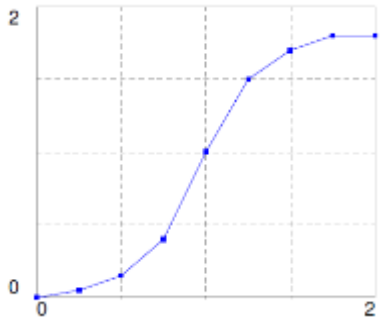
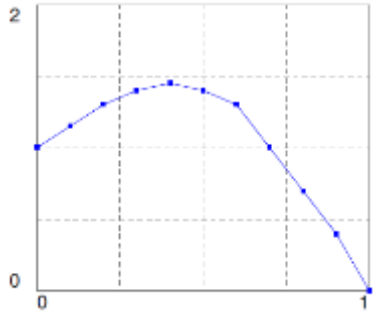
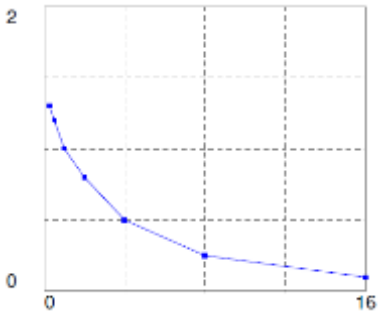
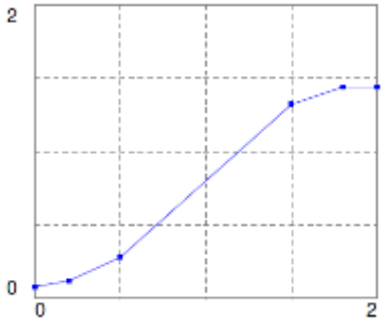
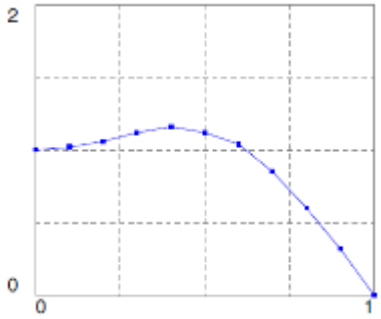
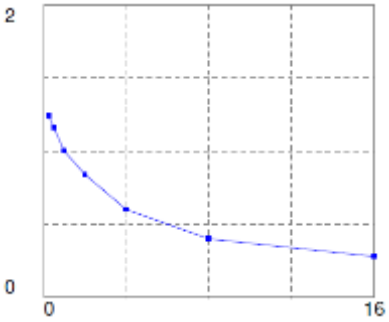
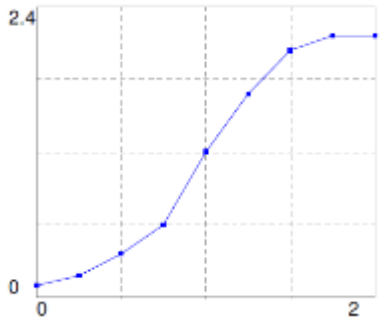
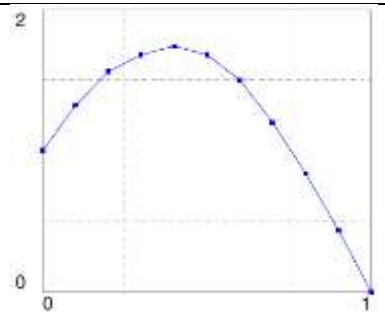
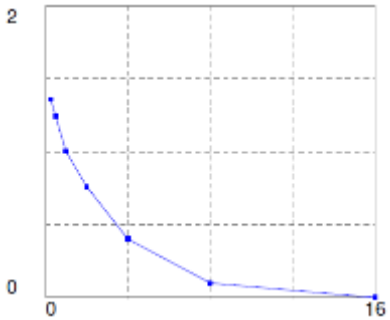
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

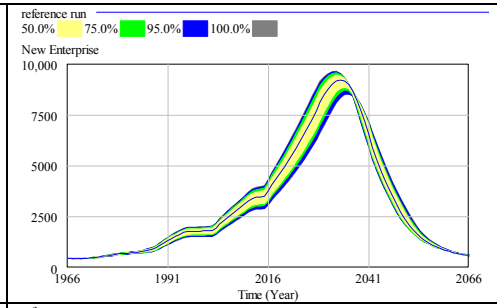
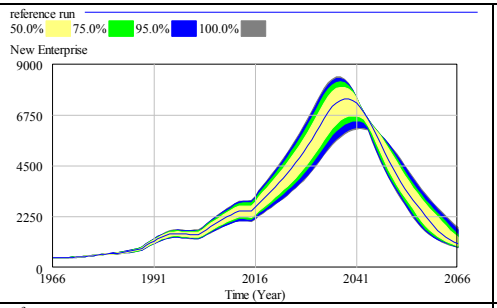
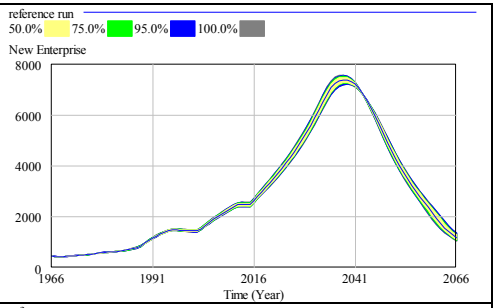
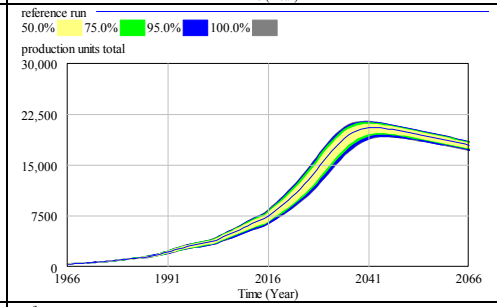
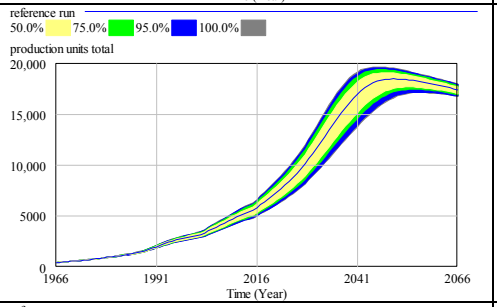
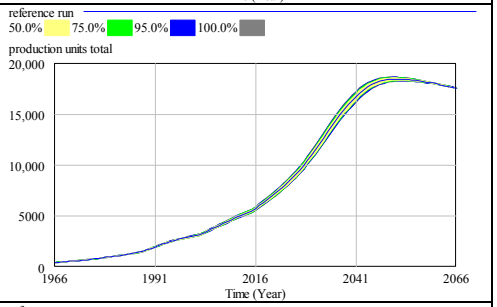
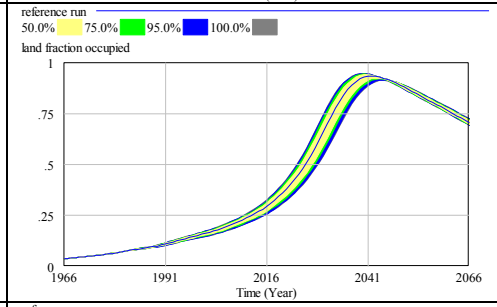
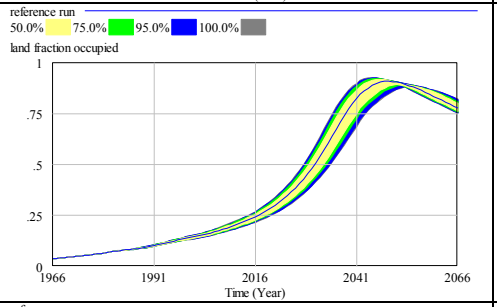
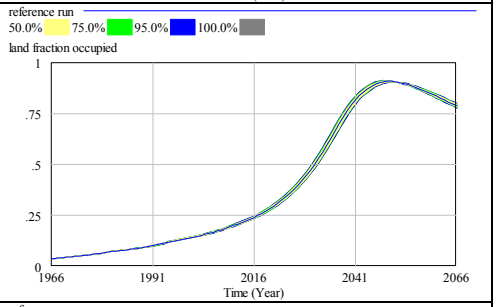
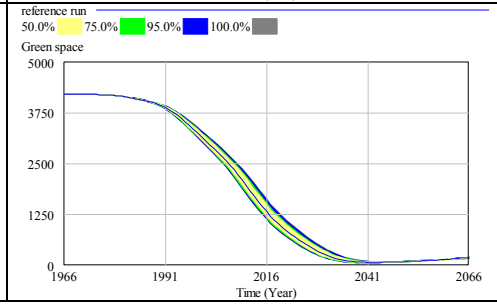
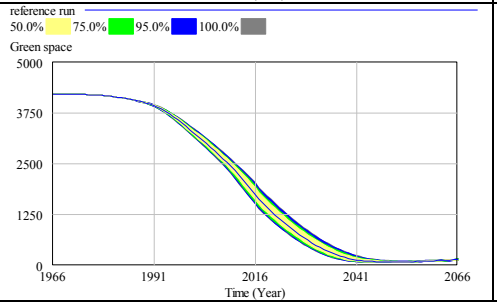
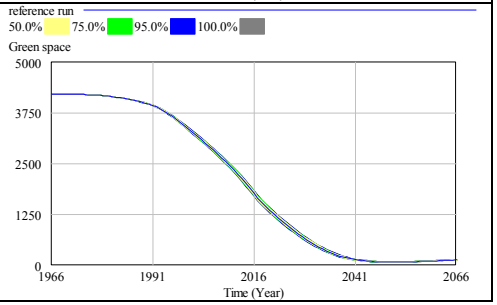
Parameter	declining industry demolition program	declining industry demolition factor	enterprise manager/job multiplier (lookup)
Units	productive unit/year	-	-
Nominal value	0	1	
Minimum plausible	0	0.8 (-20%)	
Maximum plausible	100 *(or the amount of declining industry present if that is less)*	1.2 (+20%)	

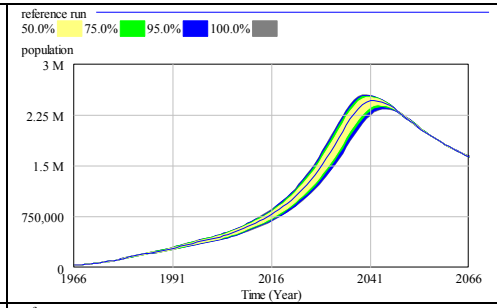
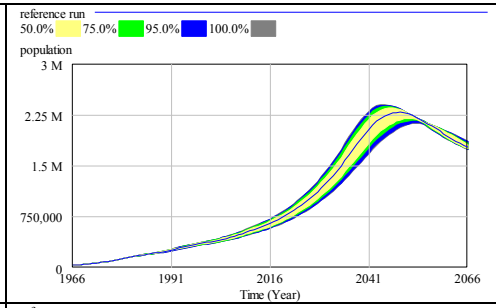
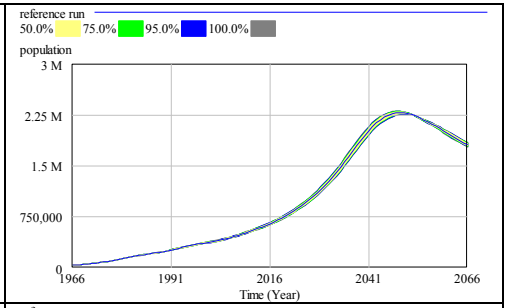
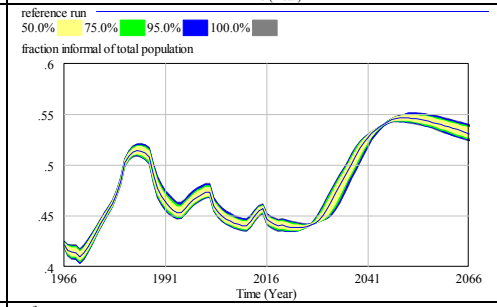
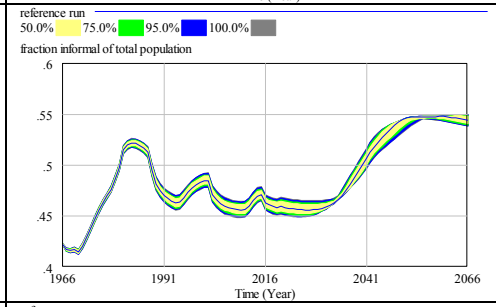
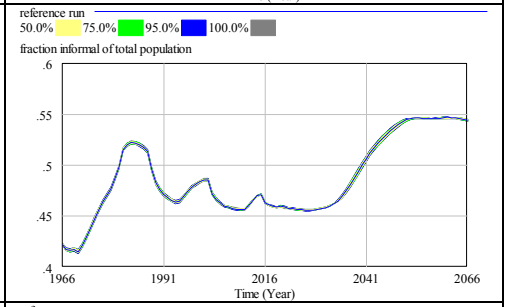
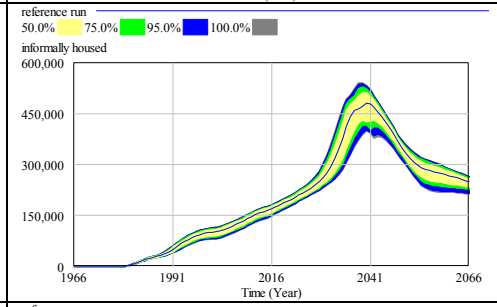
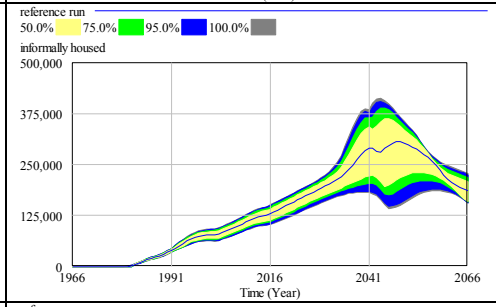
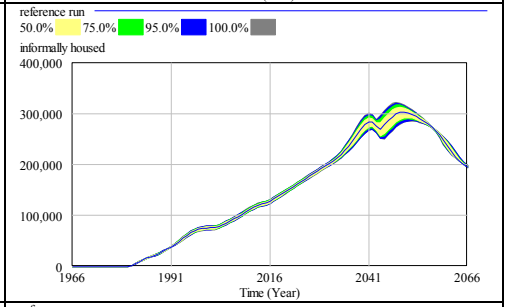
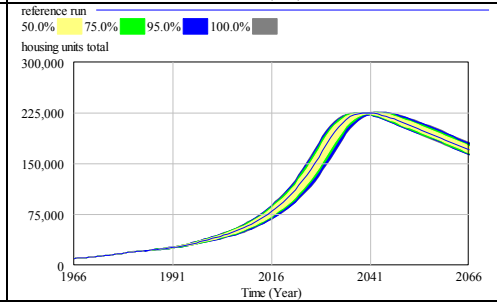
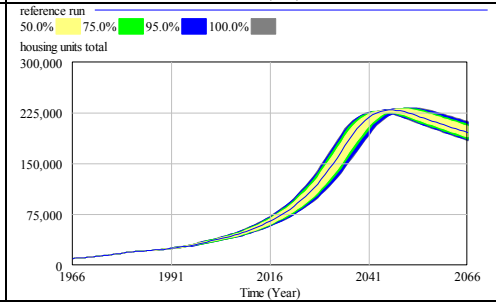
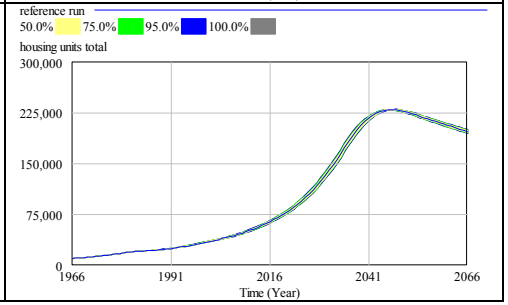
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

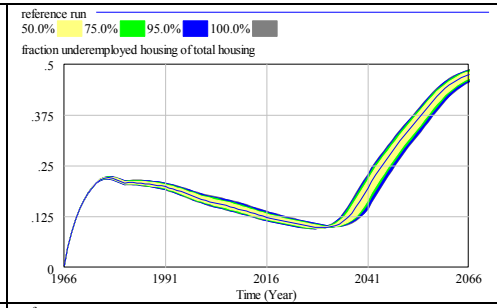
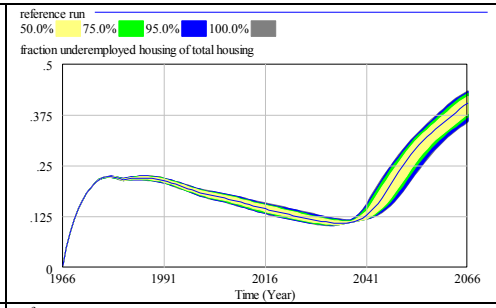
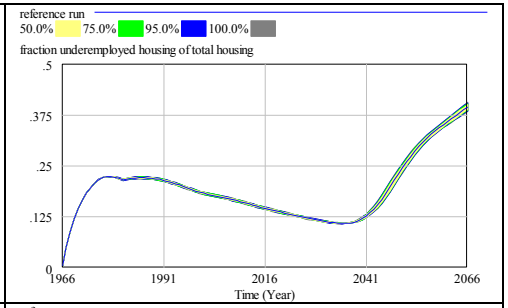
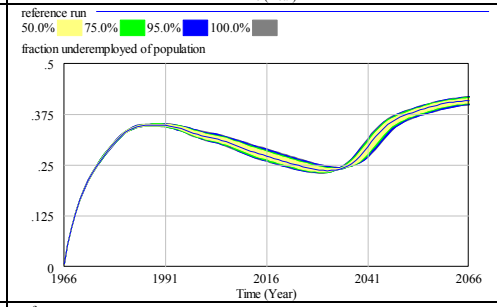
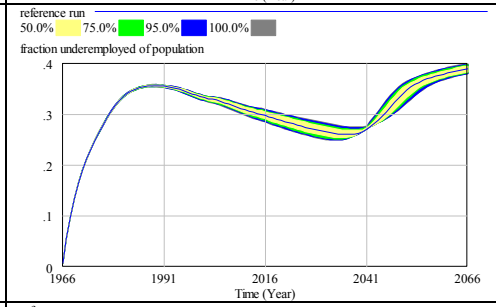
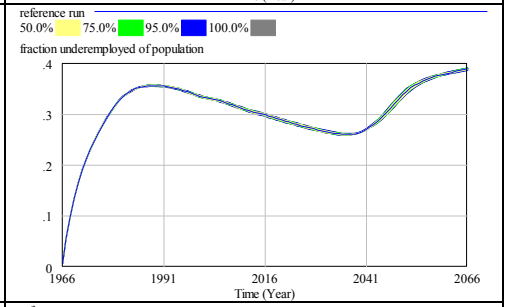
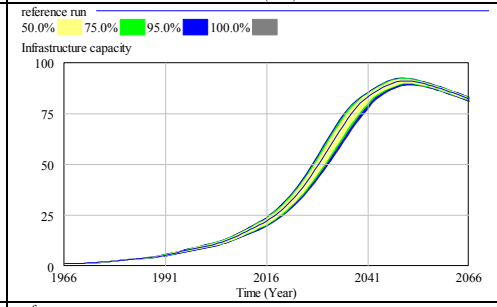
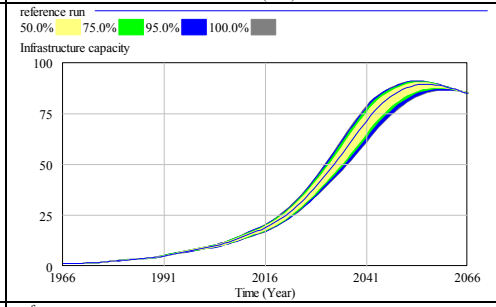
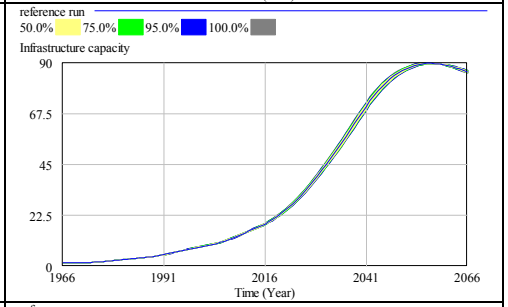
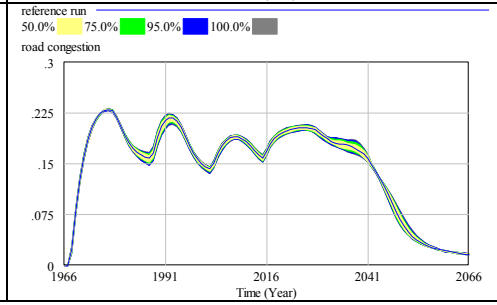
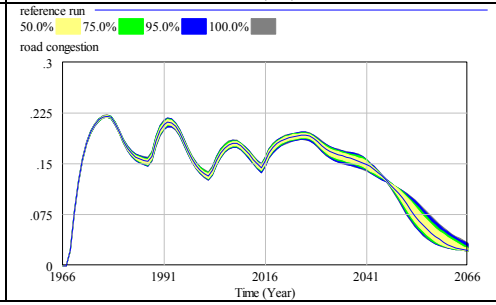
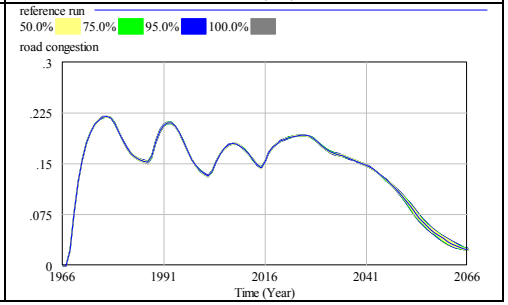
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

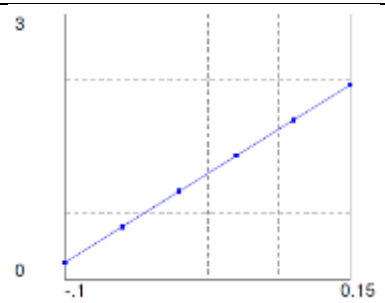
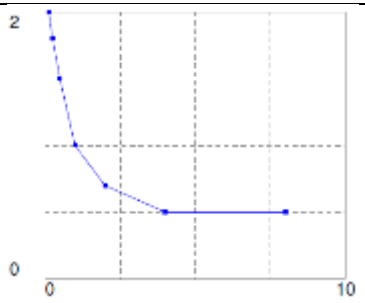
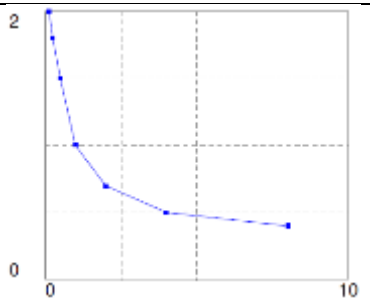
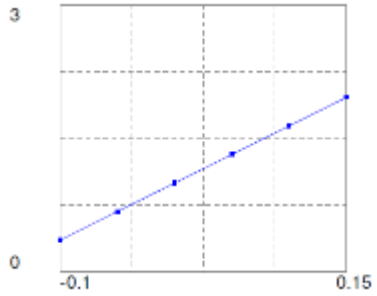
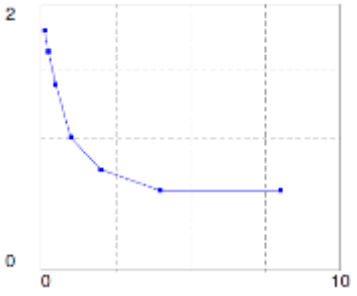
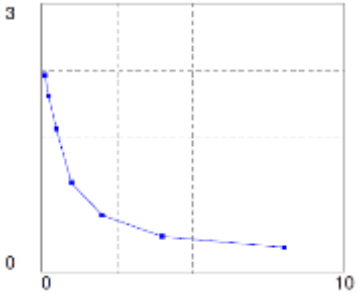
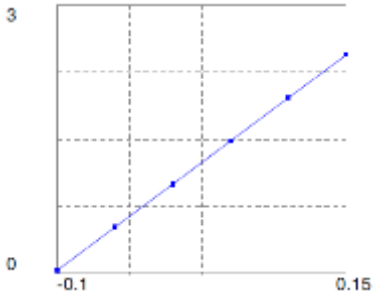
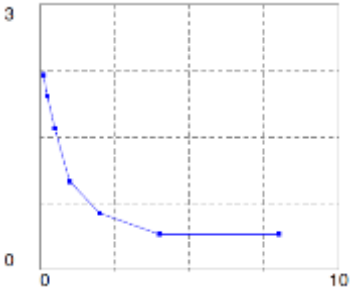
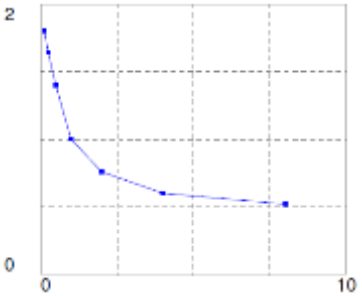
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

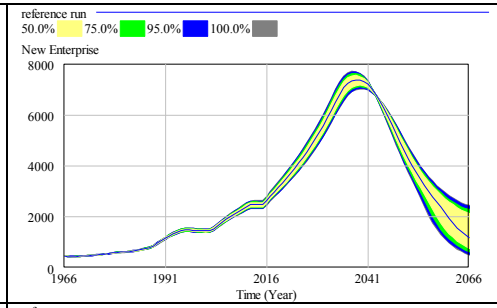
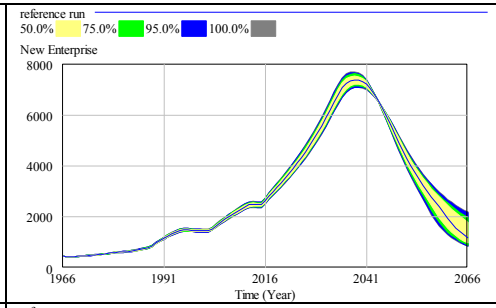
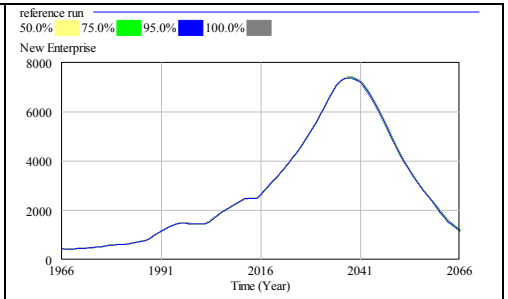
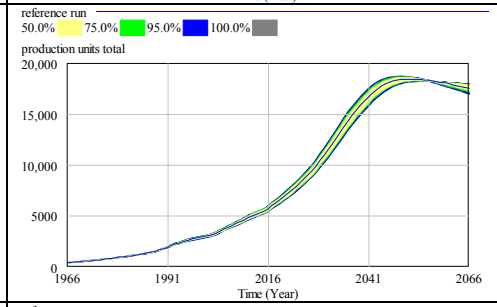
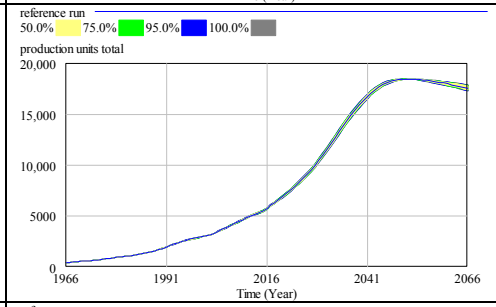
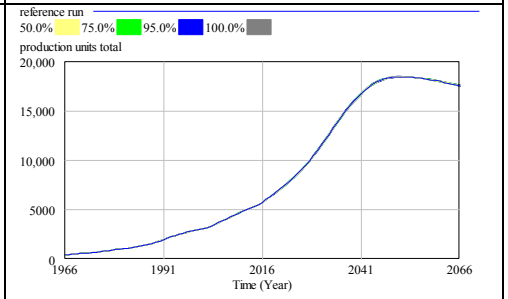
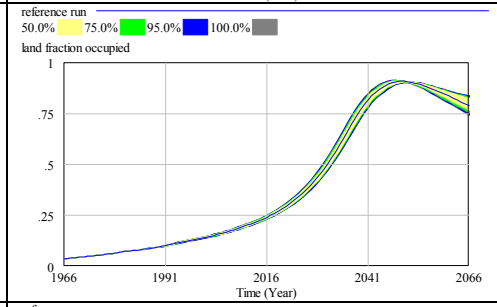
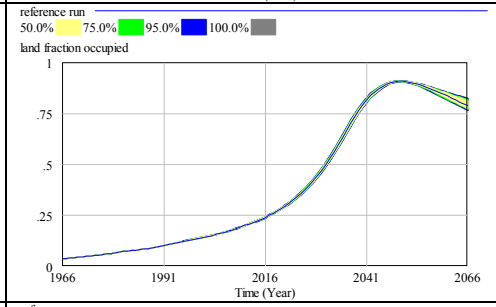
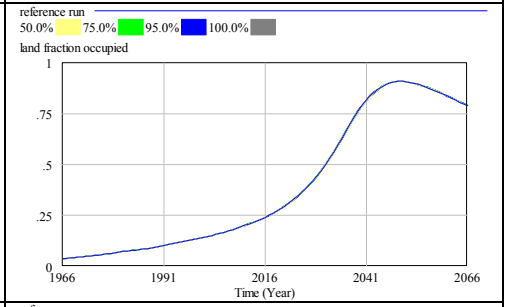
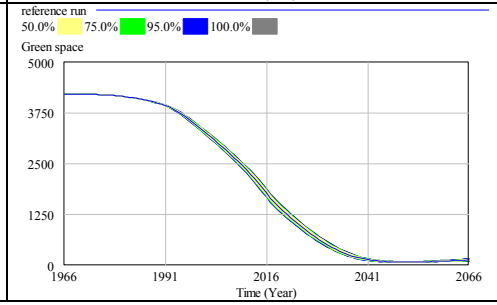
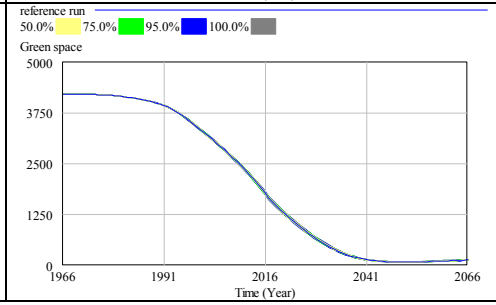
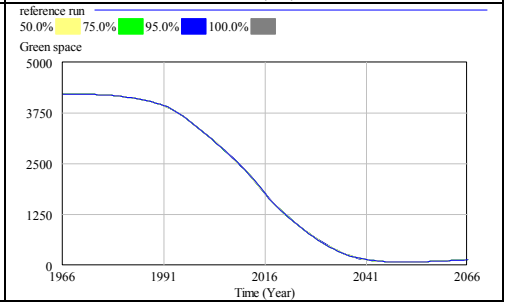
Parameter	enterprise labor/job multiplier (lookup)	enterprise land multiplier (lookup)	enterprise tax multiplier (lookup)
Units	-	-	-
Nominal value			
Minimum plausible			
Maximum plausible			

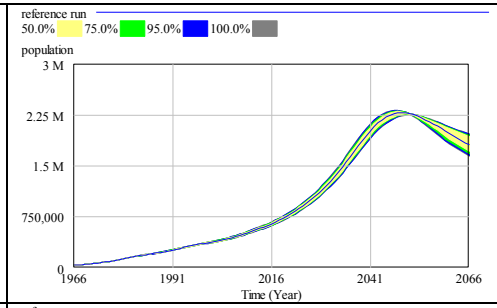
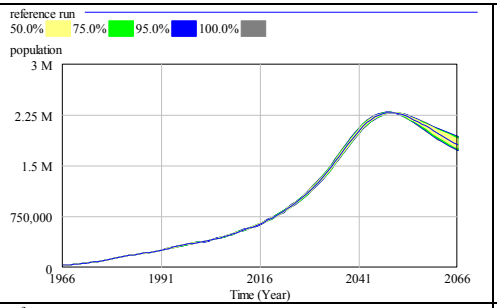
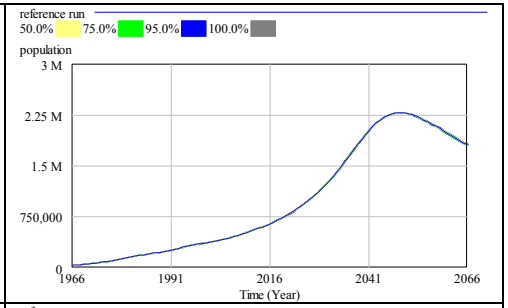
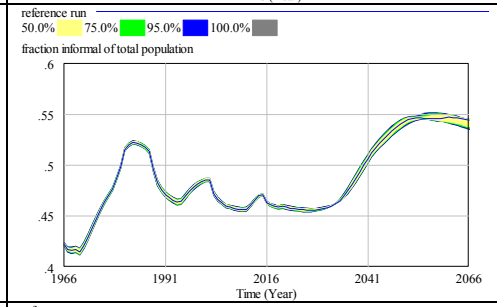
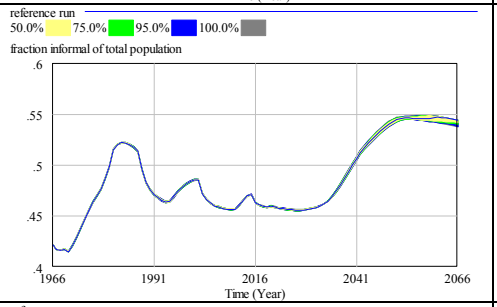
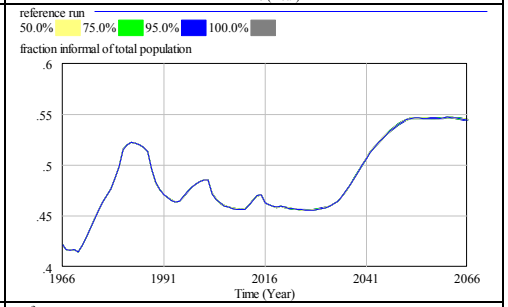
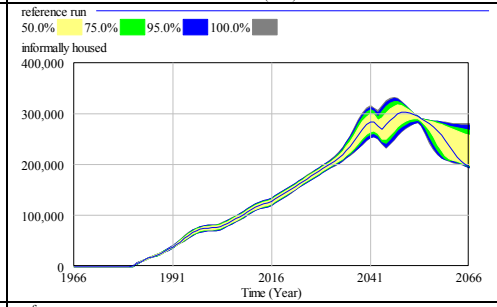
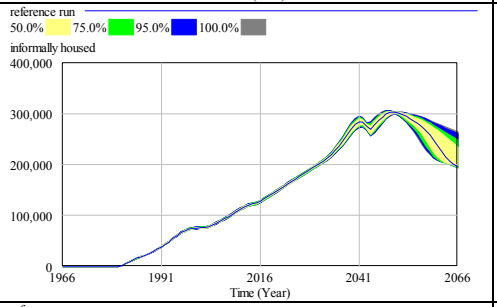
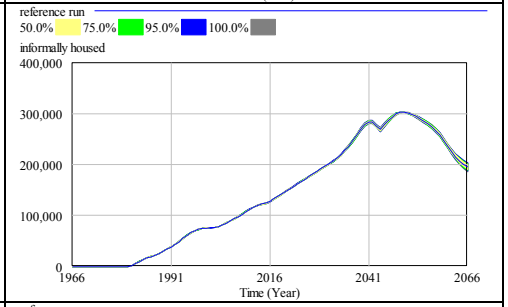
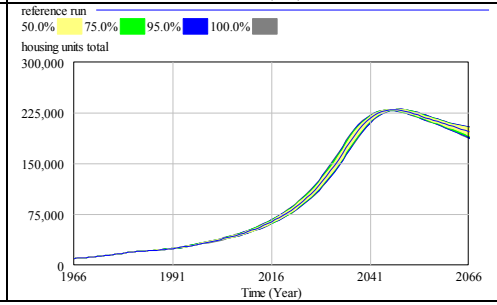
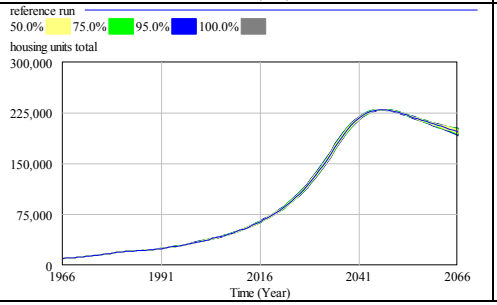
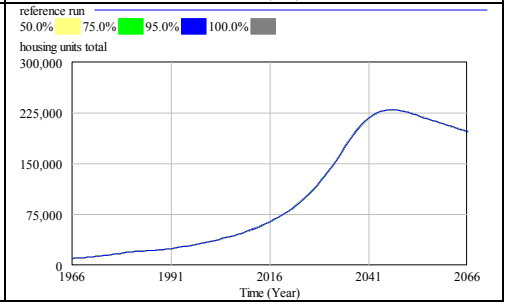
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

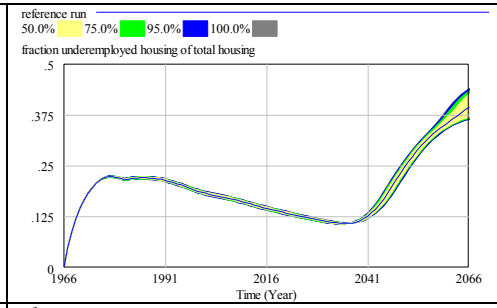
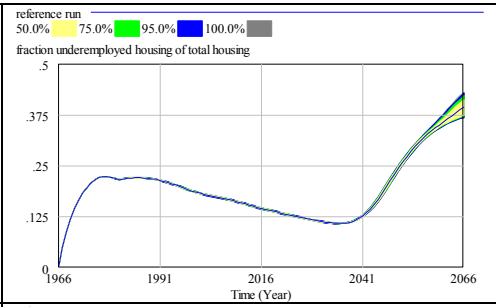
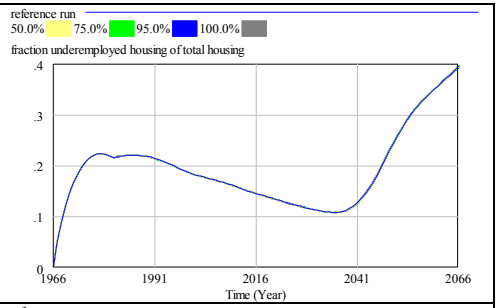
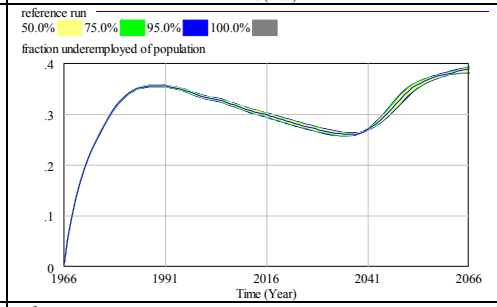
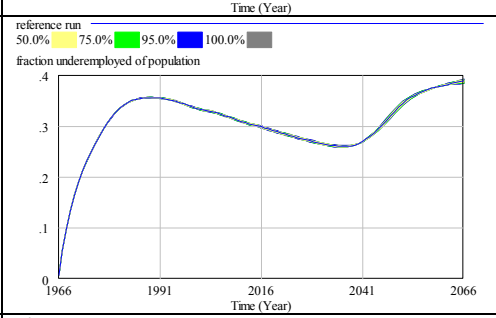
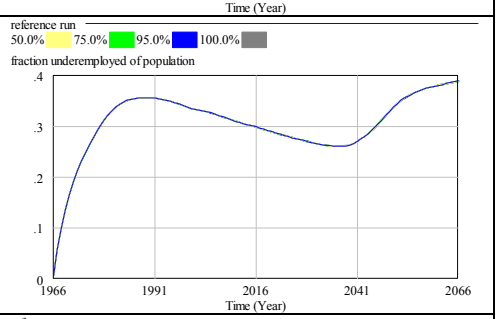
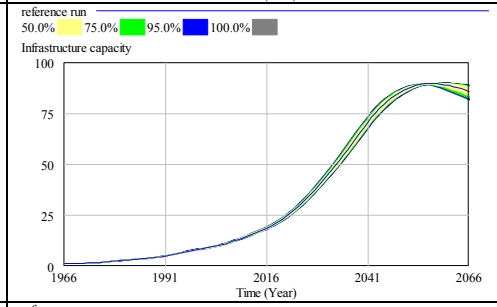
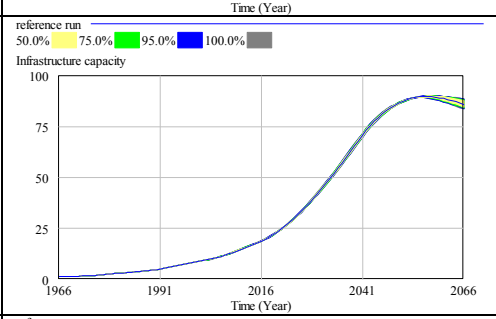
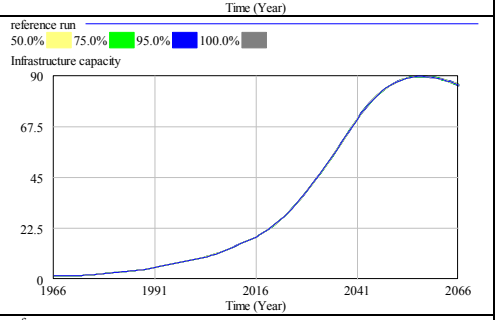
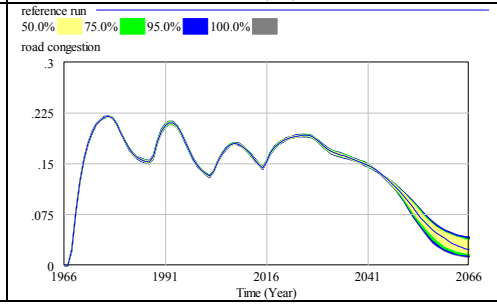
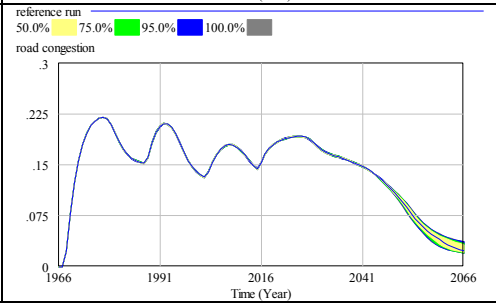
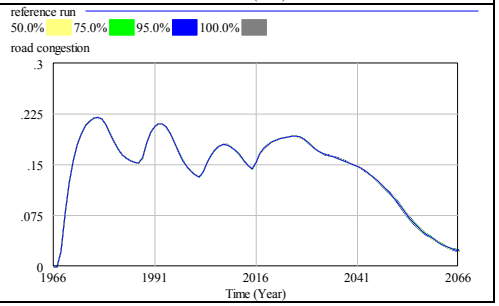
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

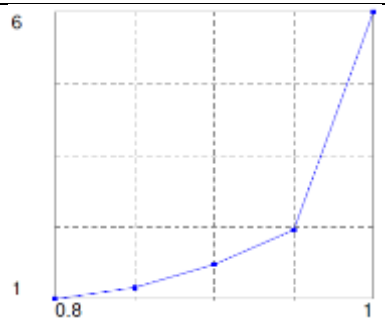
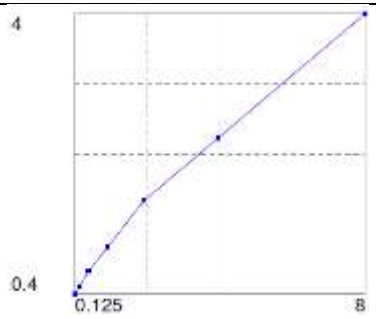
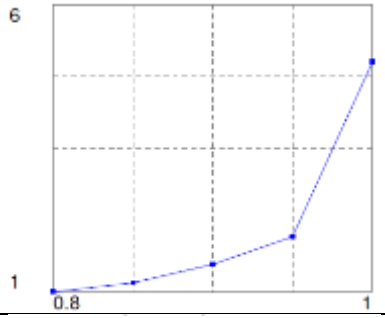
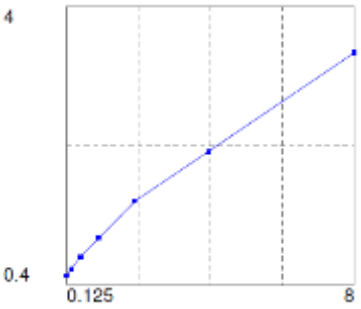
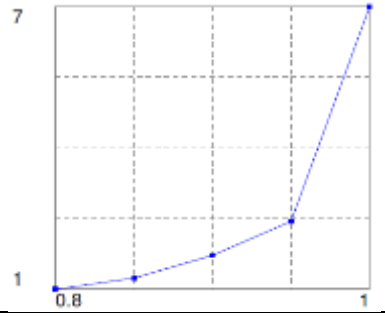
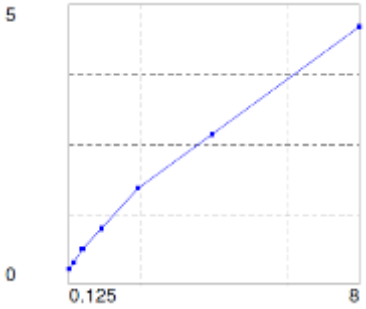
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

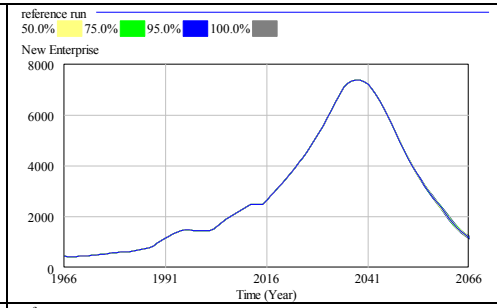
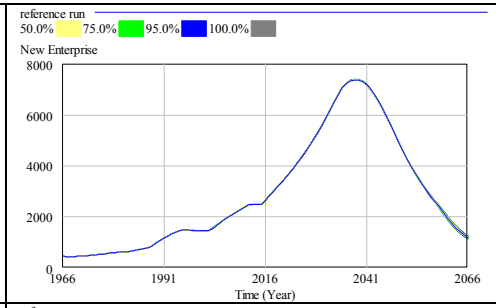
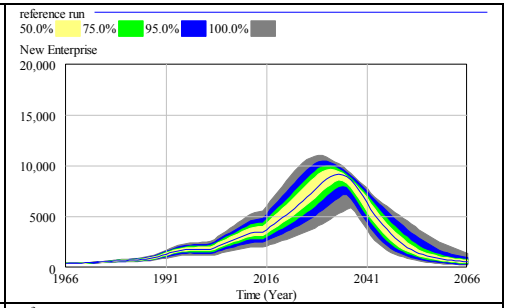
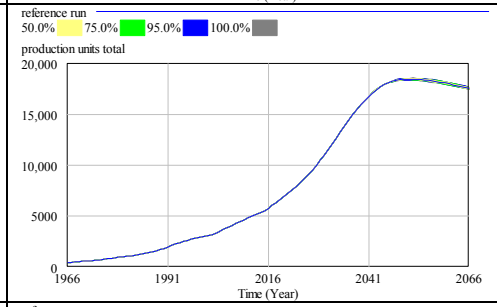
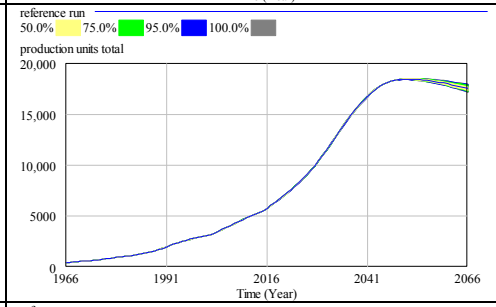
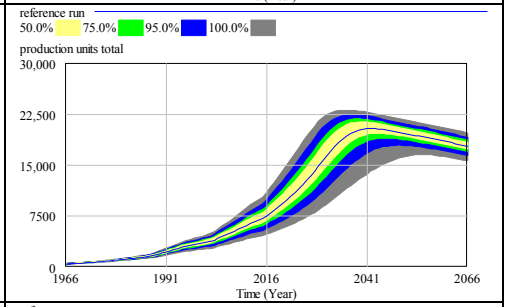
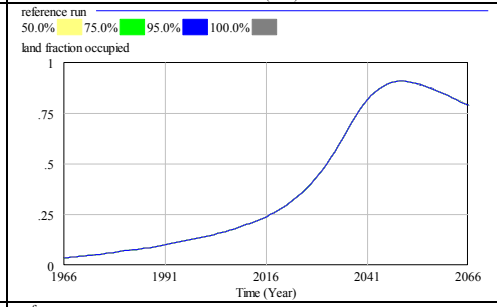
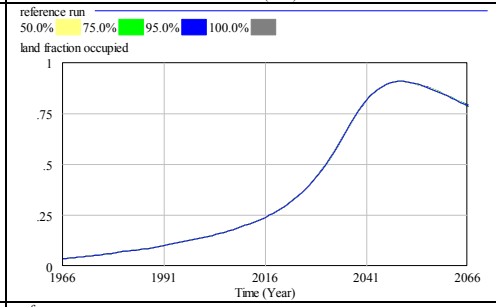
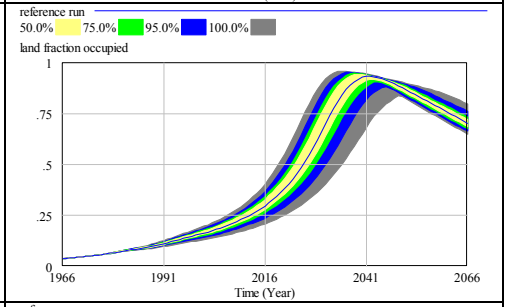
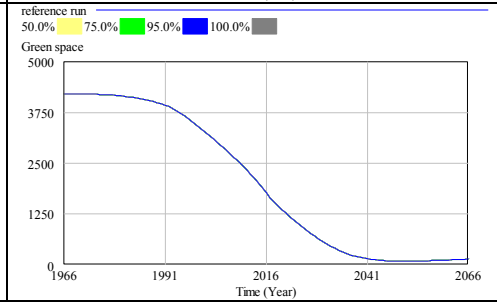
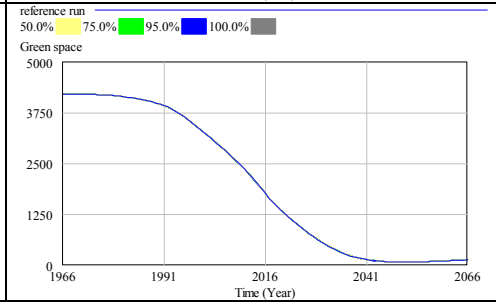
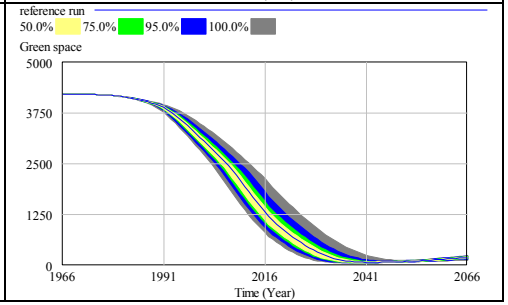
Parameter	enterprise-growth multiplier (lookup)	enterprise decline multiplier (lookup)	business decline multiplier (lookup)
Units	-	-	-
Nominal value			
Minimum plausible			
Maximum plausible			

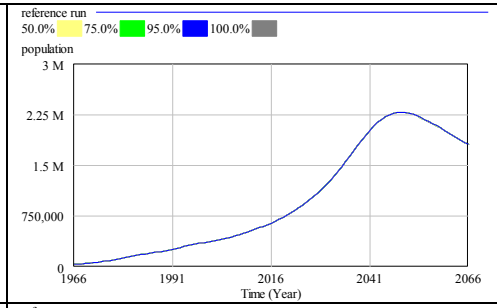
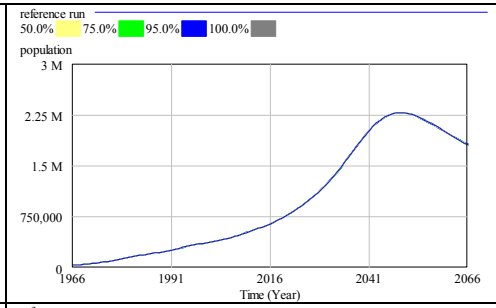
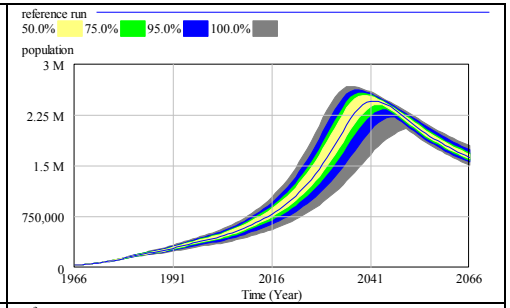
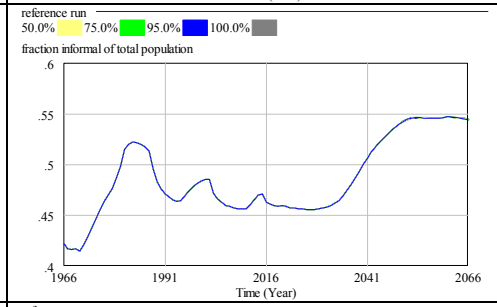
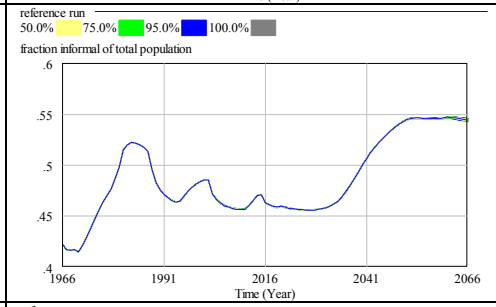
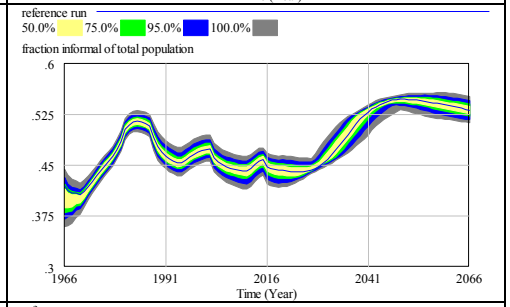
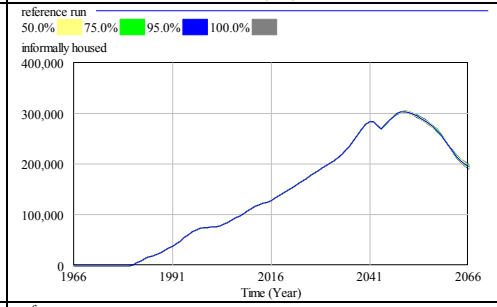
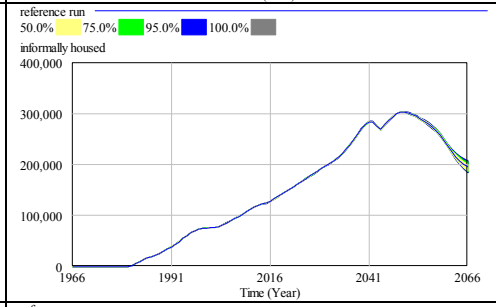
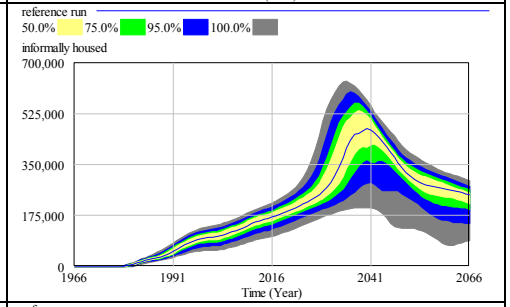
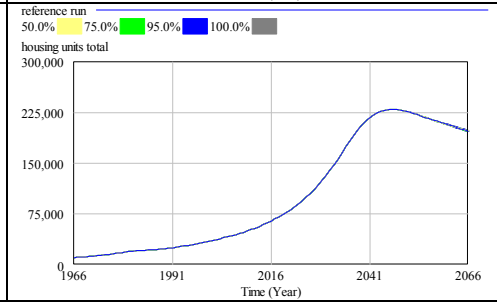
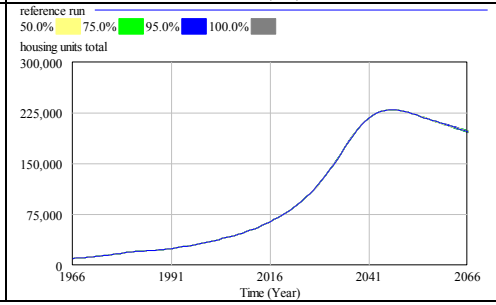
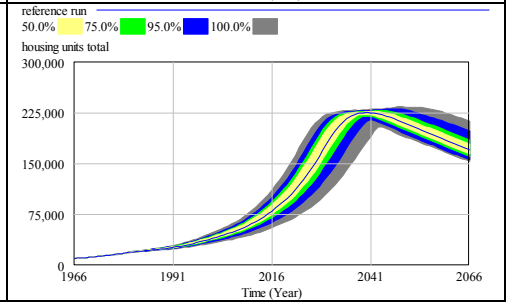
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

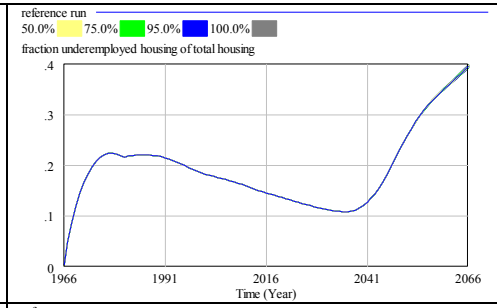
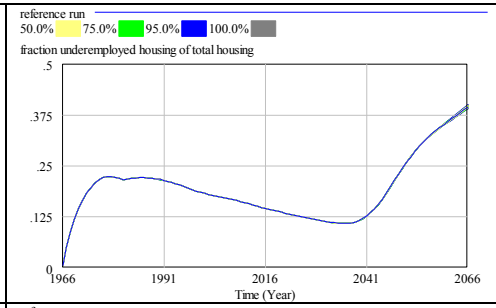
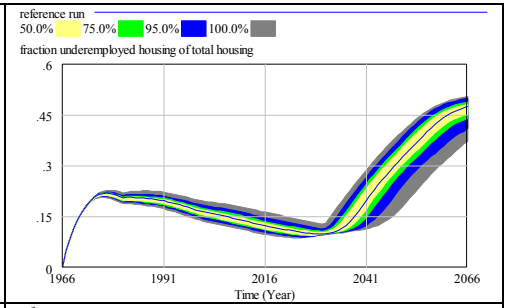
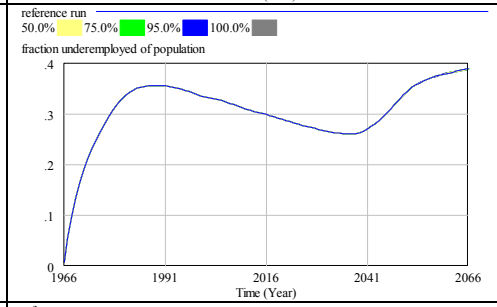
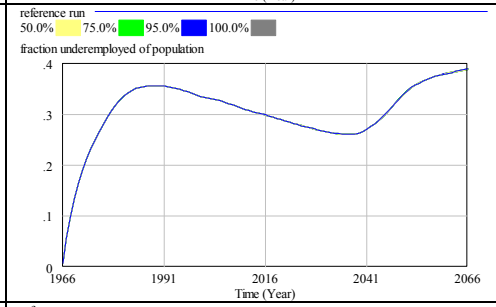
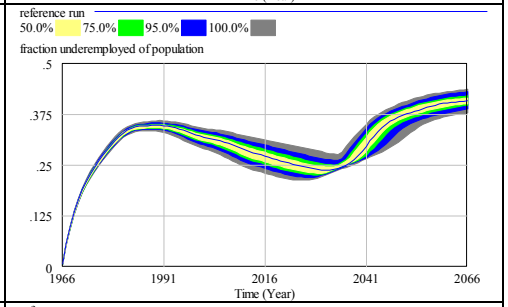
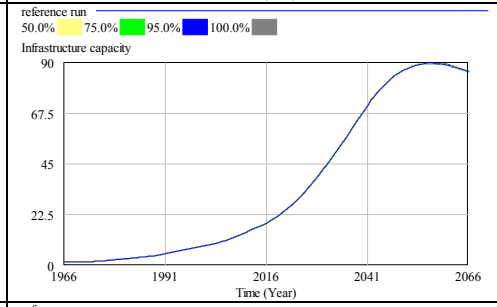
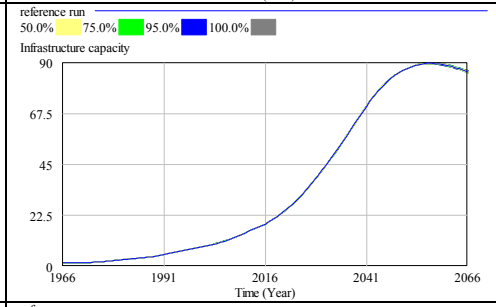
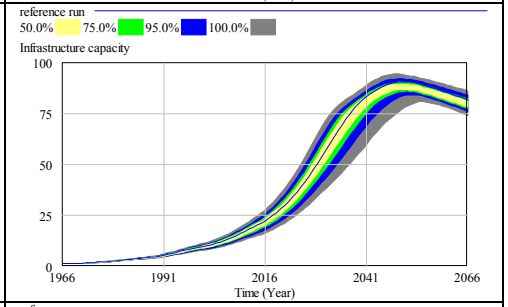
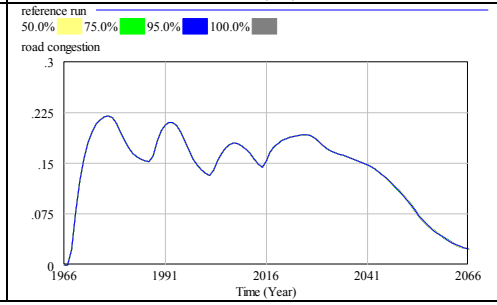
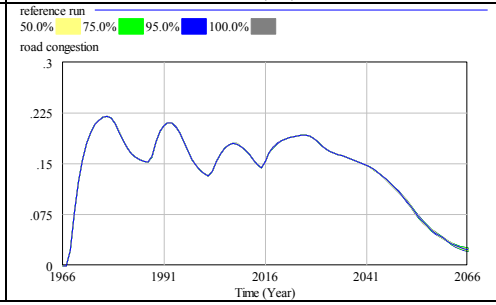
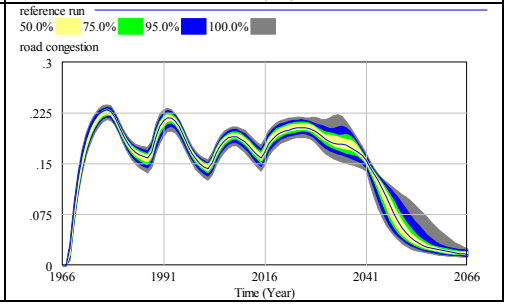
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

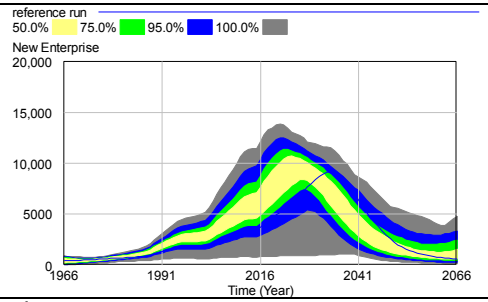
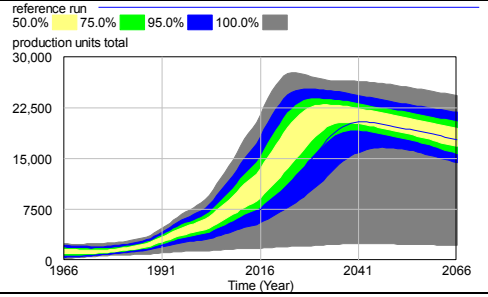
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

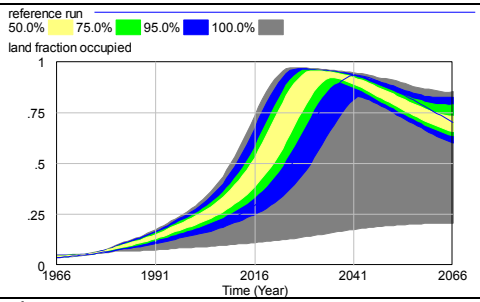
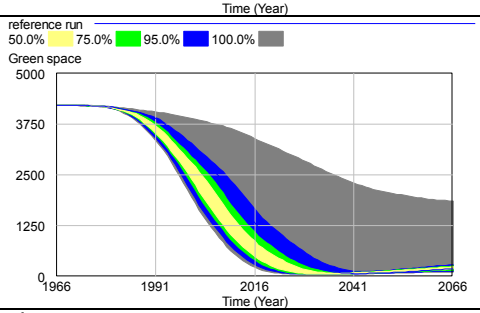
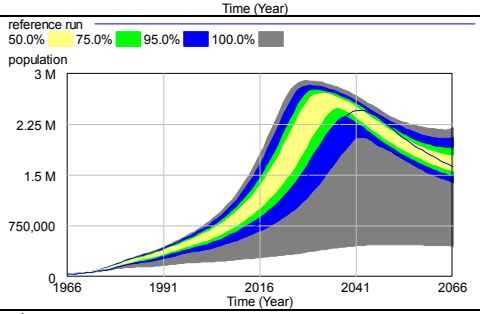
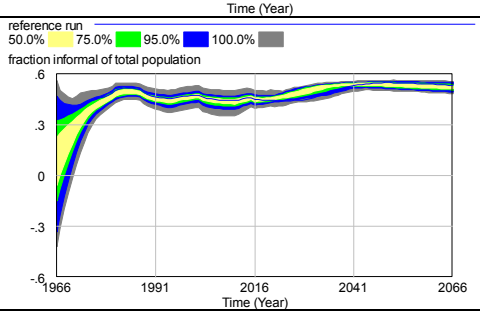
Parameter	declining enterprise land multiplier (lookup)	declining-industry enterprise multiplier (lookup)	Multivariate, all parameters (except construction/demolition programs, scaling factors)
Units	-	-	-
Nominal value			-
Minimum plausible			-10%
Maximum plausible			+10%

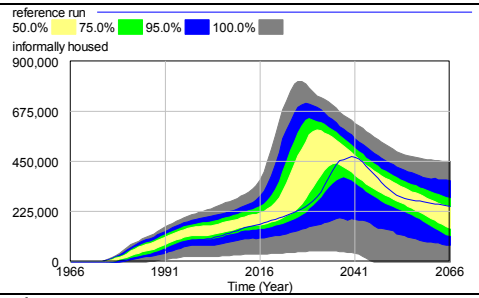
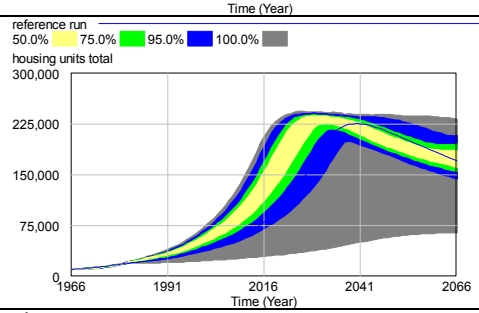
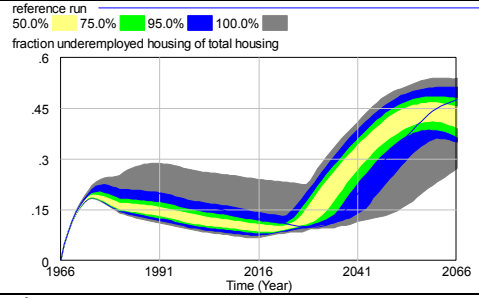
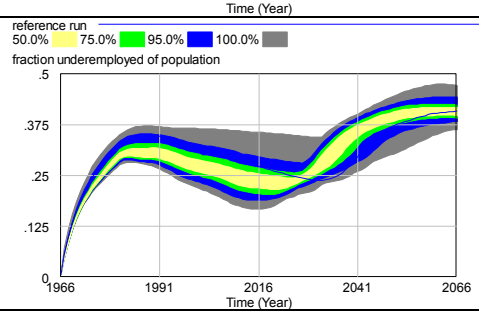
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

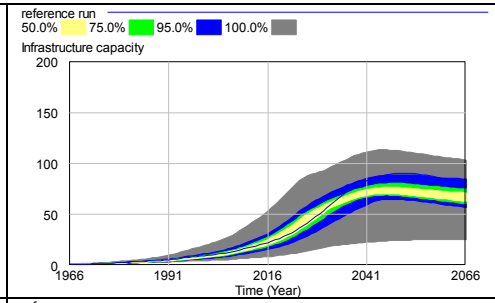
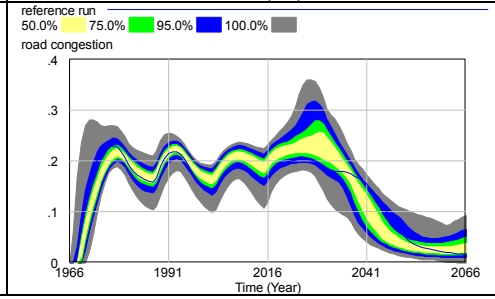
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

Parameter	Multivariate, all parameters		
Units	-		
Nominal value	-		
Minimum plausible	Respective minimum value per variable		
Maximum plausible	Respective maximum value per variable		
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			

Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			

Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			

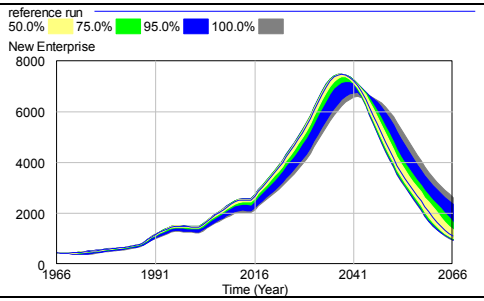
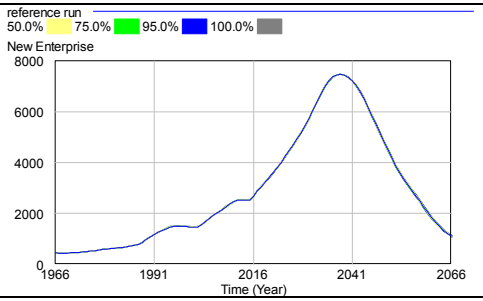
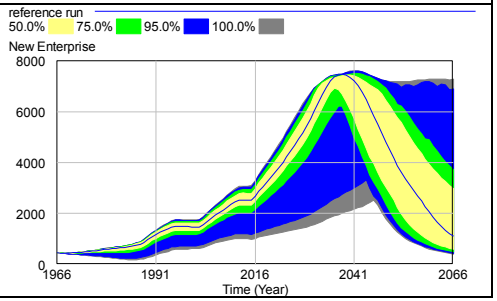
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

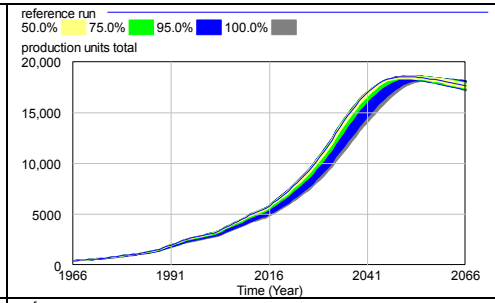
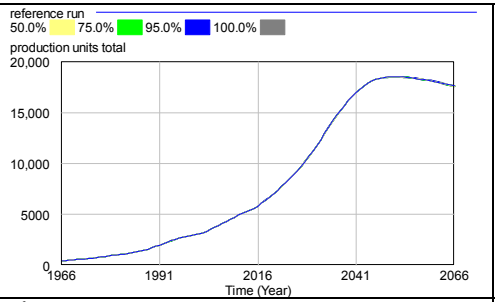
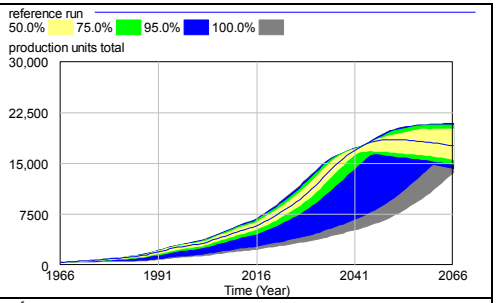
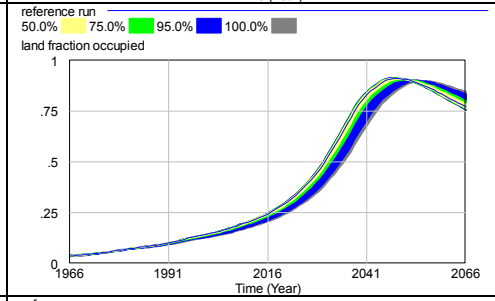
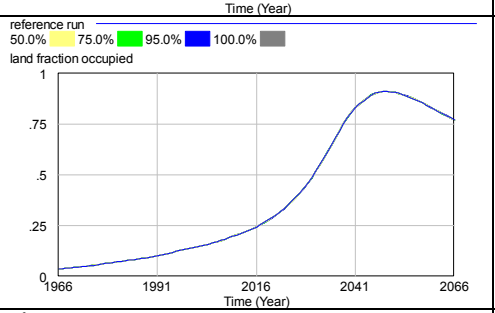
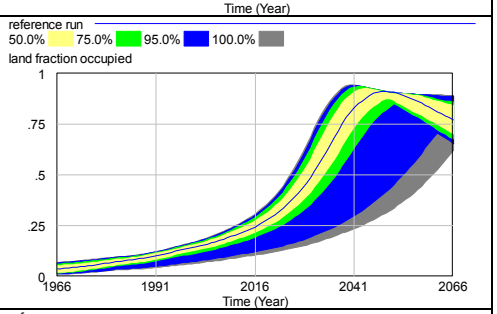
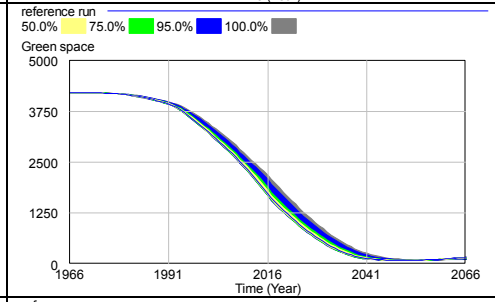
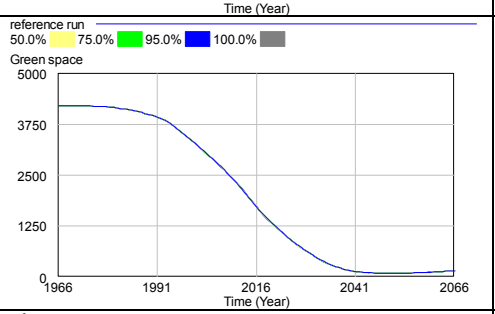
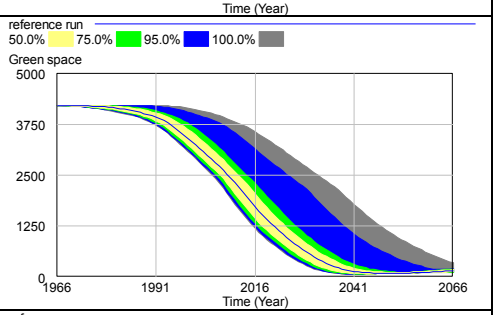
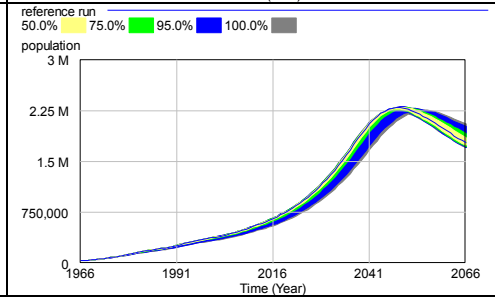
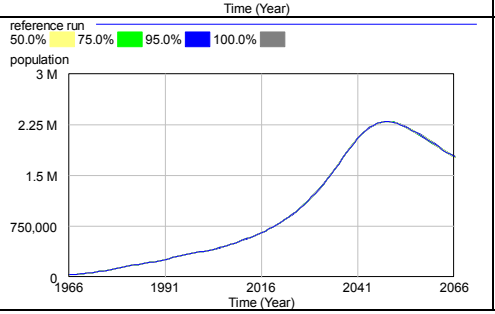
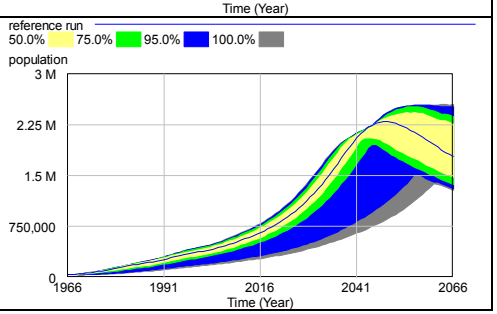
4.5 Housing Chain sensitivity

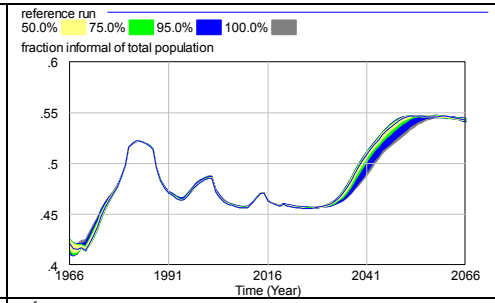
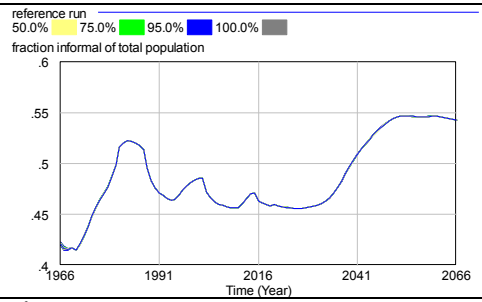
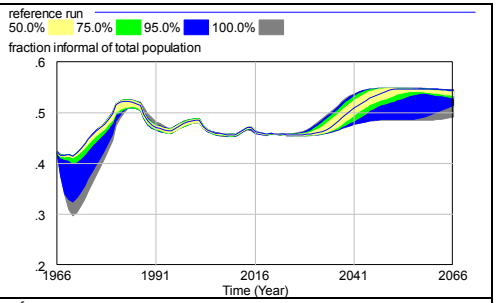
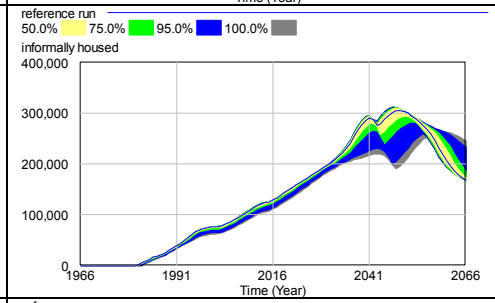
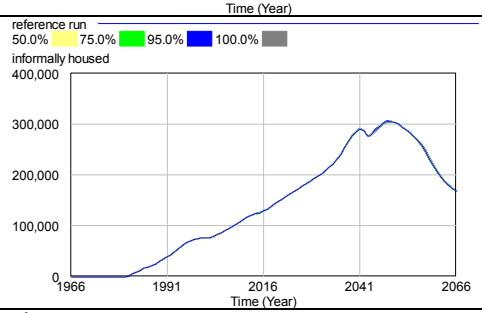
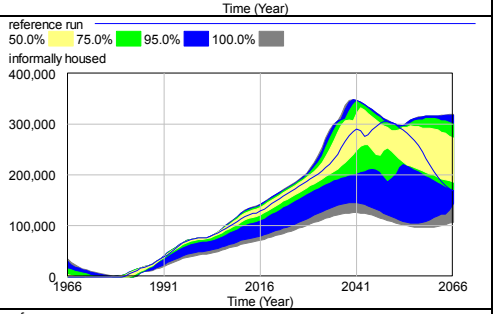
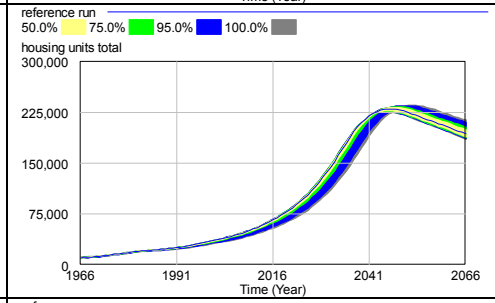
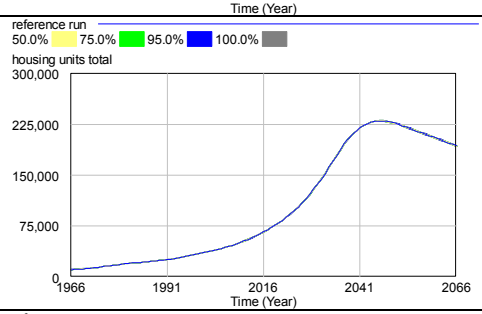
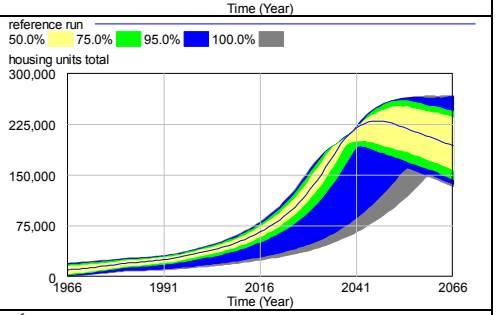
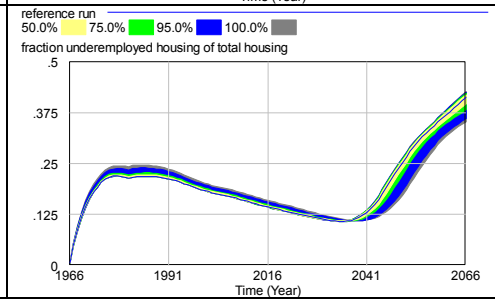
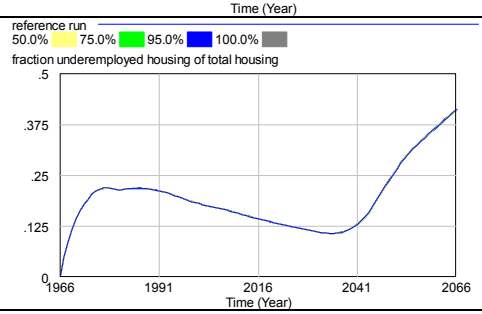
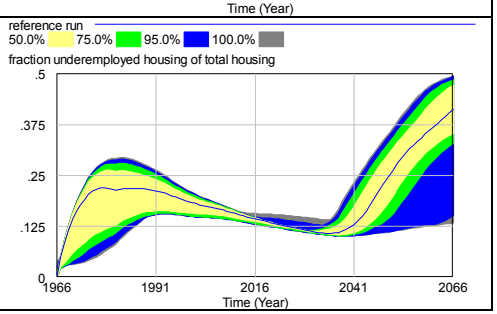
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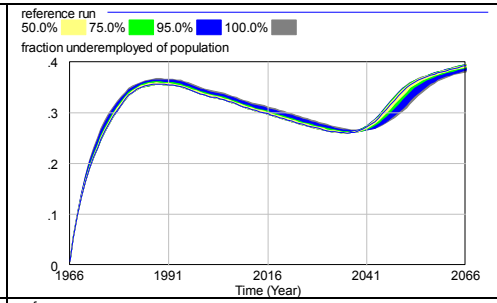
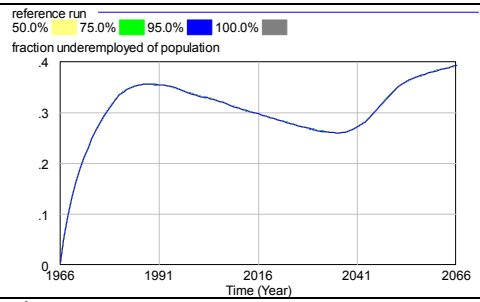
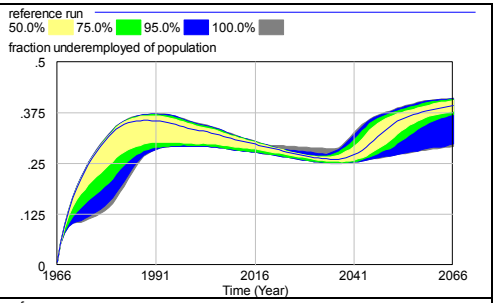
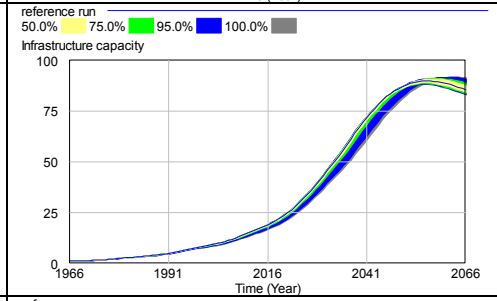
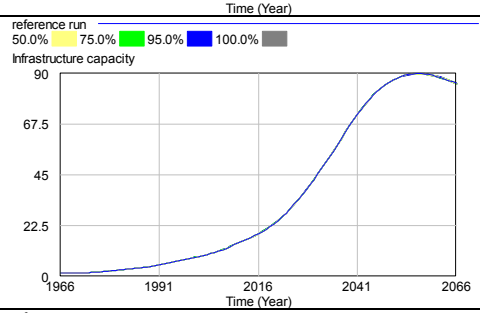
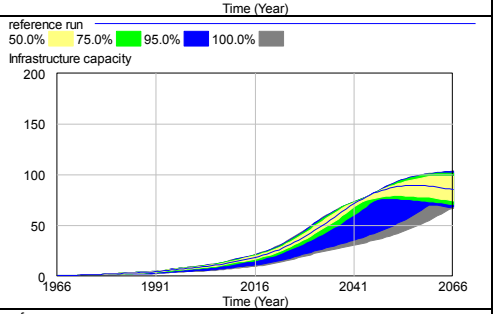
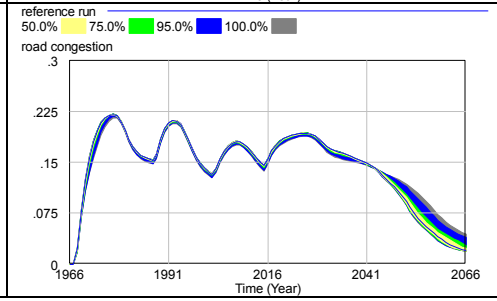
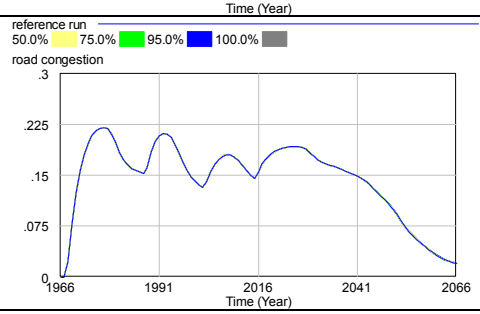
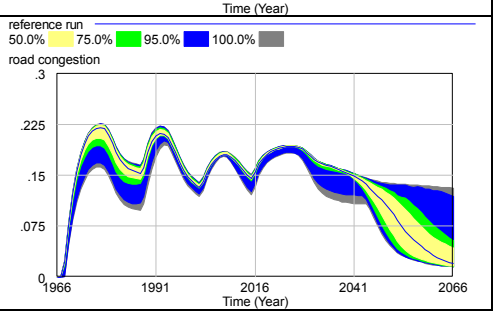
premium housing construction normal	worker housing obsolescence normal	premium housing obsolescence multiplier (lookup)
premium housing construction program	slum refurbishment program	Premium housing growth multiplier (lookup)
premium housing factor	low-cost housing program	worker housing land multiplier (lookup)
premium housing averaging time	slum housing demolition normal	worker housing adequacy multiplier (lookup)
premium housing growth rate initial	slum housing demolition program	worker housing underemployed multiplier (lookup)
premium housing obsolescence normal	slum housing demolition factor	worker housing growth multiplier (lookup)
premium housing population density	underemployed housing population density	worker housing obsolescence multiplier (lookup)

worker housing construction program	underemployed family size	
worker housing construction normal	premium housing adequacy multiplier (lookup)	worker housing tax multiplier (lookup)
worker housing factor	premium housing enterprise multiplier (lookup)	worker housing enterprise multiplier (lookup)
worker-housing population density	premium housing population multiplier	slum housing land multiplier (lookup)
worker housing averaging time	premium housing tax multiplier	slum housing abandoned multiplier (lookup)
worker housing growth rate initial		

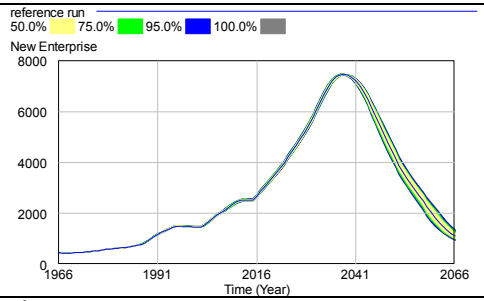
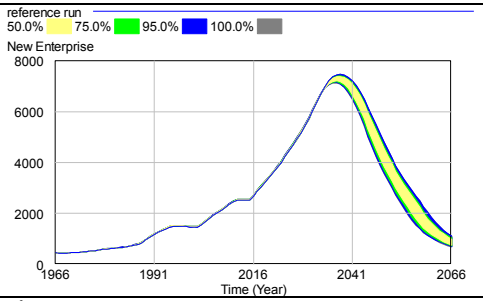
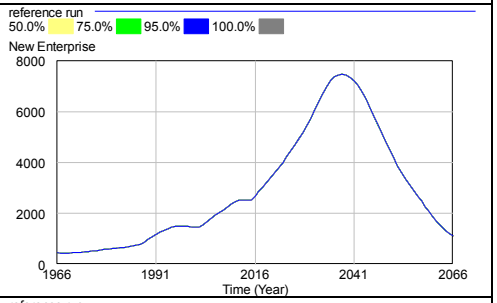
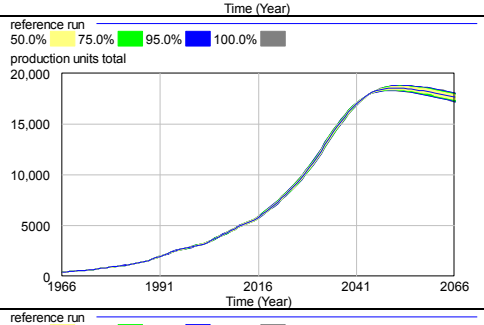
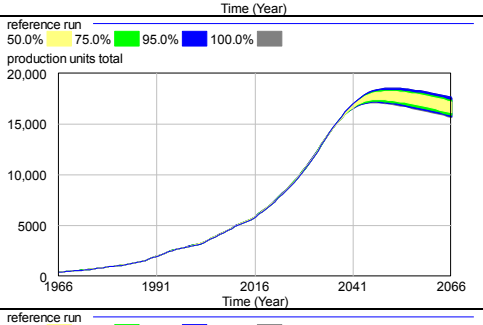
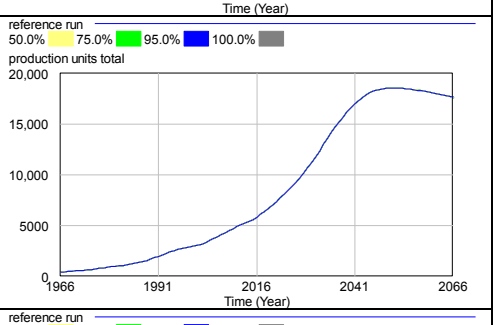
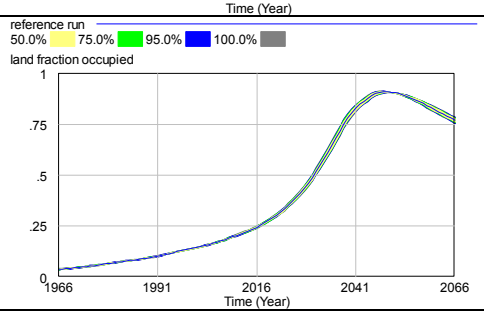
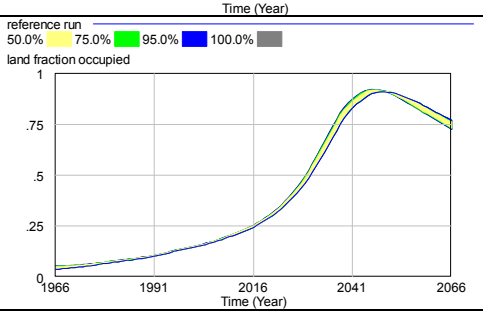
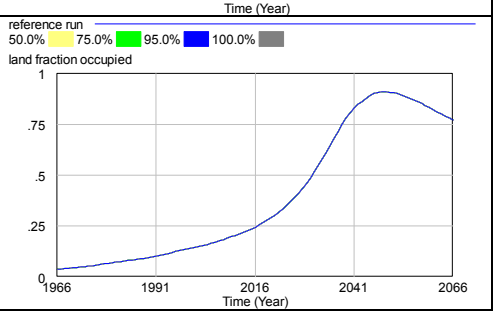
Parameter	Premium Housing initial	Premium Housing initial	Worker Housing initial
Units	Housing unit	Housing unit	Housing unit
Nominal value	973	973	9727
Minimum plausible	0 (-100%)	875.7 (-10%)	0 (-100%)
Maximum plausible	1946 (+100%)	1070.3 (+10%)	19454 (+100%)
Sensitivity plot: New Enterprise			

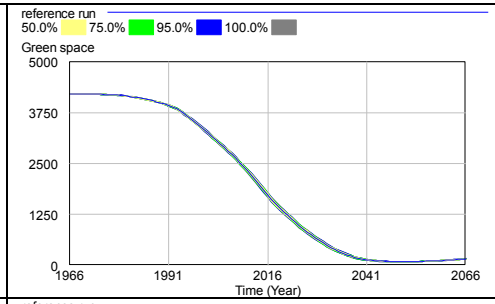
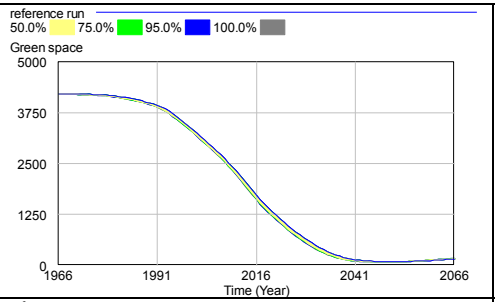
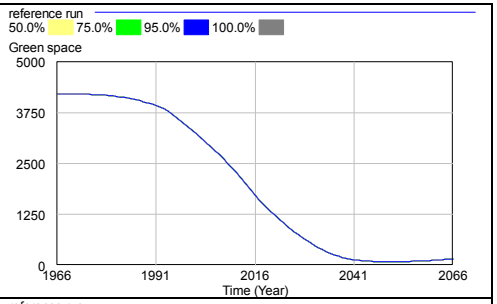
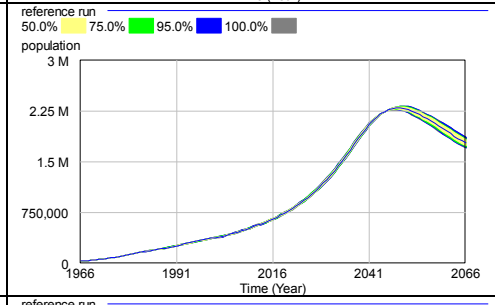
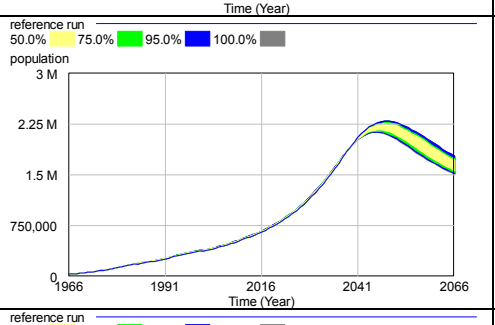
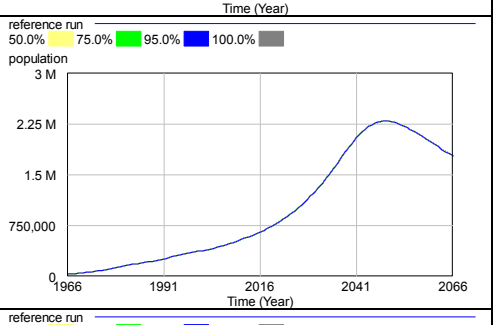
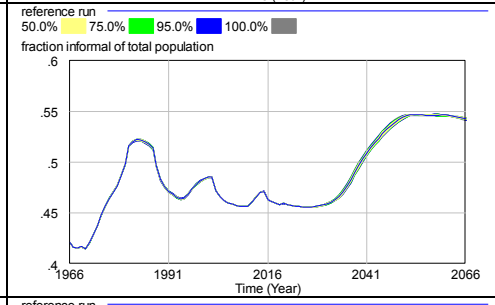
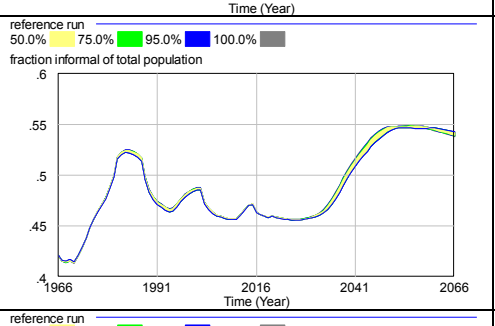
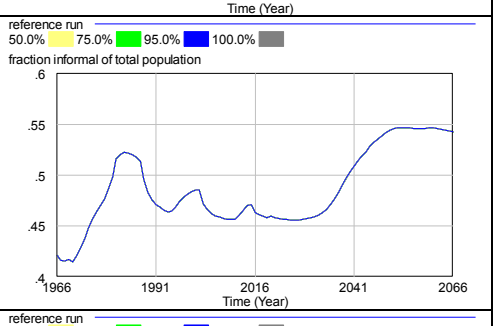
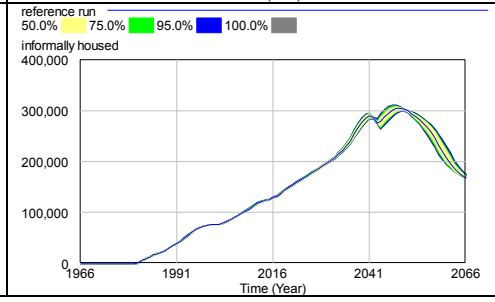
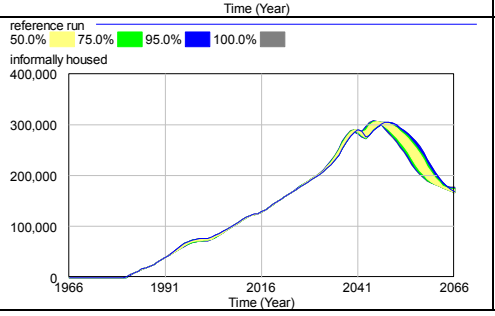
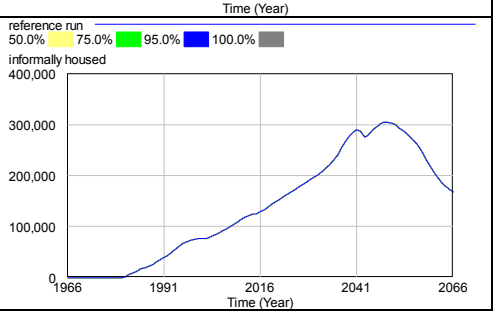
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

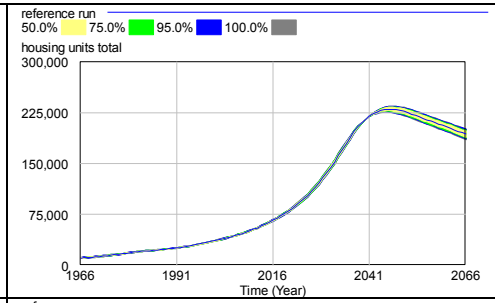
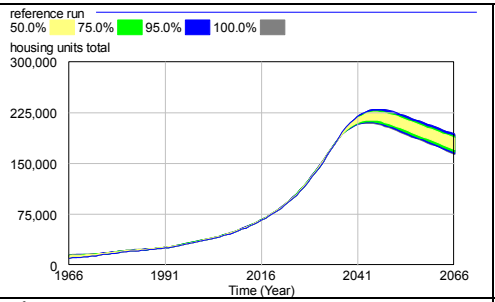
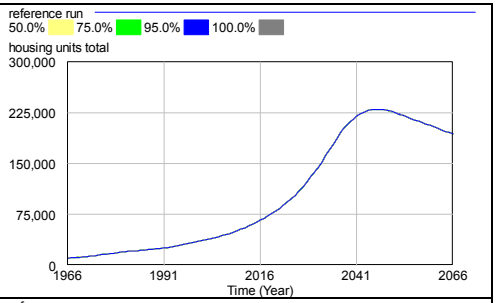
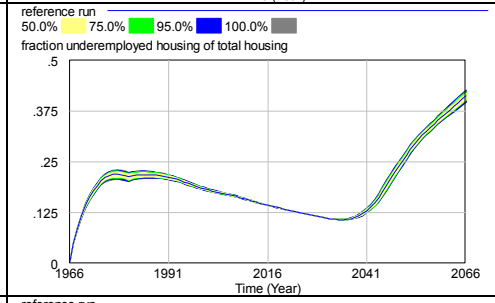
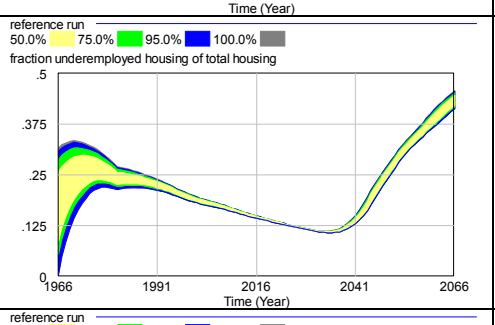
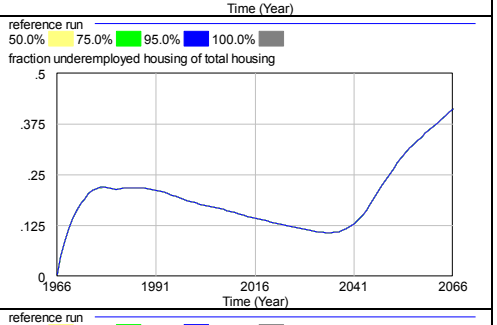
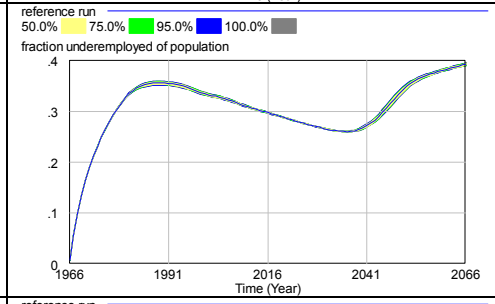
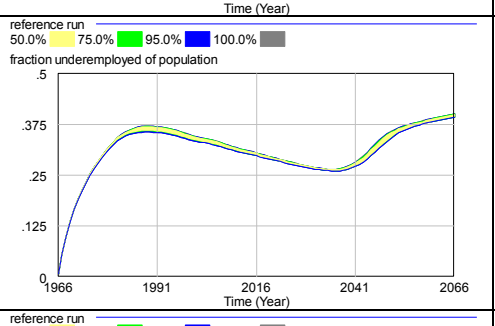
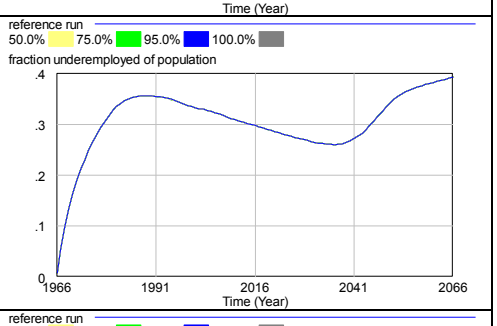
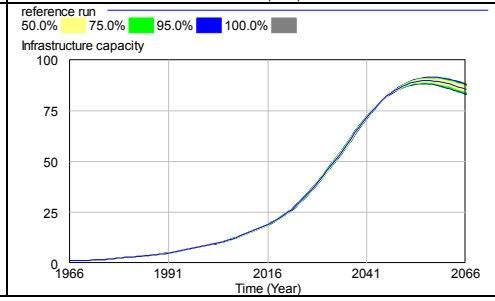
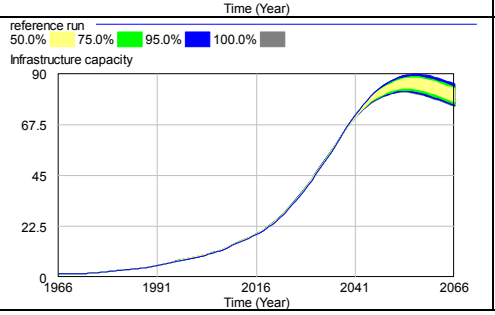
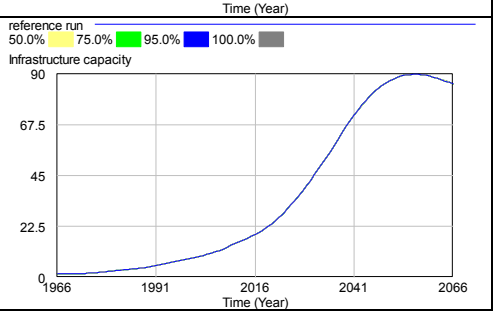
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

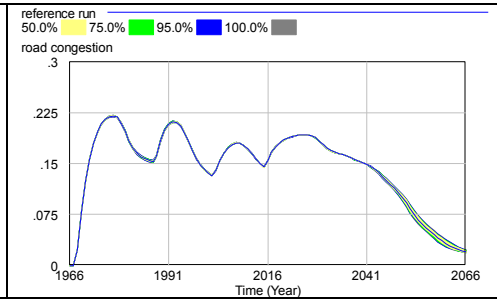
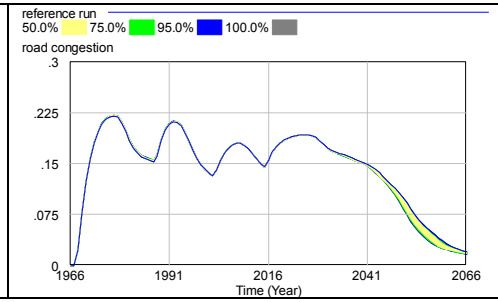
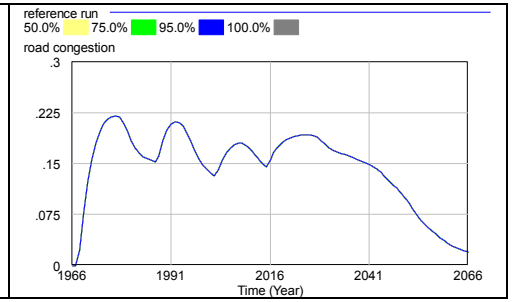
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

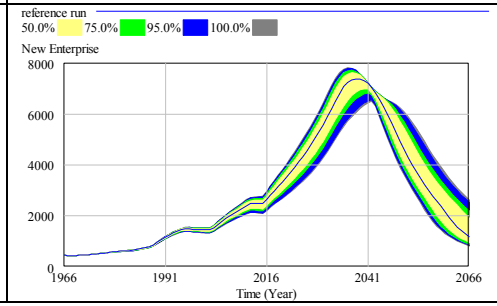
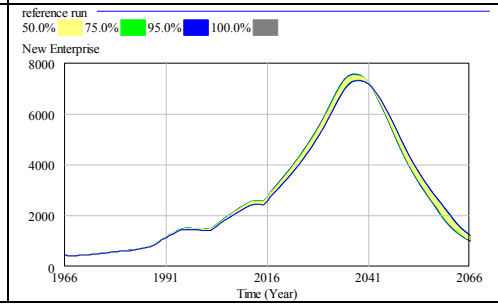
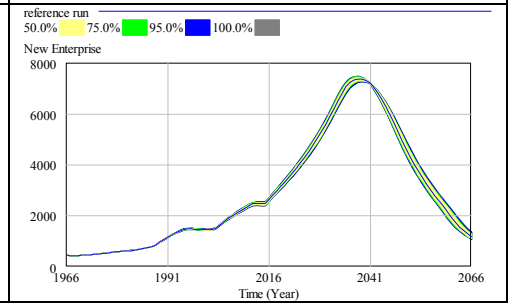
Parameter	Worker Housing initial	Underemployed Housing initial	Underemployed Housing initial
Units	Housing unit	Housing unit	Housing unit
Nominal value	9727	50	50
Minimum plausible	8754.3 (-10%)	0	45 (-10%)

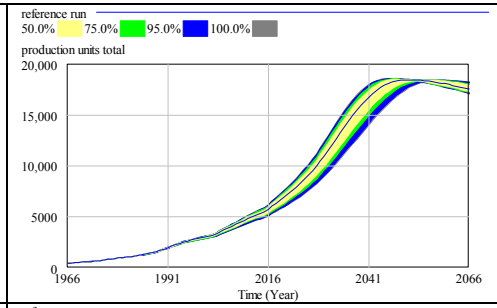
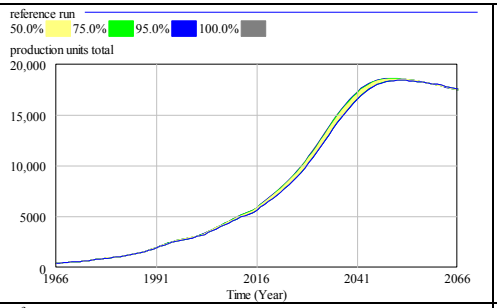
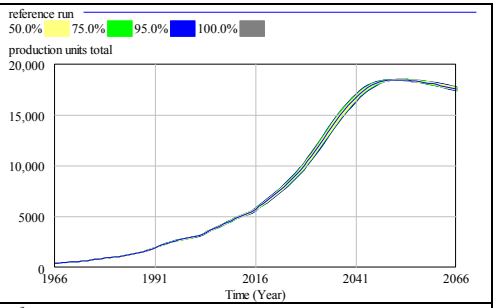
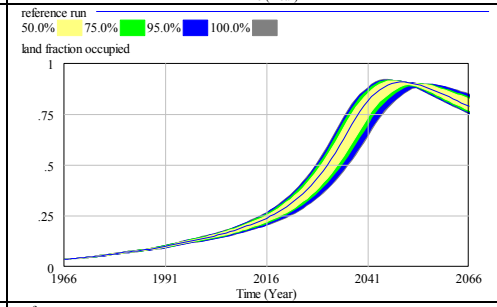
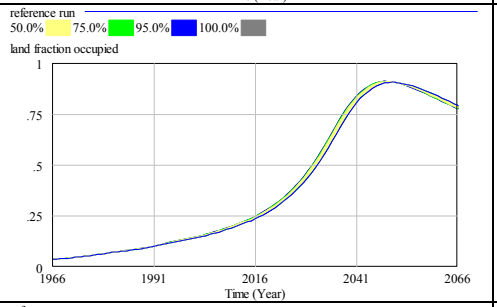
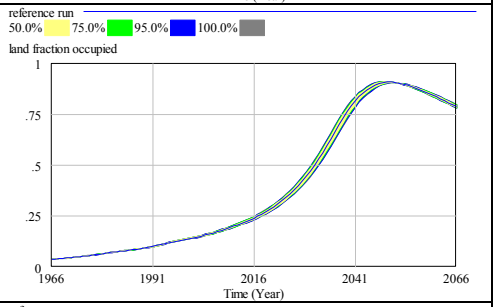
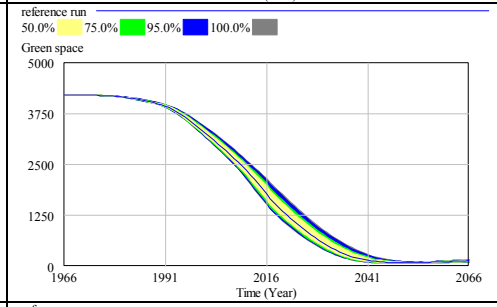
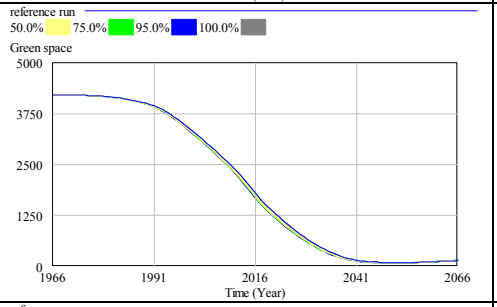
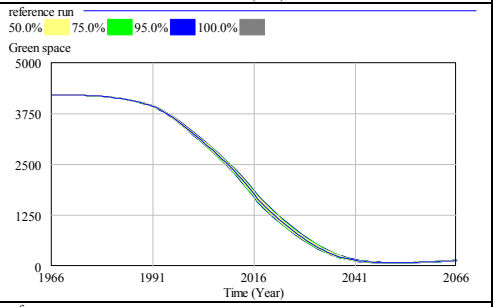
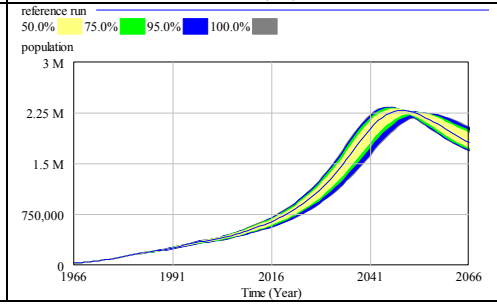
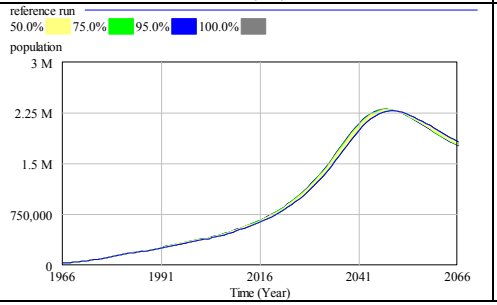
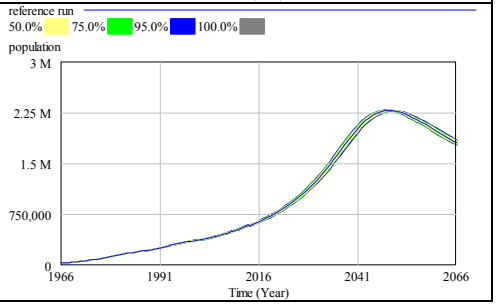
Maximum plausible	10699.7 (+10%)	5000	55 (+10%)
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			

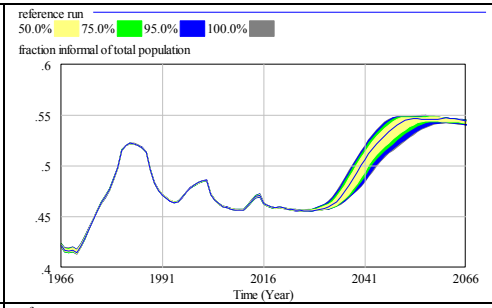
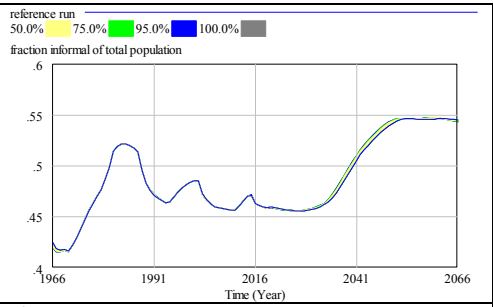
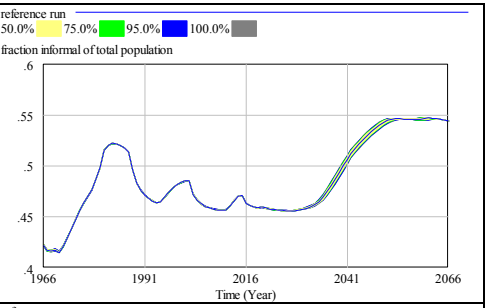
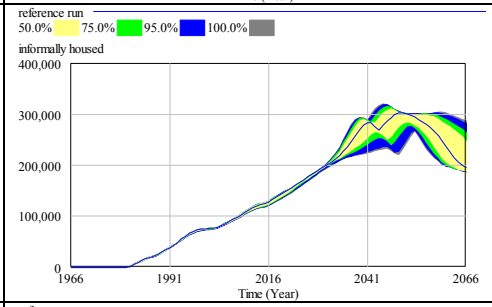
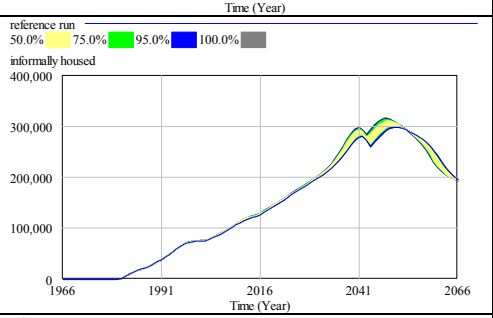
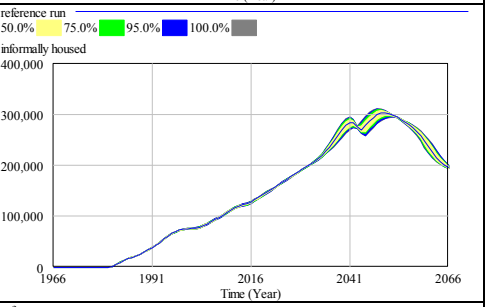
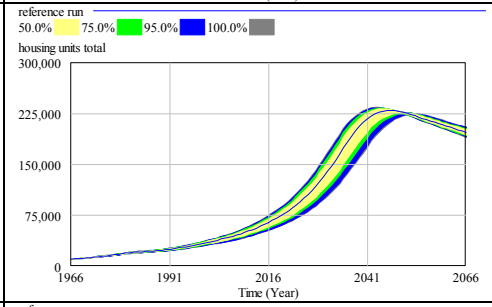
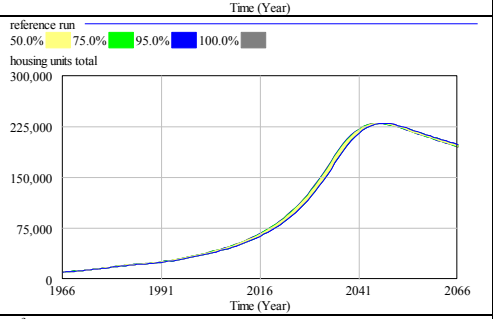
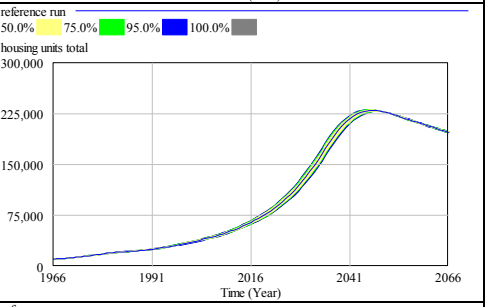
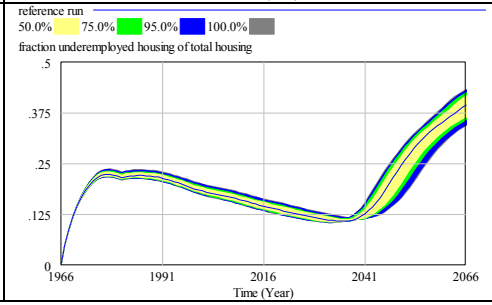
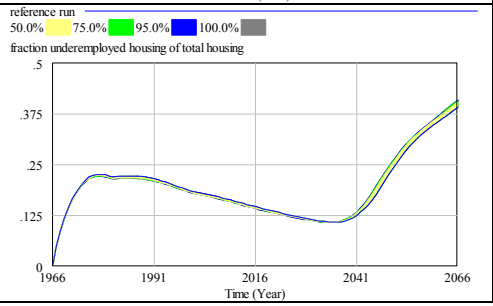
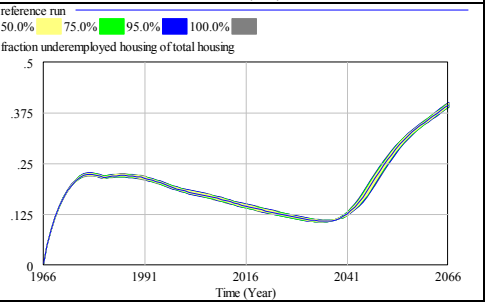
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			

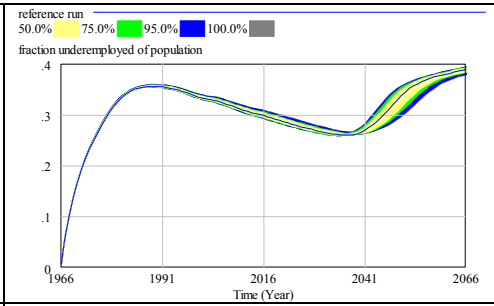
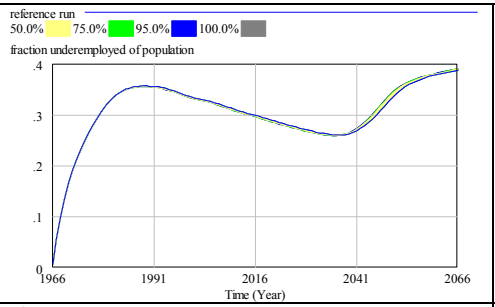
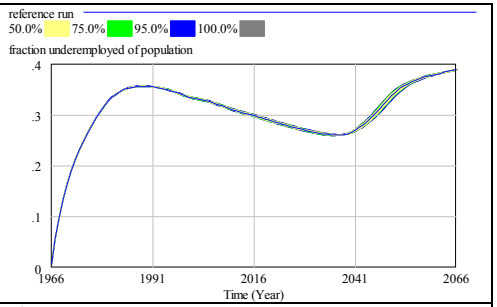
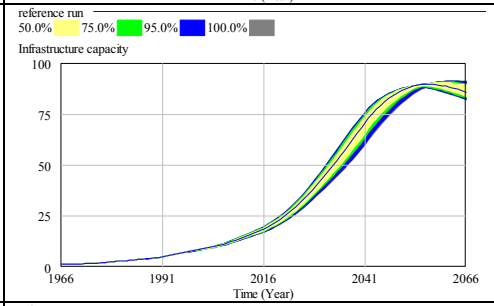
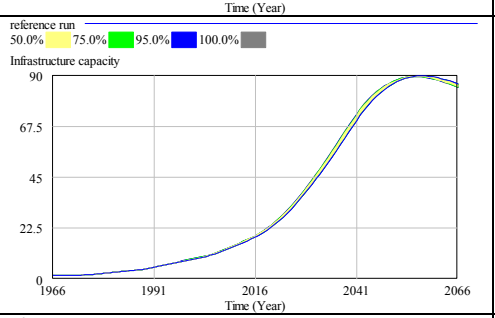
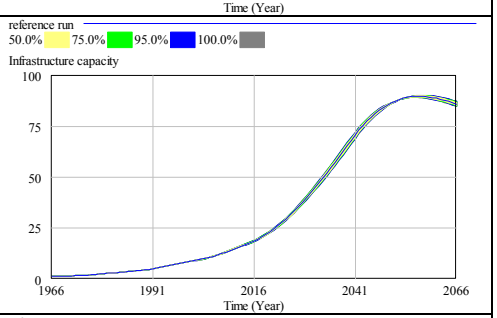
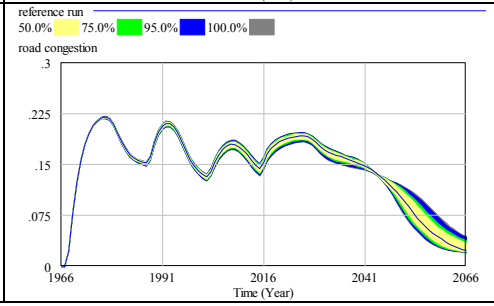
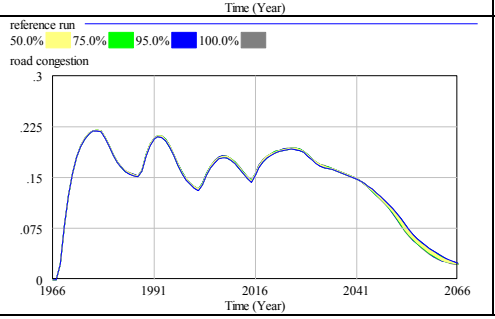
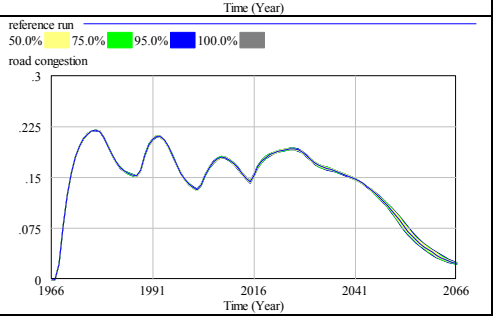
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			

Sensitivity plot: road congestion			

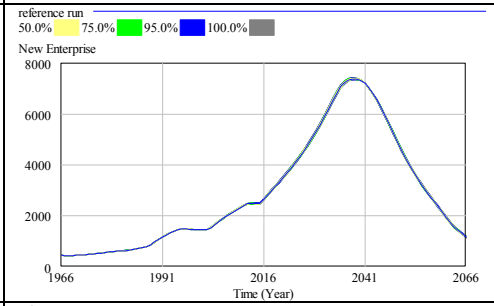
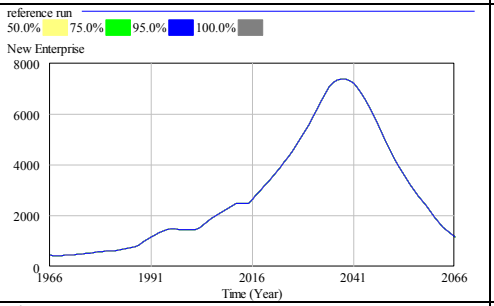
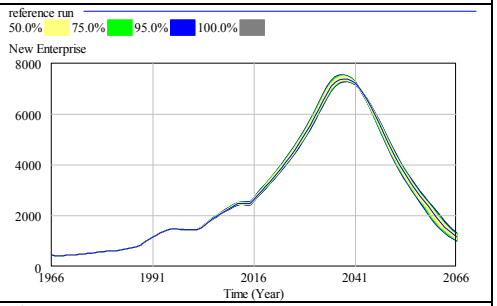
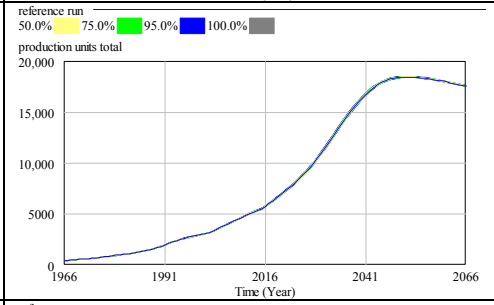
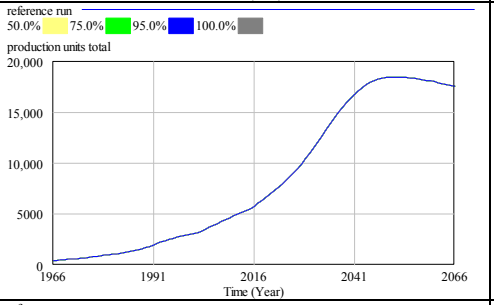
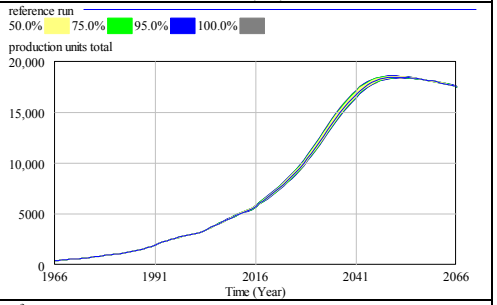
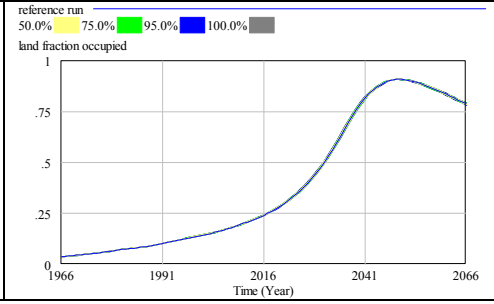
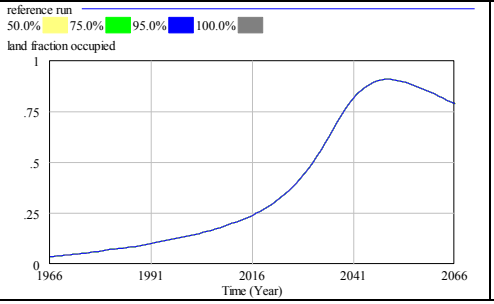
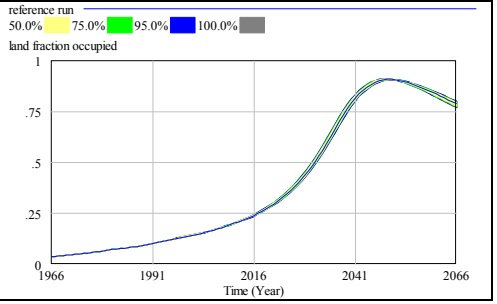
Parameter	premium housing construction normal	Premium housing construction program	premium housing factor
Units	1/year	Housing unit/year	-
Nominal value	0.03	175/4 (1966-1970), 738/11 (1970-1981)	1
Minimum plausible	0.015 (-50%)	0	0.8
Maximum plausible	0.045 (+50%)	100 (continous)	1.2
Sensitivity plot: New Enterprise			

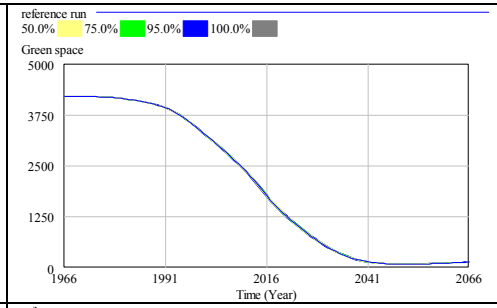
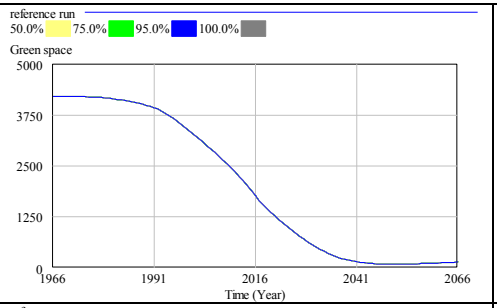
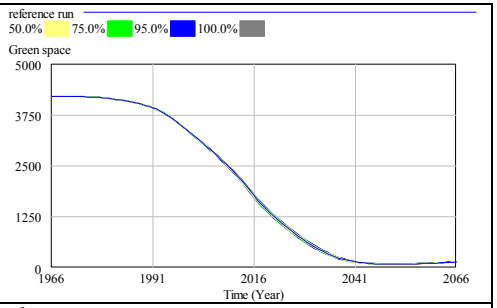
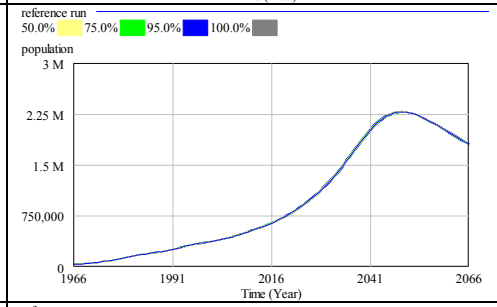
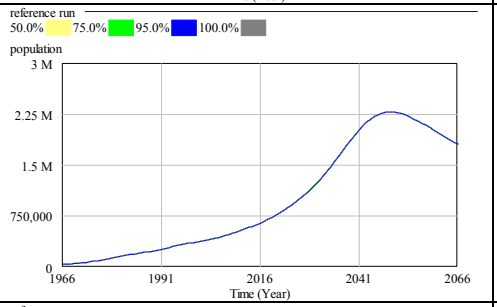
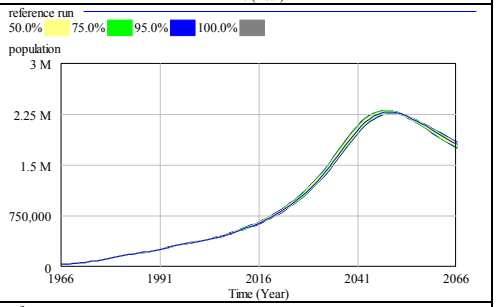
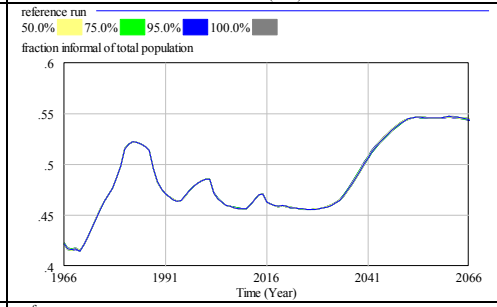
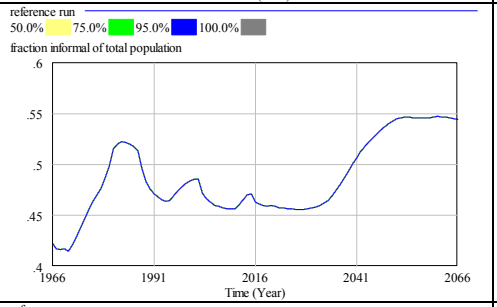
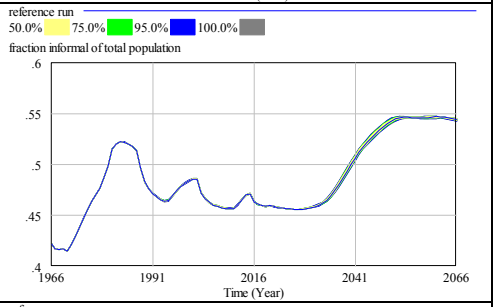
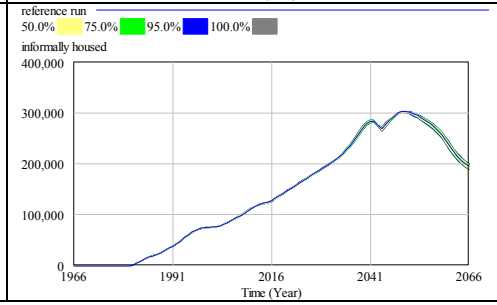
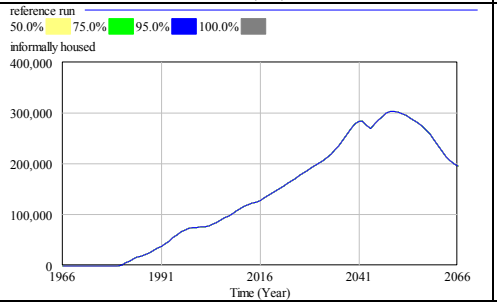
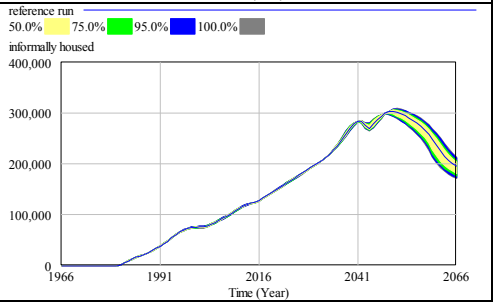
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

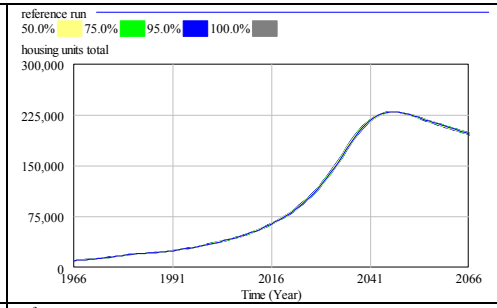
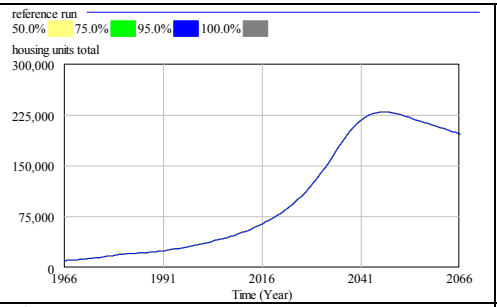
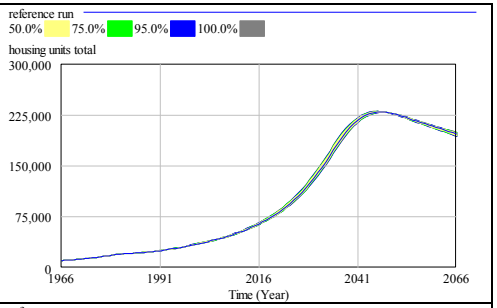
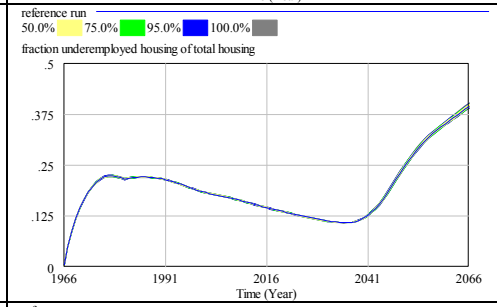
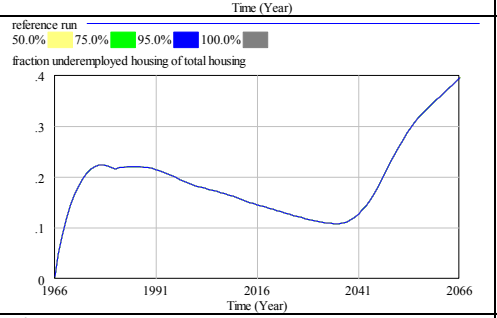
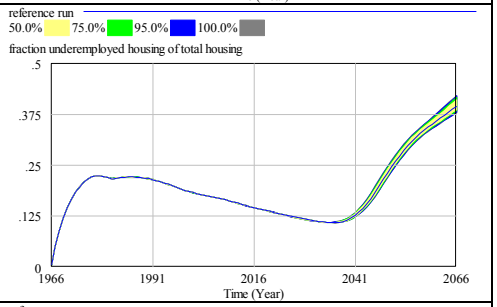
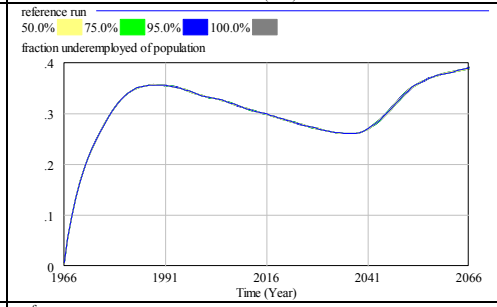
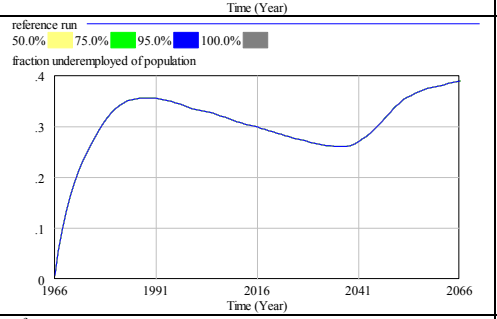
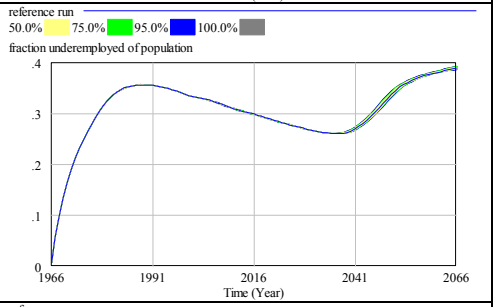
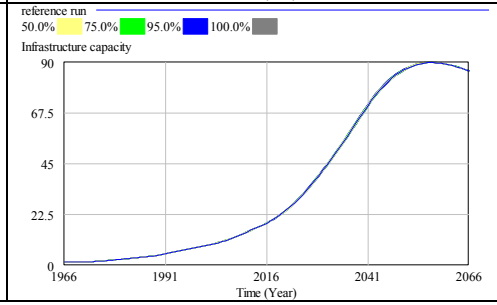
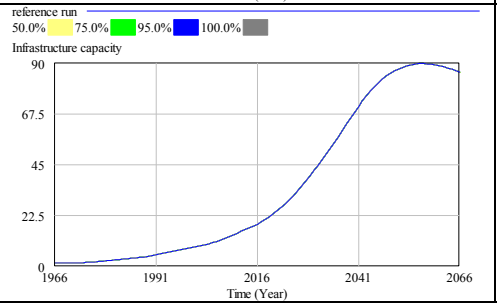
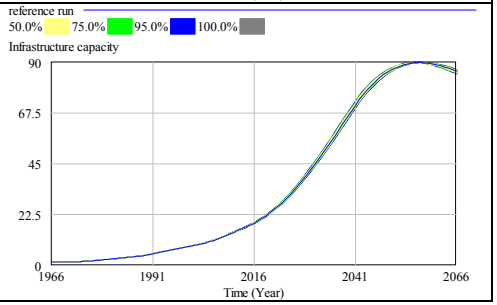
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

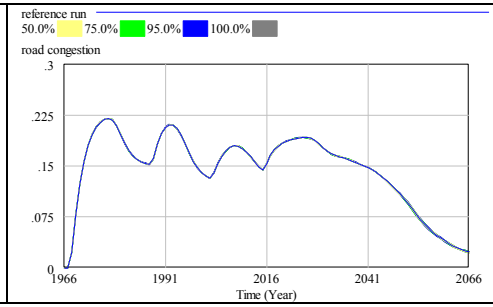
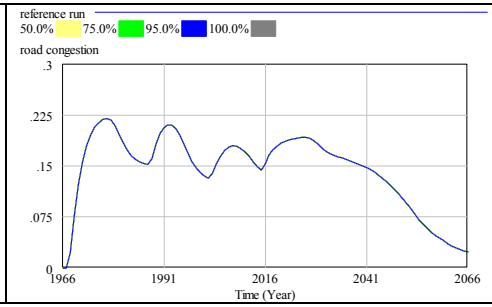
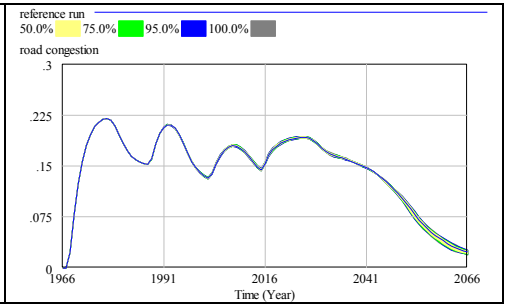
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

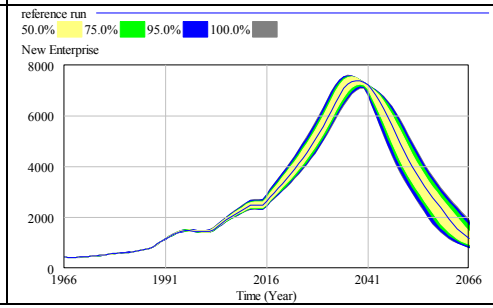
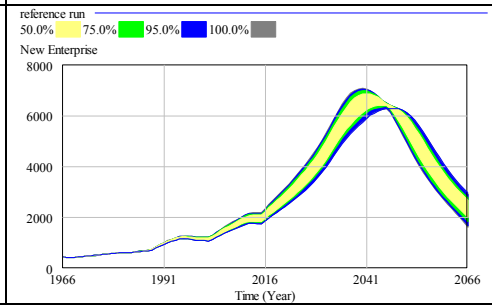
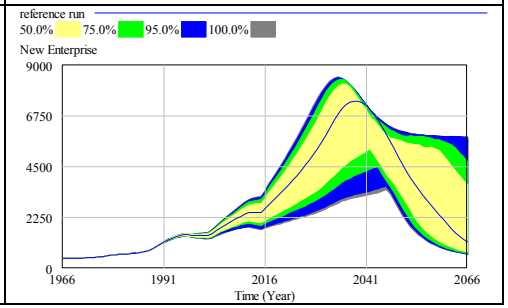
Parameter	premium housing averaging time	premium housing growth rate initial	premium housing obsolescence normal
Units	Year	1/Year	
Nominal value	10	0.03	0.03 (averagely 33 years)
Minimum plausible	5	0.015	0.025 (40 years, +20%)

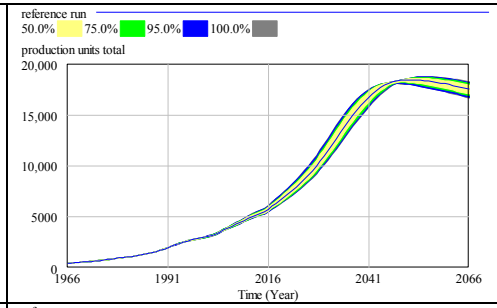
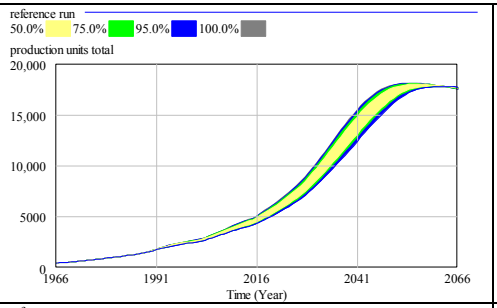
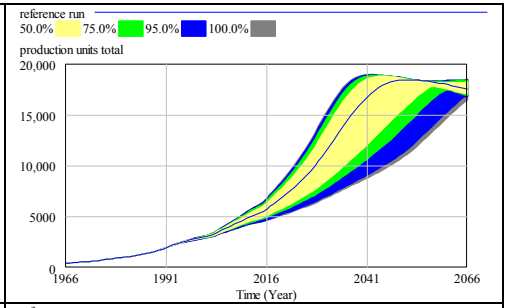
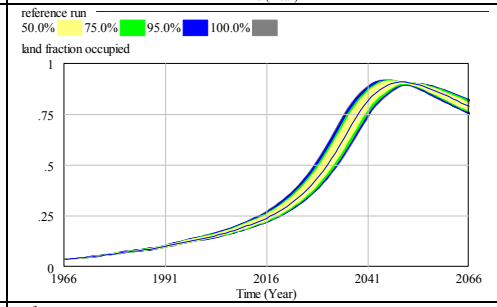
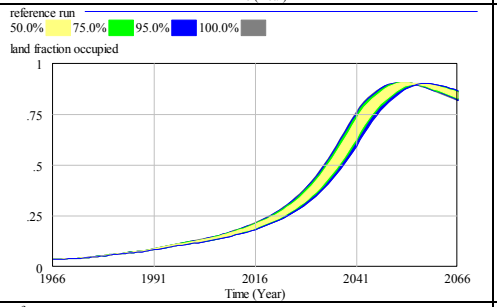
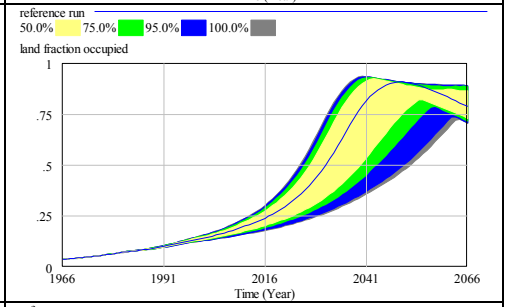
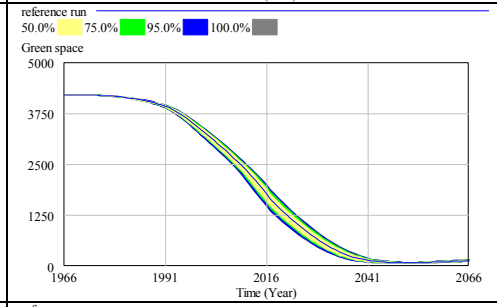
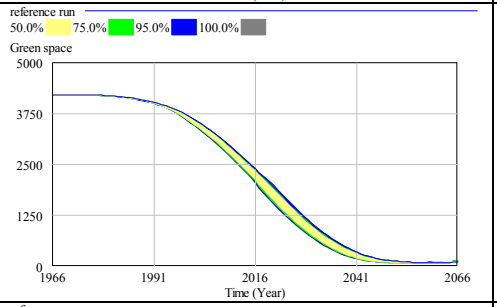
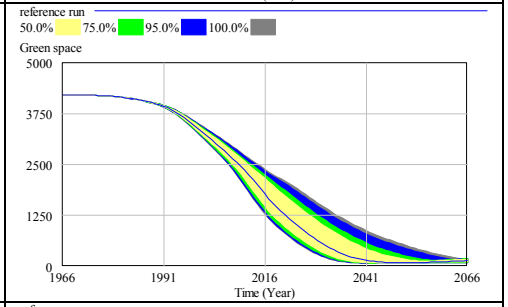
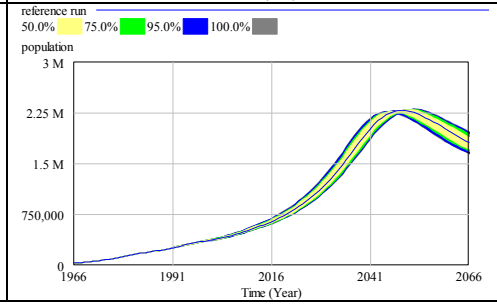
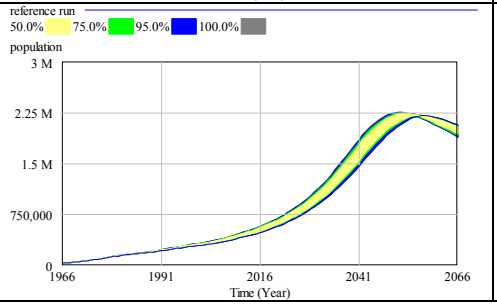
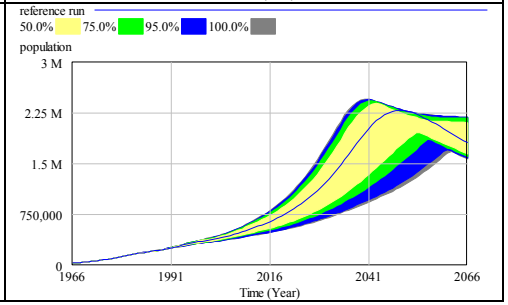
Maximum plausible	15	0.045	0.0375 (26,7 years, -20%)
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			

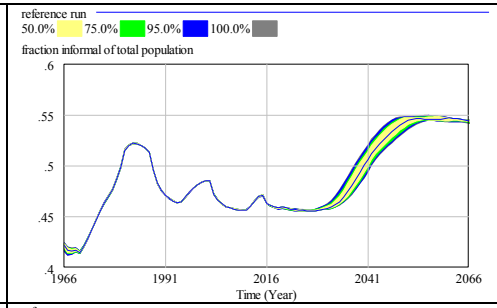
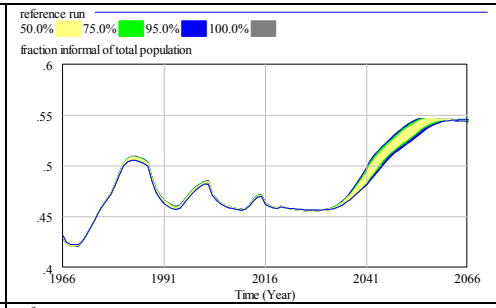
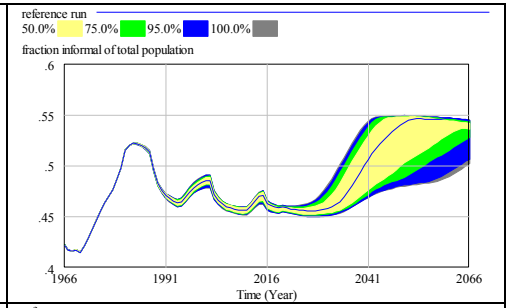
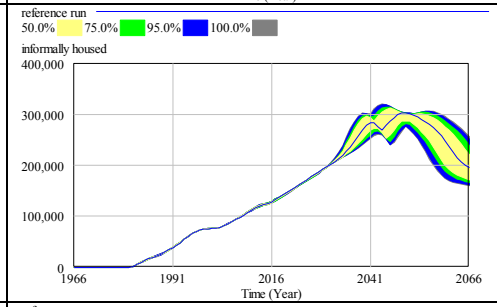
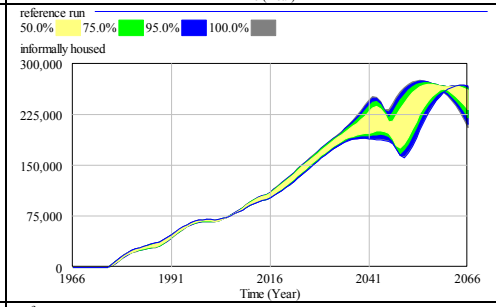
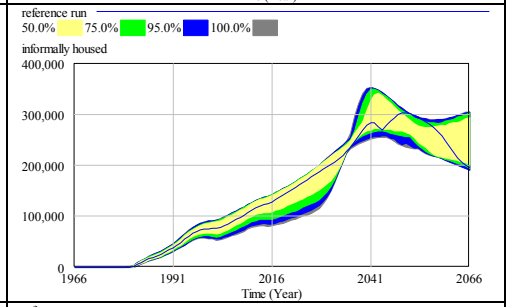
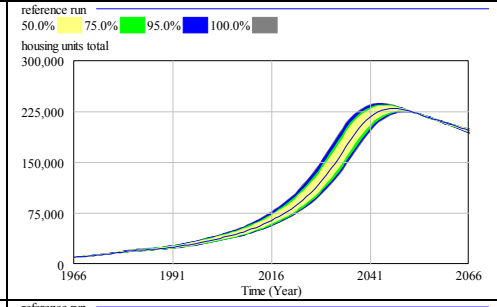
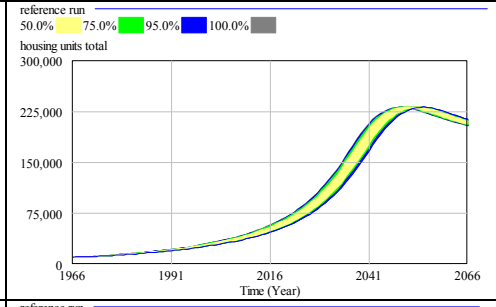
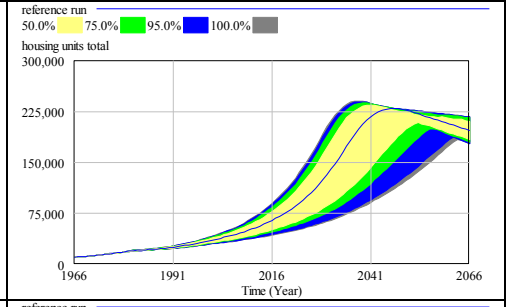
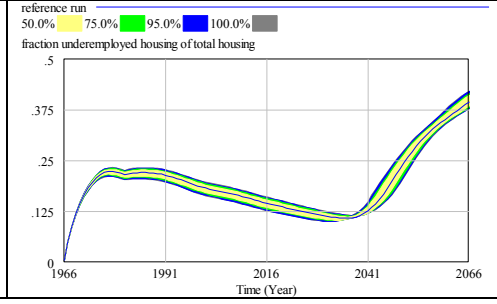
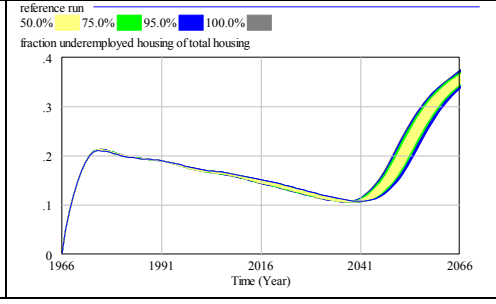
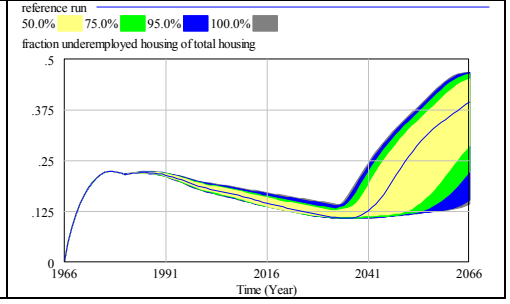
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			

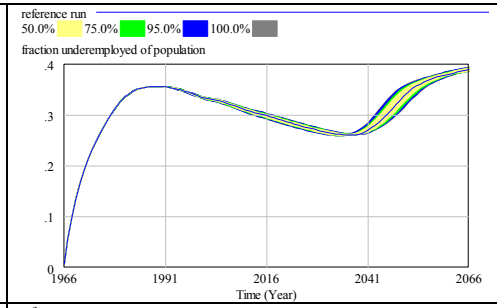
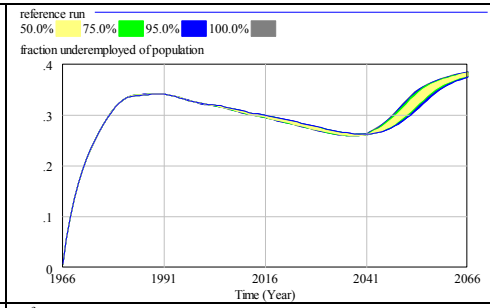
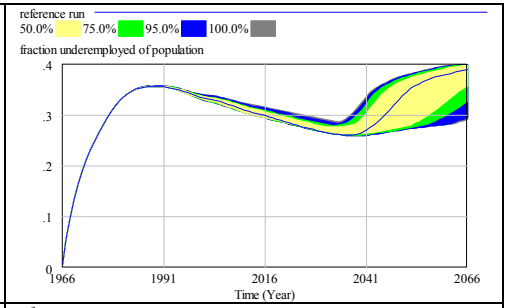
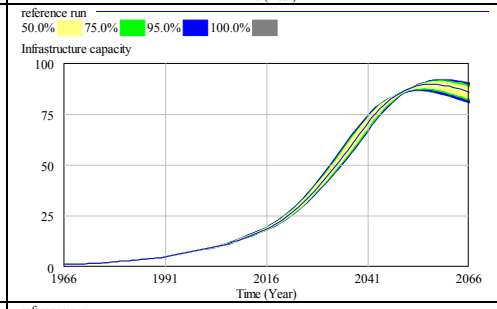
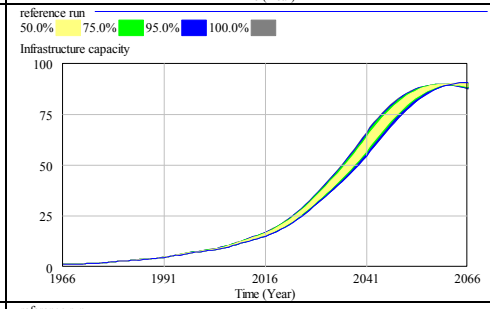
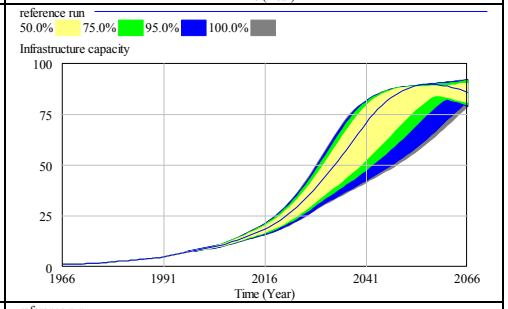
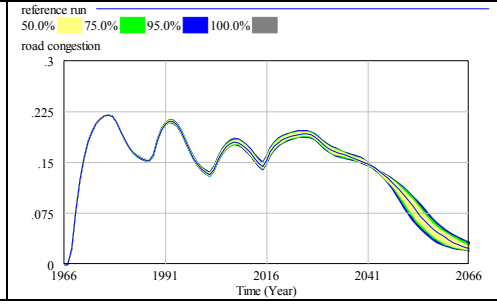
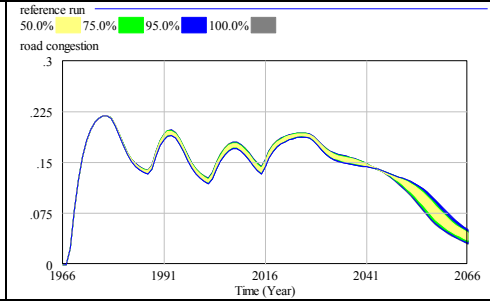
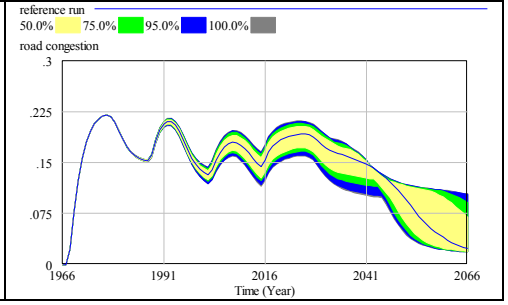
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			

Sensitivity plot: road congestion			

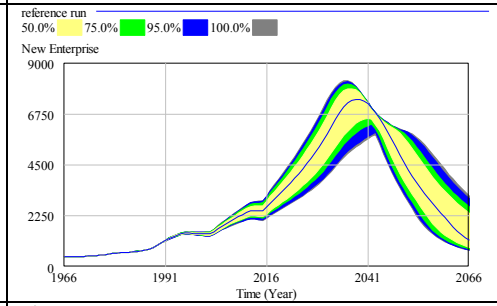
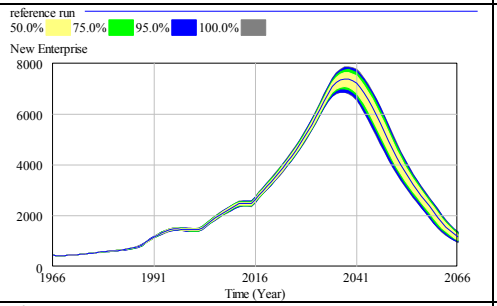
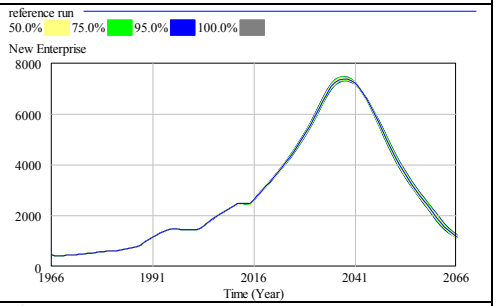
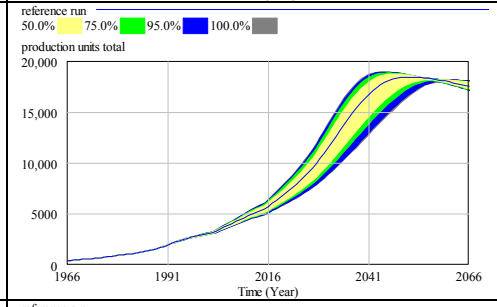
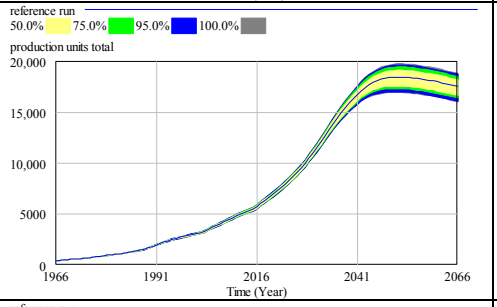
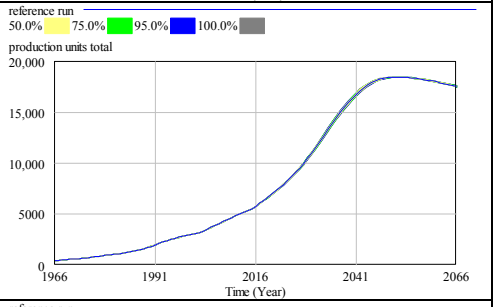
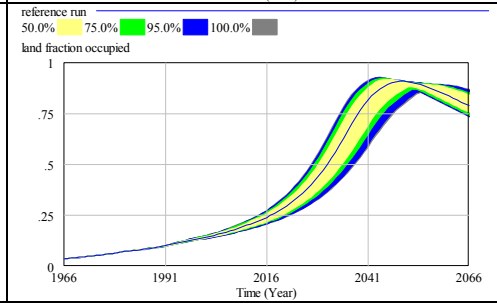
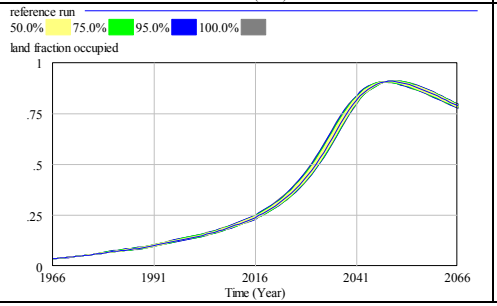
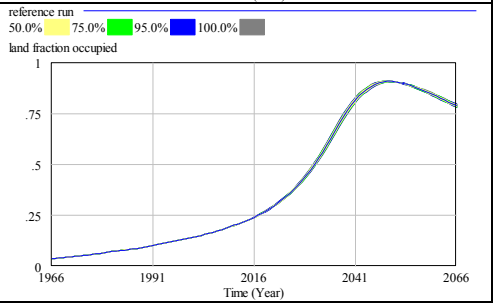
Parameter	premium housing population density	worker housing construction program	worker housing construction normal
Units	Person/housing unit	housing units/year	1/Year
Nominal value	4	1575/4 (1966-1970), 6642/11 (1970-1981)	0.02
Minimum plausible	3.2 (-20%)	0	0.01 (-50%)
Maximum plausible	4.8 (+20%)	100 (continuous, instead of TDC housing program)	0.03 (+50%)
Sensitivity plot: New Enterprise			

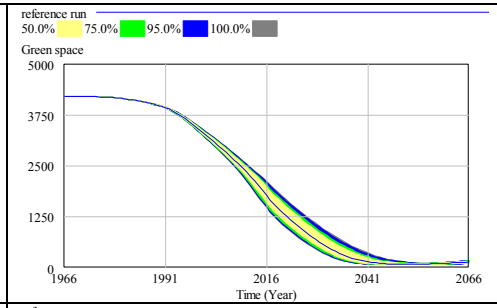
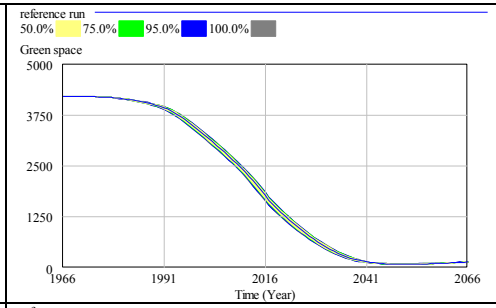
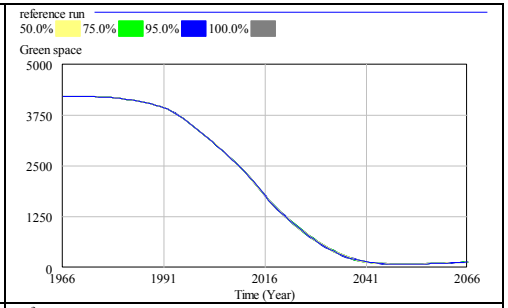
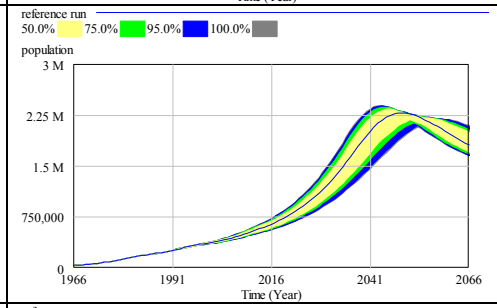
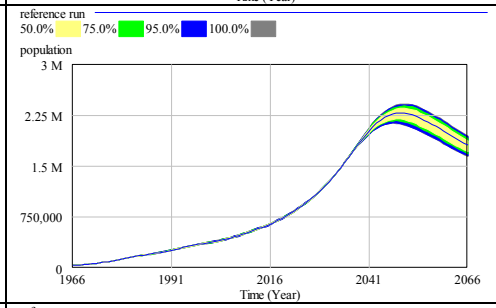
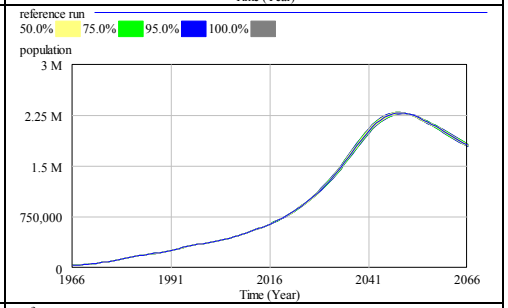
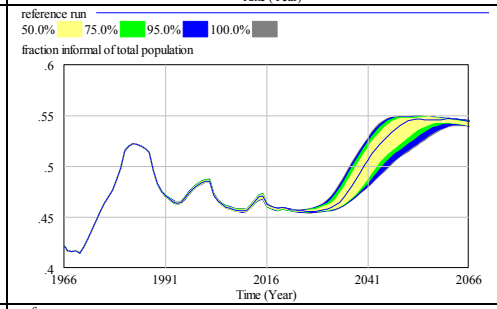
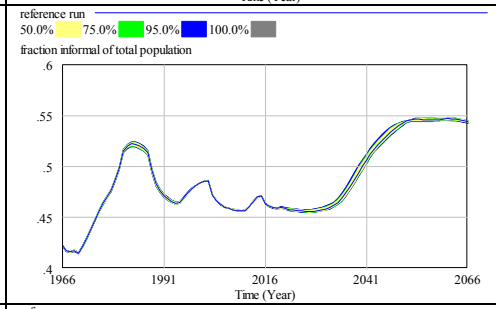
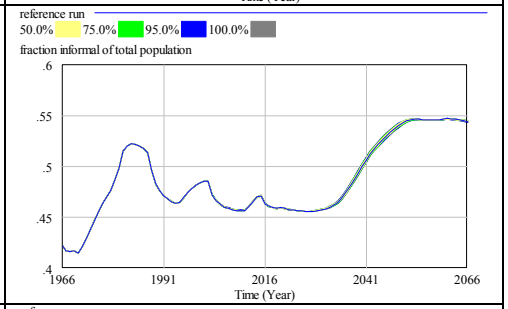
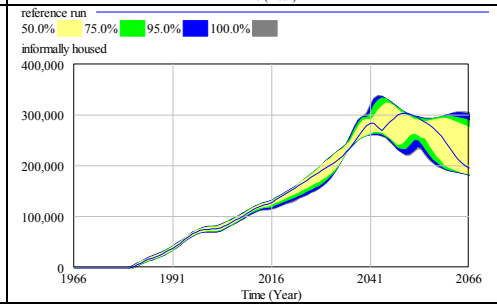
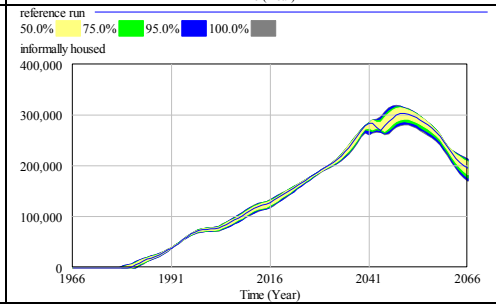
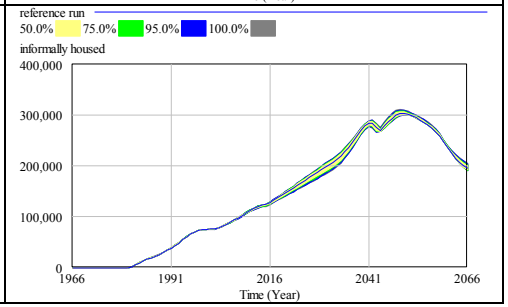
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

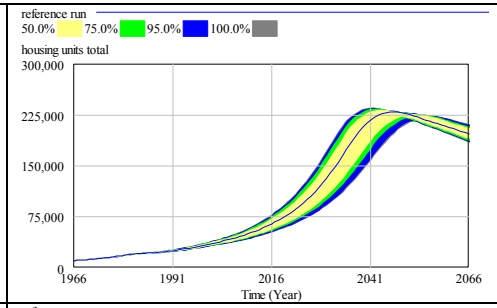
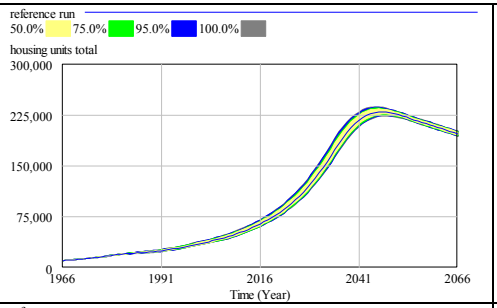
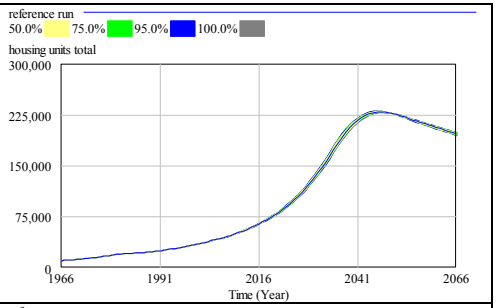
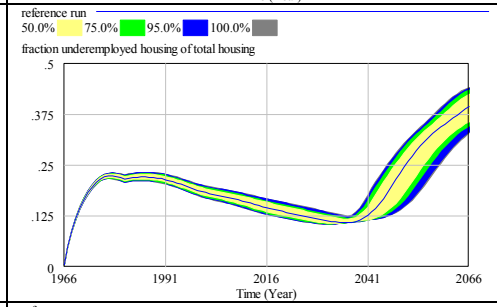
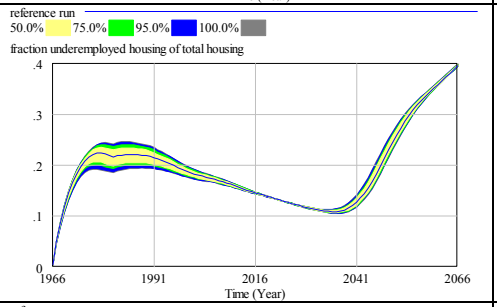
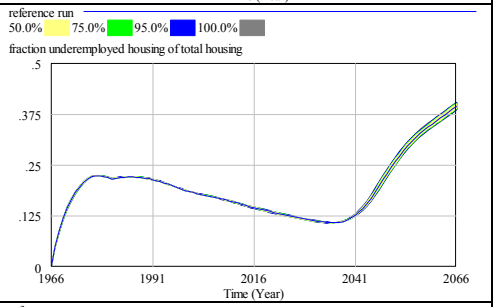
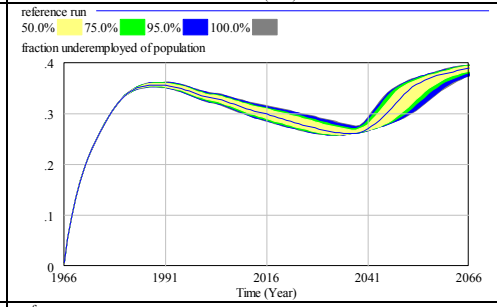
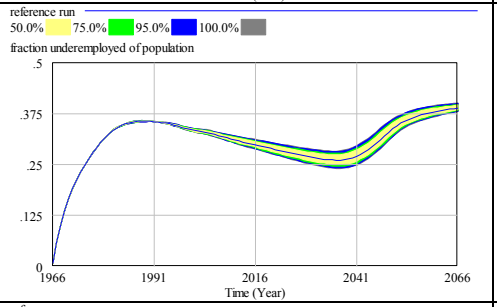
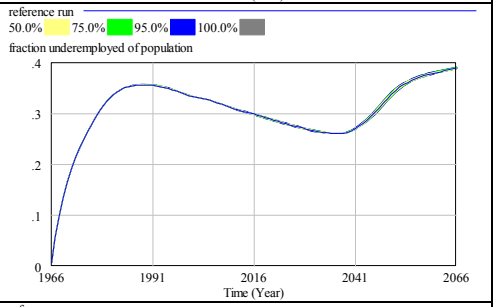
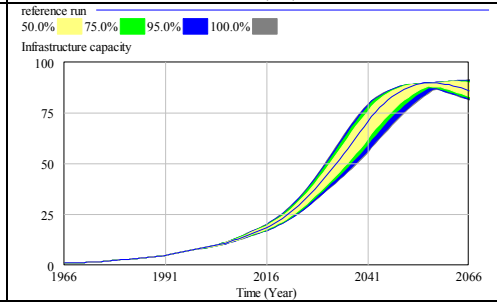
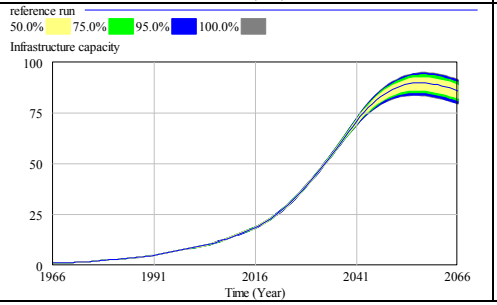
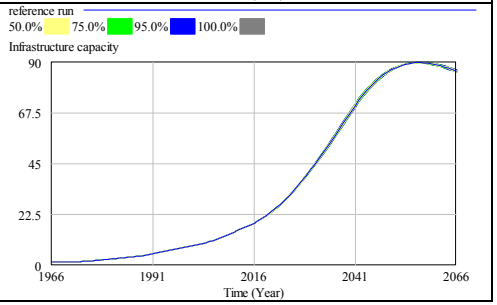
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

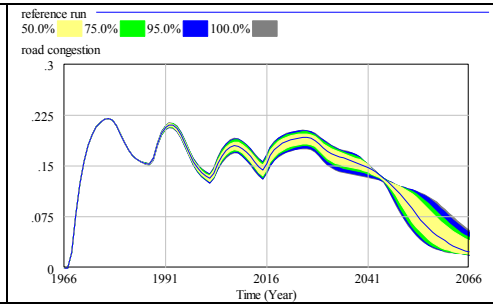
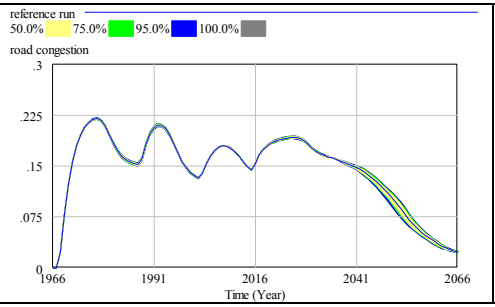
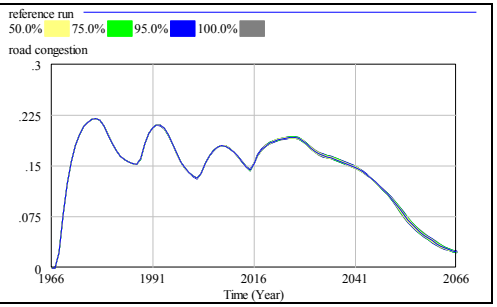
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

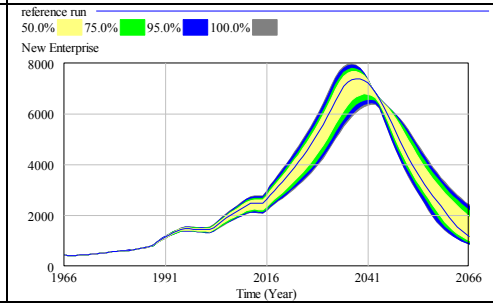
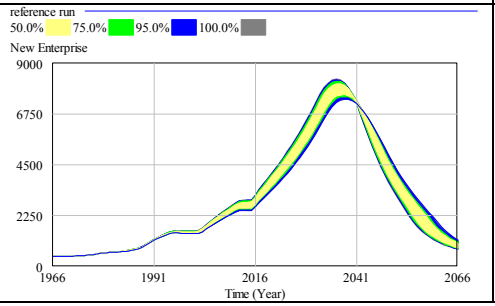
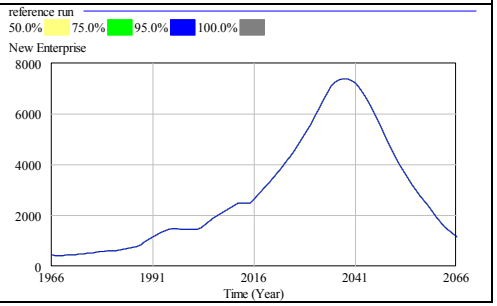
Parameter	worker housing factor	worker-housing population density	worker housing averaging time
Units	-	Person/housing unit	Year
Nominal value	1	8	10
Minimum plausible	0.8	6.4 (-20%)	5 (-50%)

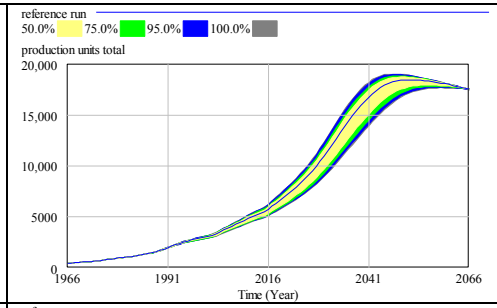
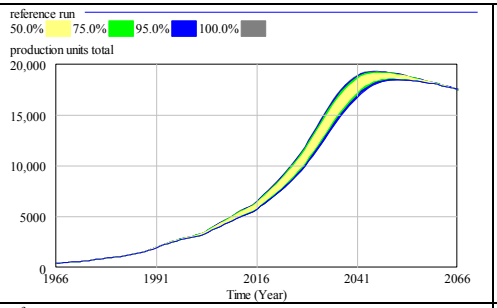
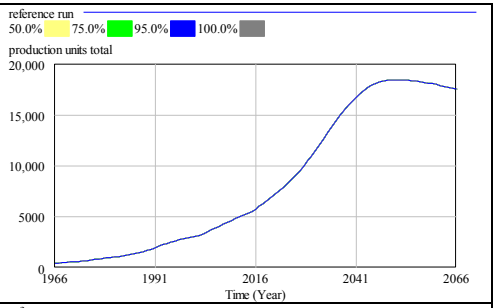
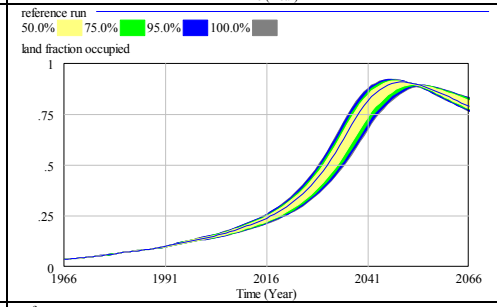
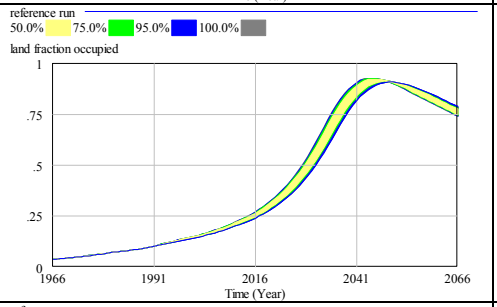
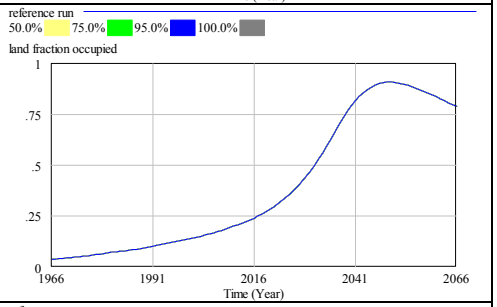
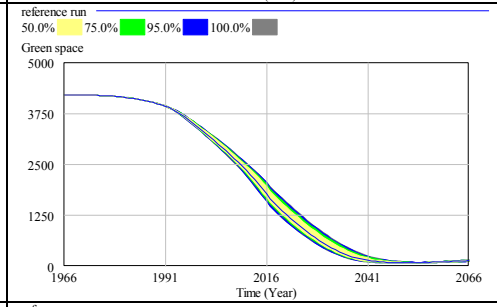
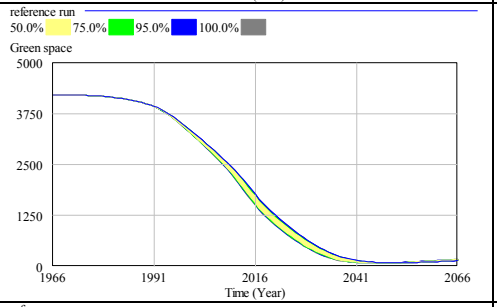
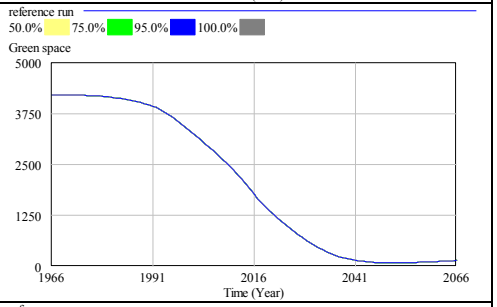
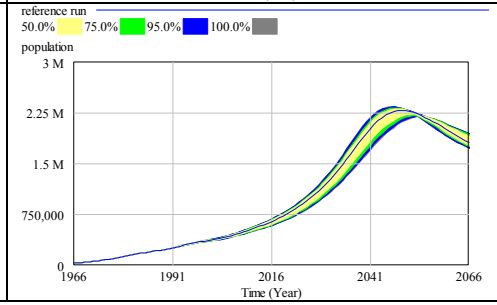
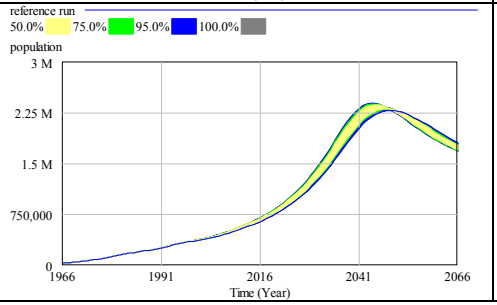
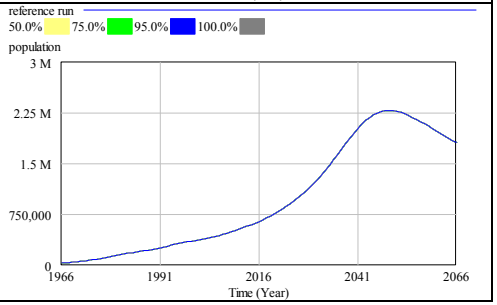
Maximum plausible	1.2	9.6 (+20%)	15 (+50%)
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			

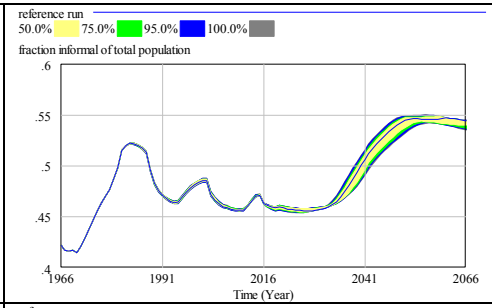
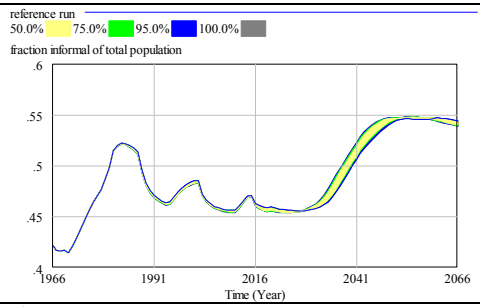
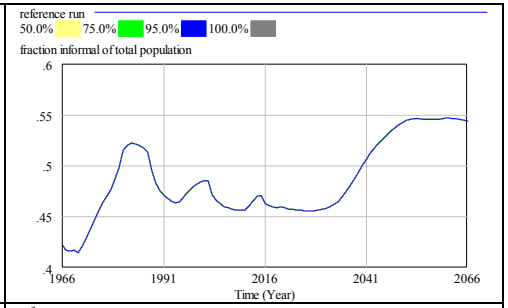
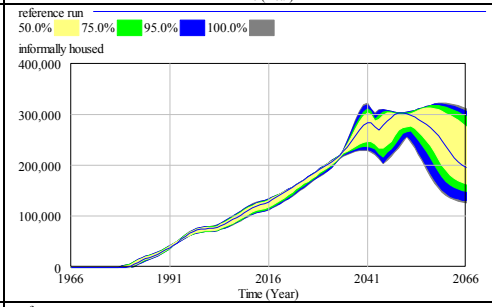
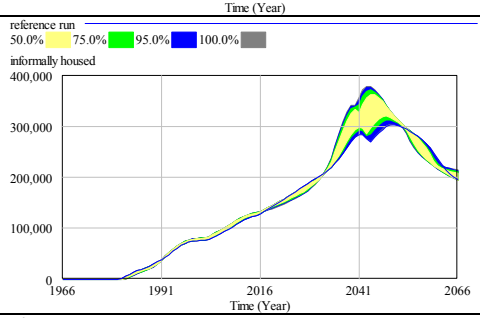
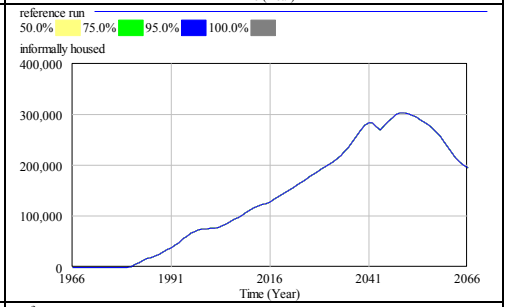
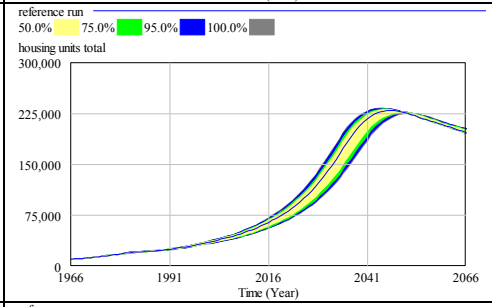
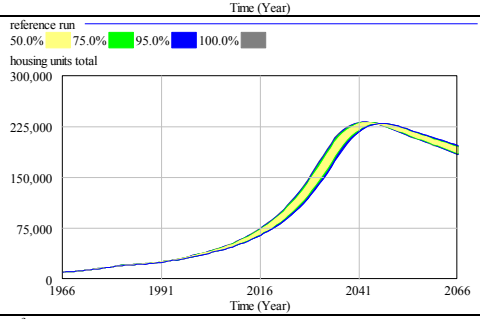
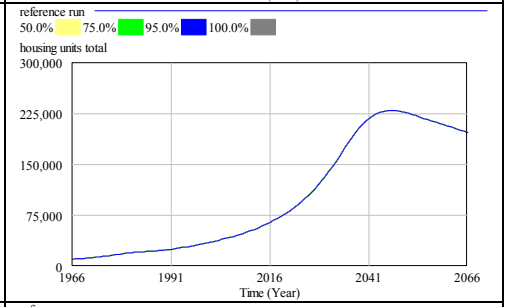
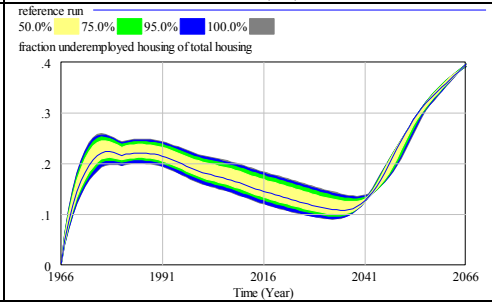
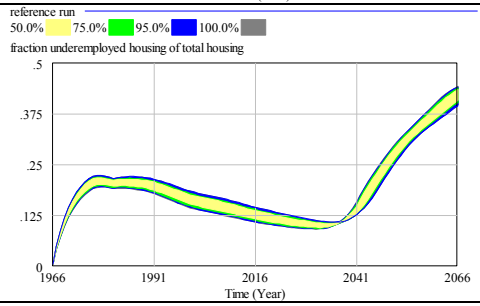
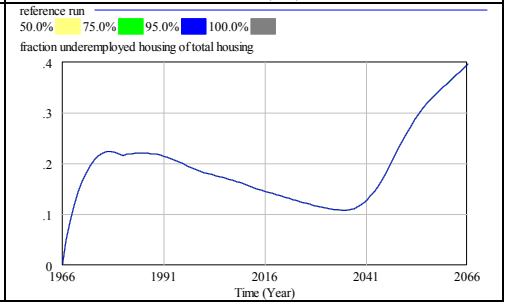
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			

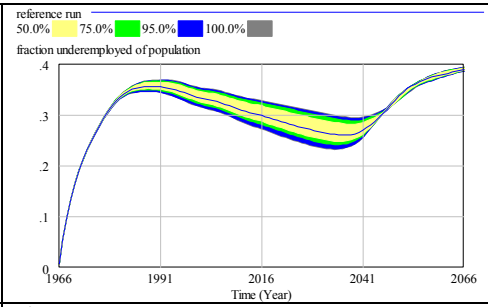
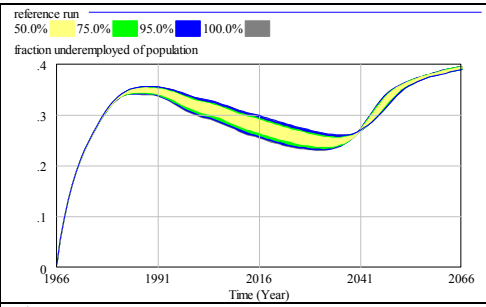
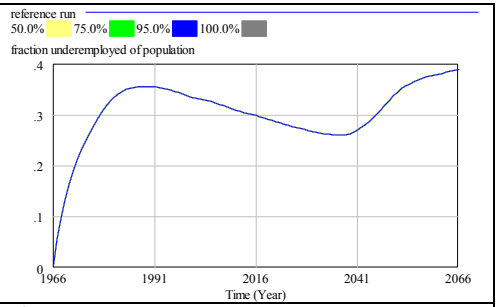
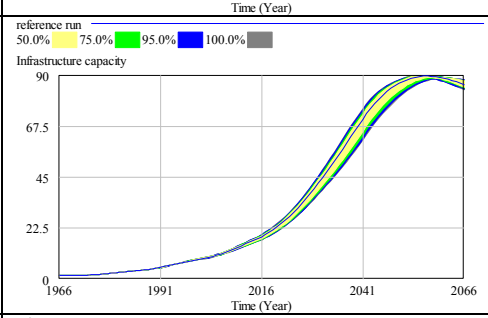
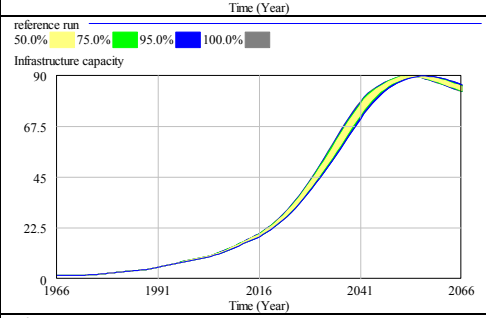
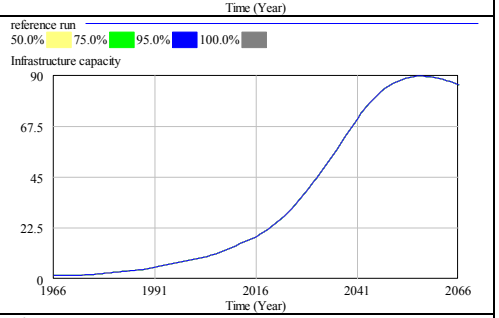
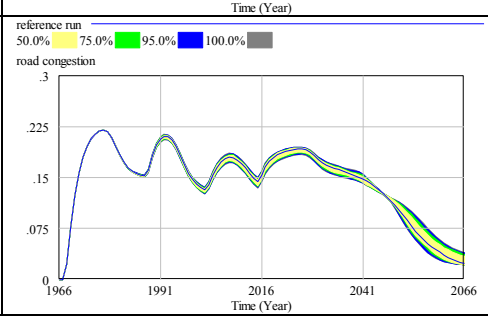
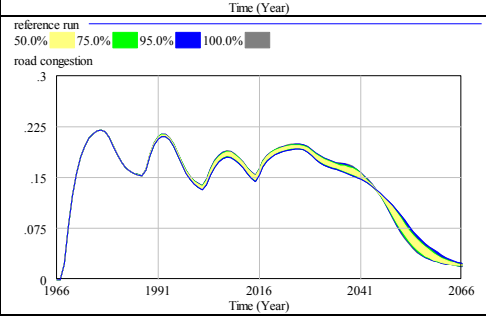
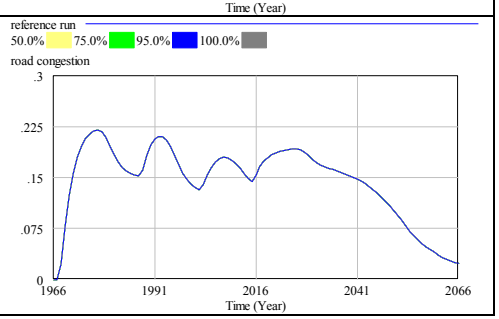
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			

Sensitivity plot: road congestion			

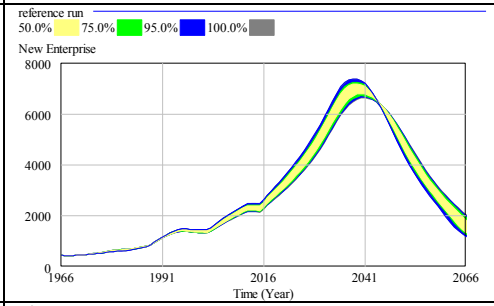
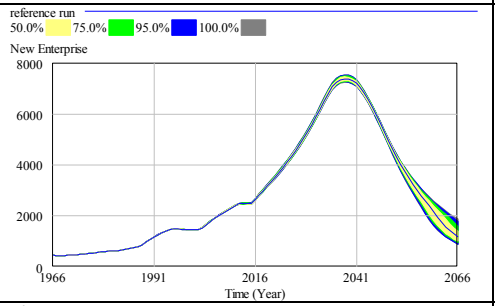
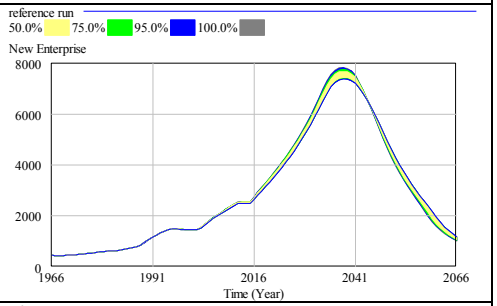
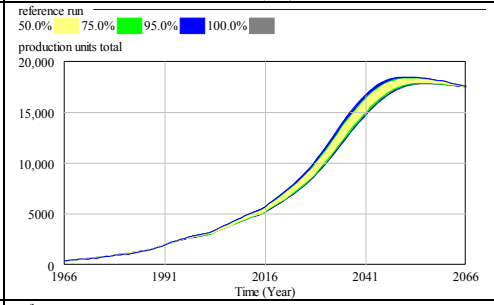
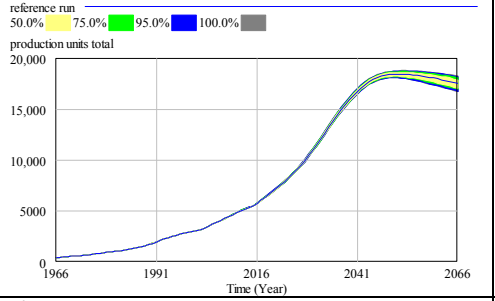
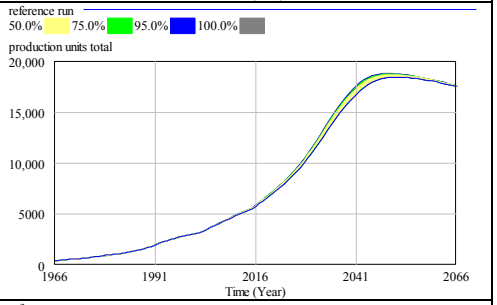
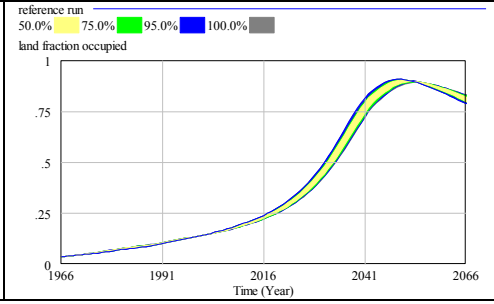
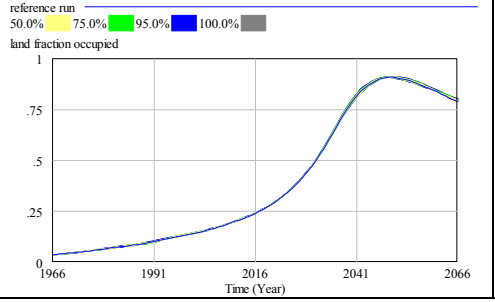
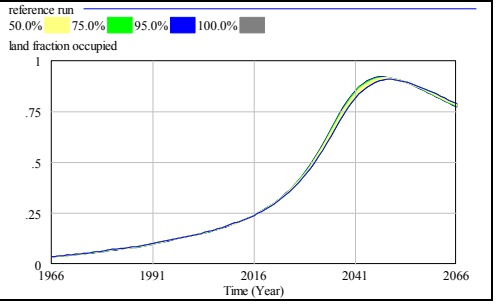
Parameter	worker housing obsolescence normal	slum refurbishment program	worker housing growth rate initial
Units	1/Year	Housing unit/Year	1/Year
Nominal value	0.025 (after 40 years averagely)	0	0.03
Minimum plausible	0.02 (after 50 years)	0	0.015
Maximum plausible	0.0333 (after 30 years)	100 (or the amount of underemployed housing)	0.045
Sensitivity plot: New Enterprise			

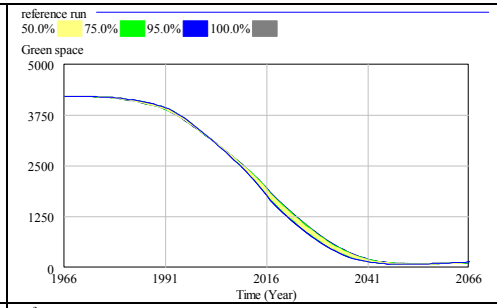
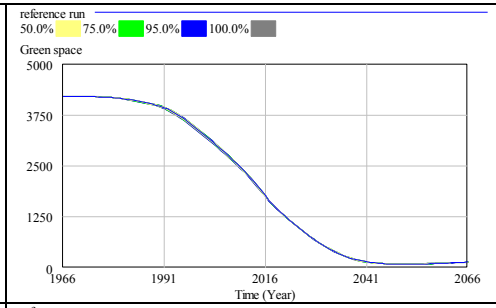
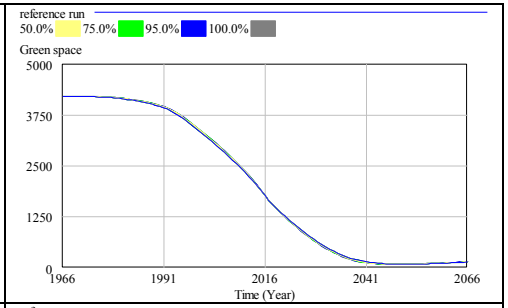
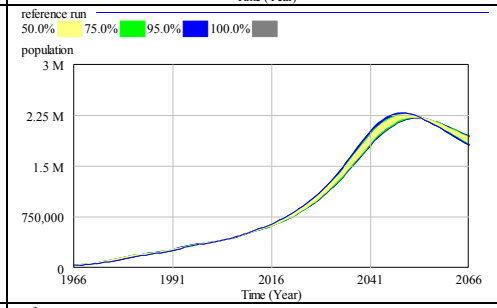
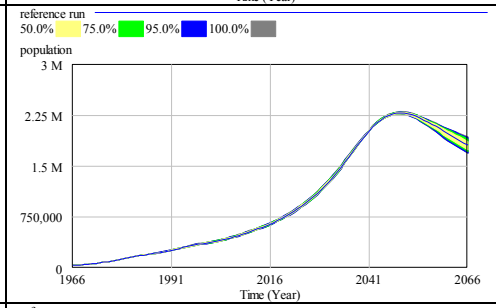
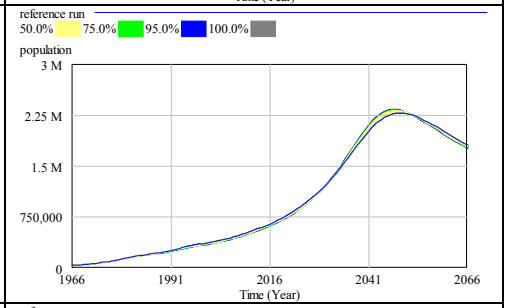
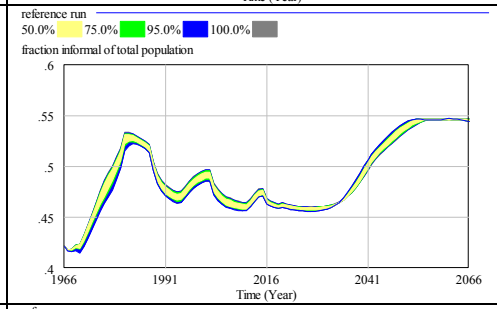
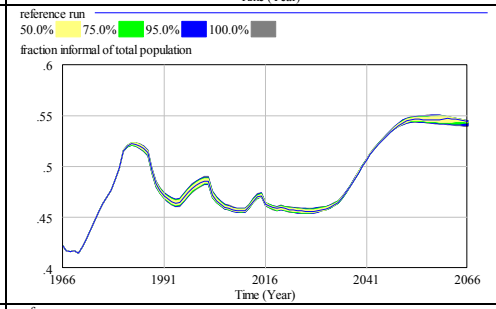
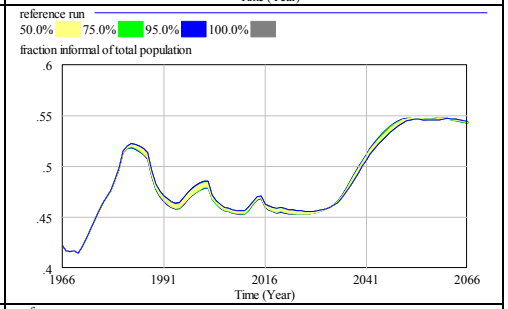
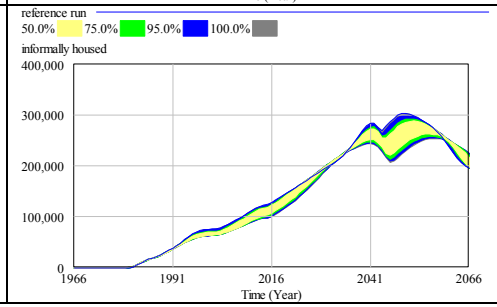
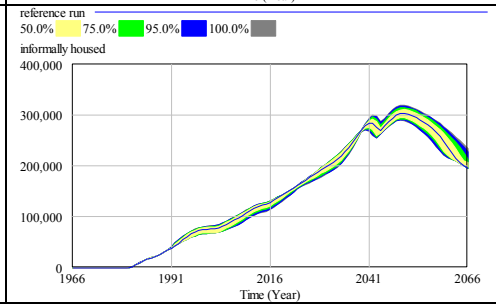
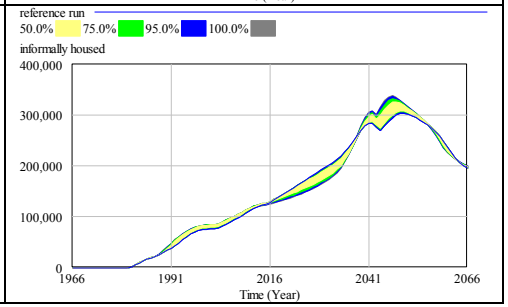
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

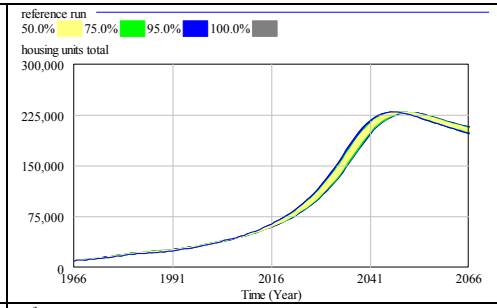
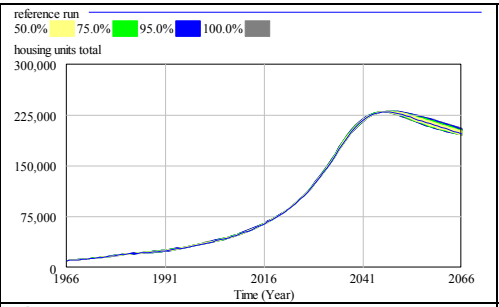
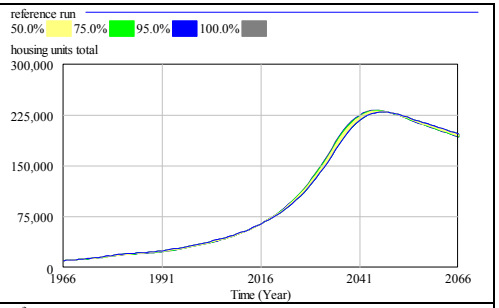
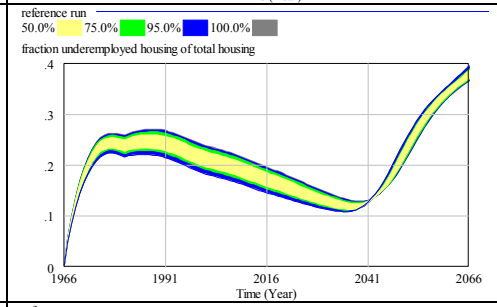
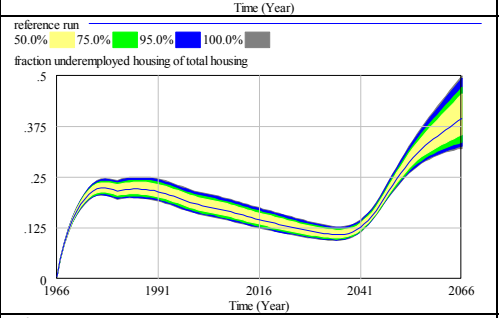
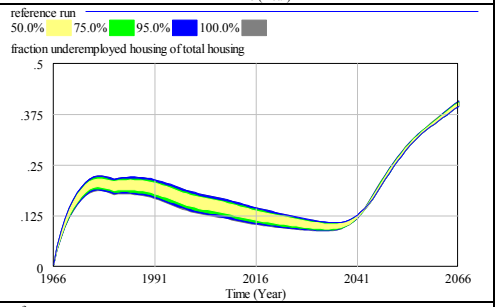
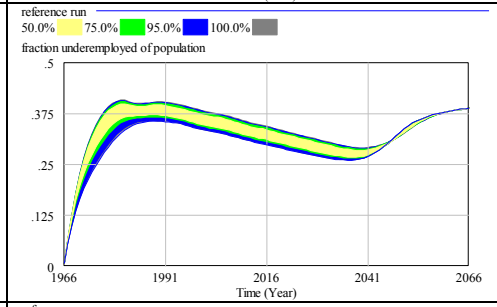
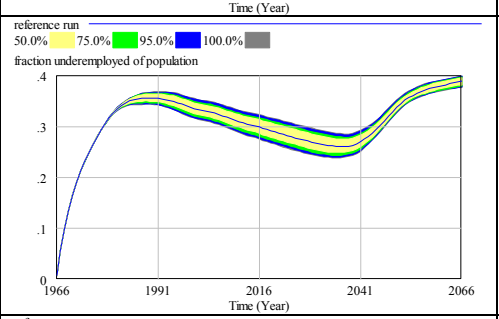
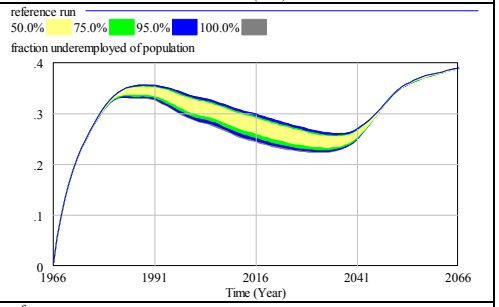
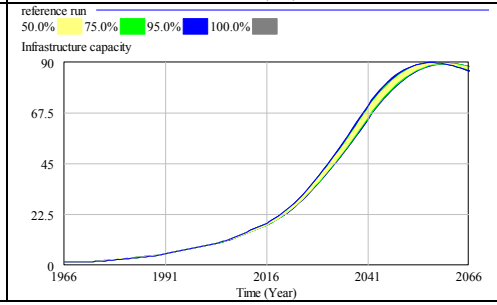
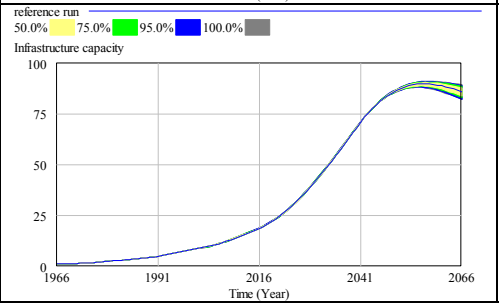
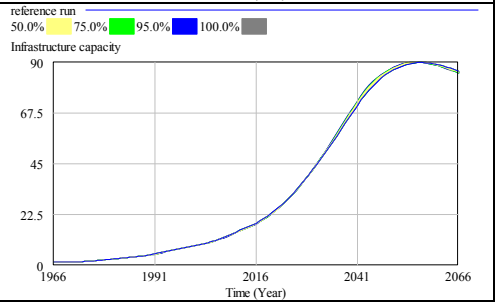
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

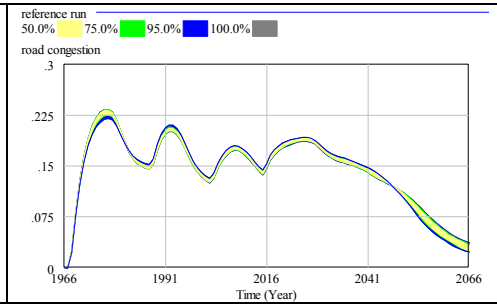
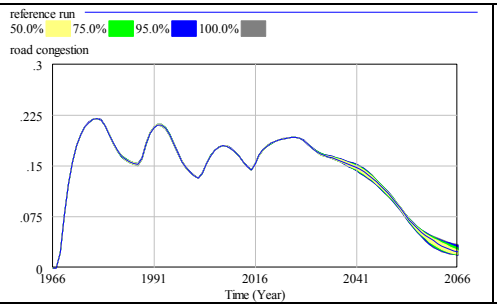
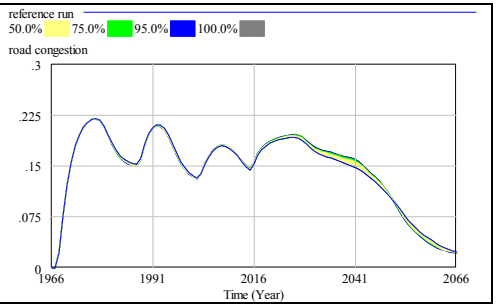
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

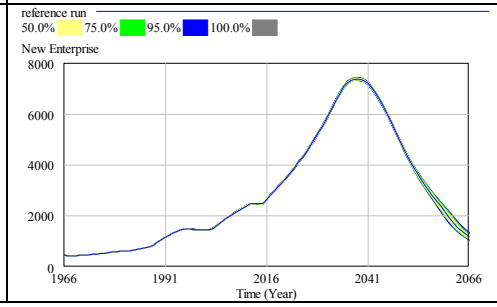
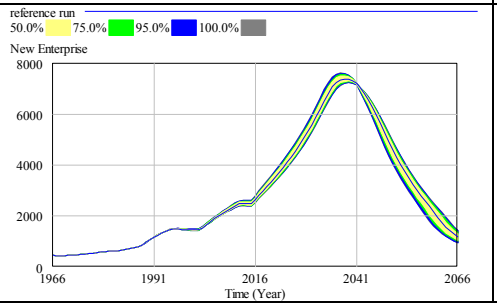
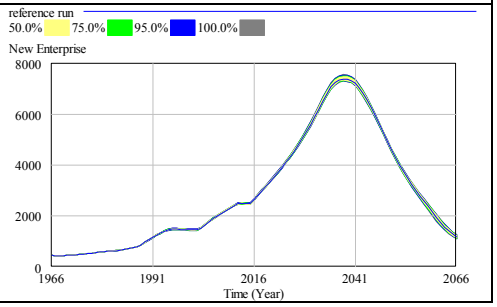
Parameter	low-cost housing program	slum housing demolition normal	slum housing demolition program
Units	Housing units/year	1/year	Housing units/year
Nominal value	0	0.02	0
Minimum plausible	0	0.01	0

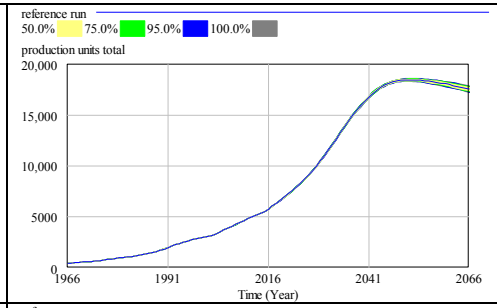
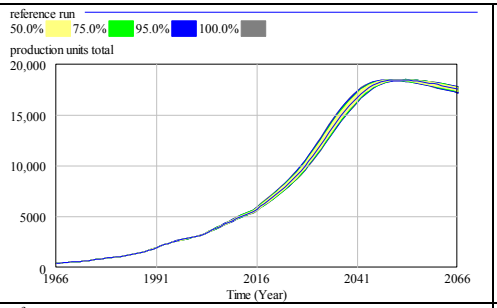
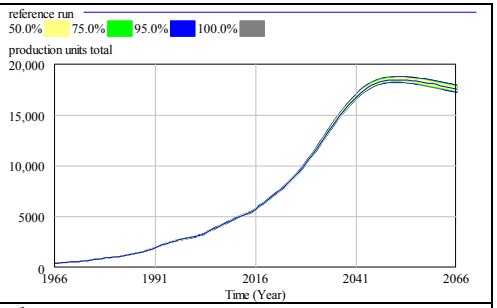
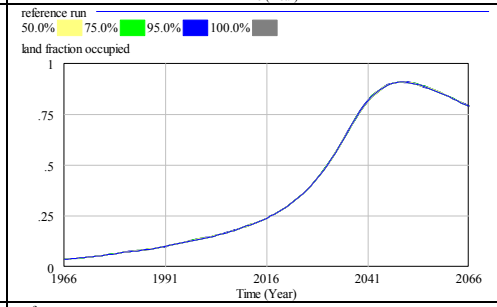
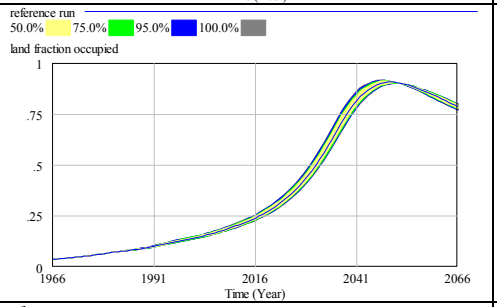
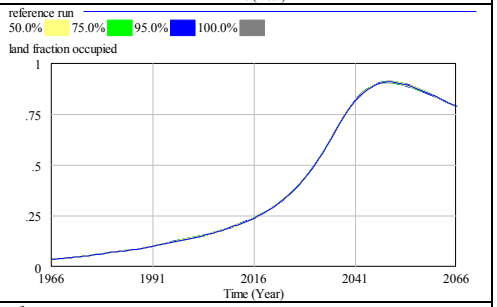
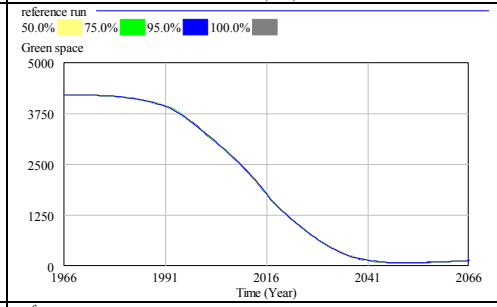
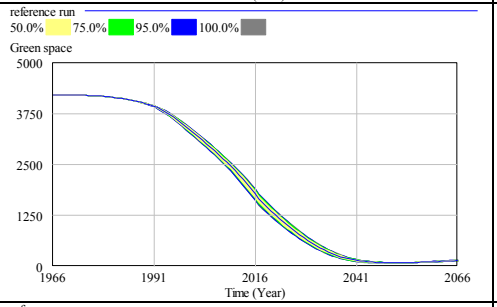
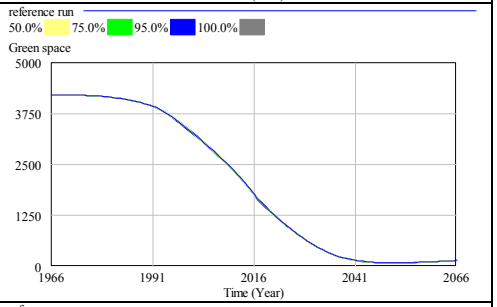
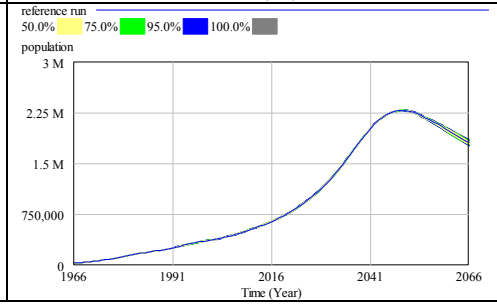
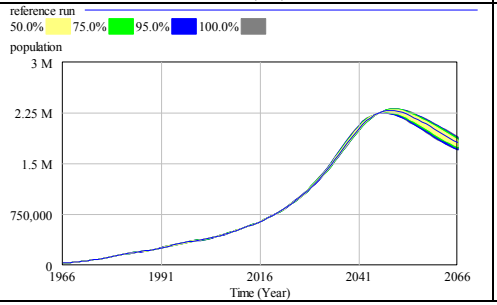
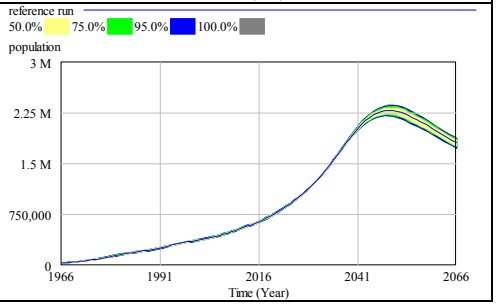
Maximum plausible	100	0.03	100 (or the amount of underemployed housing present)
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			

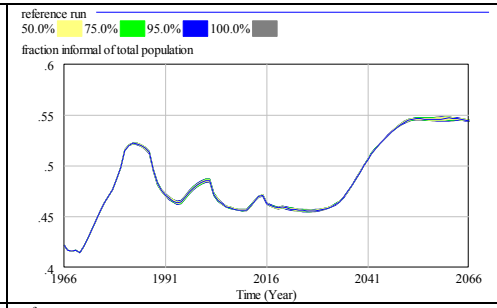
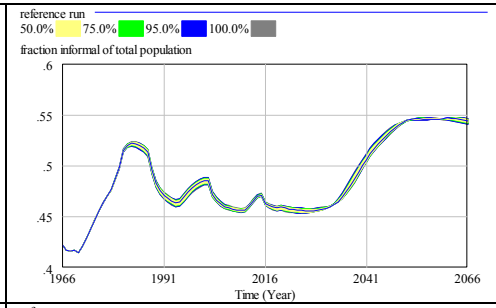
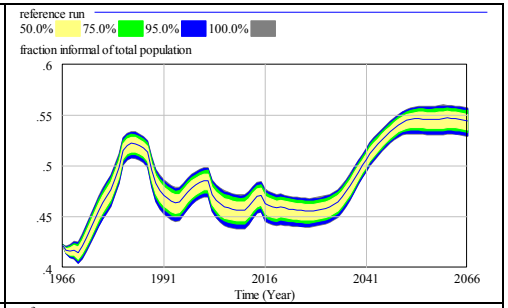
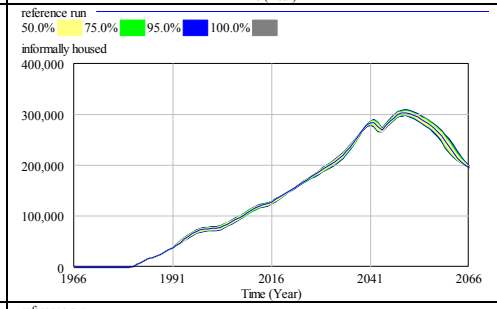
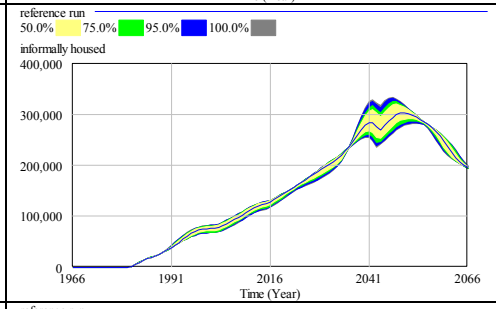
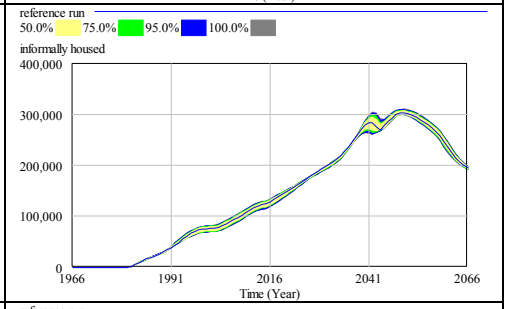
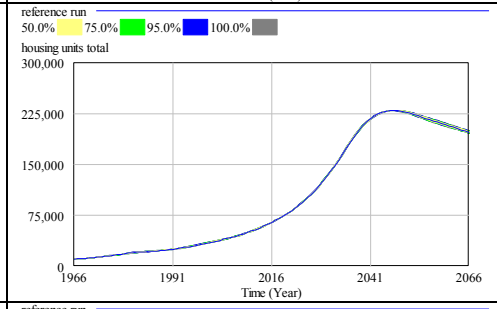
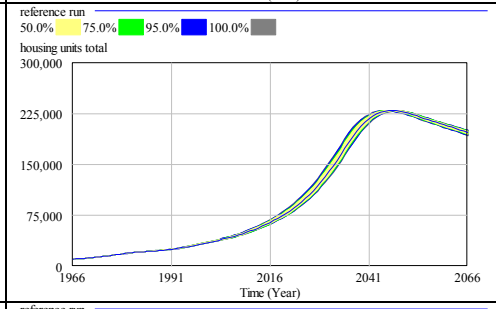
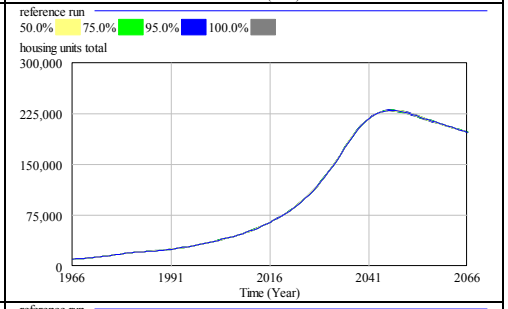
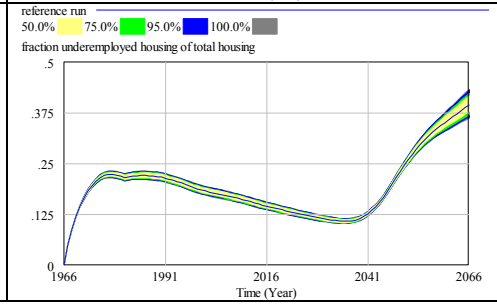
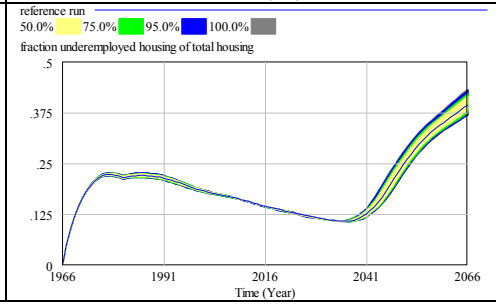
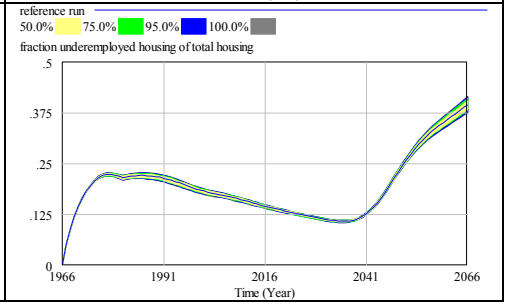
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			

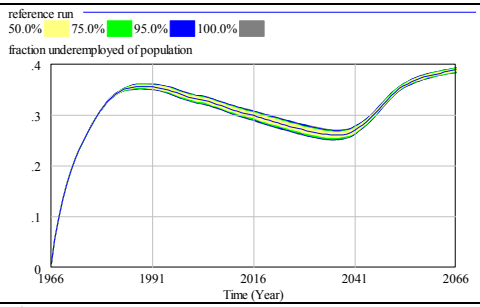
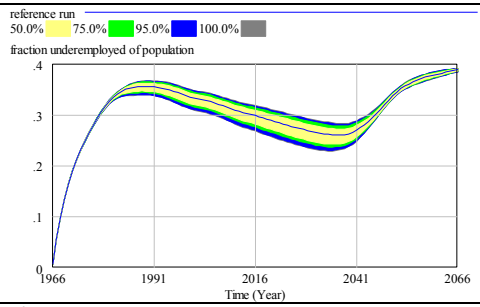
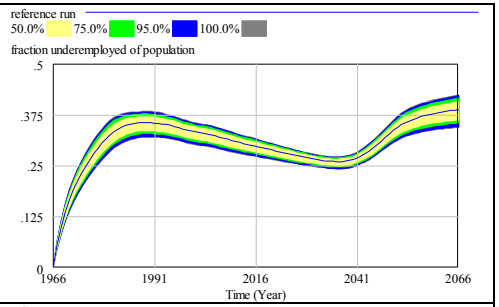
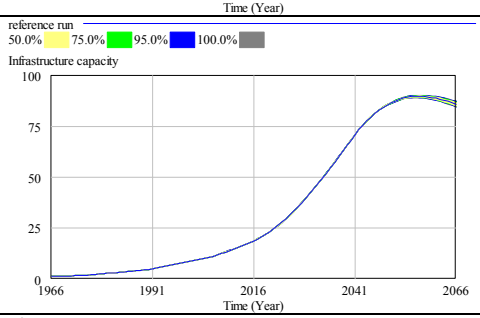
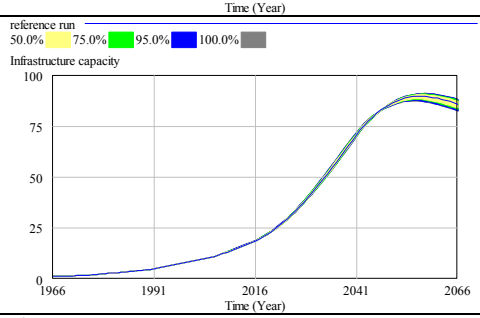
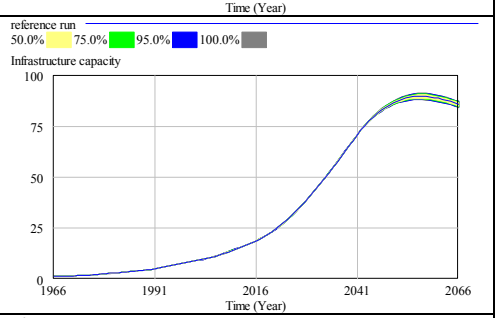
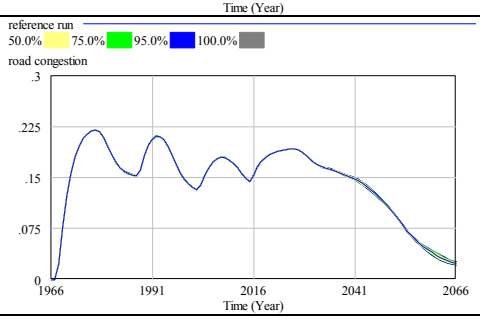
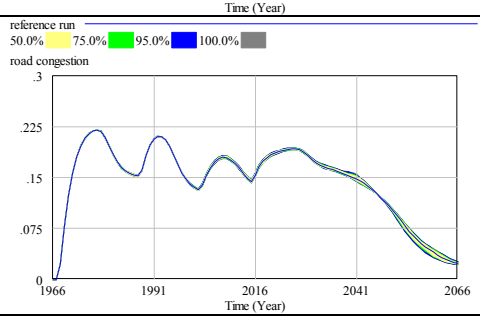
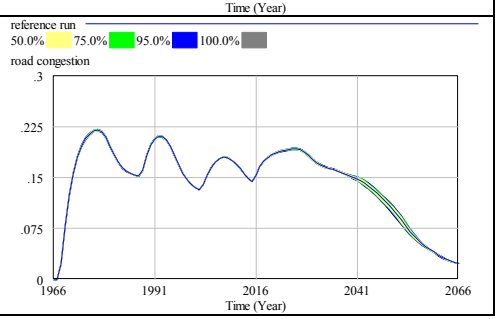
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			

Sensitivity plot: road congestion			

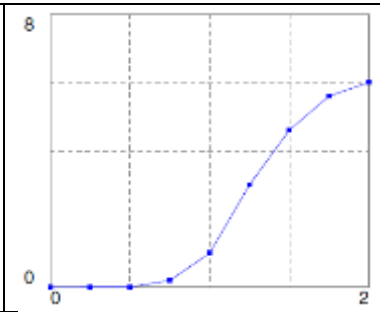
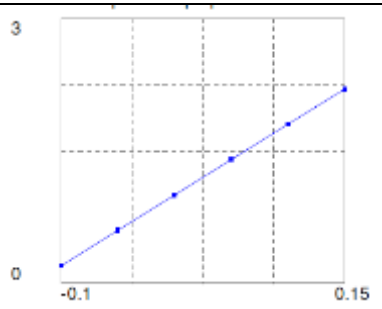
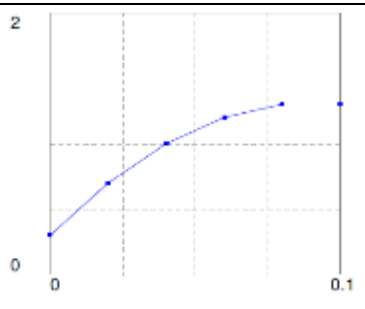
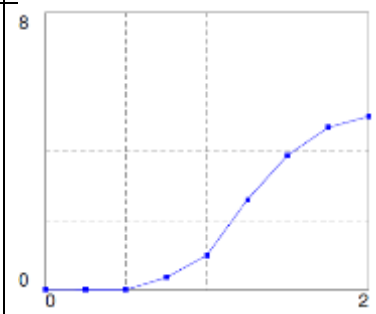
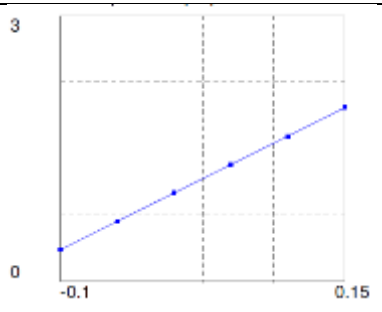
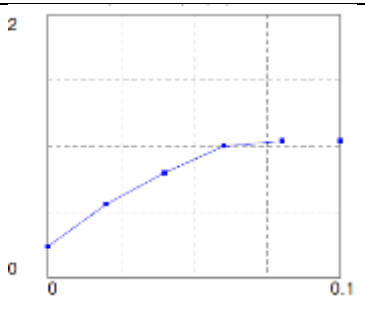
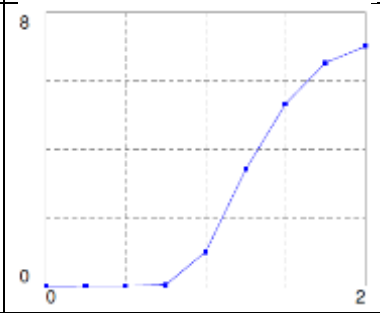
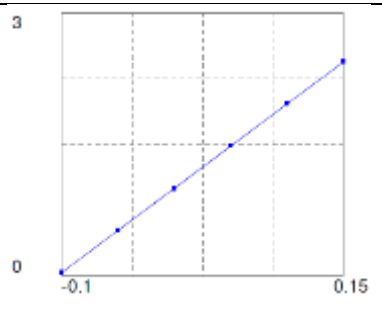
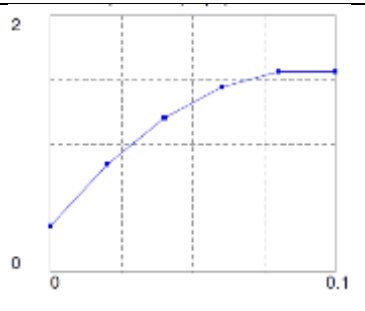
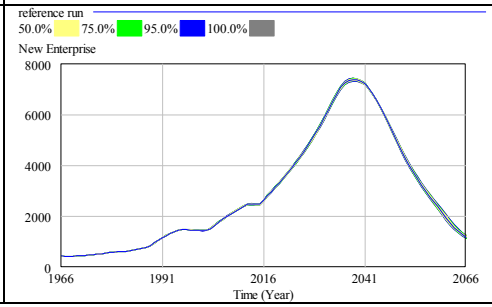
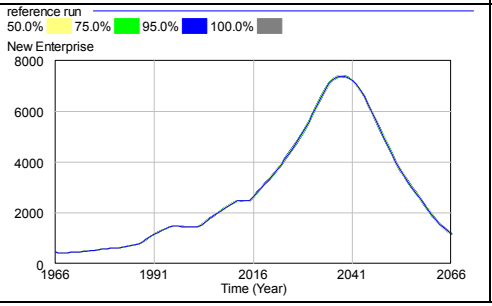
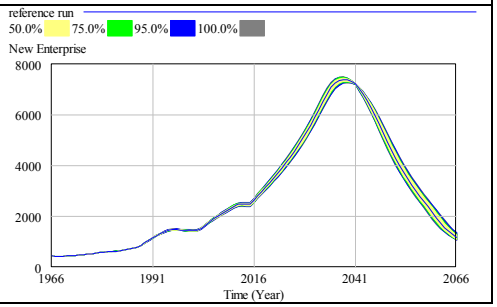
Parameter	slum housing demolition factor	underemployed housing population density	underemployed family size
Units	-	Person/housing unit	Person/worker
Nominal value	1	18	3
Minimum plausible	0.8	14.4	2.4
Maximum plausible	1.2	21.6	3.6
Sensitivity plot: New Enterprise			

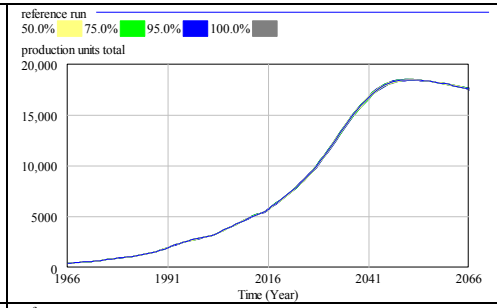
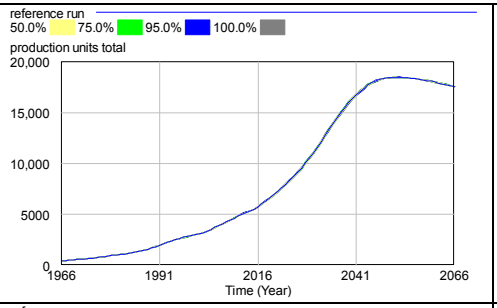
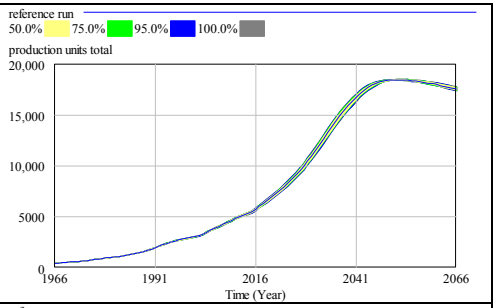
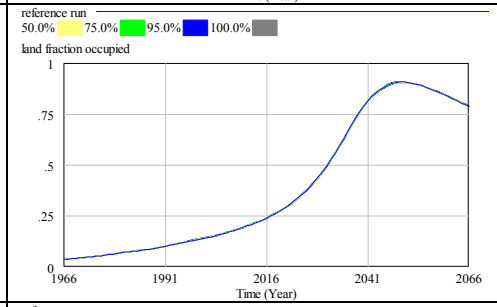
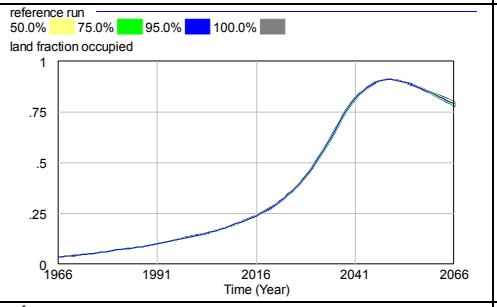
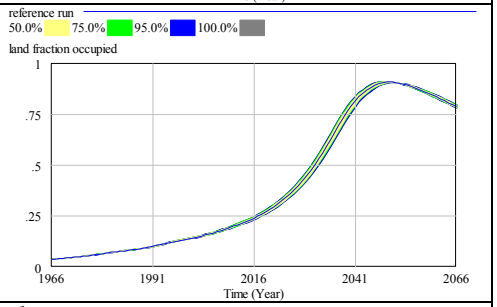
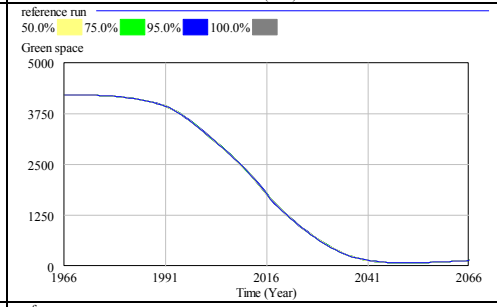
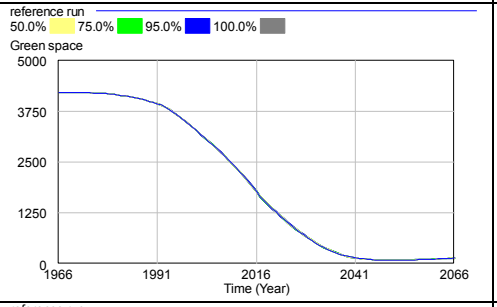
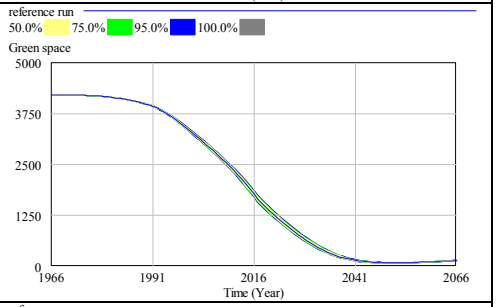
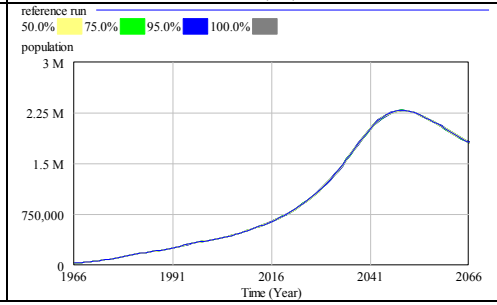
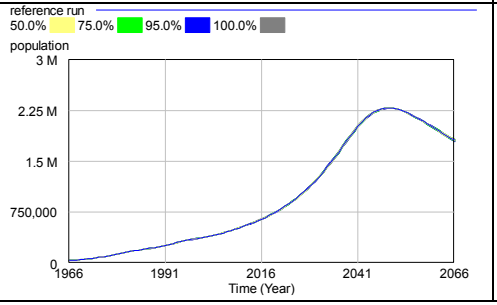
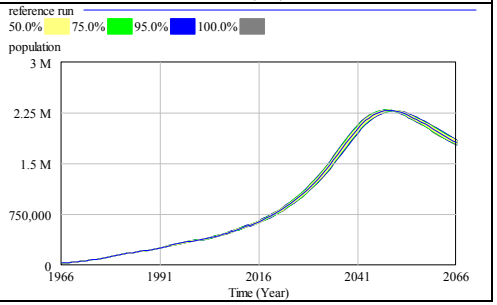
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

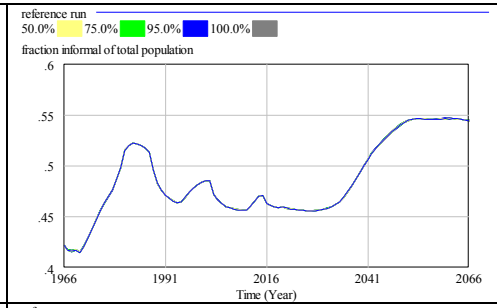
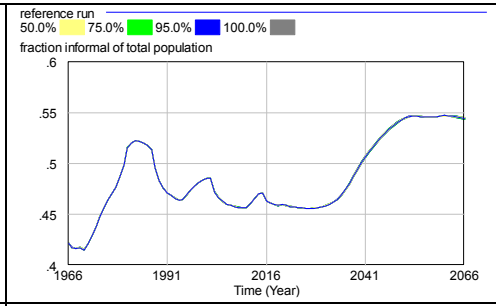
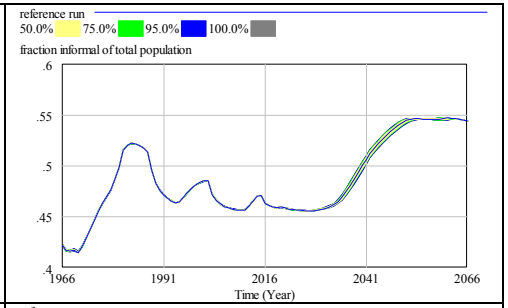
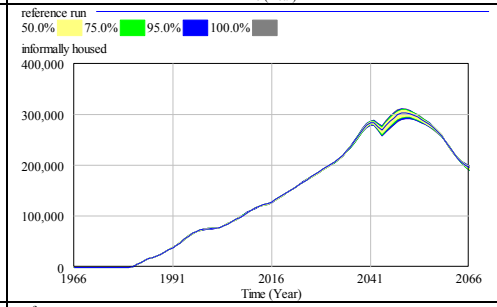
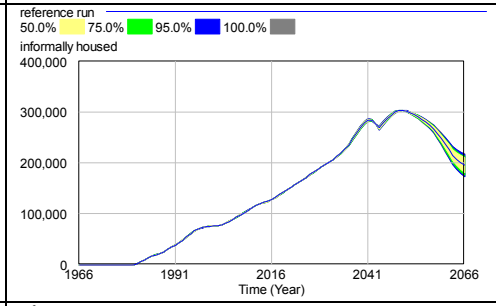
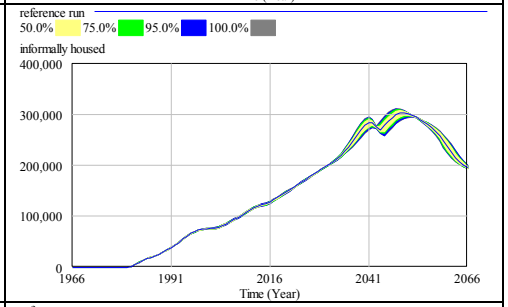
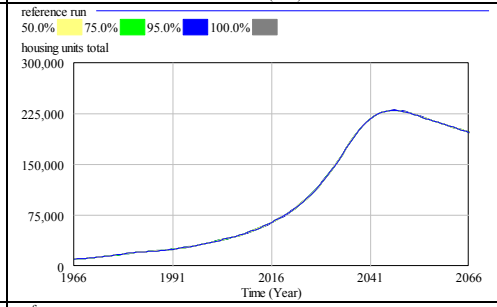
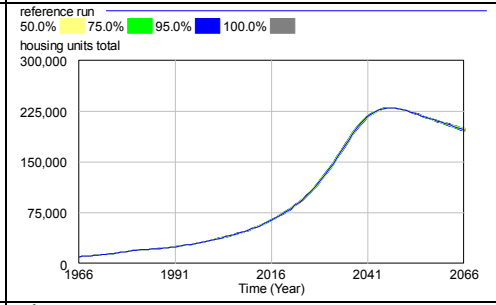
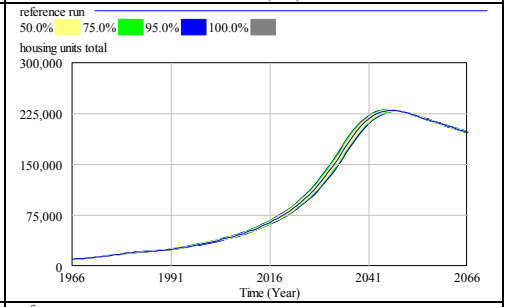
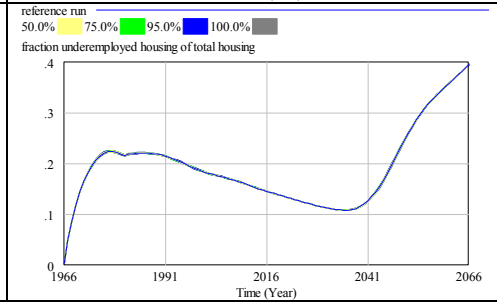
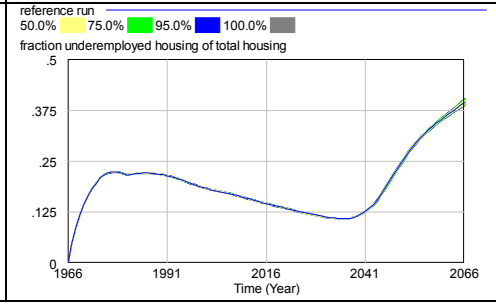
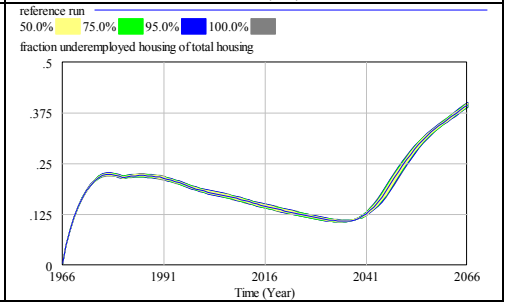
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

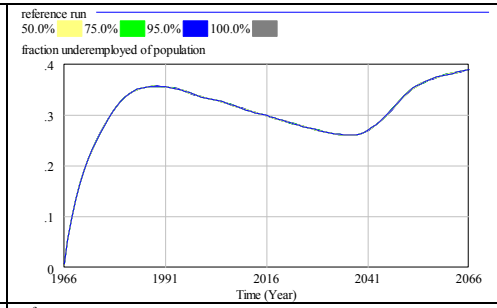
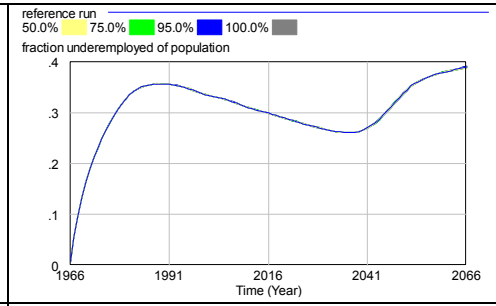
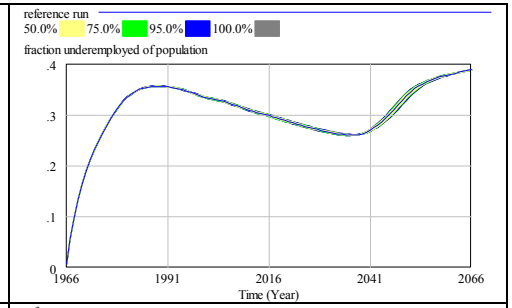
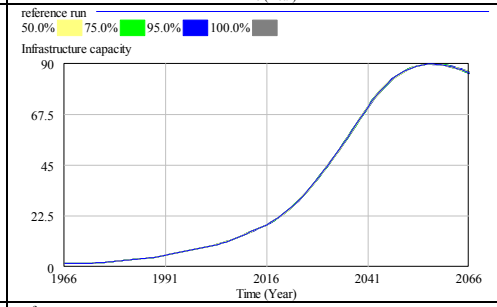
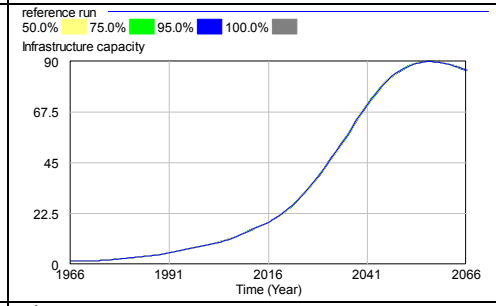
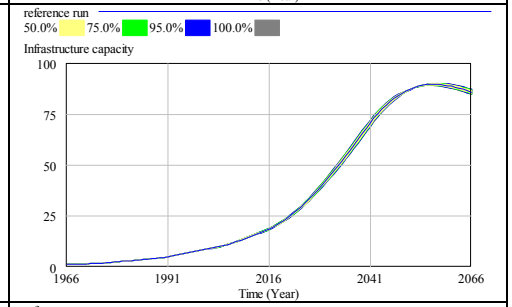
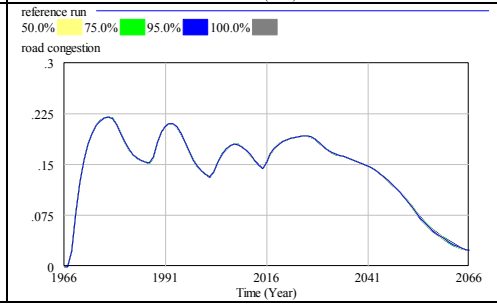
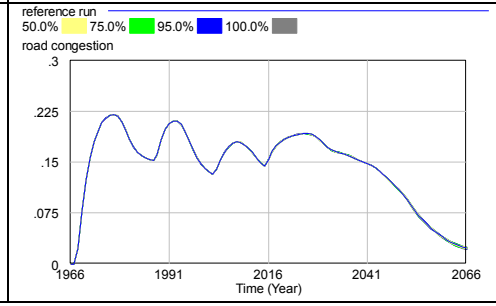
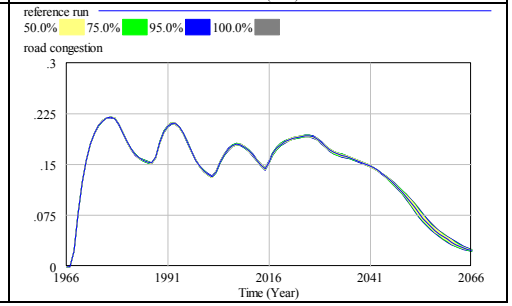
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

Parameter	premium housing adequacy multiplier (lookup)	premium housing enterprise multiplier (lookup)	premium housing population multiplier
Units	-	-	-

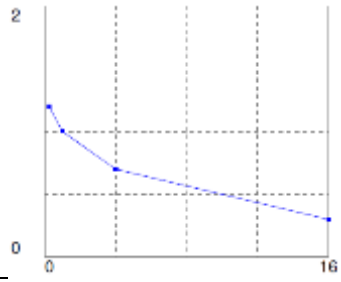
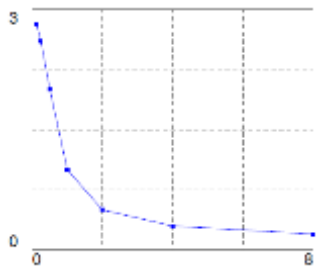
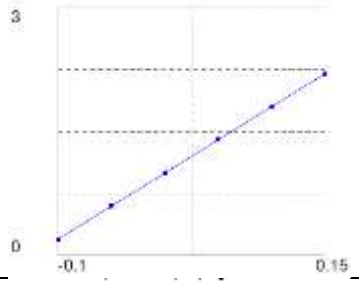
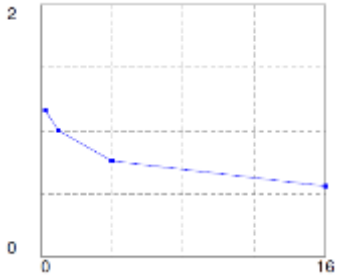
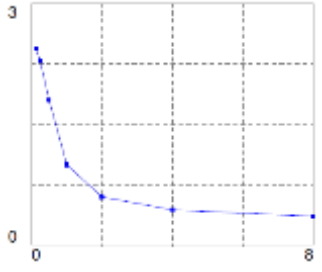
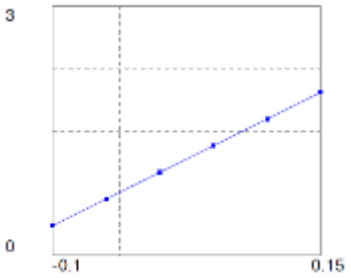
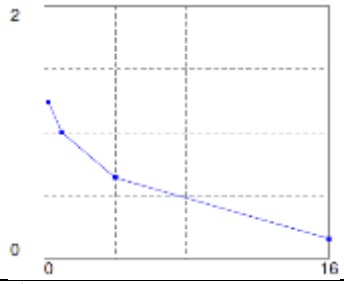
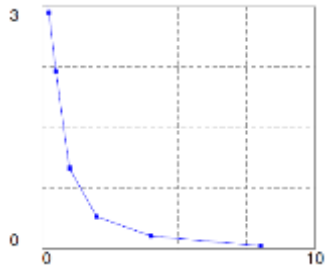
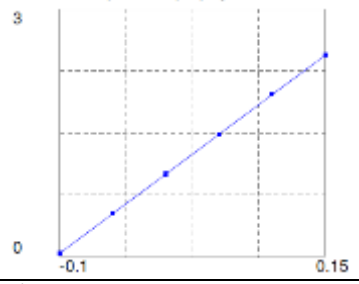
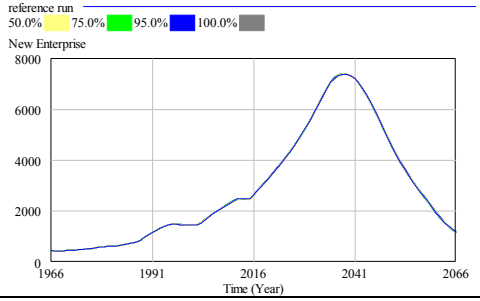
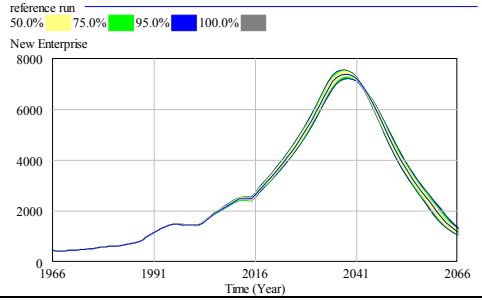
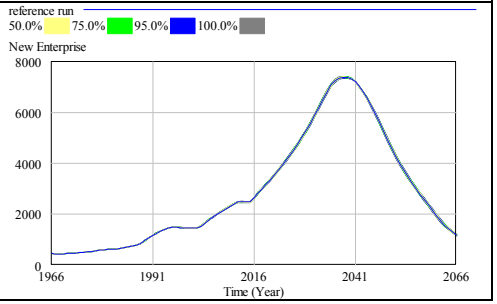
Nominal value			
Minimum plausible			
Maximum plausible			
Sensitivity plot: New Enterprise			

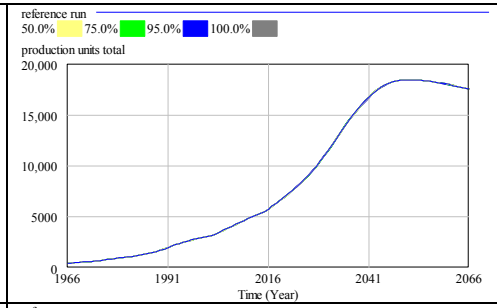
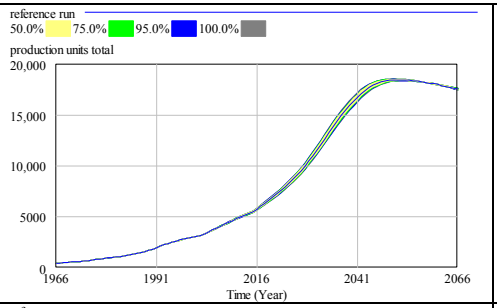
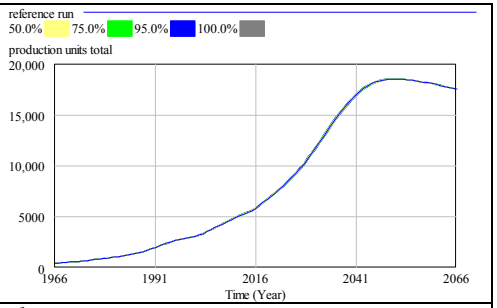
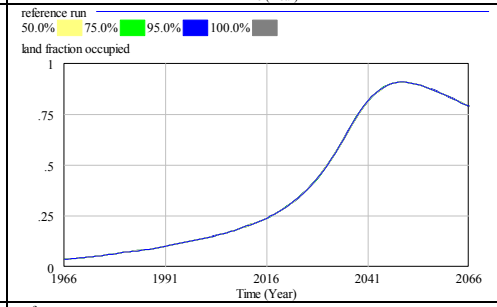
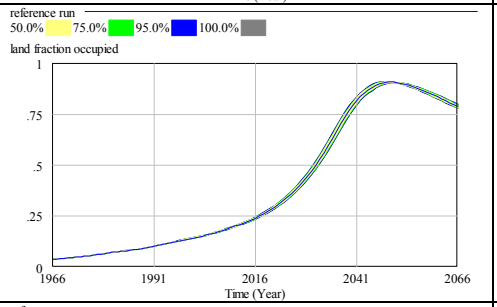
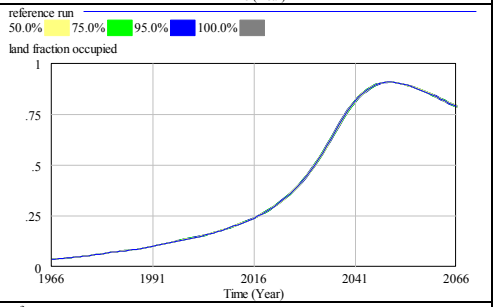
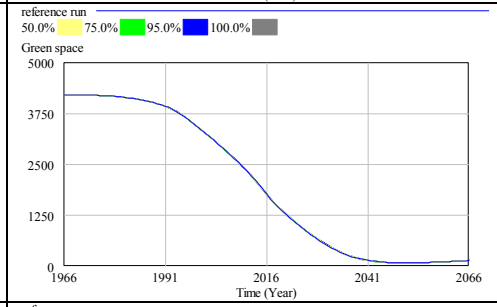
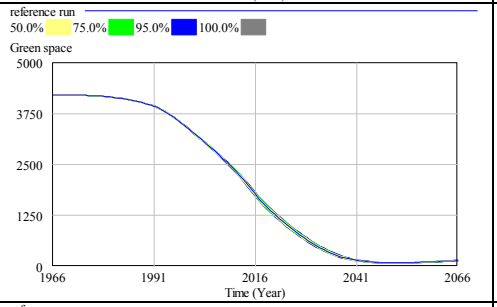
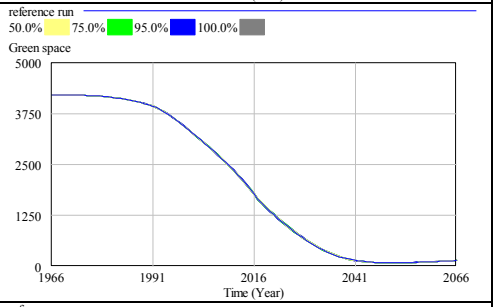
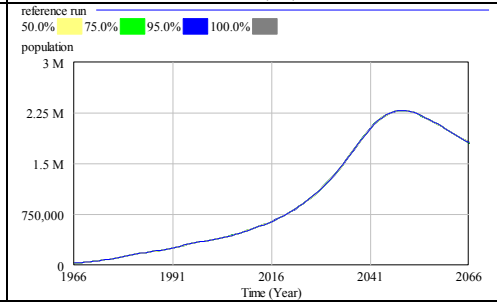
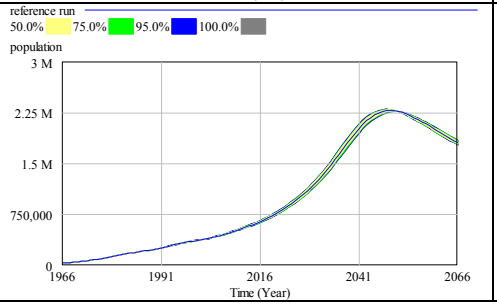
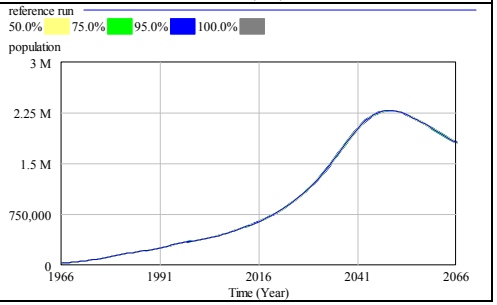
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

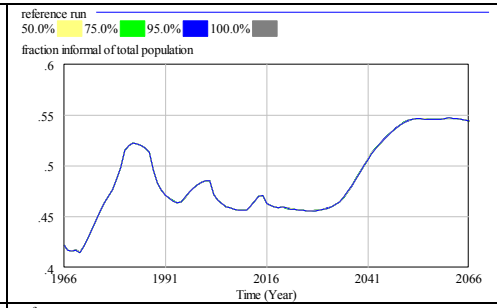
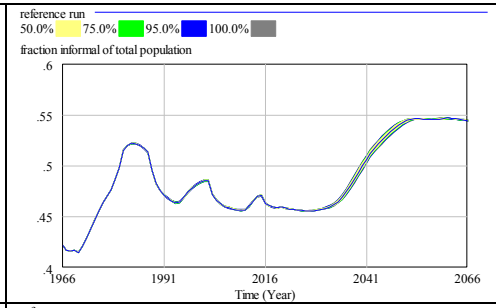
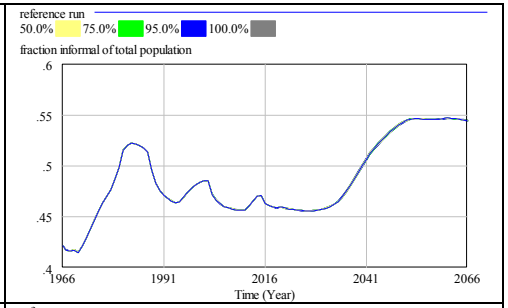
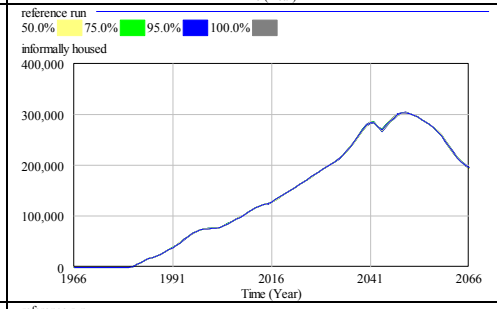
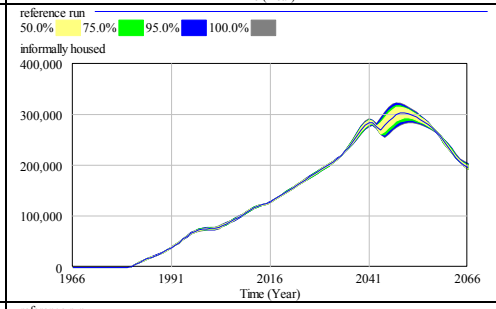
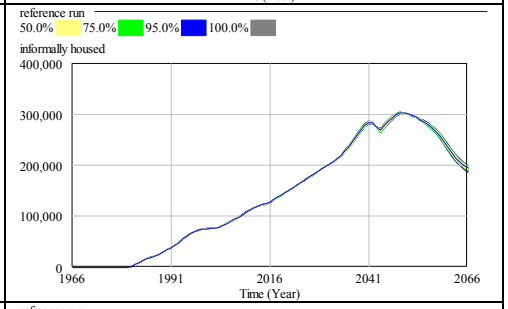
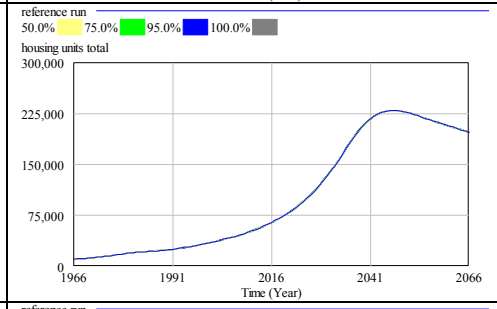
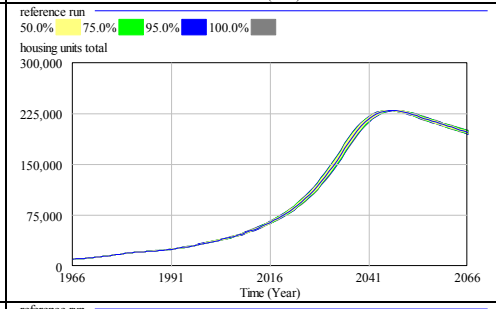
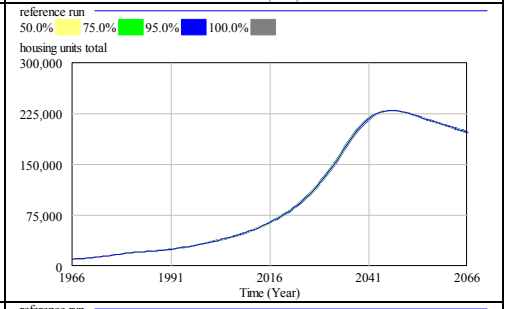
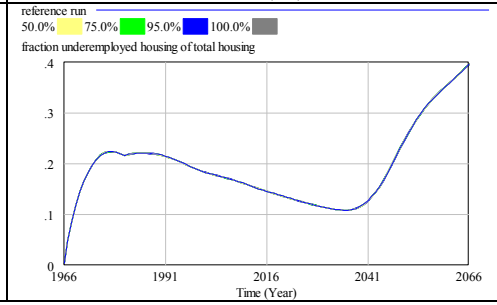
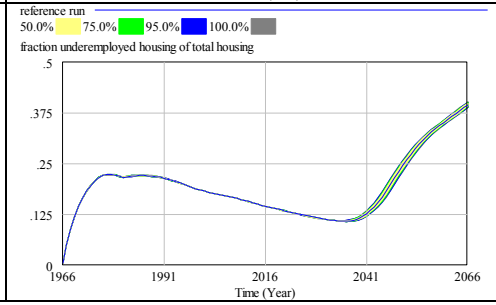
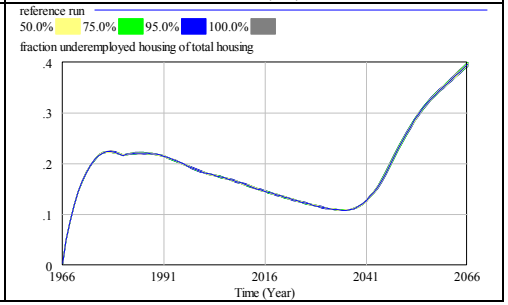
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

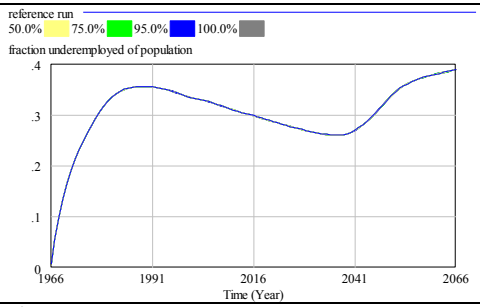
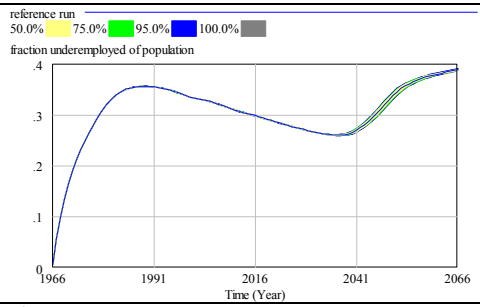
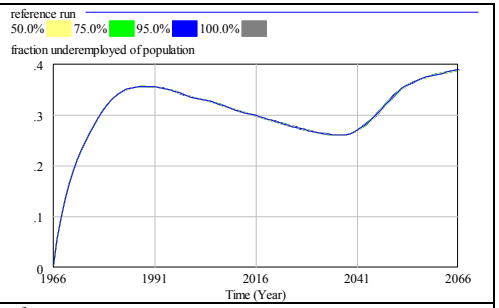
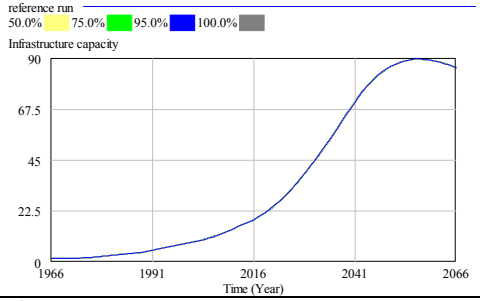
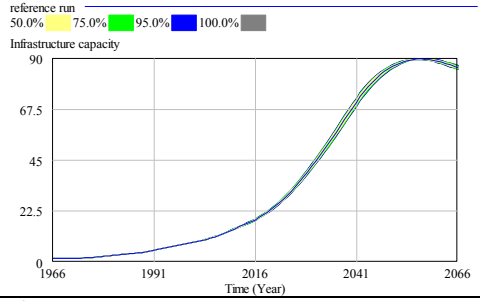
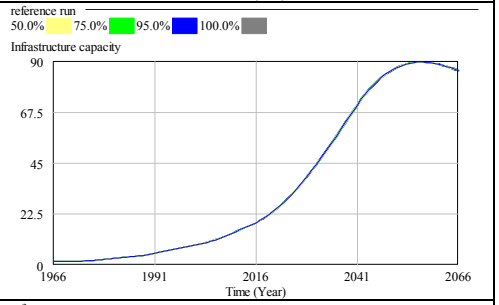
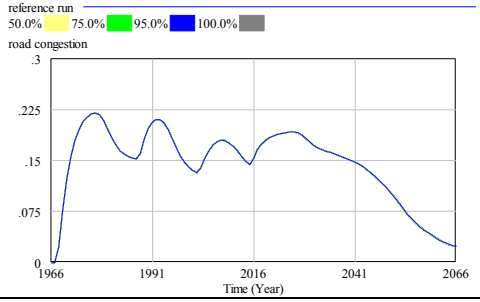
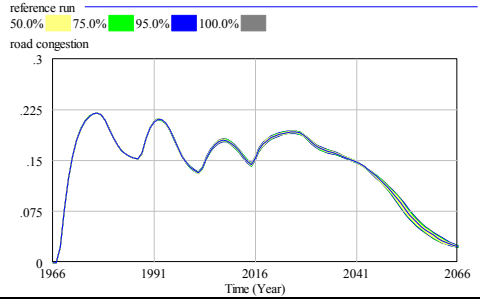
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

Parameter	premium housing tax multiplier	premium housing obsolescence multiplier (lookup)	Premium housing growth multiplier (lookup)
Units	-	-	-

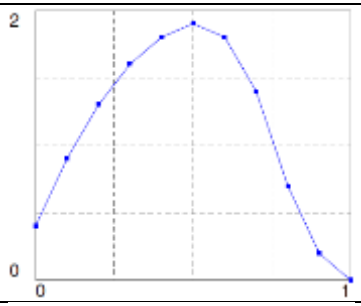
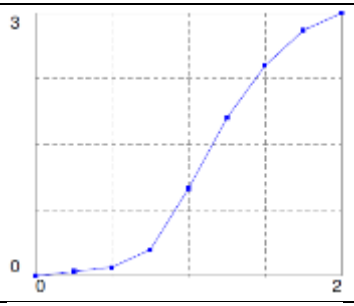
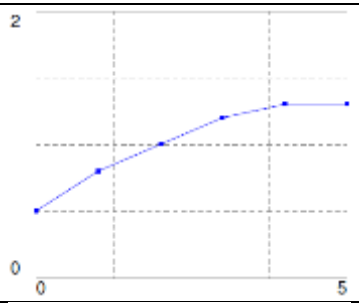
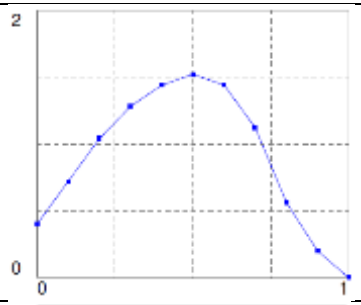
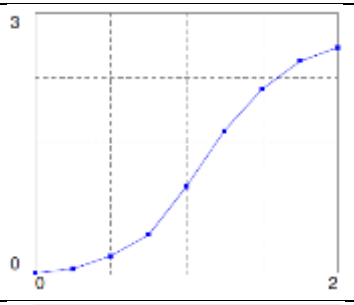
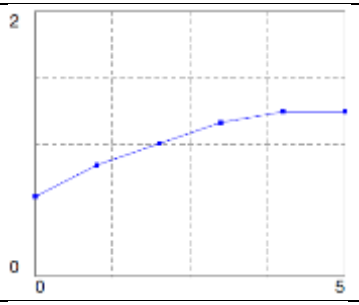
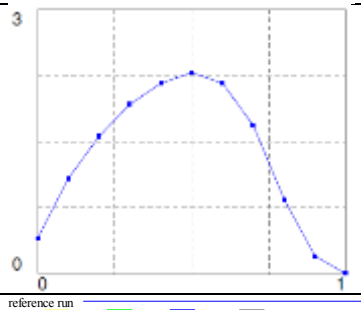
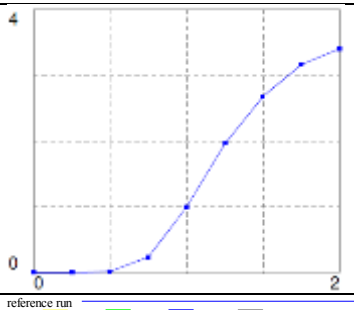
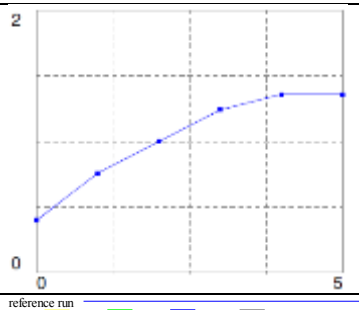
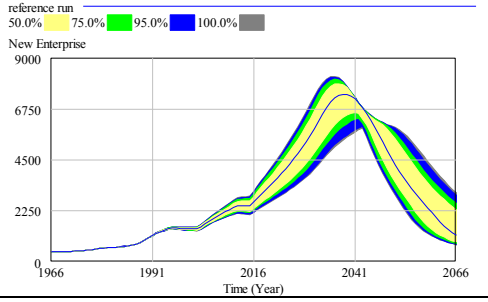
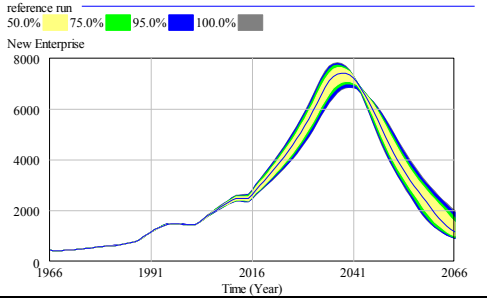
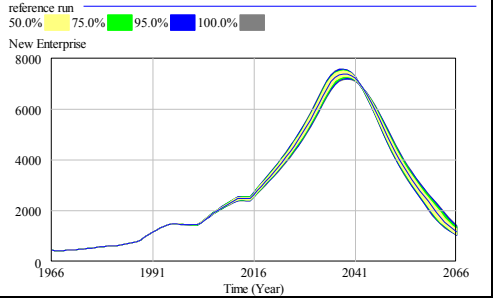
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Maximum plausible			
Sensitivity plot: New Enterprise			

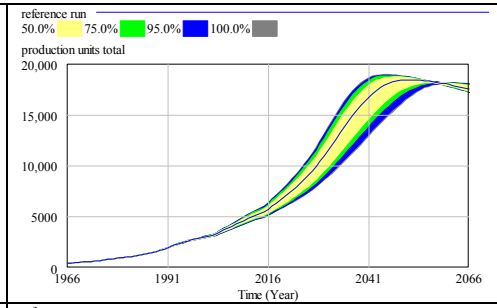
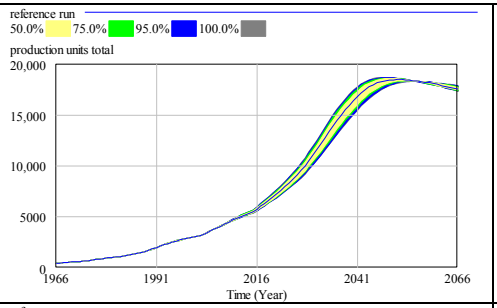
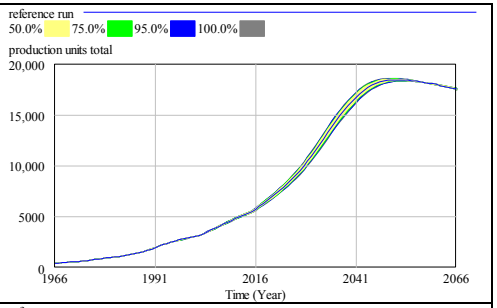
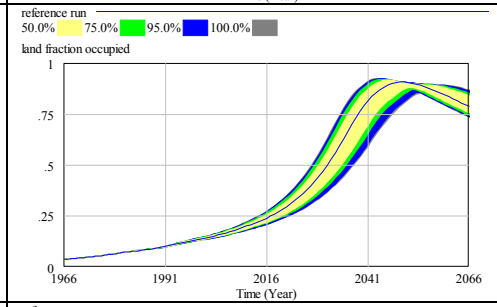
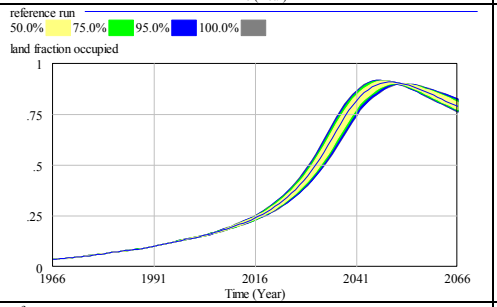
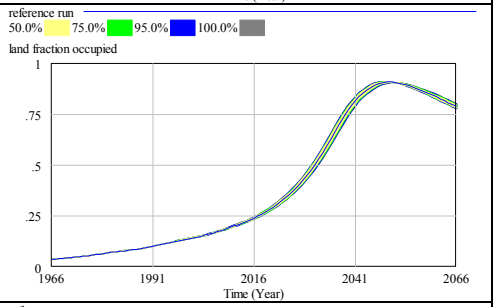
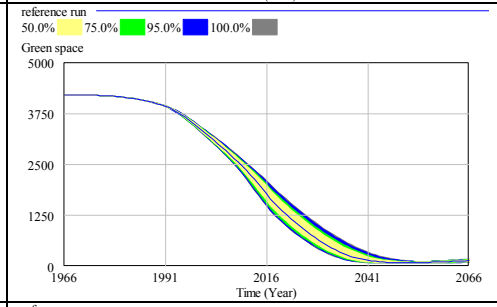
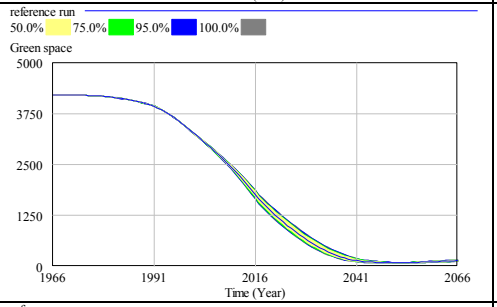
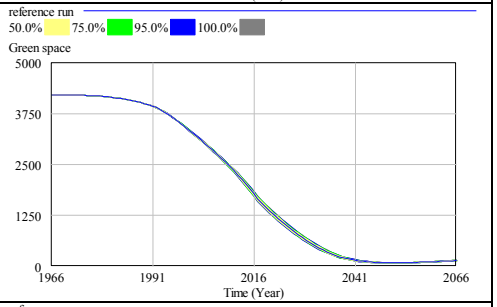
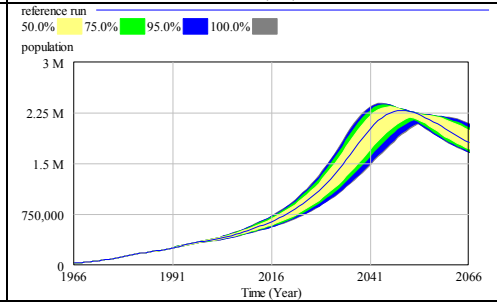
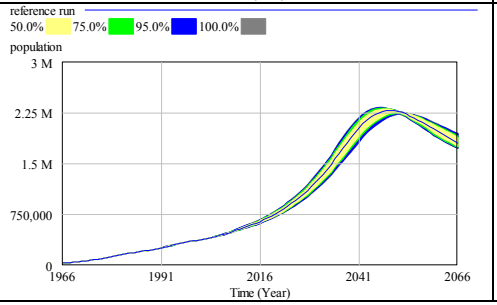
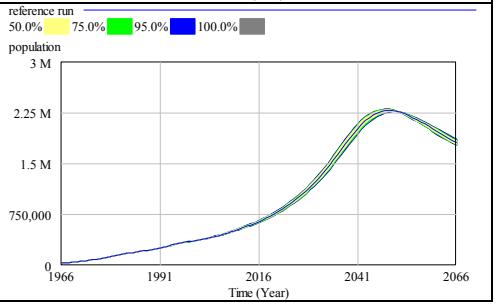
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

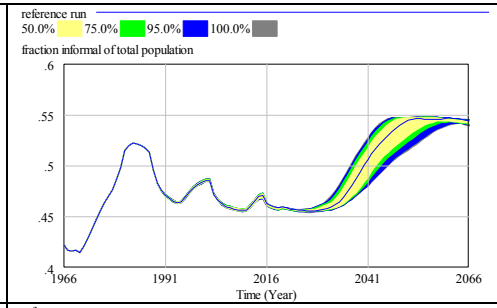
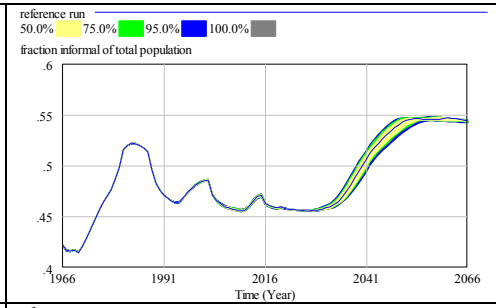
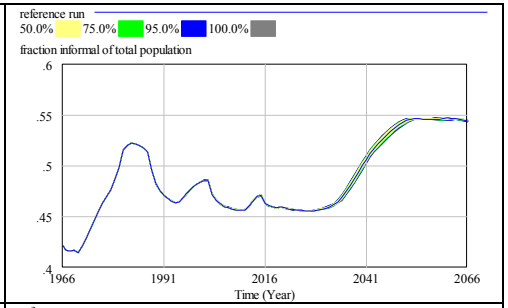
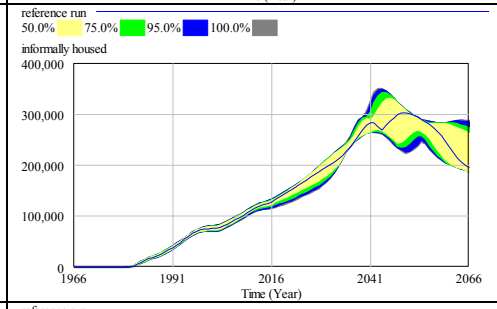
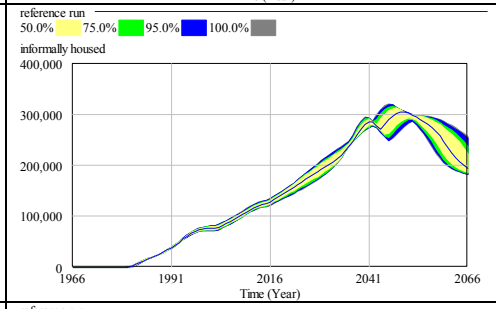
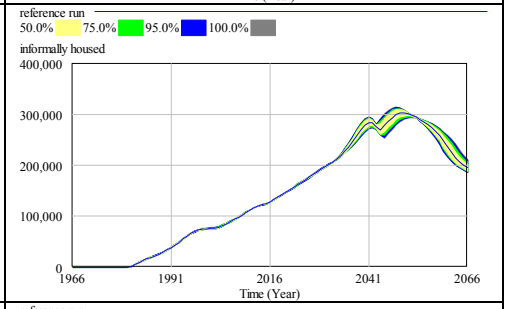
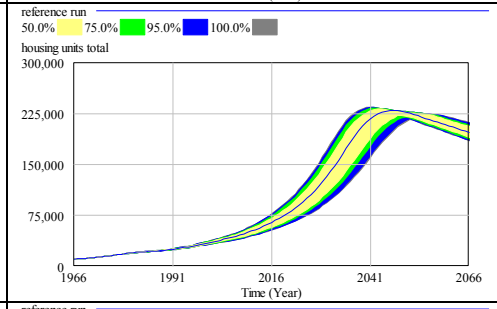
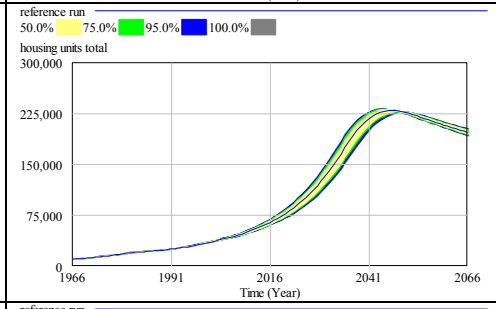
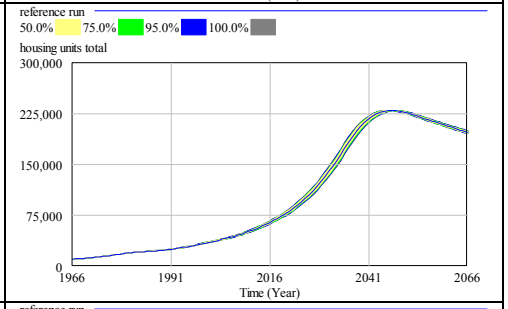
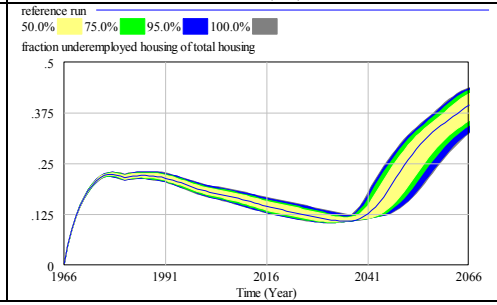
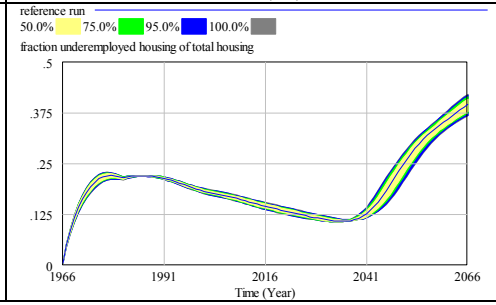
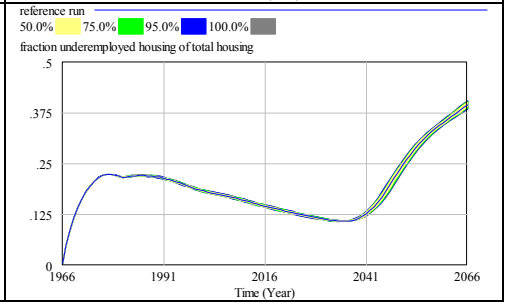
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

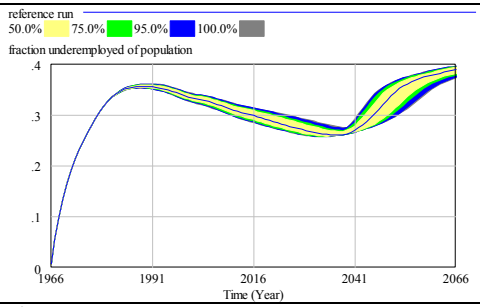
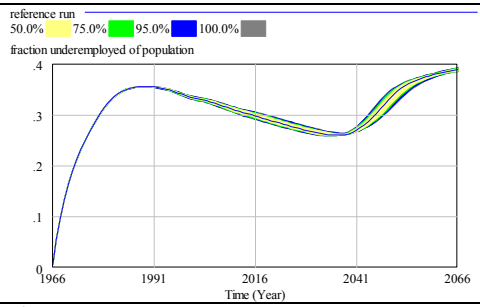
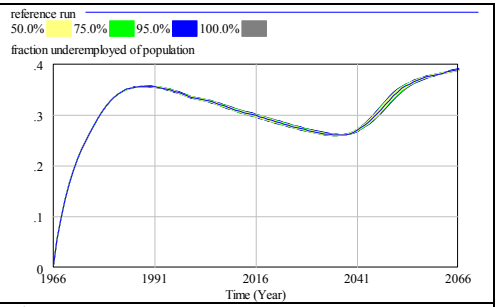
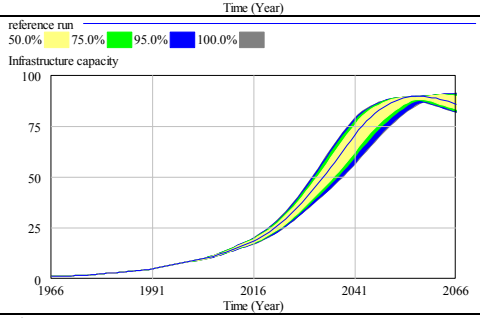
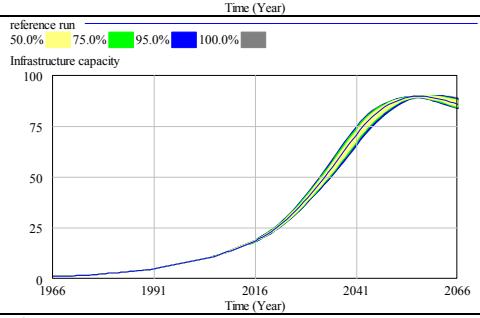
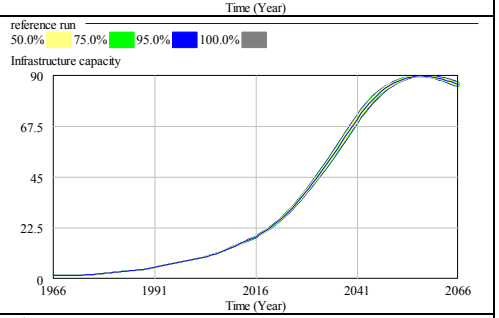
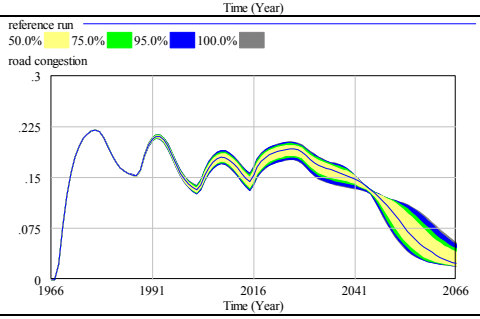
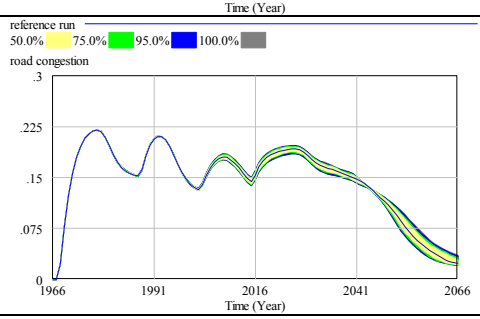
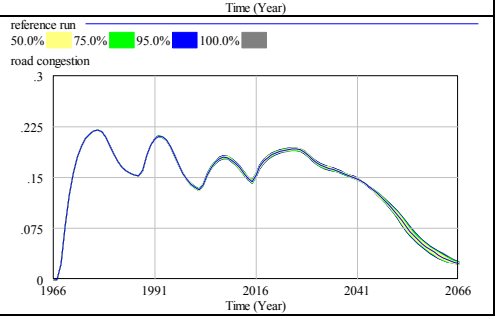
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

Parameter	worker housing land multiplier (lookup)	worker housing adequacy multiplier (lookup)	worker housing underemployed multiplier (lookup)
Units	-	-	-

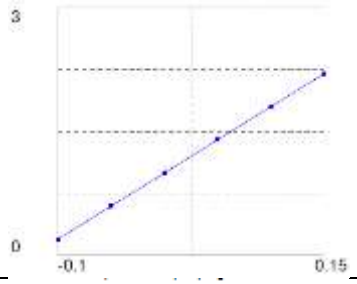
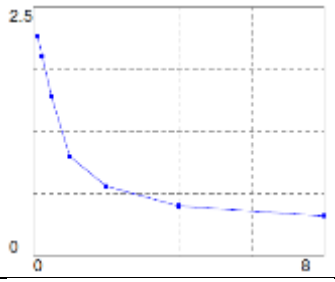
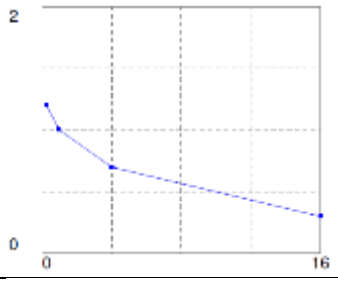
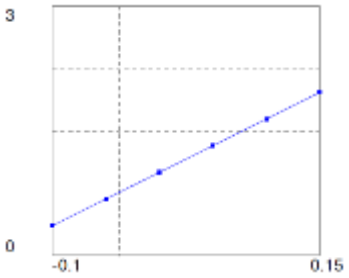
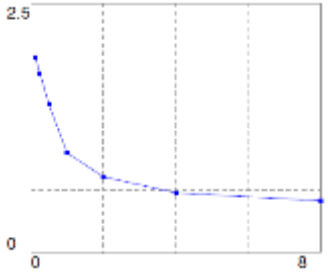
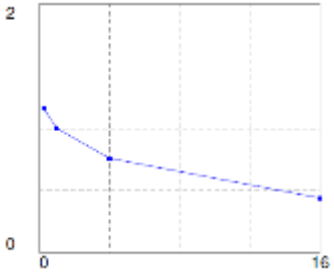
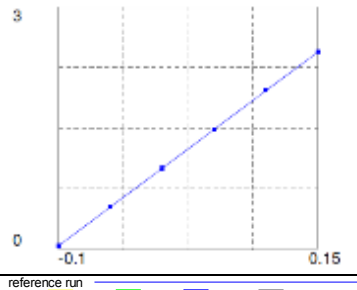
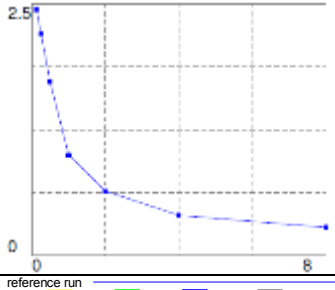
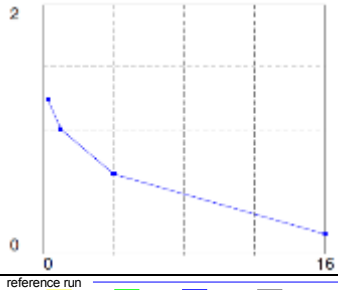
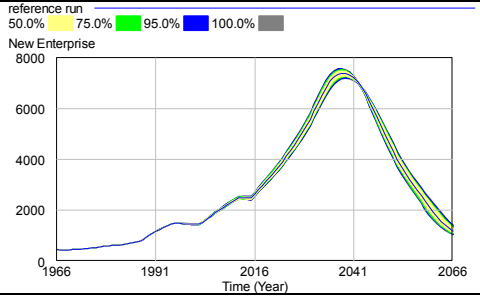
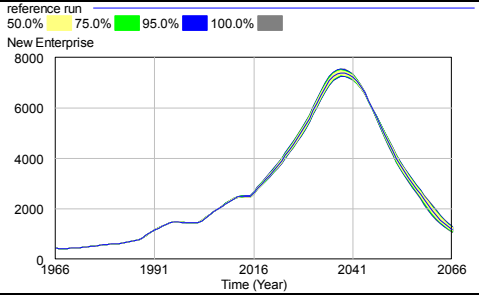
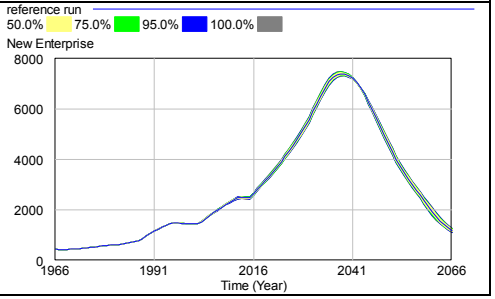
Nominal value			
Minimum plausible			
Maximum plausible			
Sensitivity plot: New Enterprise			

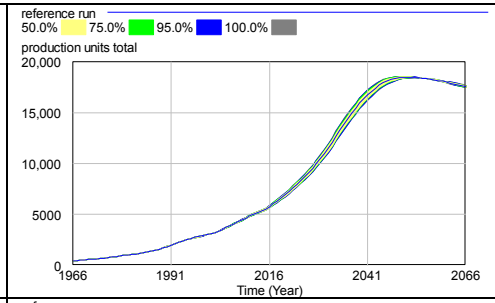
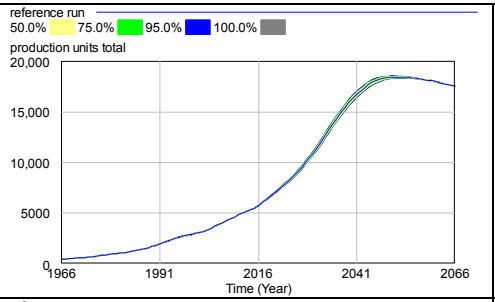
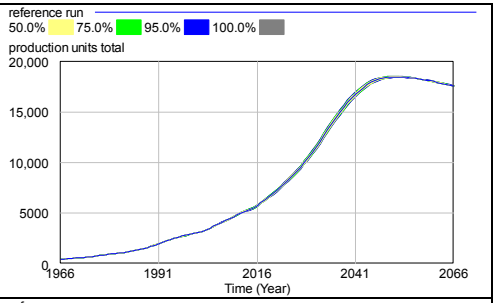
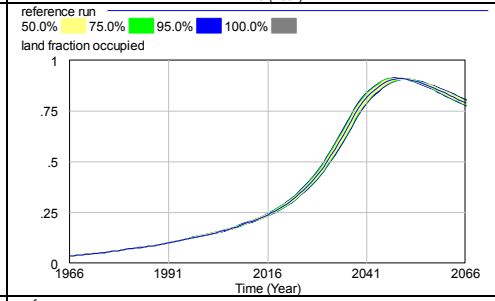
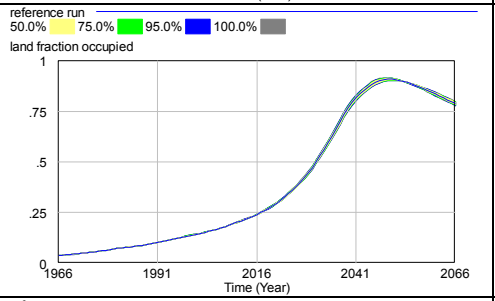
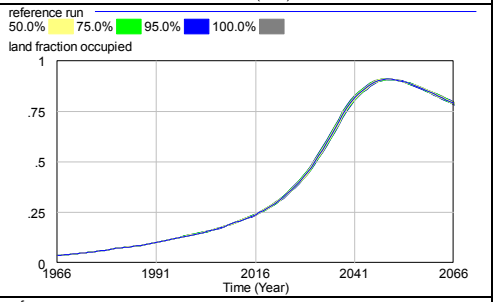
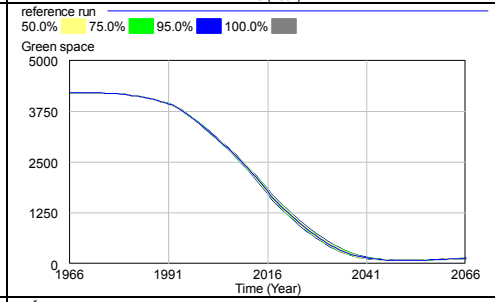
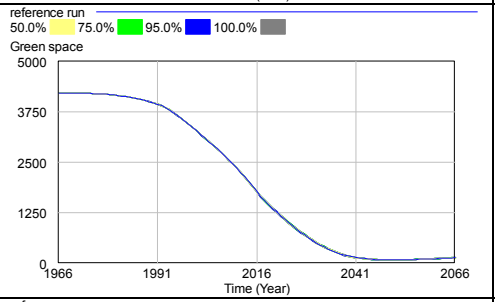
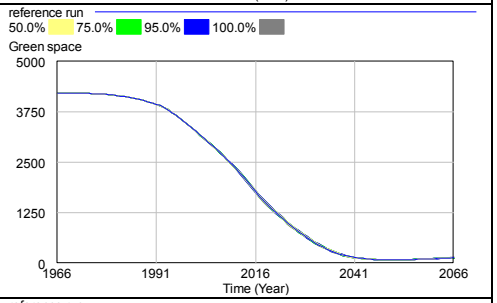
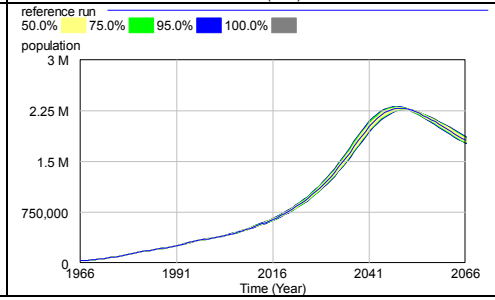
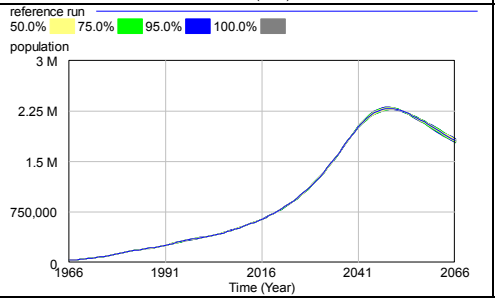
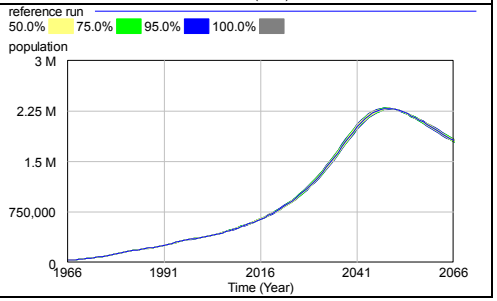
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

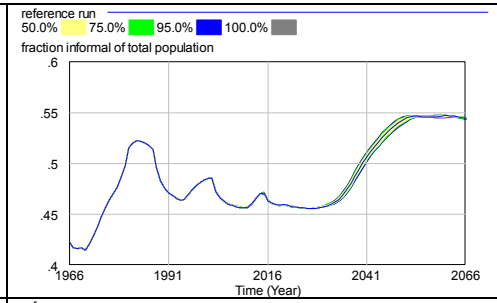
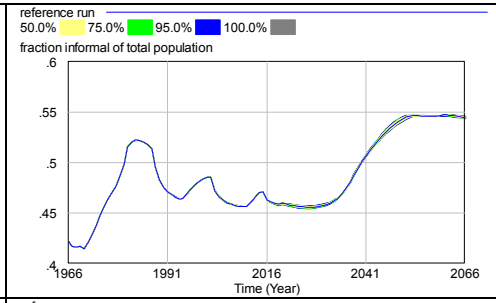
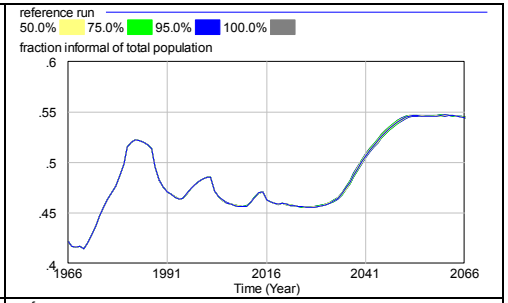
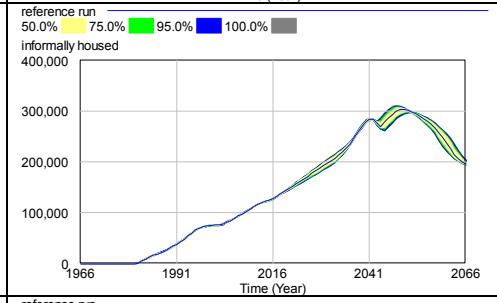
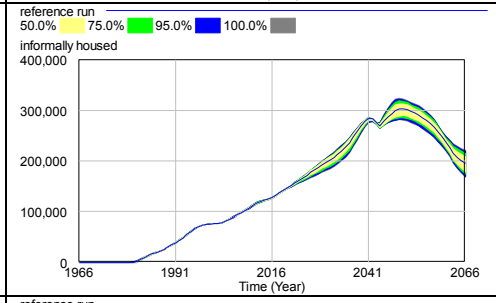
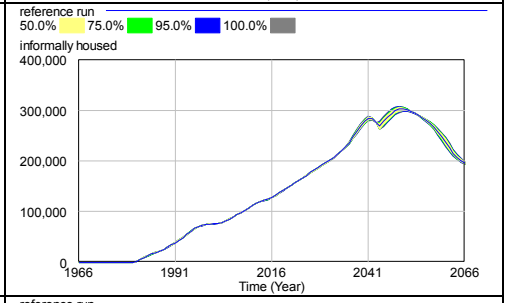
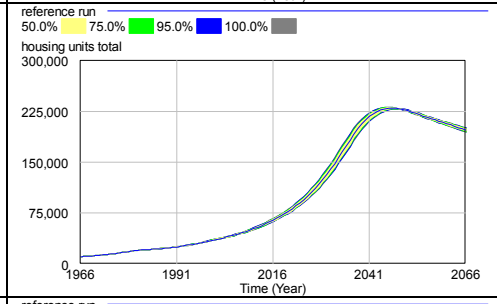
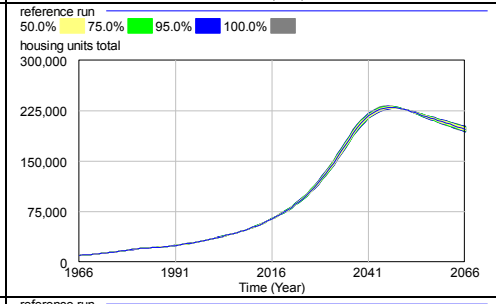
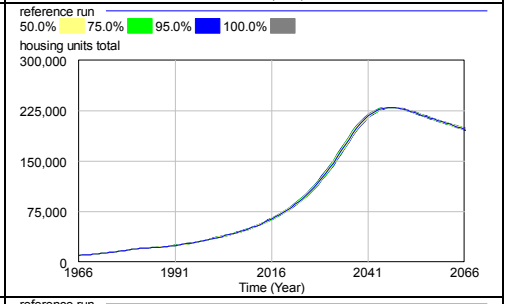
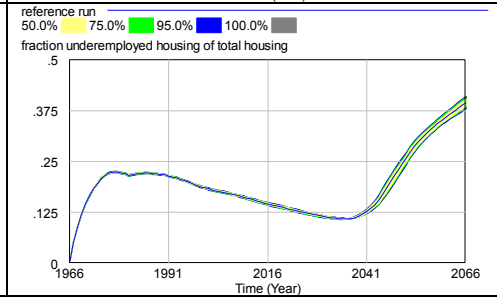
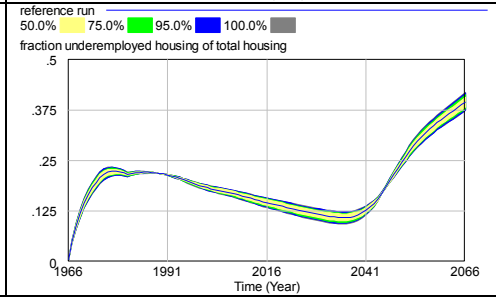
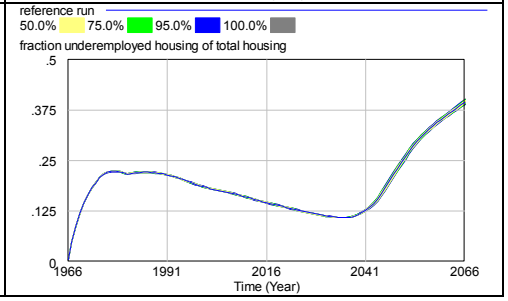
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

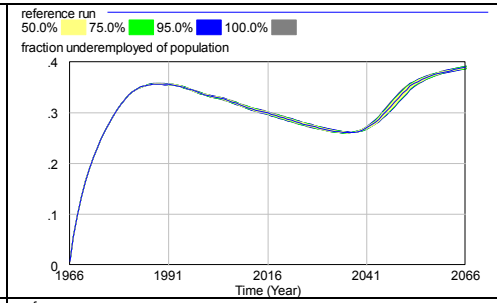
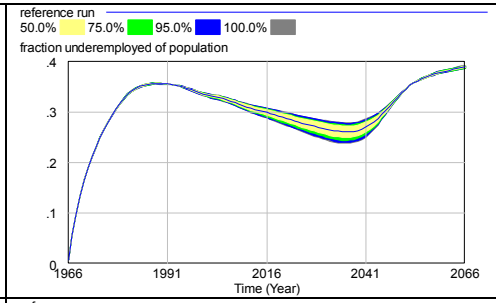
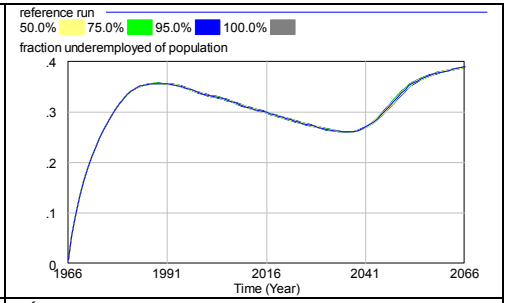
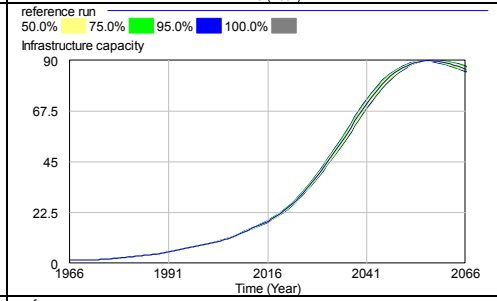
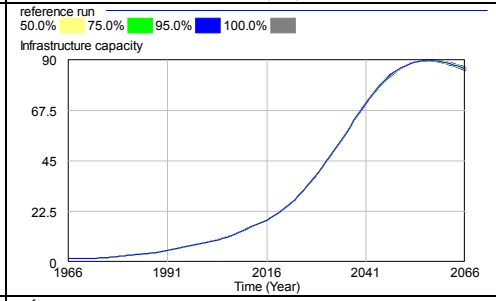
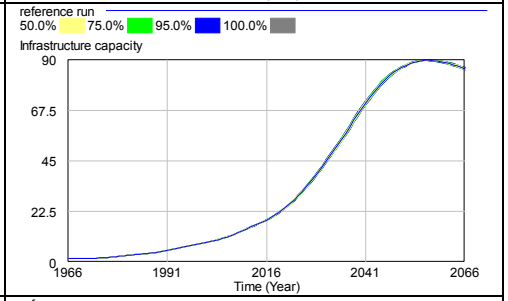
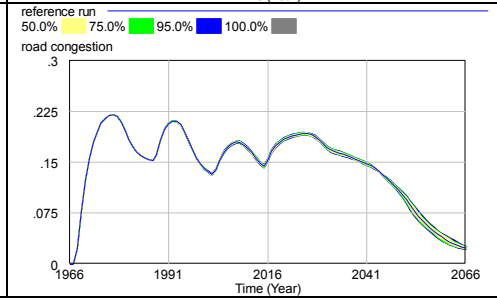
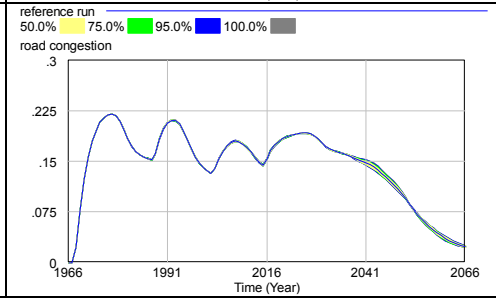
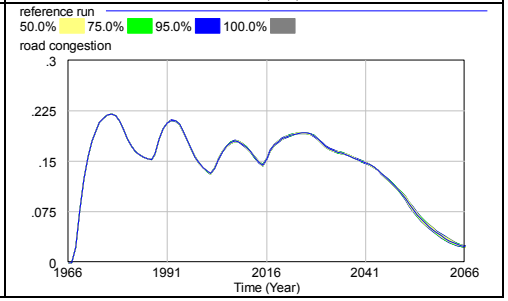
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

Parameter	worker housing growth multiplier (lookup)	worker housing obsolescence multiplier (lookup)	worker housing tax multiplier (lookup)
Units	-	-	-

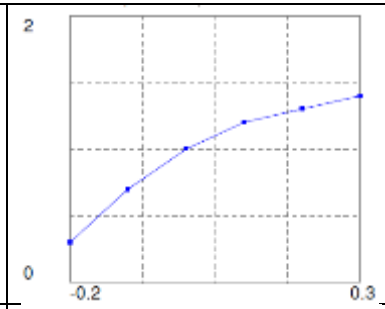
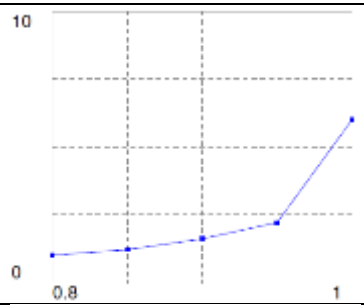
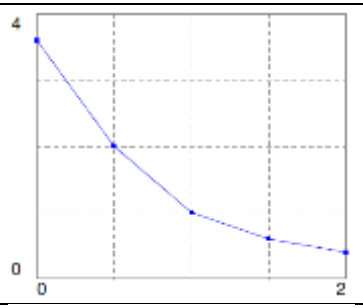
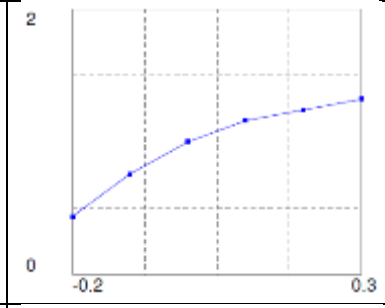
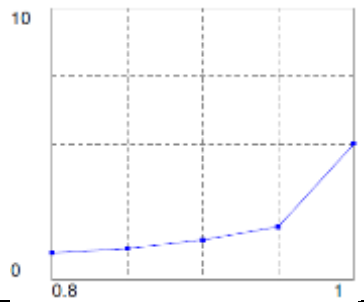
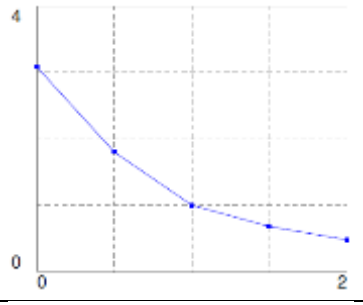
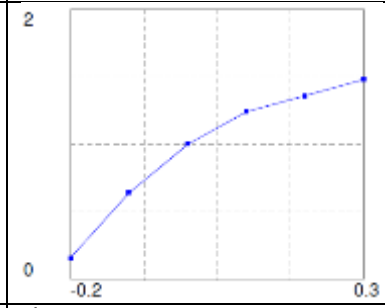
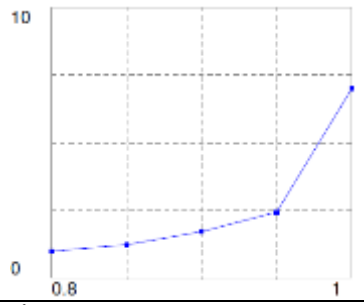
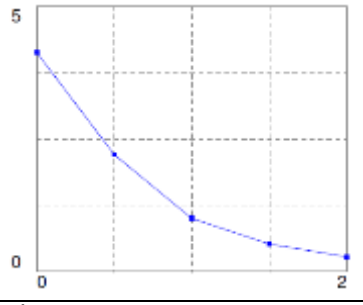
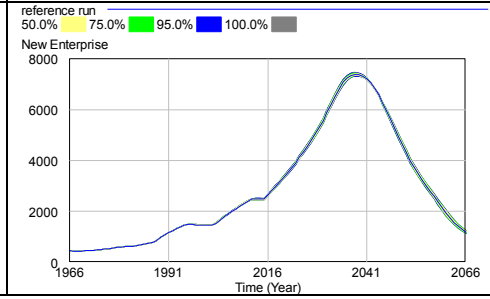
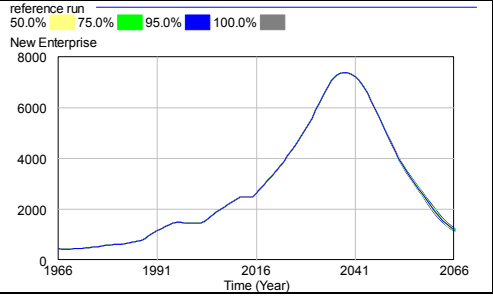
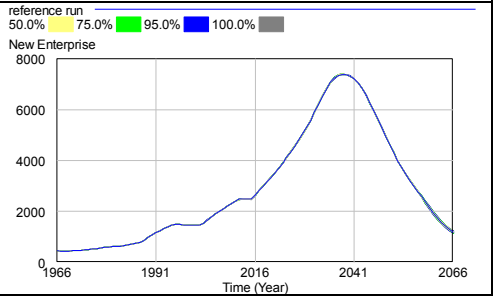
Nominal value			
Minimum plausible			
Maximum plausible			
Sensitivity plot: New Enterprise			

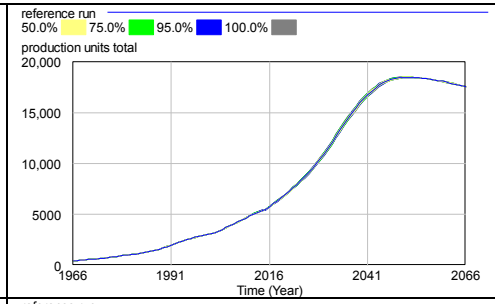
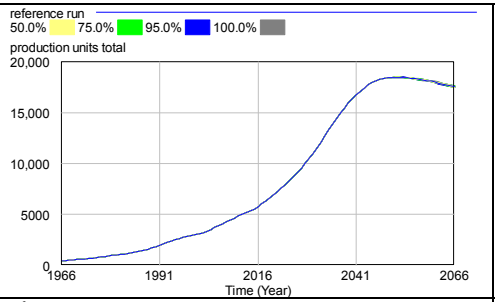
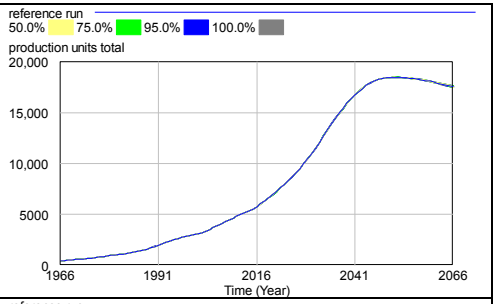
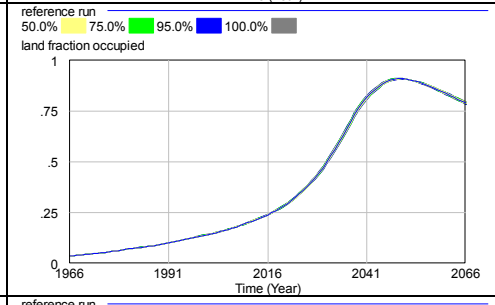
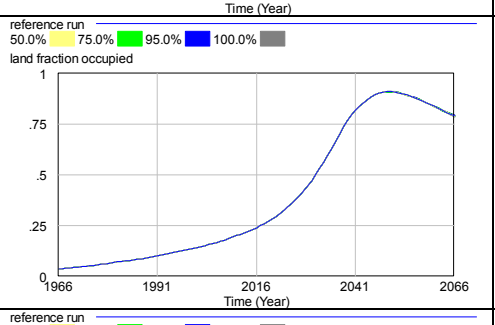
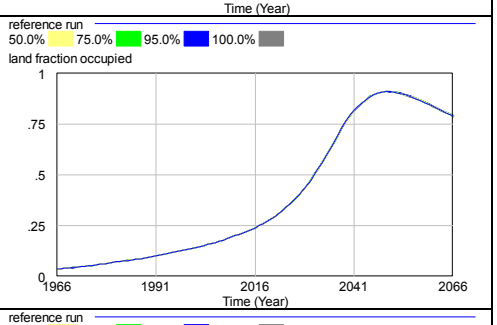
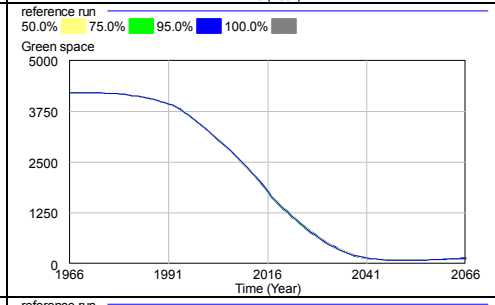
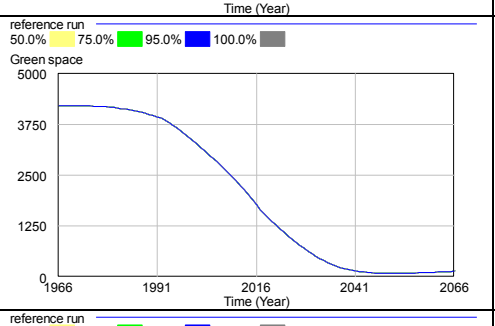
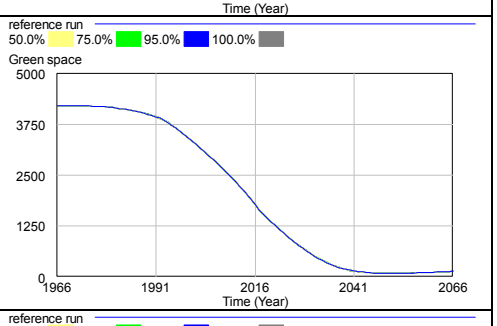
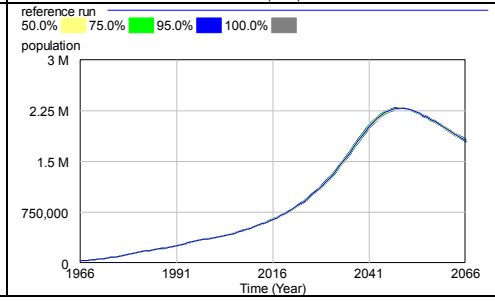
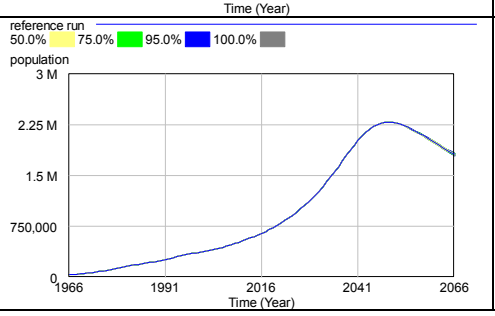
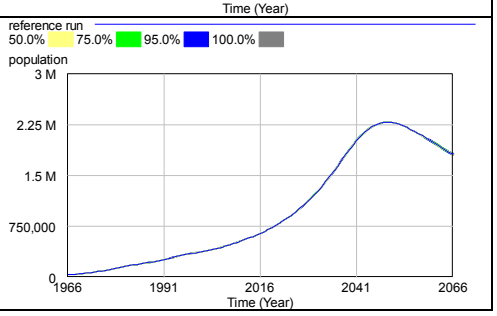
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

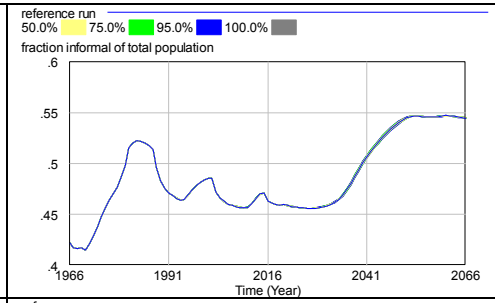
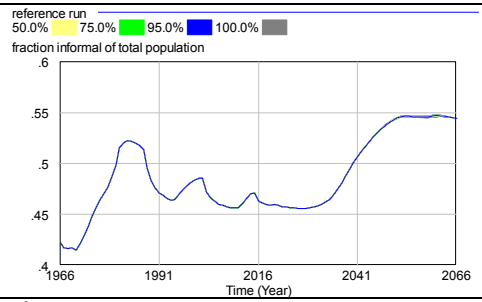
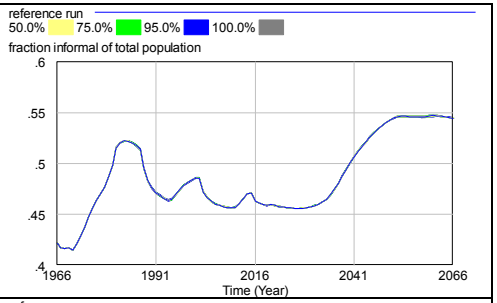
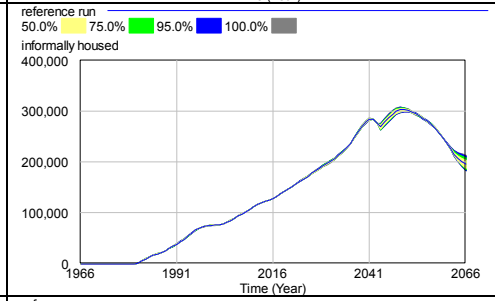
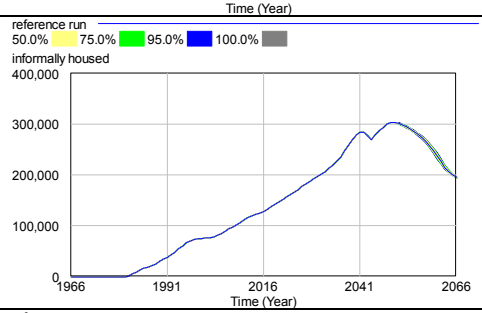
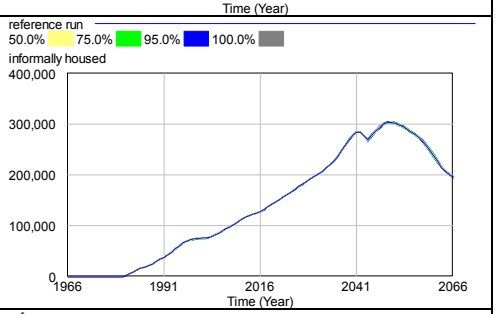
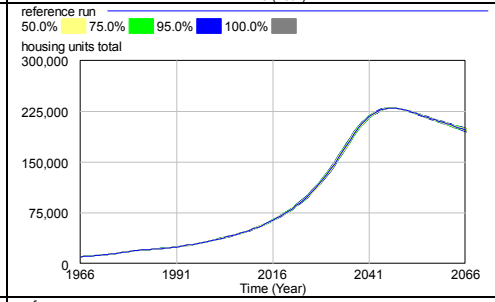
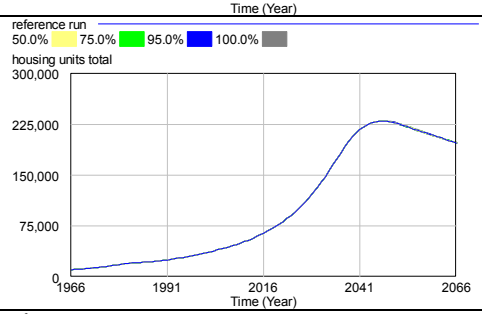
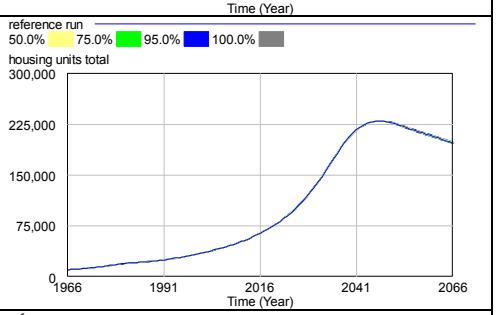
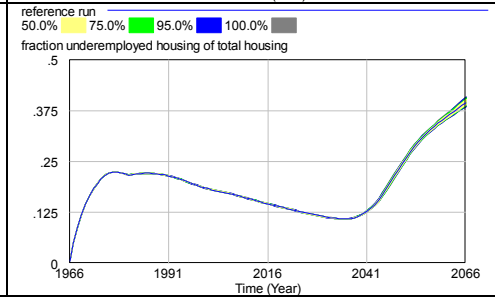
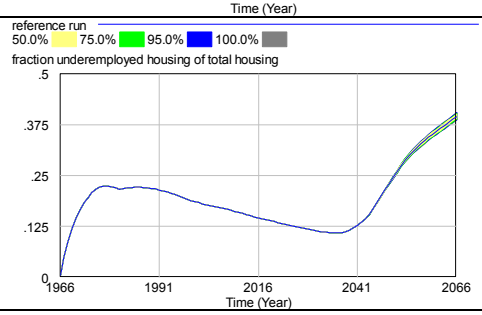
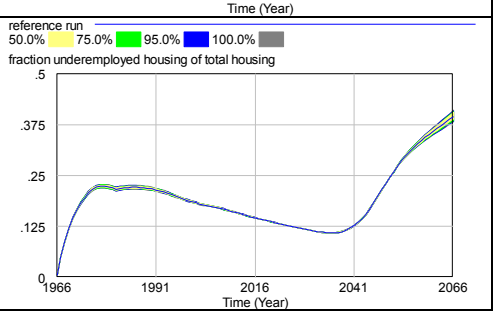
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

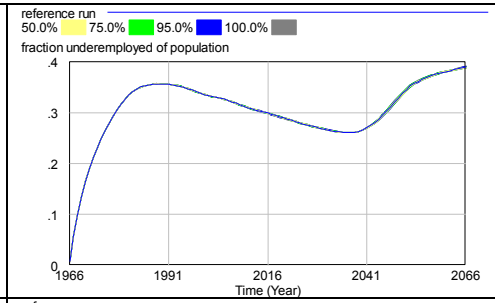
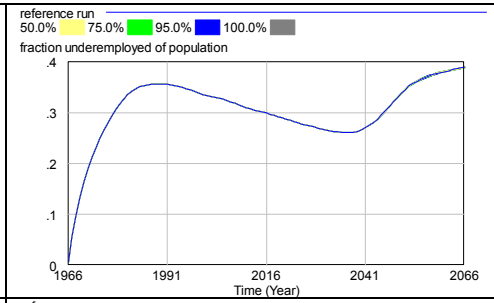
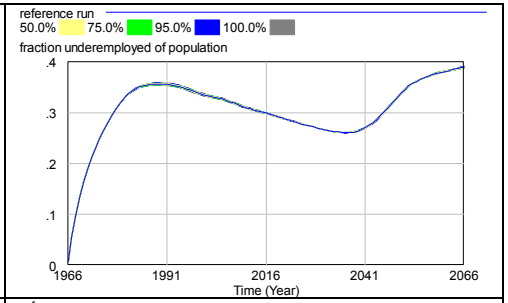
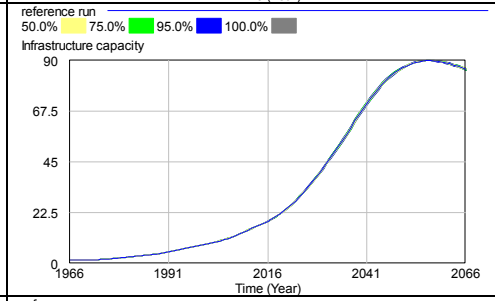
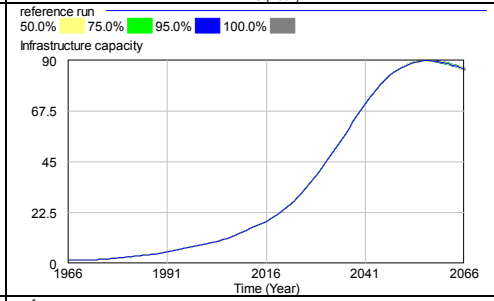
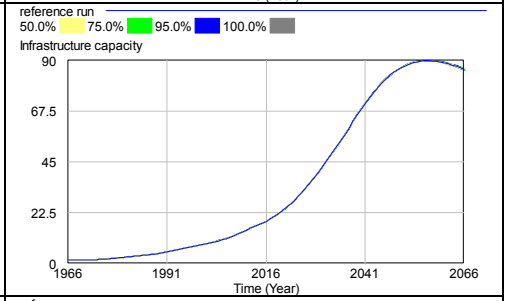
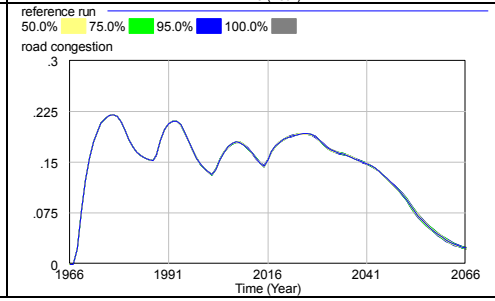
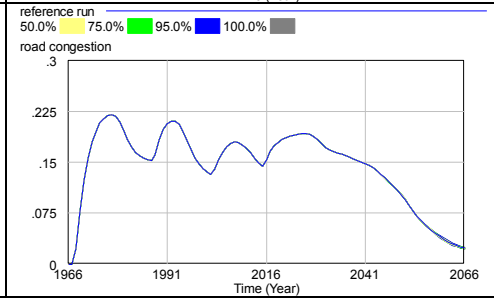
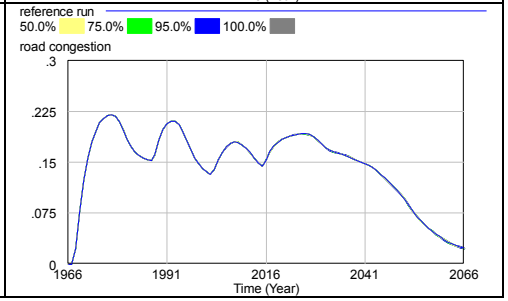
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

Parameter	worker housing enterprise multiplier (lookup)	slum housing land multiplier (lookup)	slum housing abandoned multiplier (lookup)
Units	-	-	-

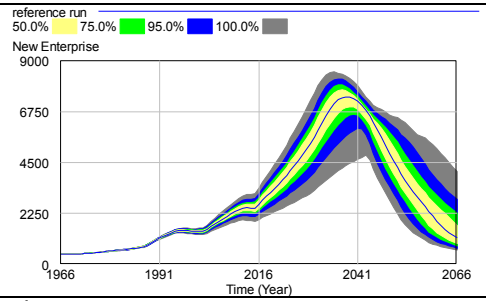
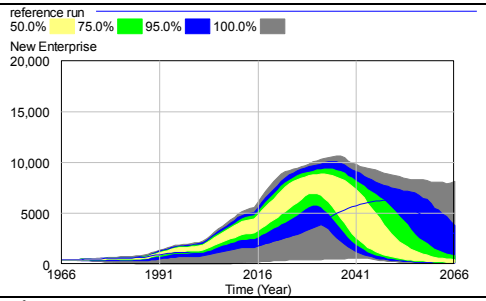
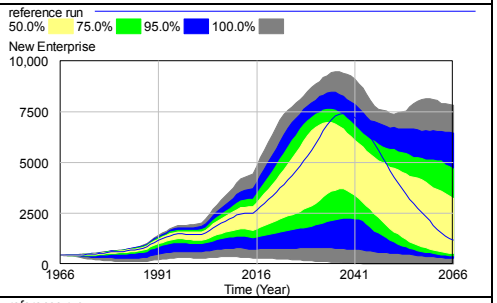
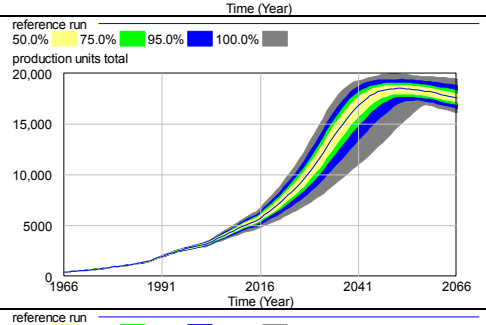
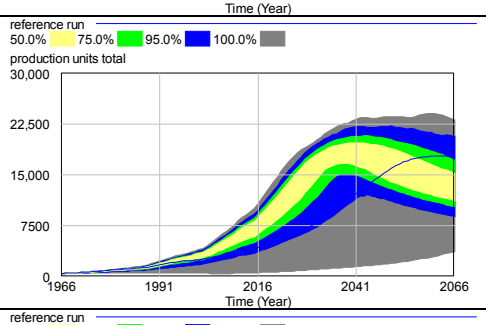
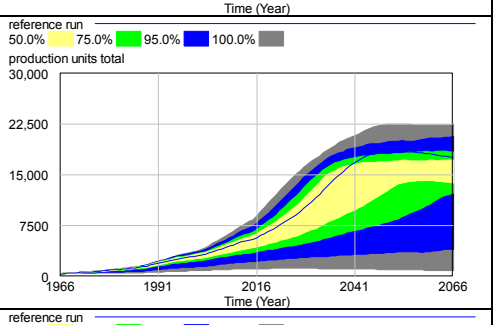
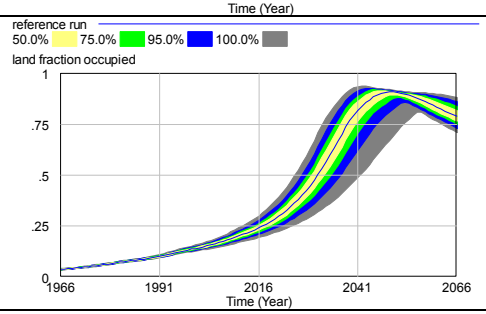
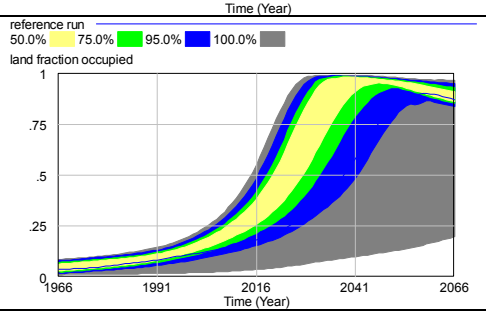
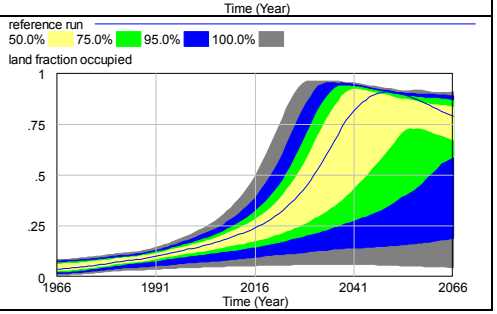
Nominal value			
Minimum plausible			
Maximum plausible			
Sensitivity plot: New Enterprise			

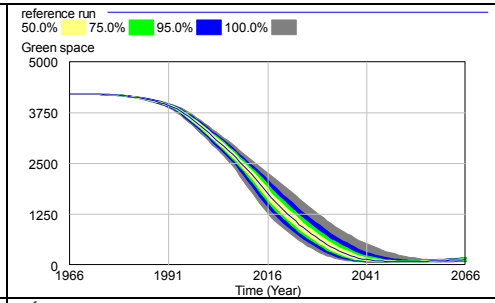
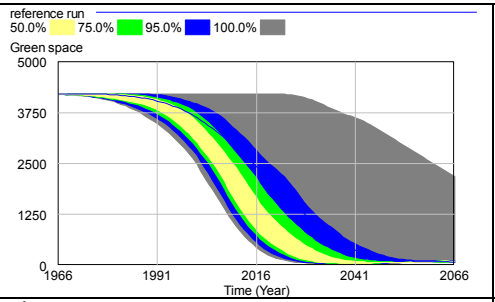
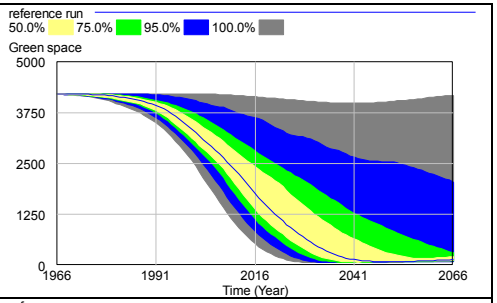
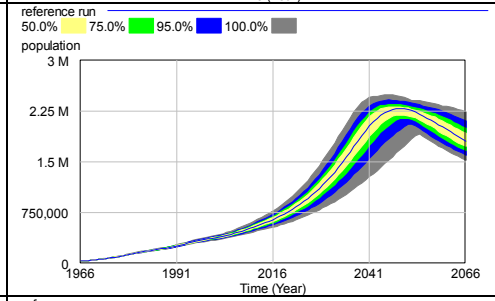
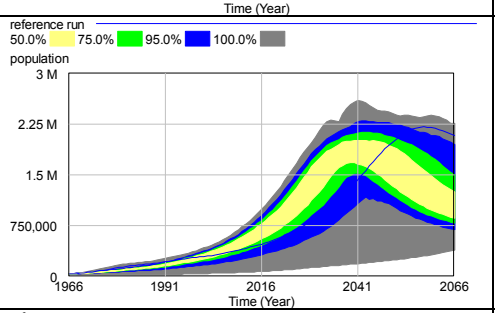
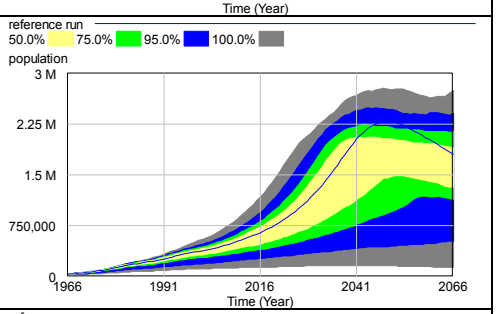
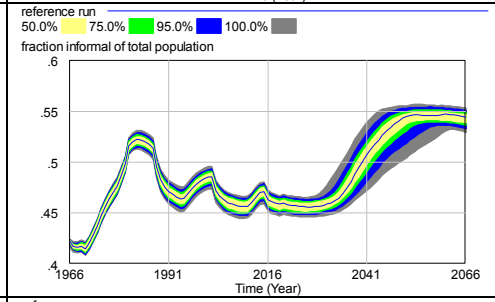
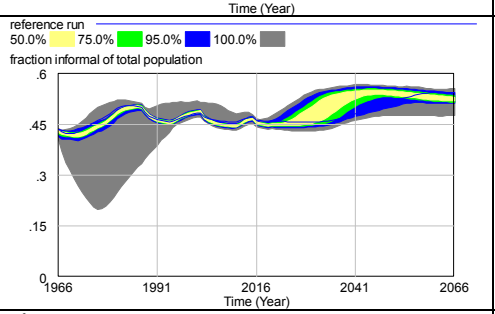
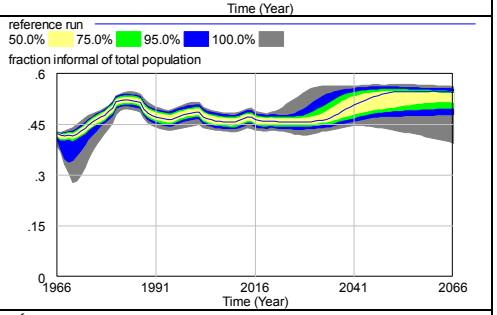
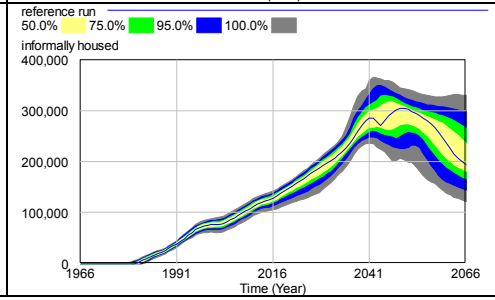
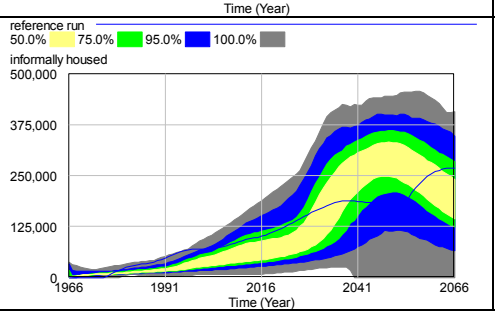
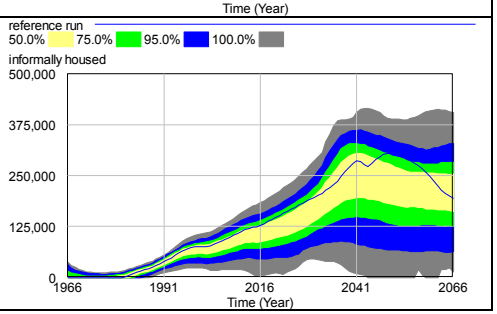
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

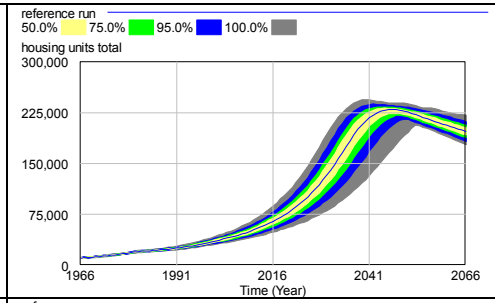
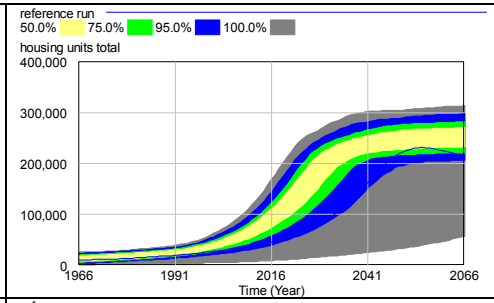
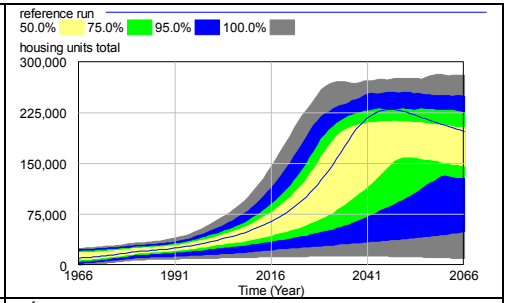
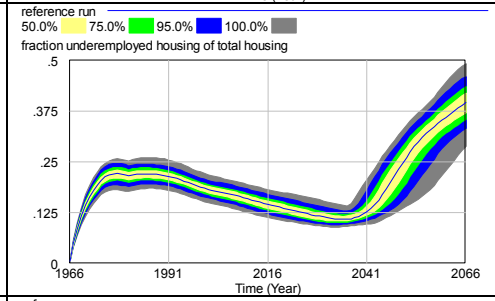
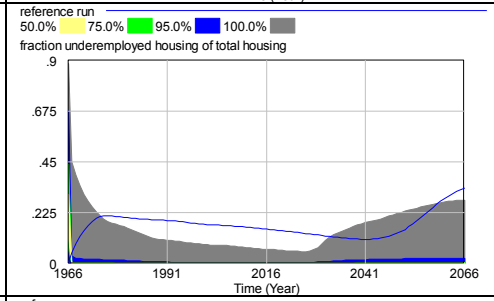
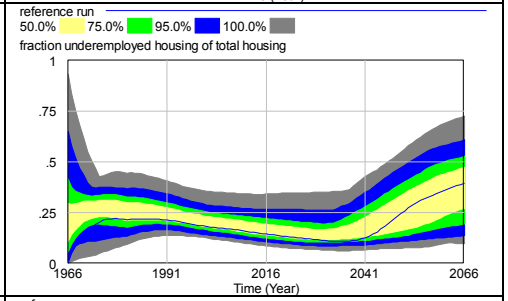
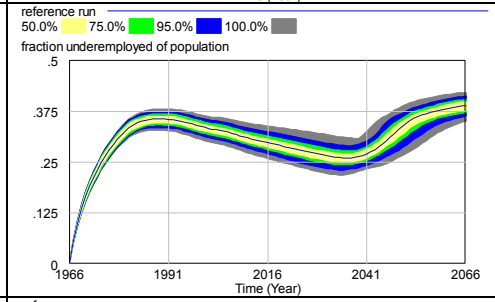
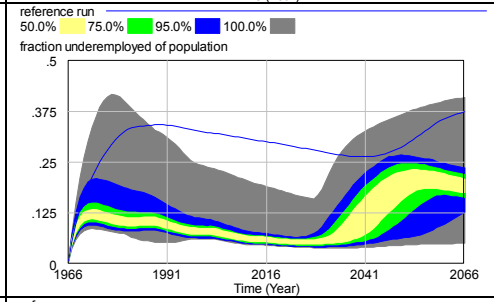
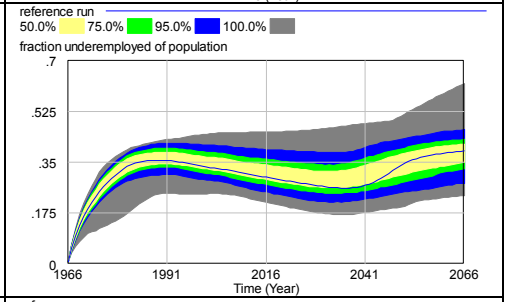
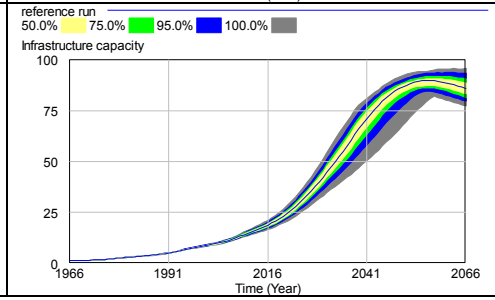
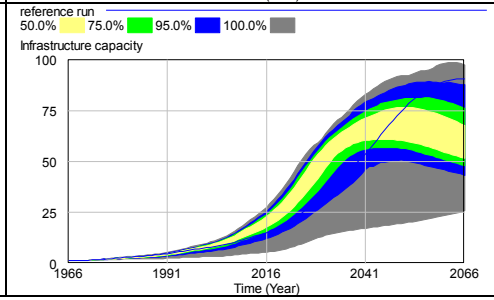
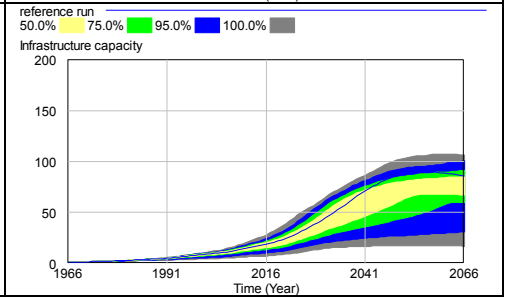
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

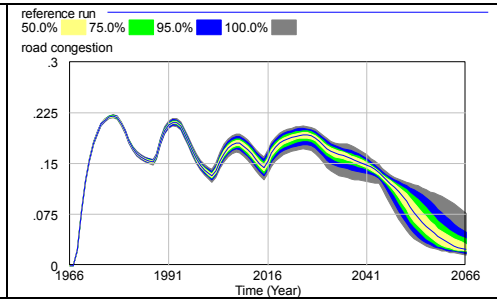
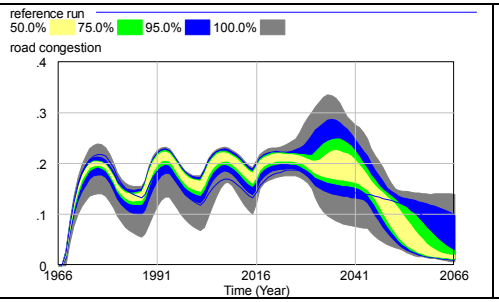
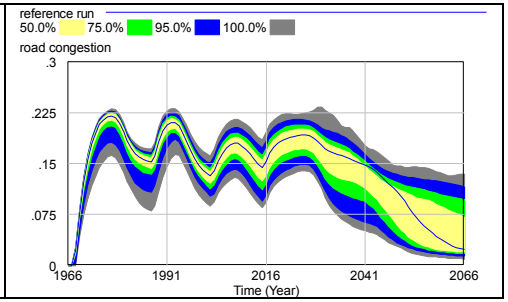
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

Parameter	Multivariate, all parameters and lookups except construction/demolition programs and factors.	Multivariate, all parameters	Multivariate, all parameters except construction/demolition/refurbish-ment programs
Units	-	-	-
Nominal value	-	-	-
Minimum plausible	-10%	Respective minimum plausible values	Respective minimum plausible values

Maximum plausible	+10%	Respective maximum plausible values	Respective maximum plausible values
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			

Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			

Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			

Sensitivity plot: road congestion			

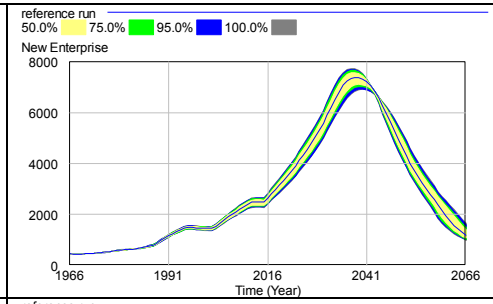
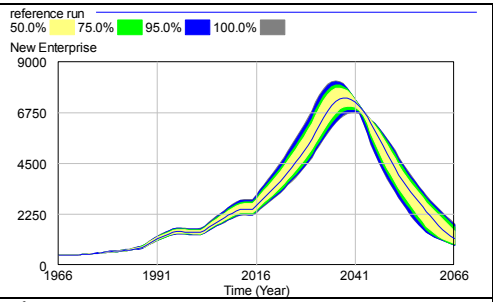
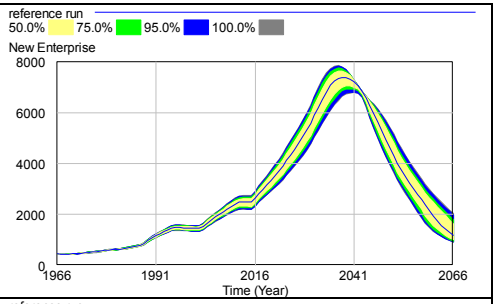
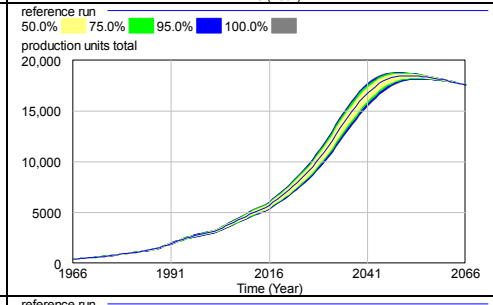
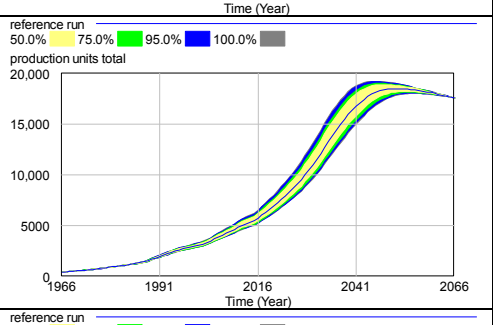
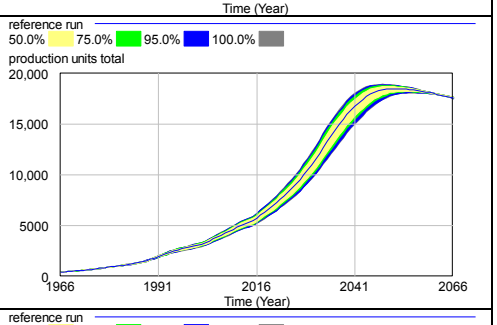
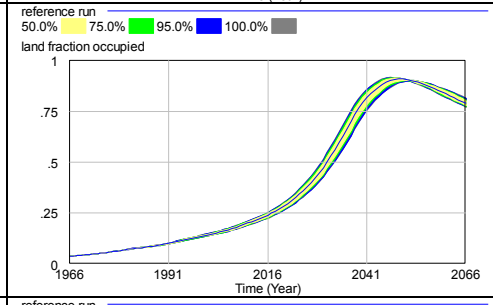
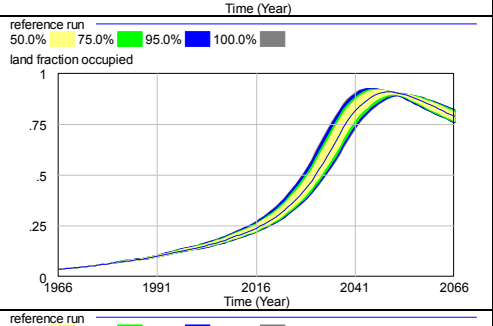
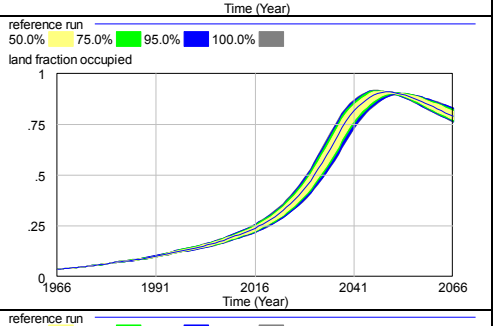
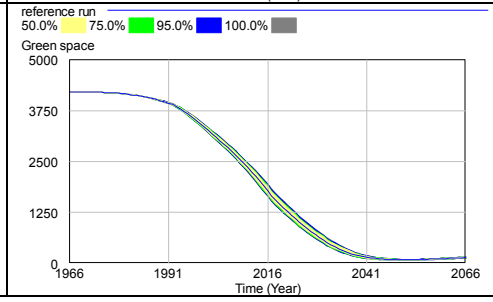
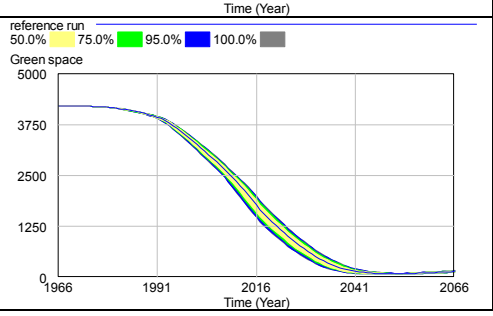
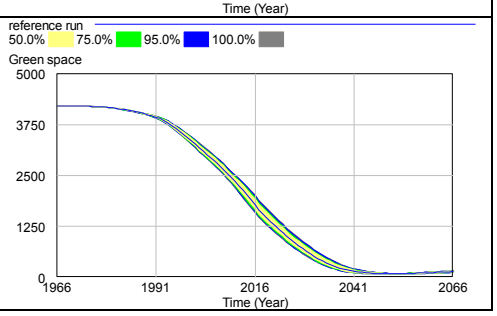
4.6 Employment Chain sensitivity

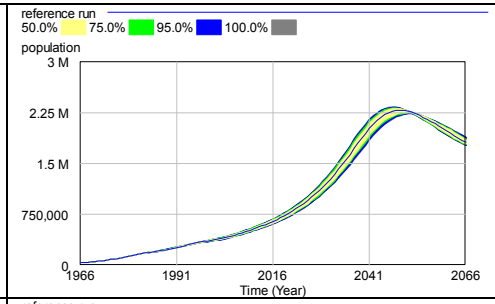
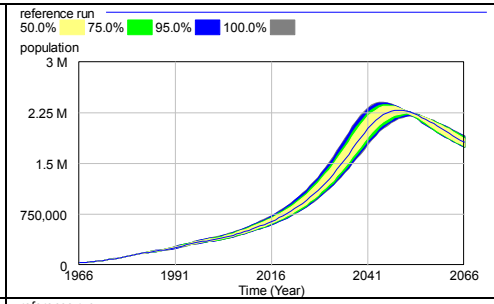
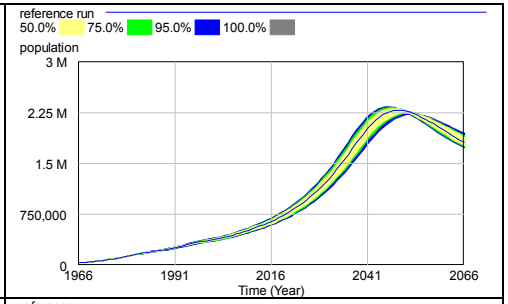
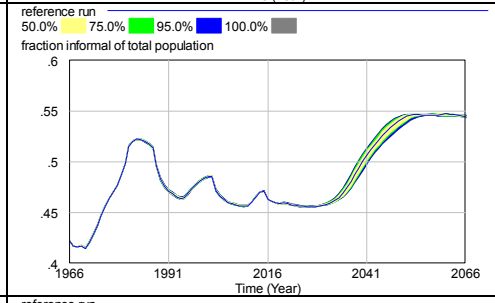
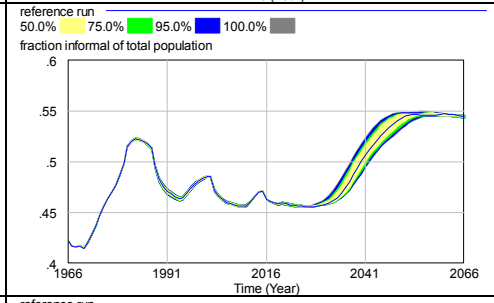
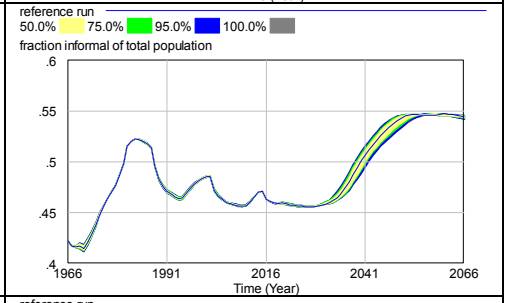
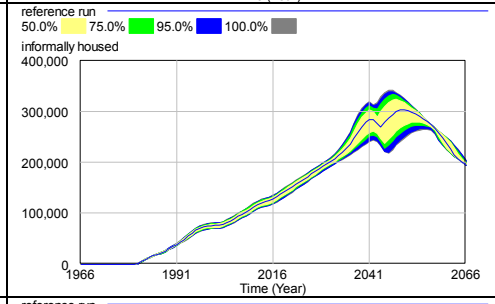
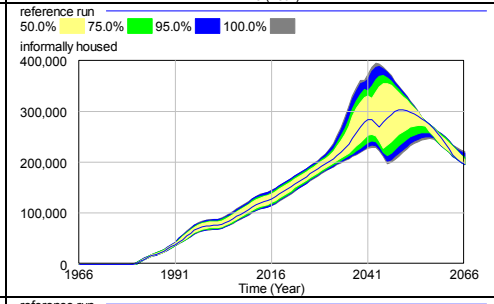
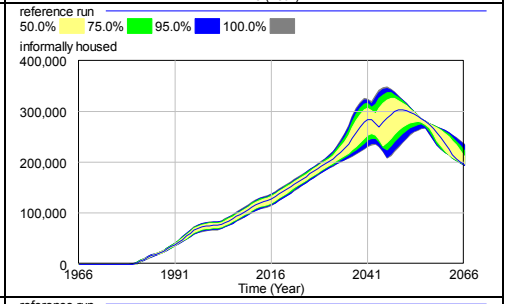
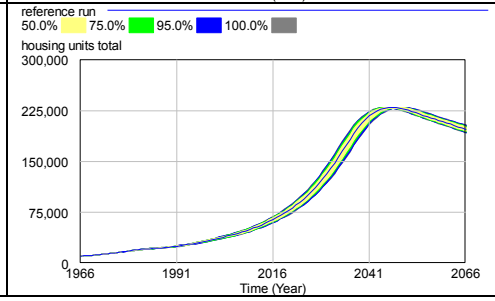
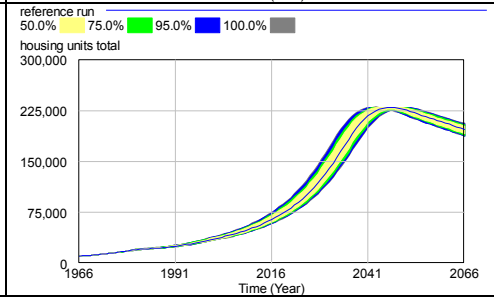
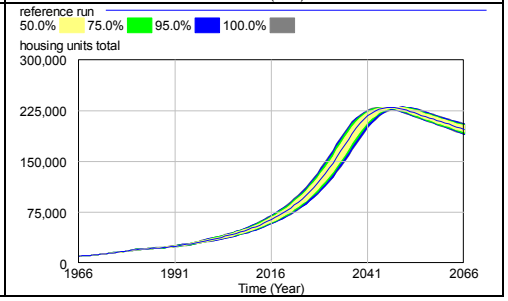
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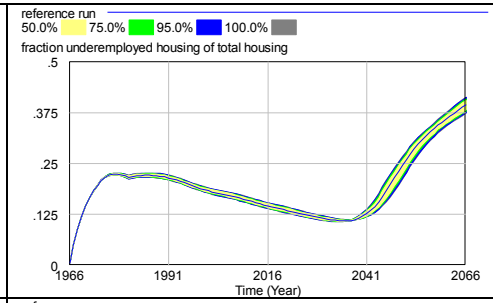
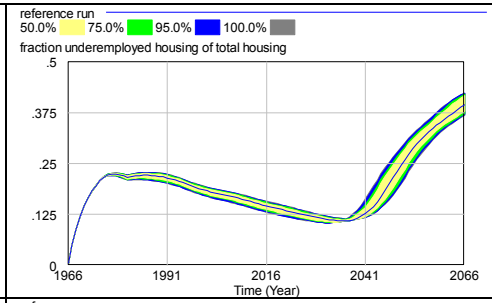
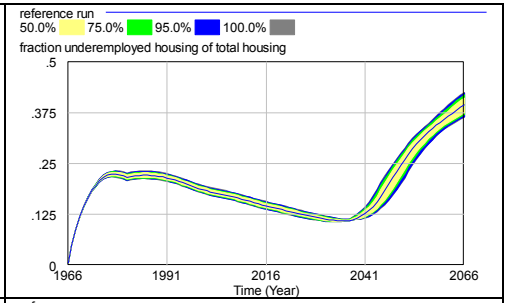
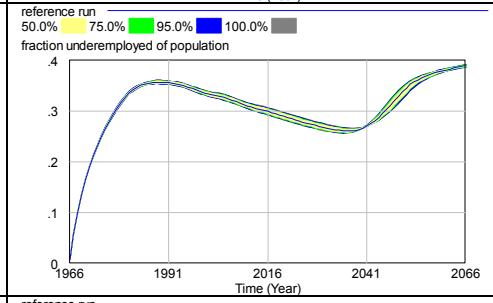
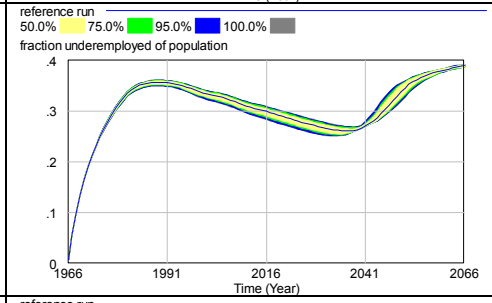
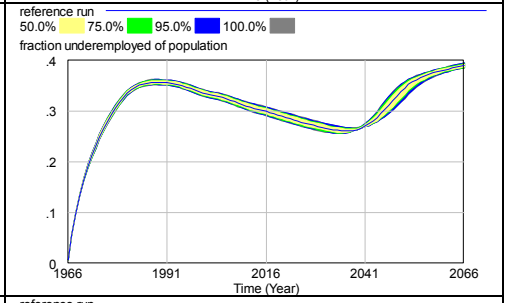
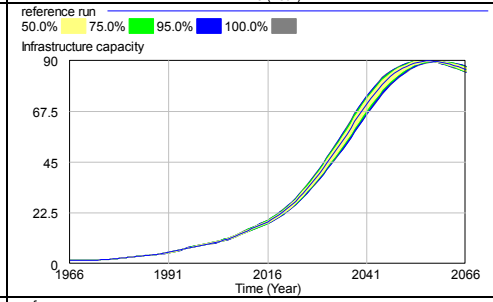
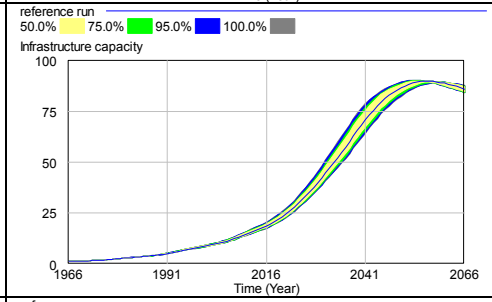
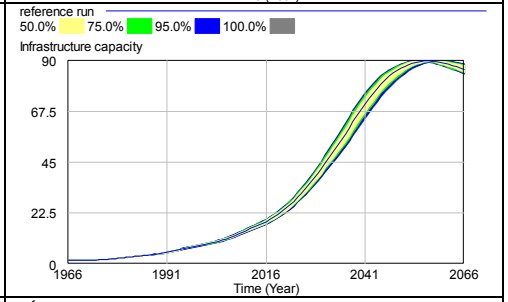
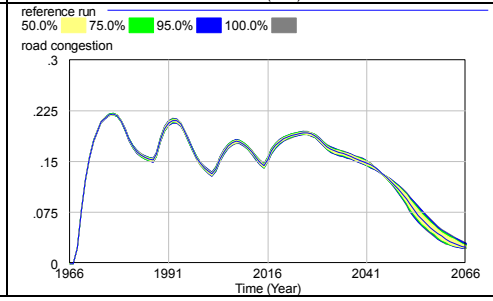
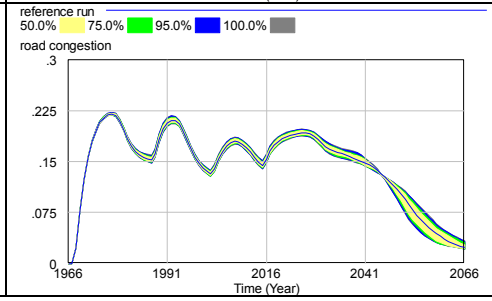
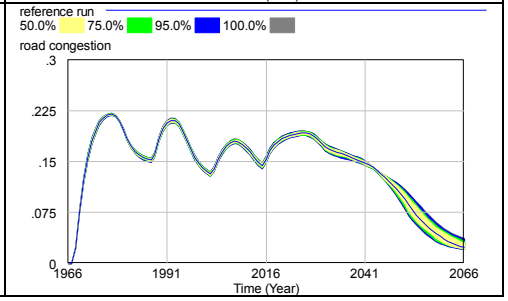
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manager departures normal	labor departures normal	manager supply multiplier (lookup)
manager arrivals normal	underemployed mobility normal	labor mobility multiplier (lookup)
Managerial-professional birth rate	underemployed mobility perception time	manager/labor multiplier (lookup)
mature business management	underemployed to labor perception time	labor educational multiplier (lookup)
new enterprise management	underemployed birth rate	labor supply multiplier (lookup)
declining industry management	underemployed arrivals normal	labor/underemployed multiplier (lookup)
manager-arrival multiplier perception time	underemployed departures normal	labor departure multiplier
labor mobility normal	attractiveness for migration multiplier perception time	underemployed educational multiplier
labor mobility multiplier perception time	attractiveness for migration factor	underemployed departure multiplier
labor training program	manager-arrival housing multiplier (lookup)	underemployed arrivals mobility multiplier
labor arrivals normal	manager-arrival population multiplier (lookup)	underemployed/job multiplier
labor arrival multiplier perception time	manager-arrival tax multiplier (lookup)	underemployed housing program multiplier
labor arrival factor	manager-arrival job multiplier (lookup)	public expenditure multiplier
		underemployed/housing multiplier

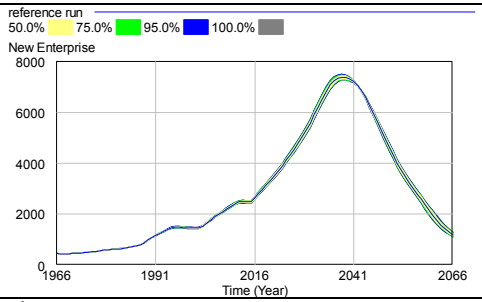
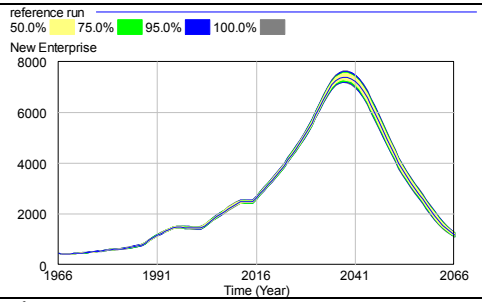
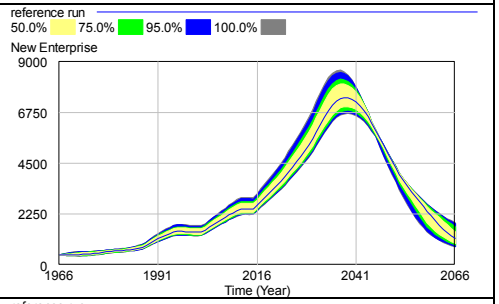
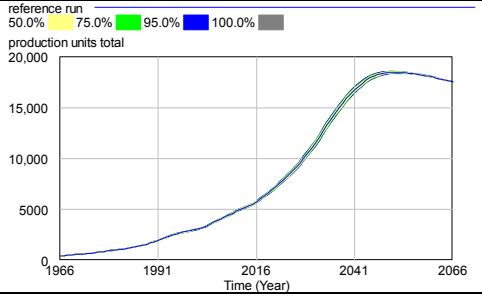
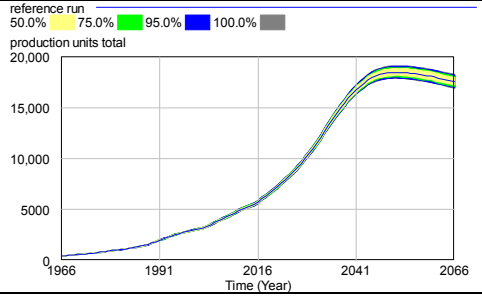
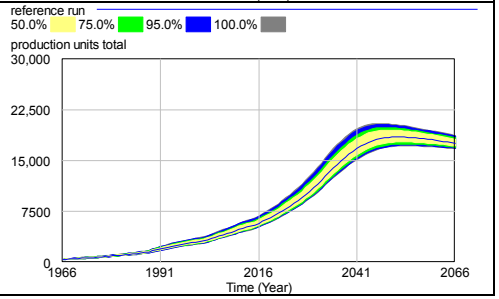
manager arrival factor	underemployed mobility normal	manager-arrival job multiplier (lookup)
manager departures normal	underemployed mobility perception time	labor arrival housing multiplier (lookup)
manager arrivals normal	underemployed to labor perception time	labor arrival tax multiplier (lookup)
Managerial-professional birth rate	underemployed birth rate	labor arrival underemployed multiplier (lookup)
mature business management	underemployed arrivals normal	labor arrival job multiplier
new enterprise management	underemployed departures normal	labor supply multiplier (lookup)
declining industry management	attractiveness for migration multiplier perception time	labor/underemployed multiplier (lookup)
manager-arrival multiplier perception time	attractiveness for migration factor	labor departure multiplier
labor mobility normal	underemployed training program	underemployed educational multiplier
labor mobility multiplier perception time	manager-arrival housing multiplier (lookup)	underemployed departure multiplier
labor training program	manager-arrival population multiplier (lookup)	underemployed arrivals mobility multiplier
labor arrivals normal	manager-arrival tax multiplier (lookup)	underemployed/job multiplier
labor arrival multiplier perception time	manager departure multiplier (lookup)	underemployed housing program multiplier
labor arrival factor	manager supply multiplier (lookup)	public expenditure multiplier
labor birth rate	manager/labor multiplier (lookup)	underemployed/housing multiplier
labor departures normal	labor educational multiplier (lookup)	

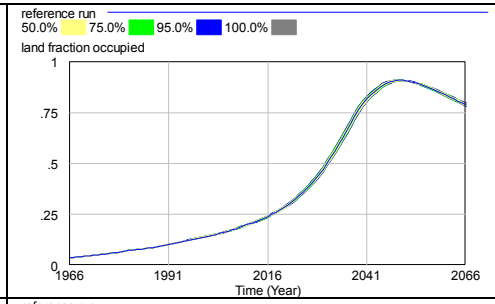
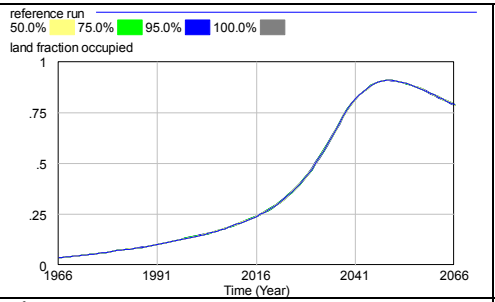
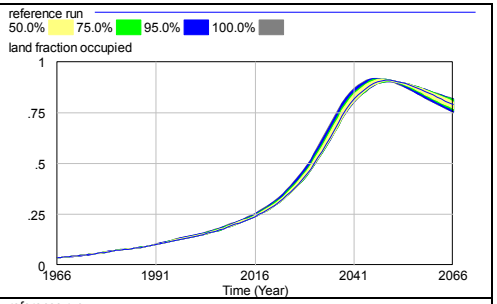
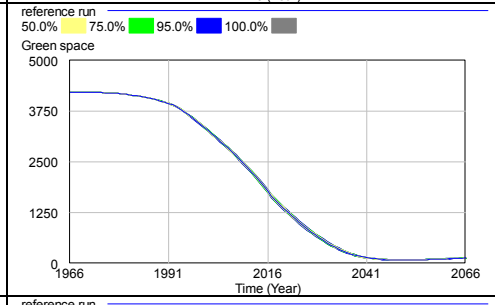
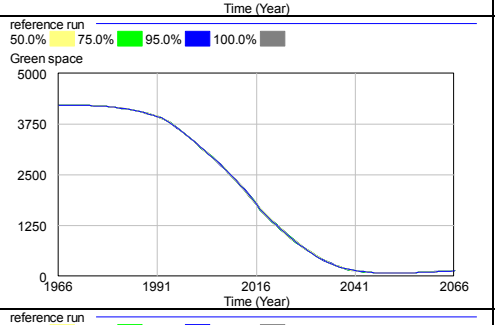
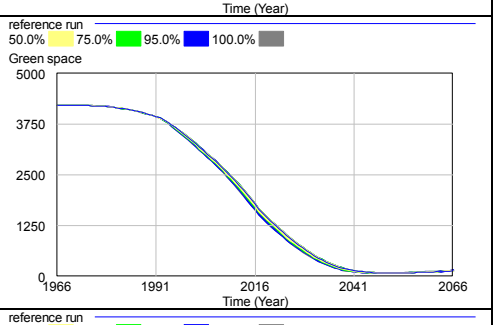
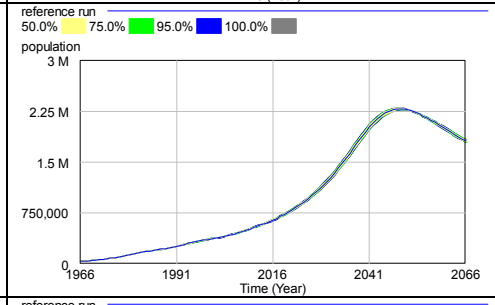
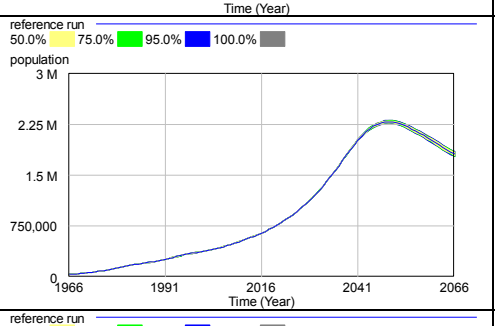
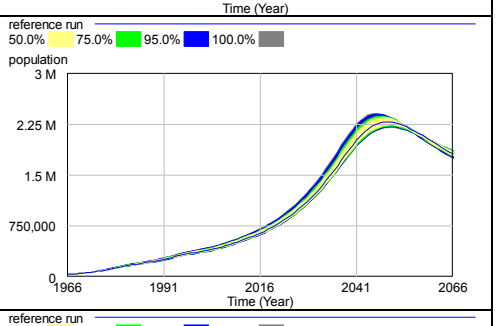
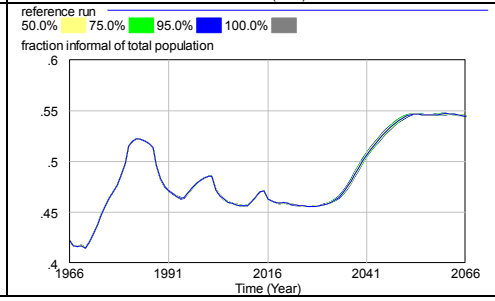
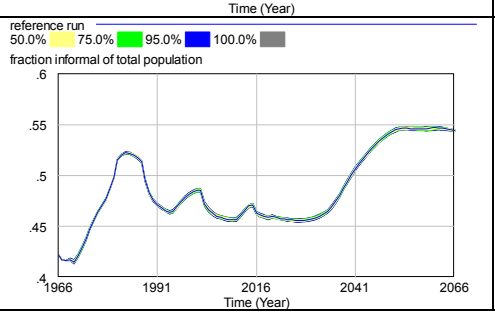
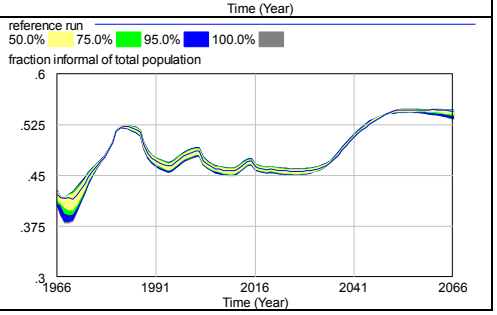
Parameter	manager arrival factor	manager departures normal	manager arrivals normal
Units	-	1/year	1/year
Nominal value	1	0.02	0.03
Minimum plausible	0.8	0.01	0.01
Maximum plausible	1.2	0.03	0.05

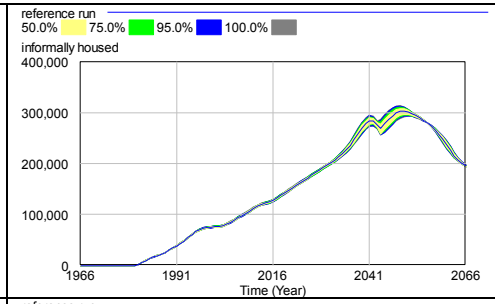
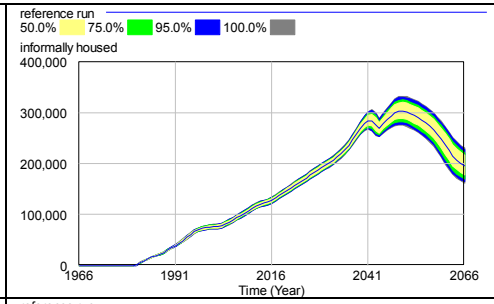
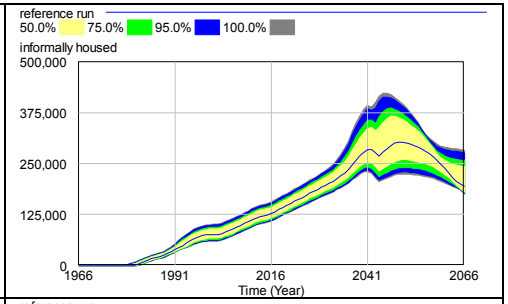
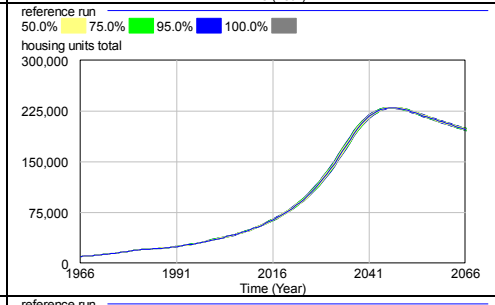
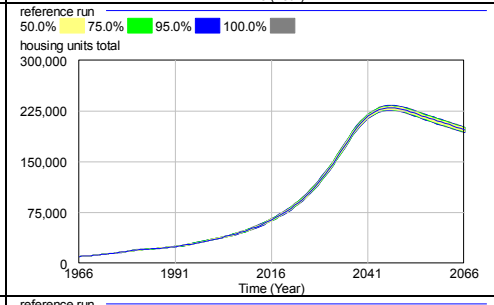
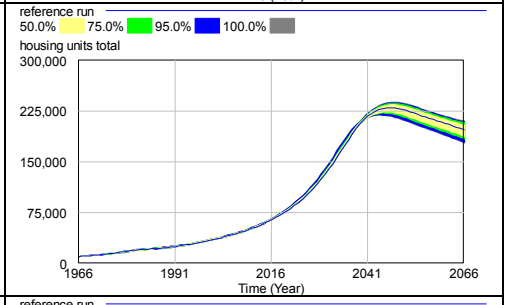
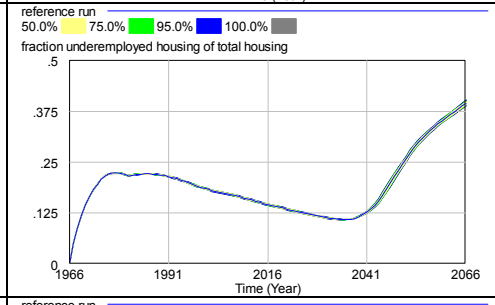
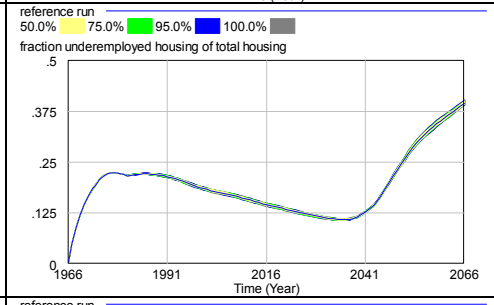
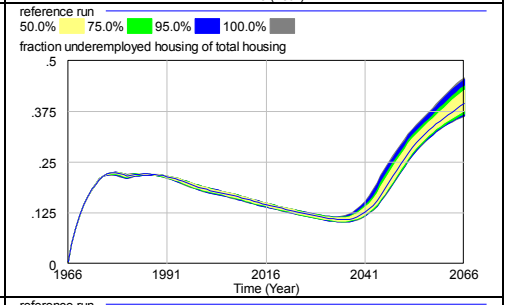
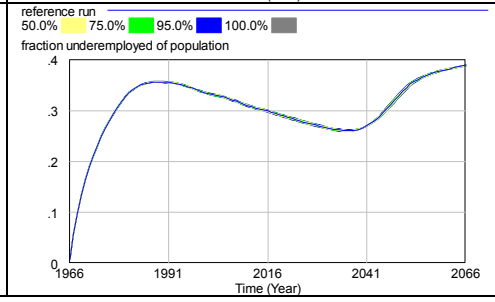
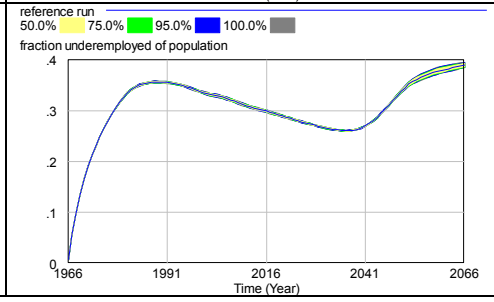
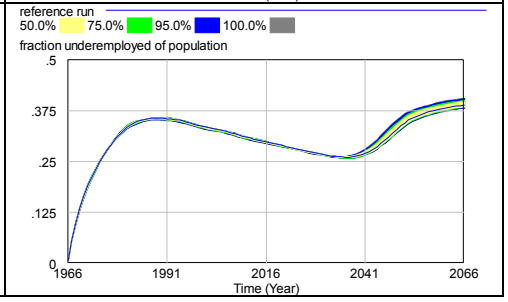
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

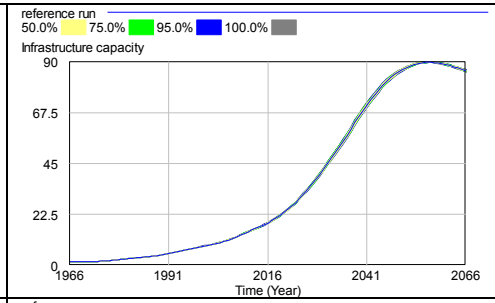
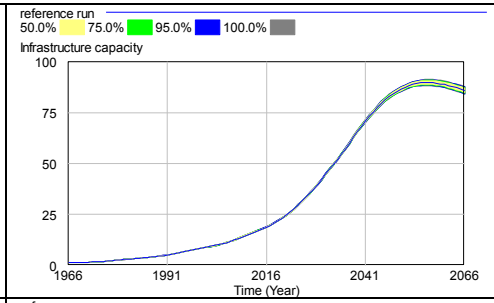
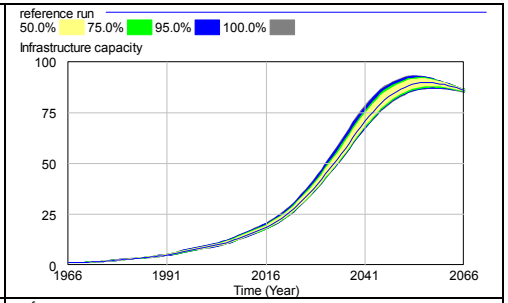
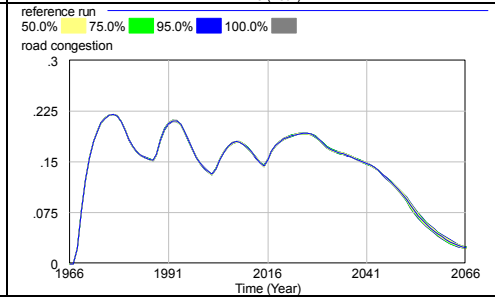
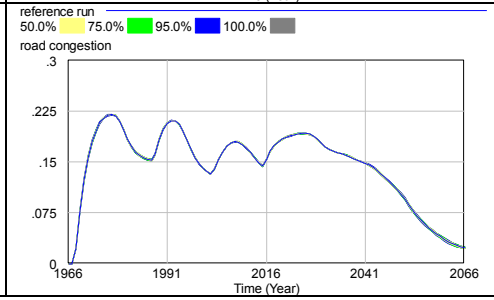
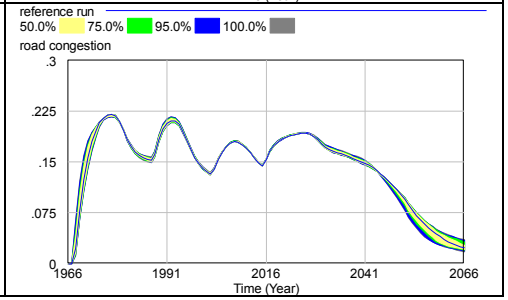
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

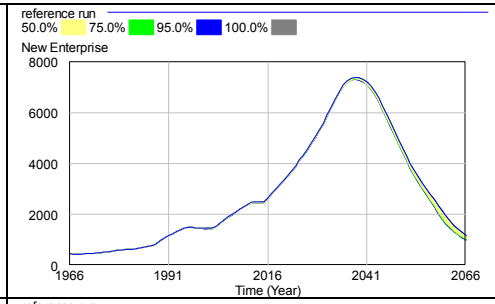
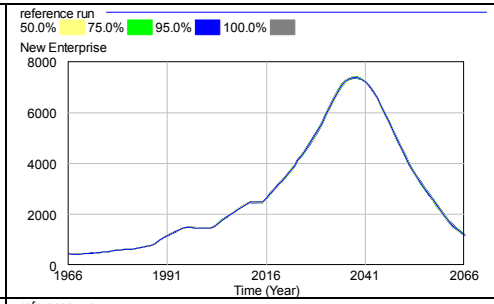
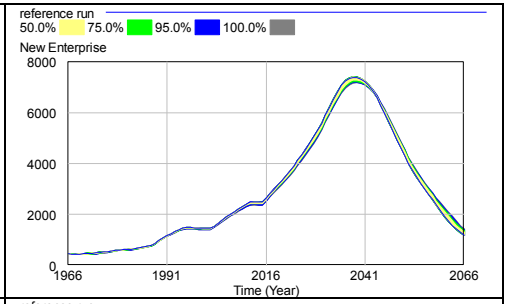
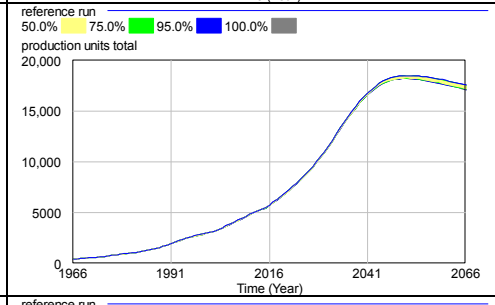
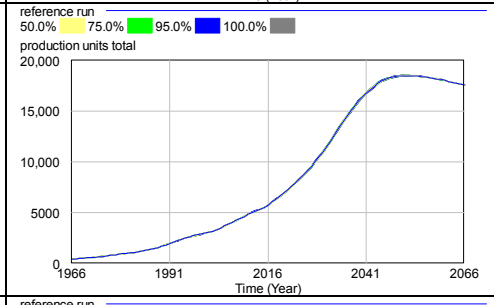
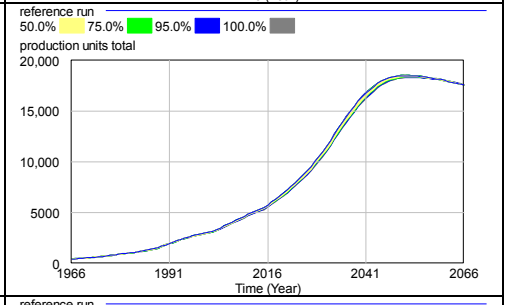
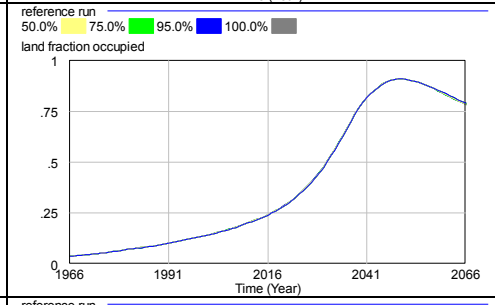
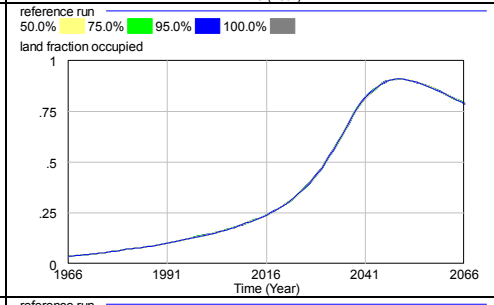
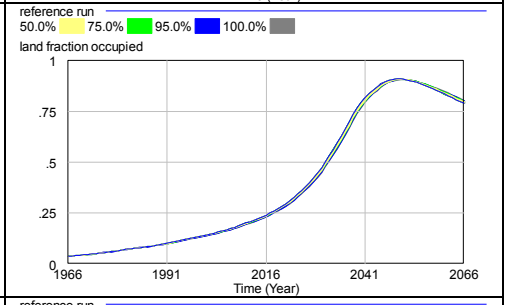
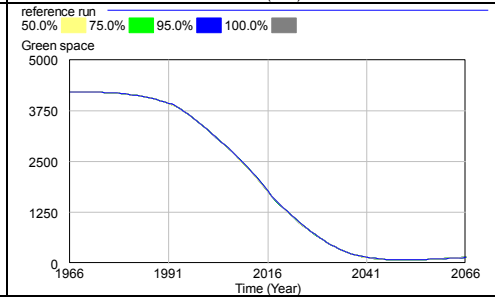
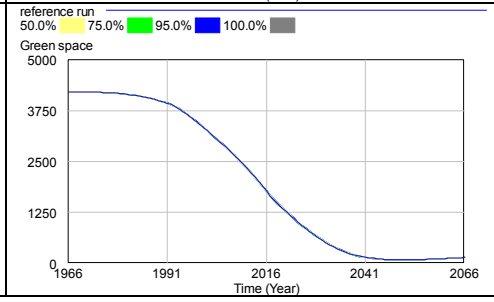
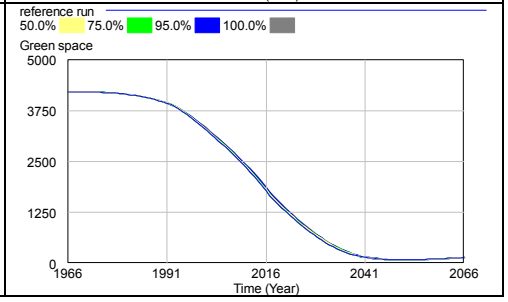
Parameter	Managerial-professional birth rate	mature business management	new enterprise management
Units	1/year	worker/productive unit	worker/productive unit
Nominal value	0.017	2	4
Minimum plausible	0.0136 (-20%)	1 (-50%)	2 (-50%)
Maximum plausible	0.0204 (+20%)	3 (+50%)	6 (+50%)
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			

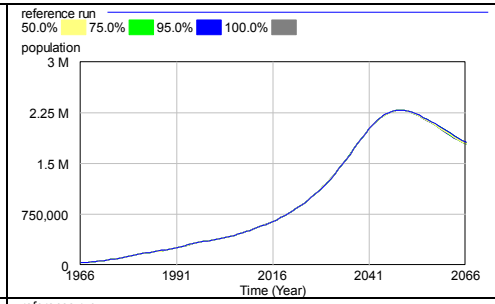
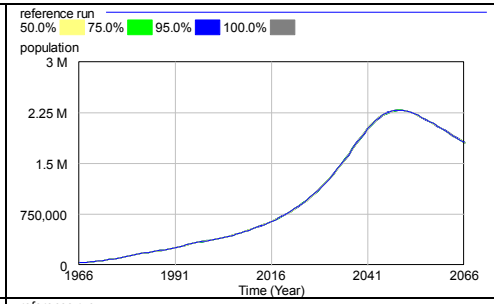
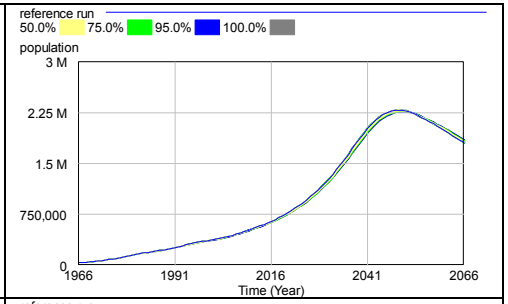
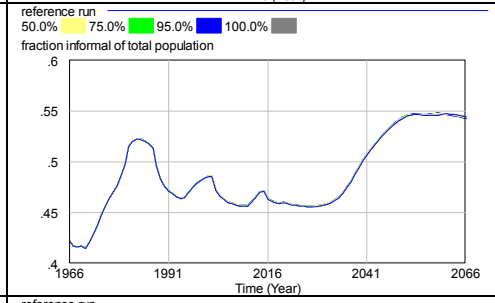
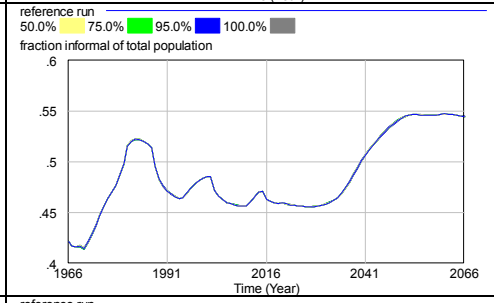
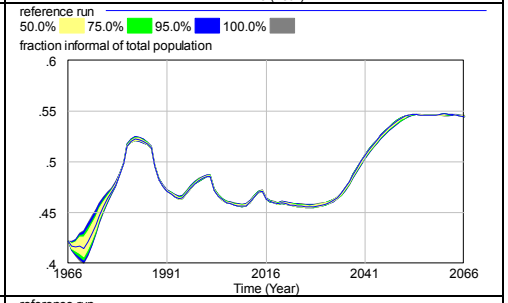
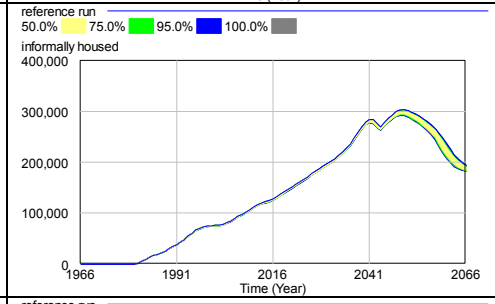
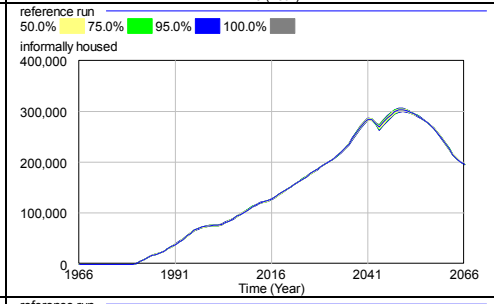
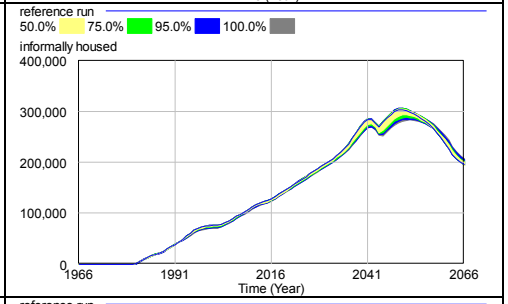
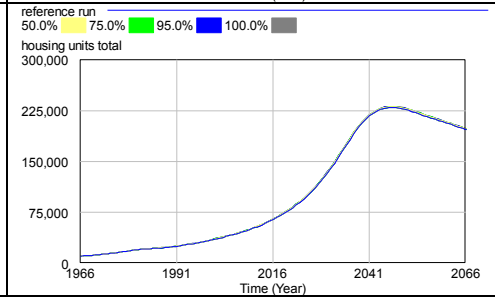
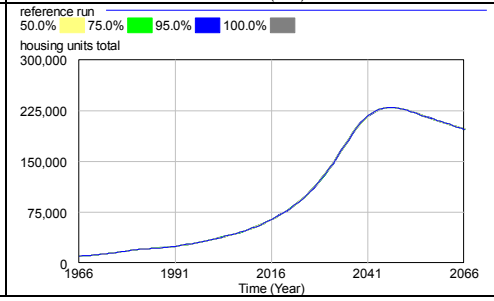
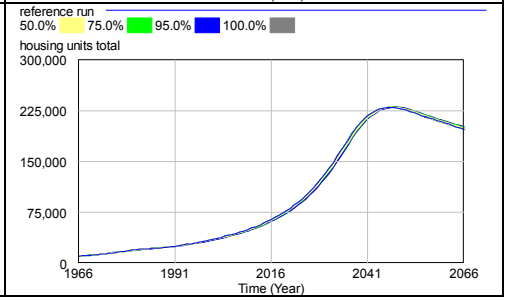
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			

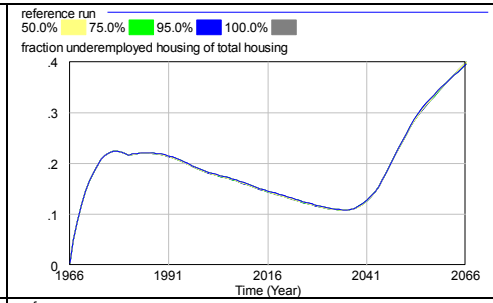
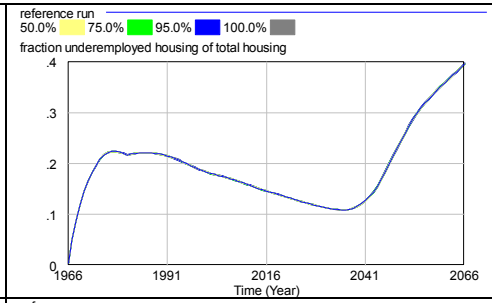
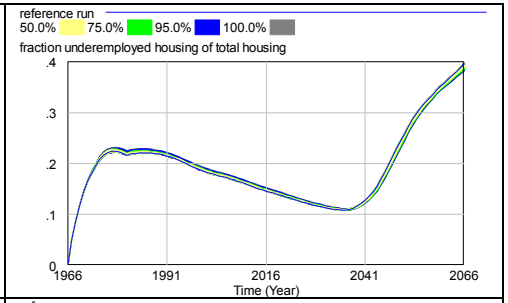
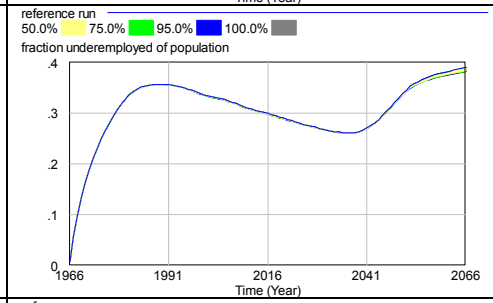
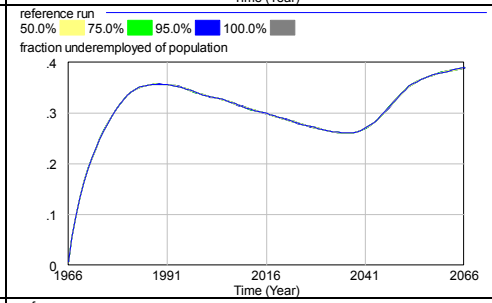
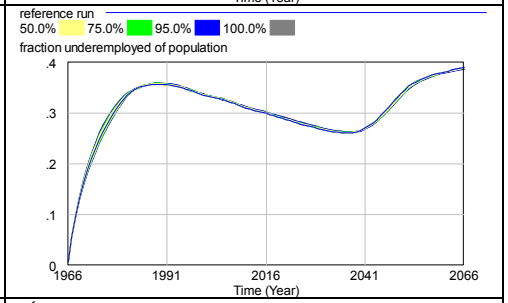
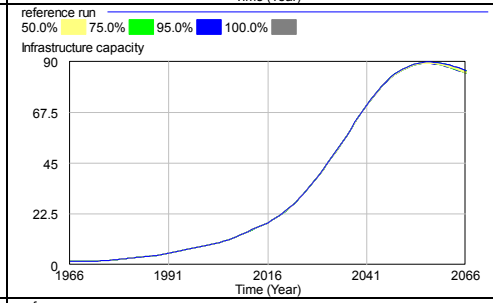
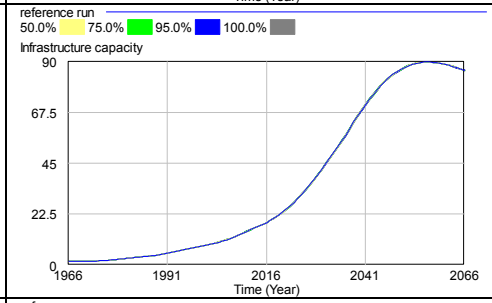
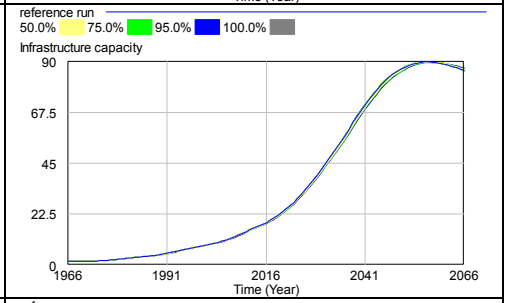
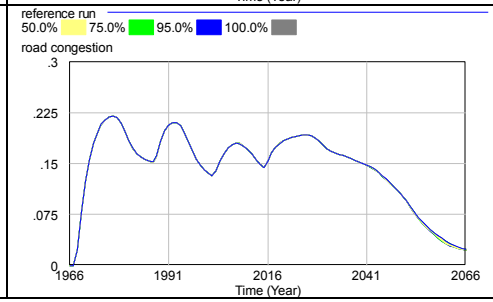
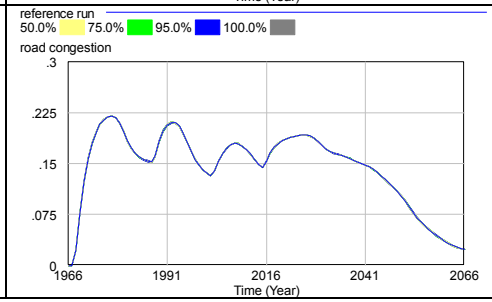
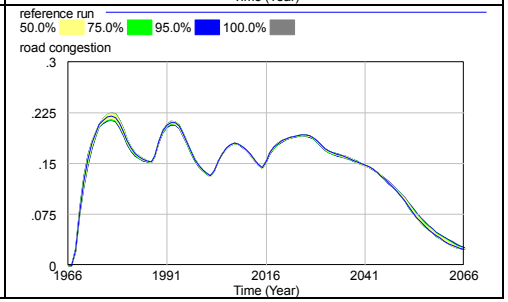
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			

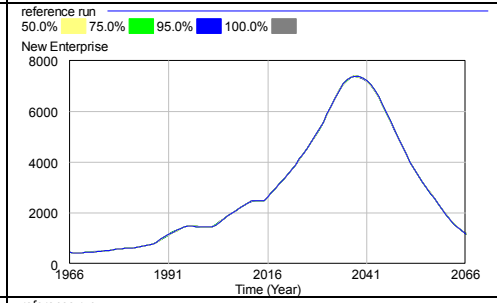
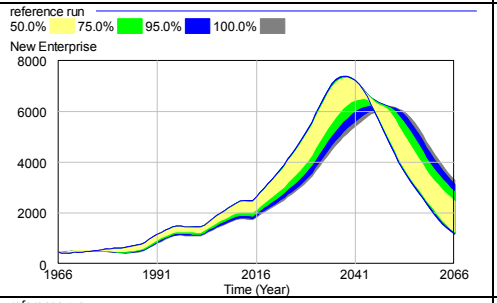
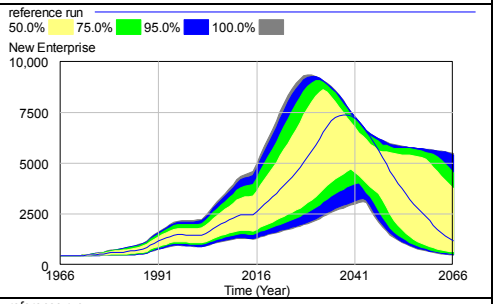
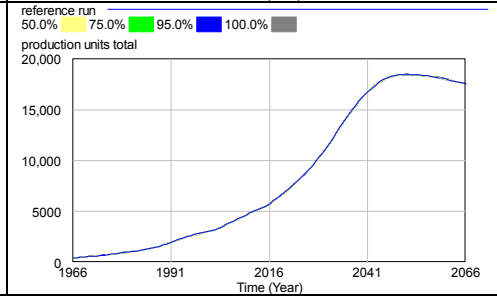
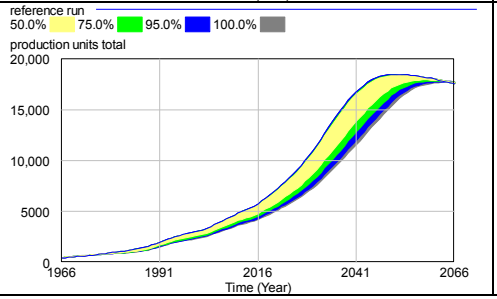
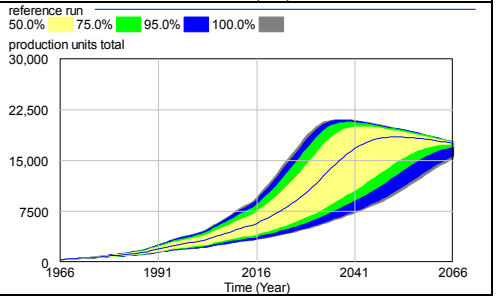
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

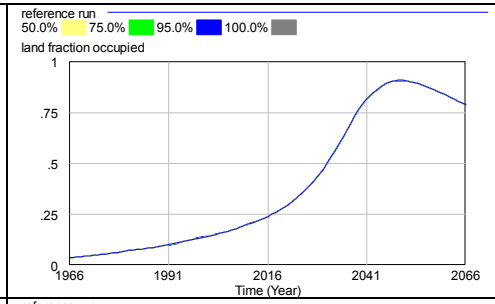
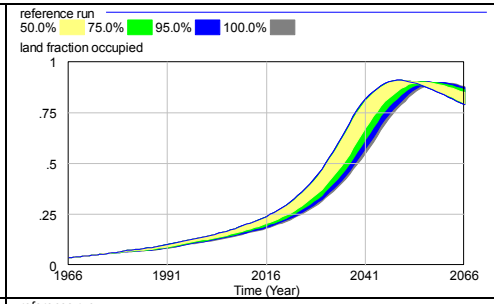
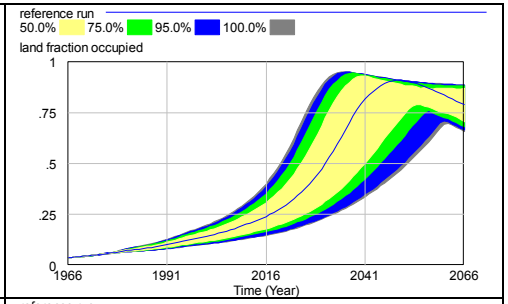
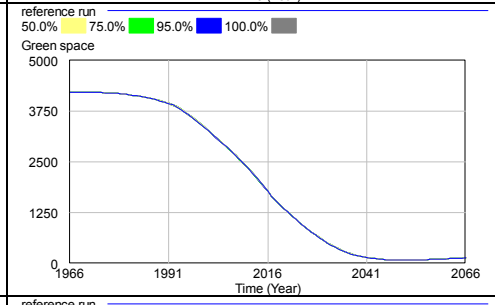
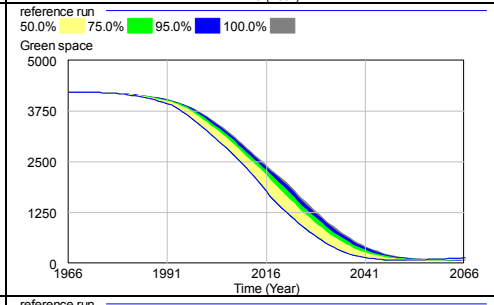
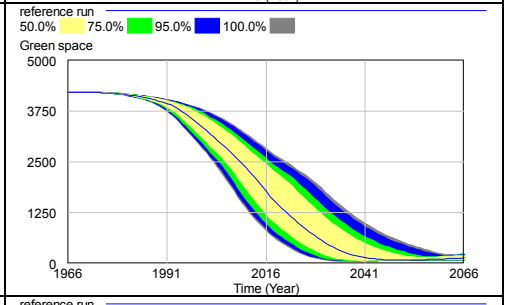
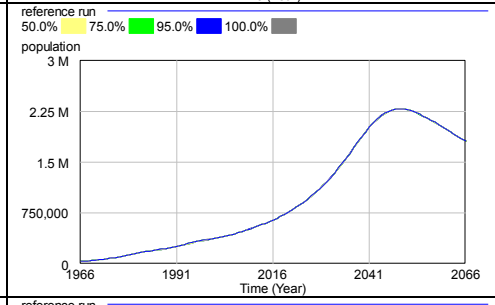
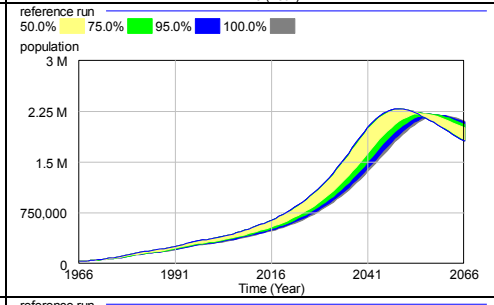
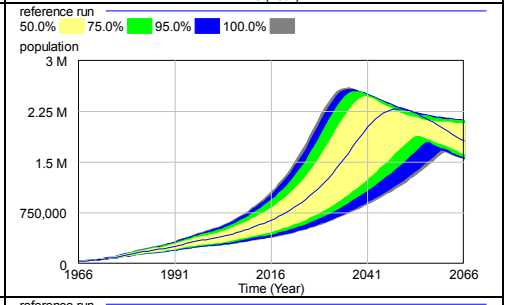
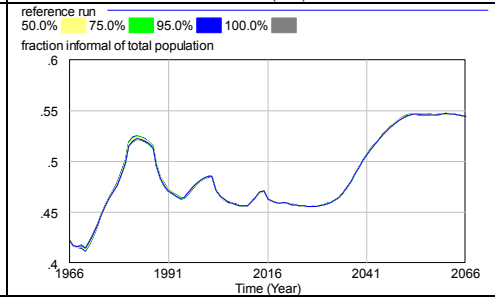
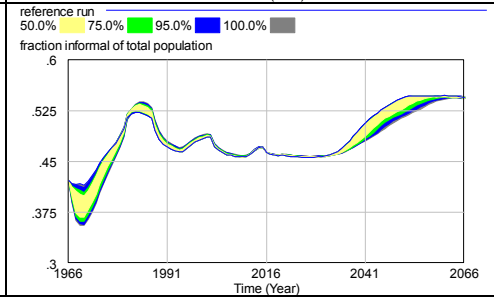
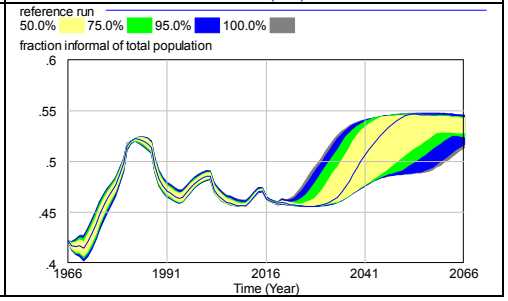
Parameter	declining industry management	manager-arrival multiplier perception time	labor mobility normal
Units	worker/productive unit	year	1/year
Nominal value	1	10	0.02
Minimum plausible	1	5	0.01 (-50%)
Maximum plausible	2 (+100%)	15	0.03 (+50%)

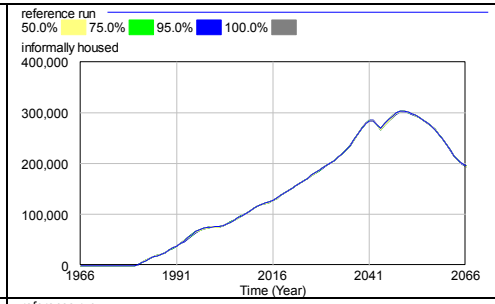
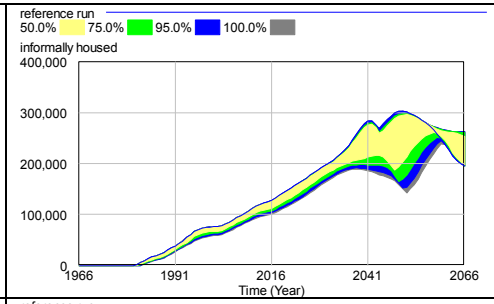
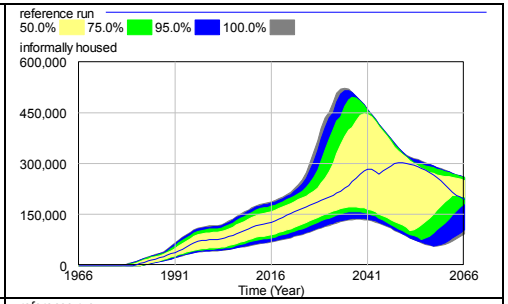
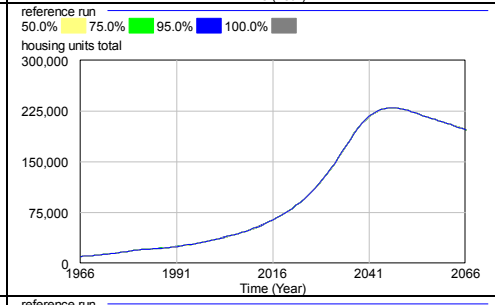
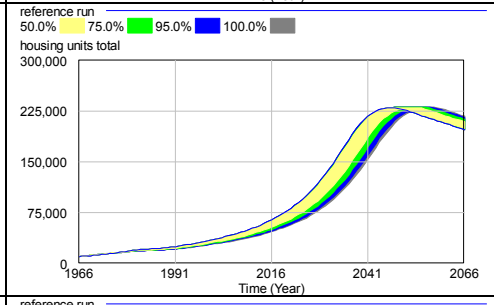
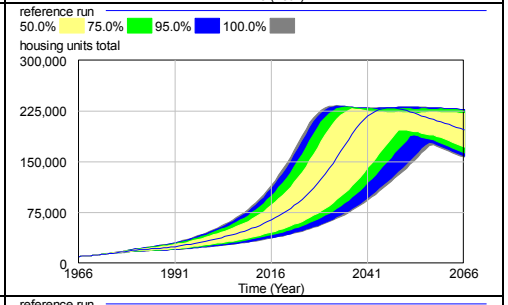
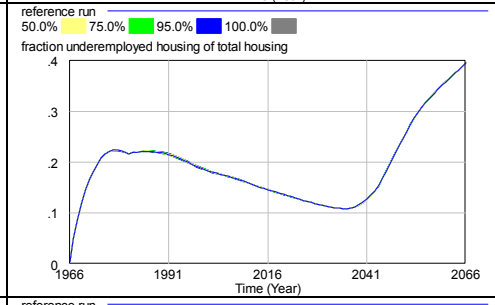
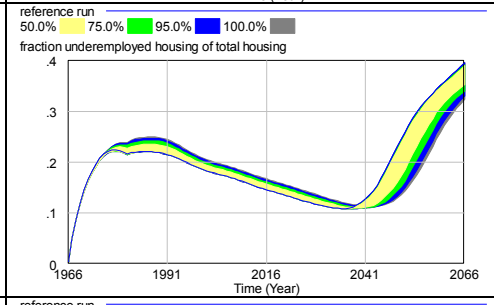
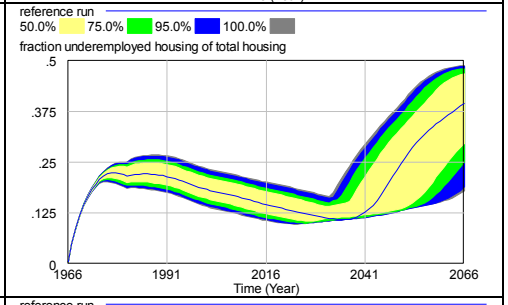
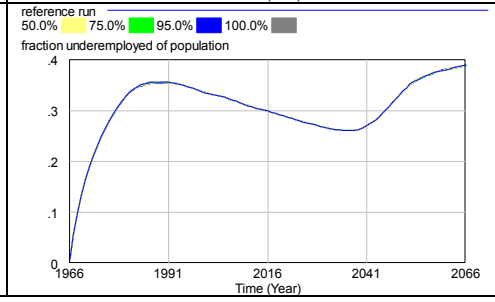
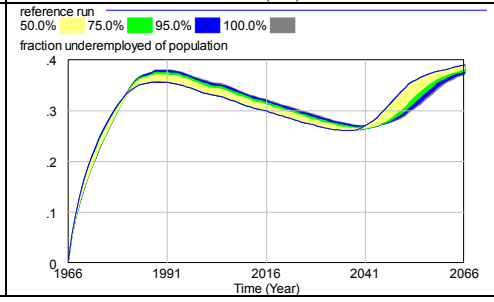
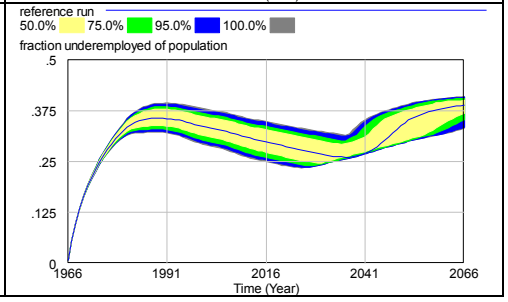
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

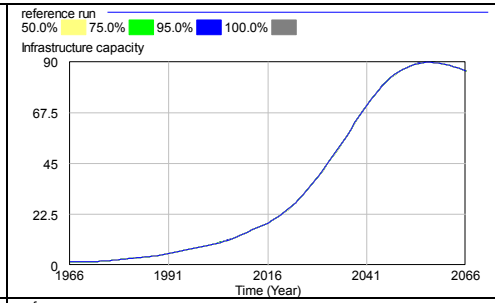
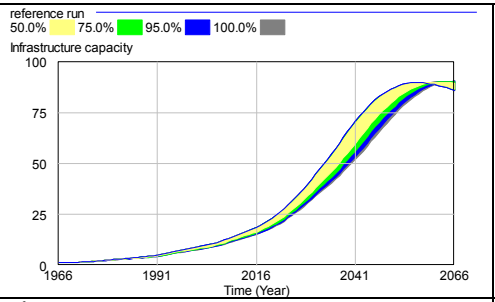
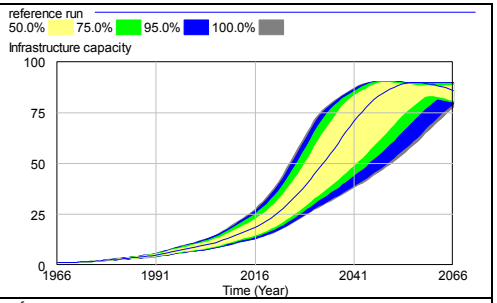
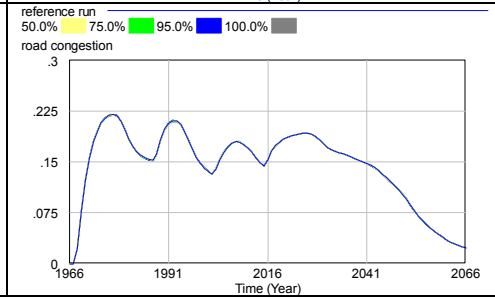
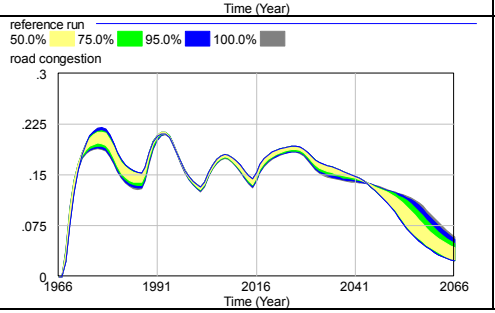
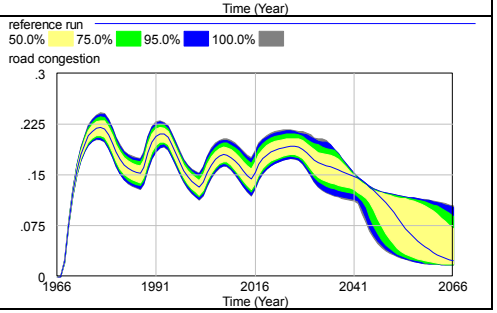
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

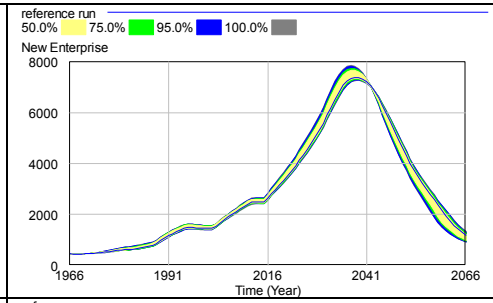
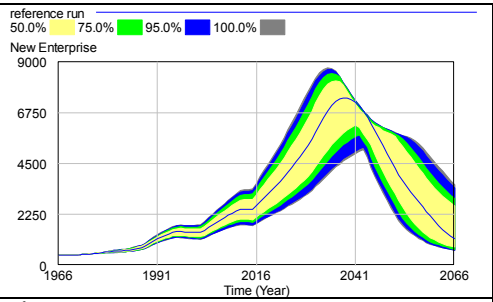
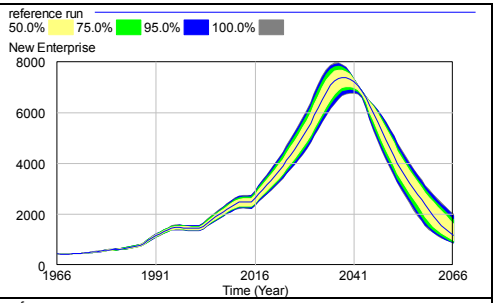
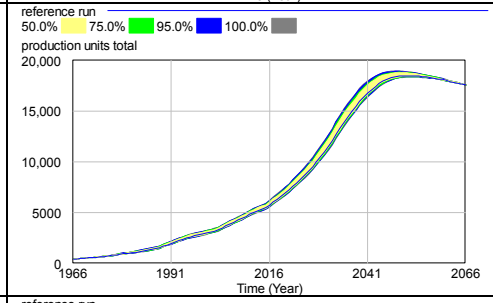
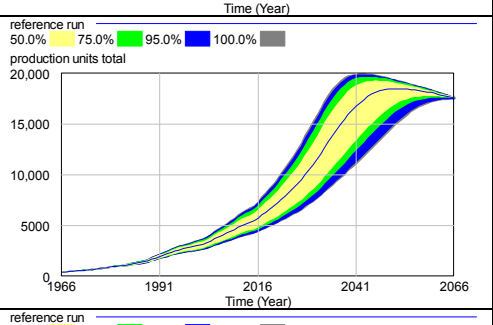
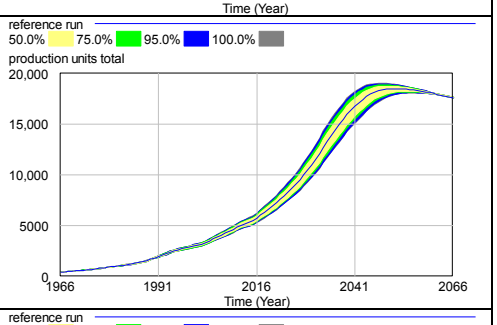
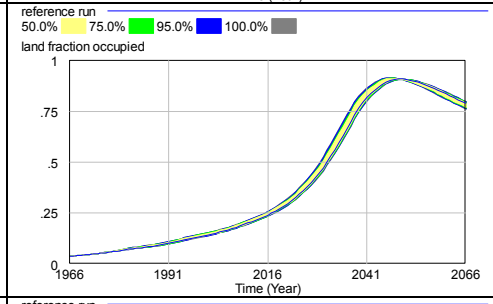
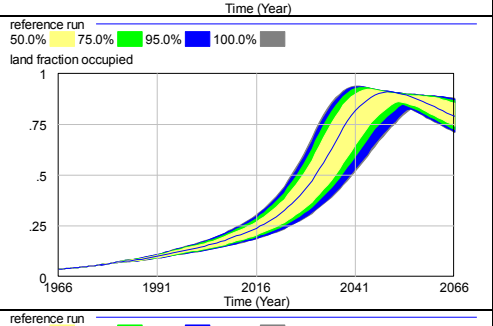
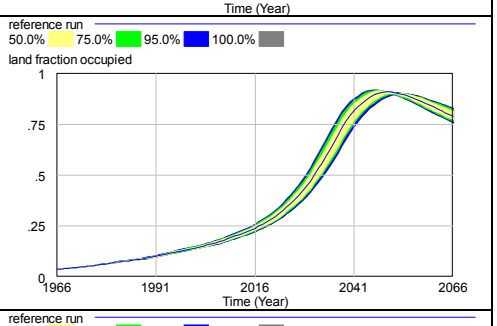
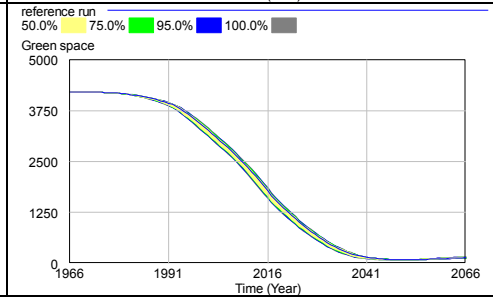
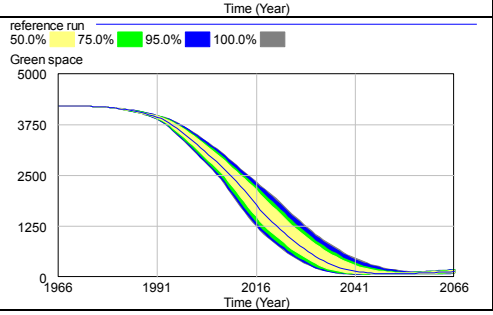
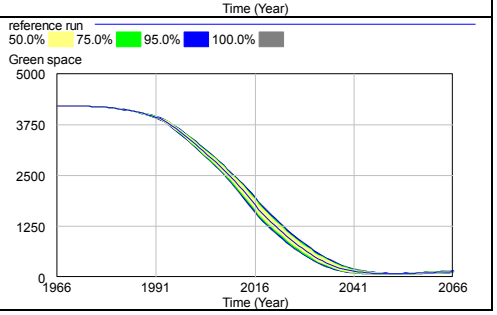
Parameter	labor mobility multiplier perception time	labor training program	labor arrivals normal
Units	Year	worker/year	1/year
Nominal value	15	0	0.03
Minimum plausible	5	0	0.015
Maximum plausible	20	500	0.045
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			

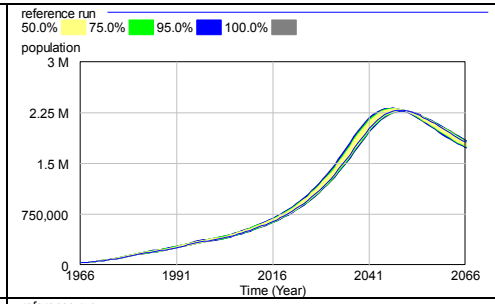
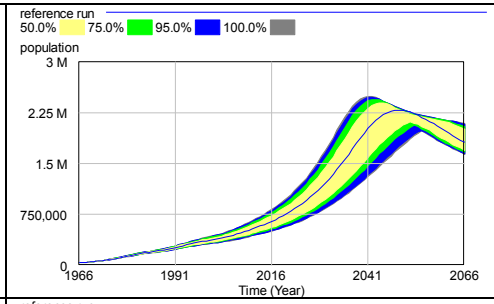
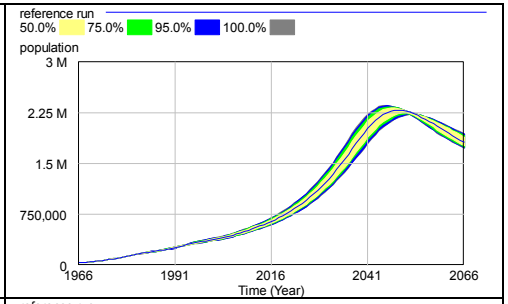
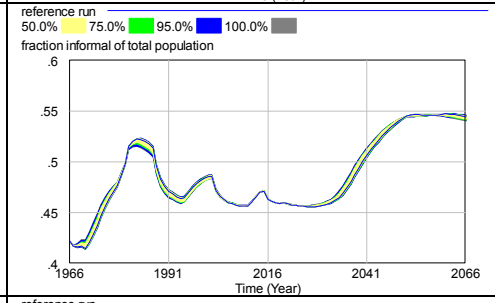
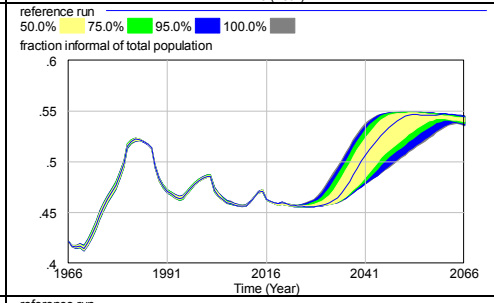
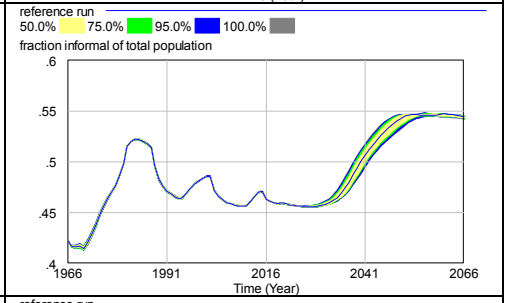
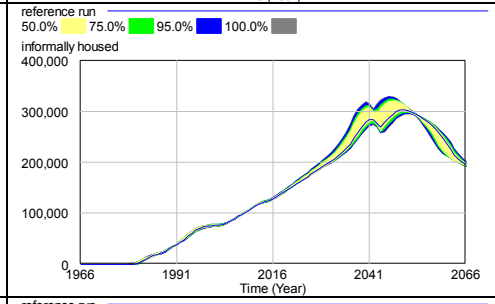
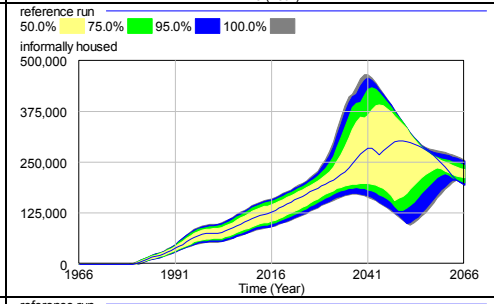
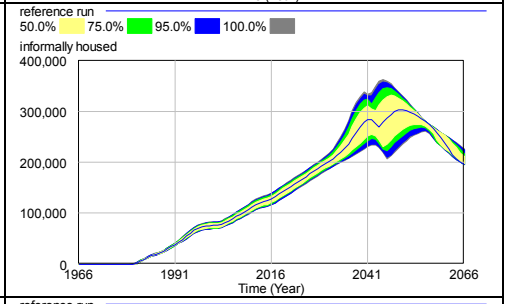
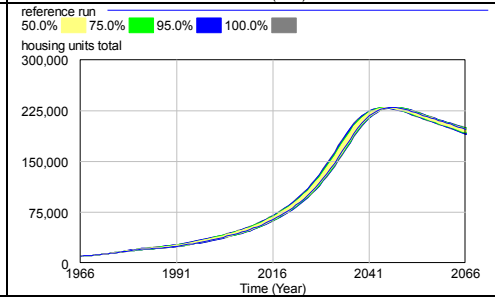
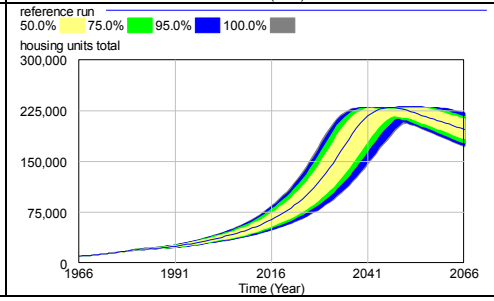
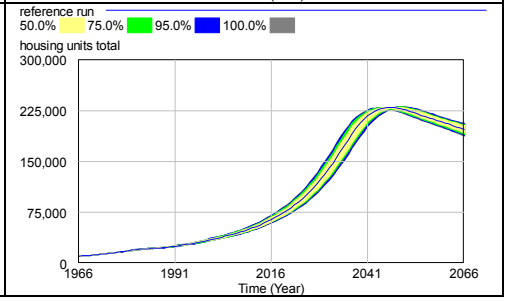
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			

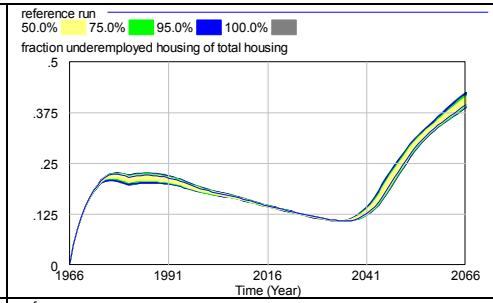
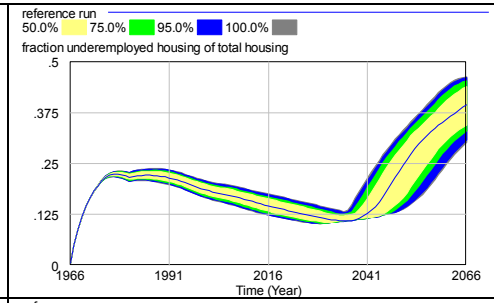
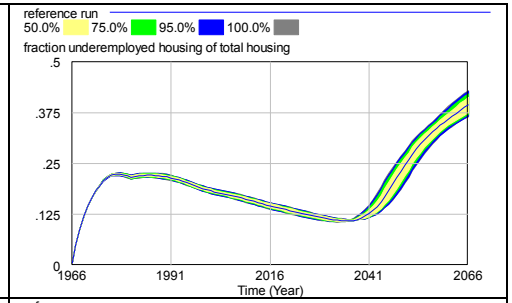
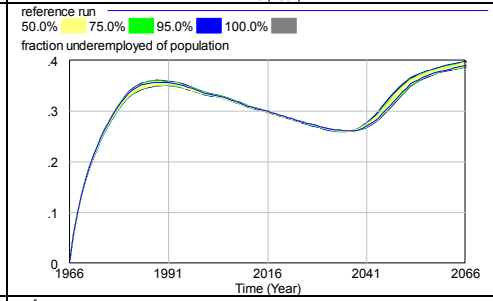
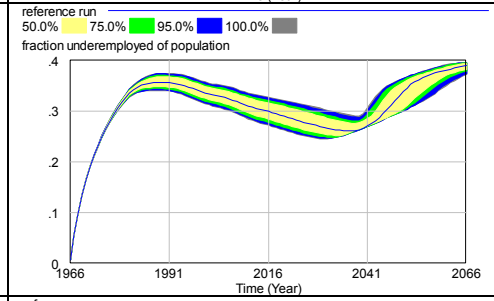
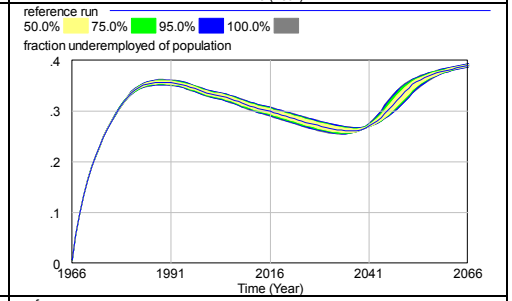
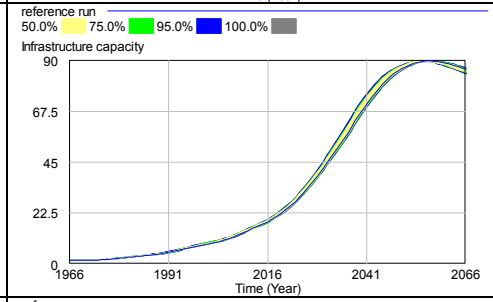
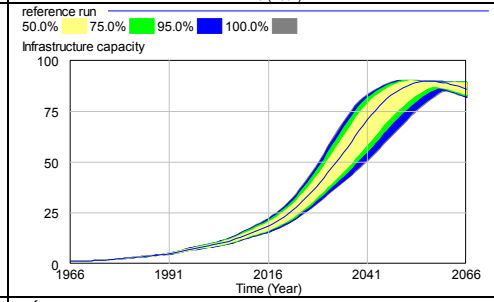
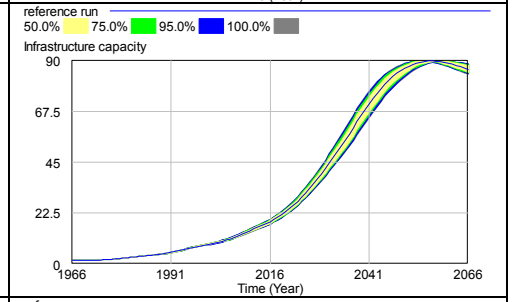
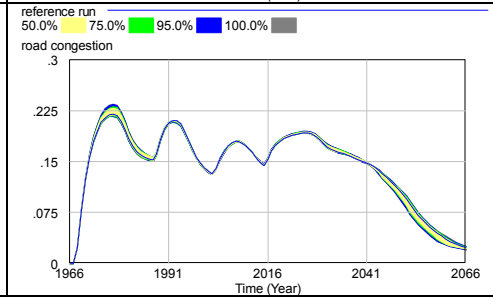
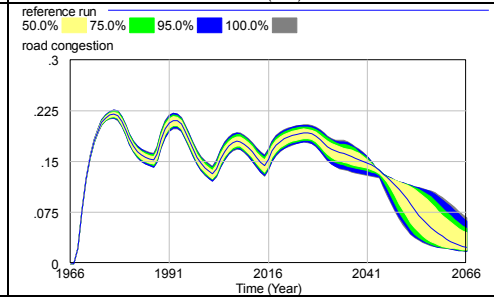
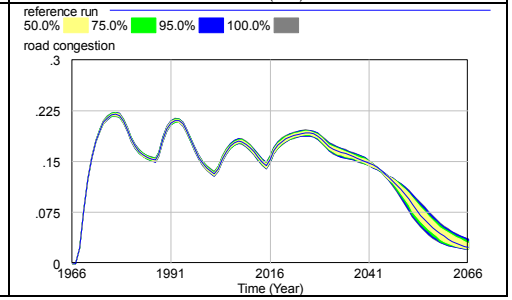
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			

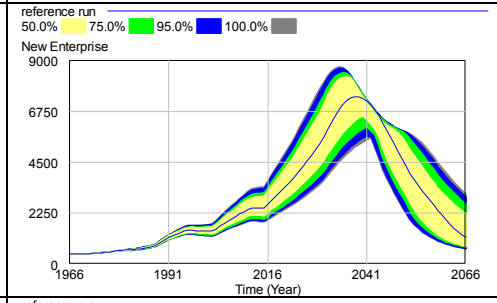
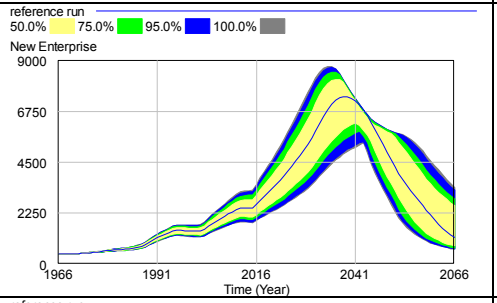
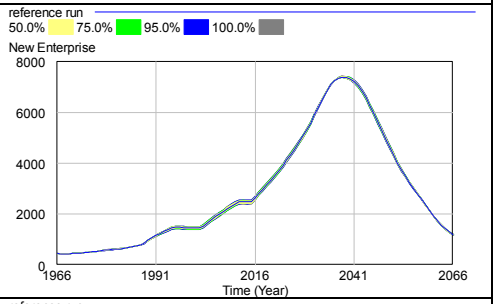
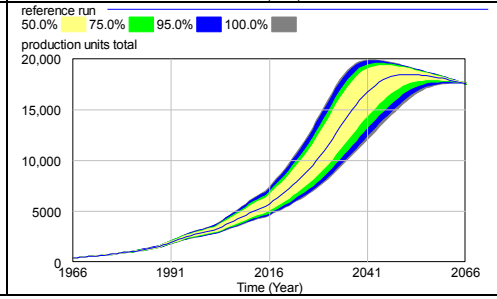
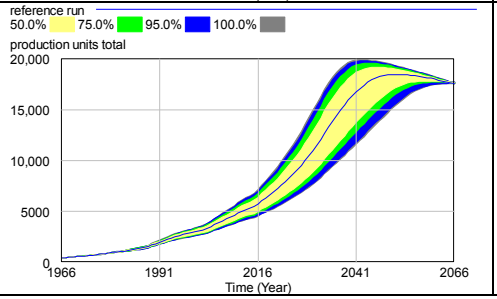
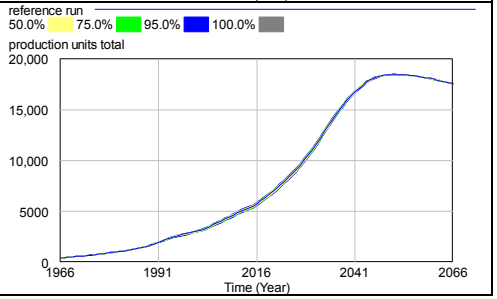
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

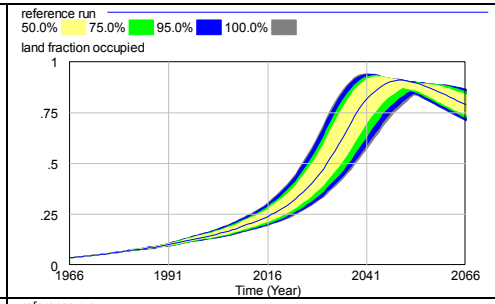
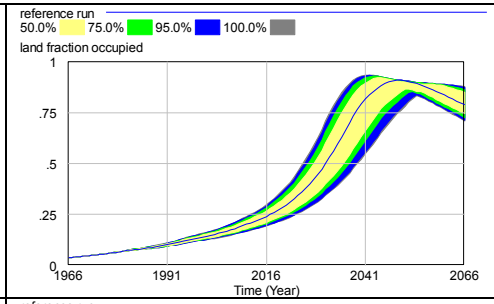
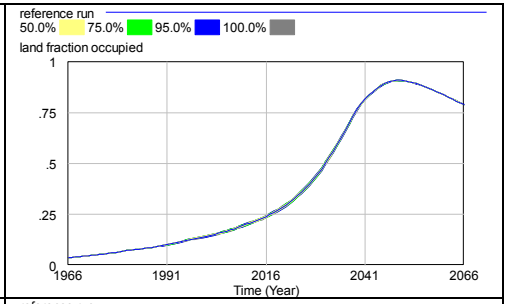
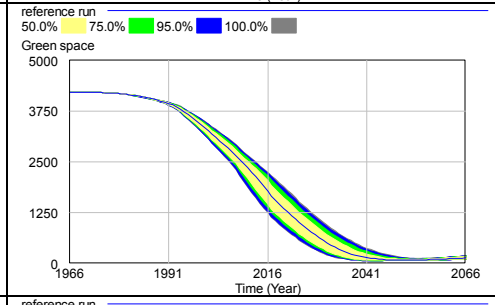
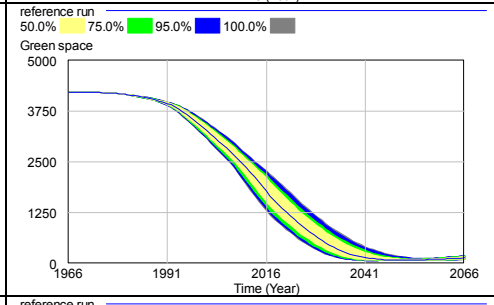
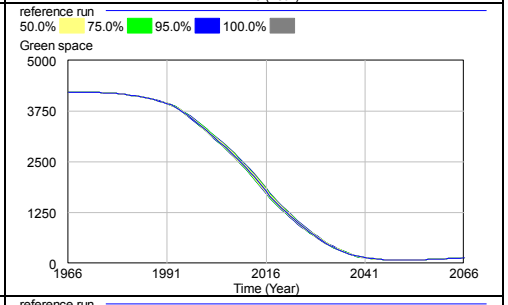
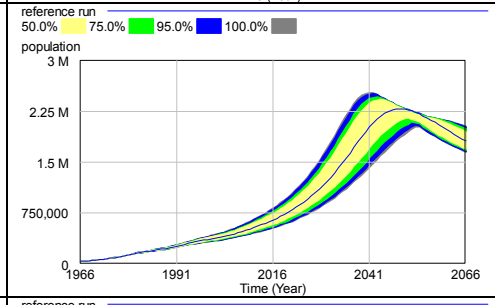
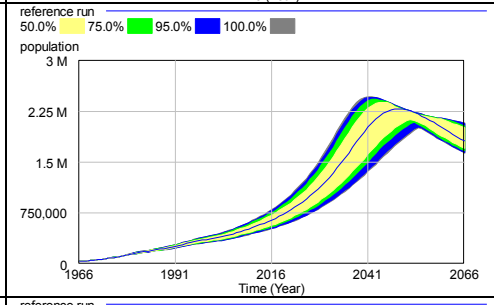
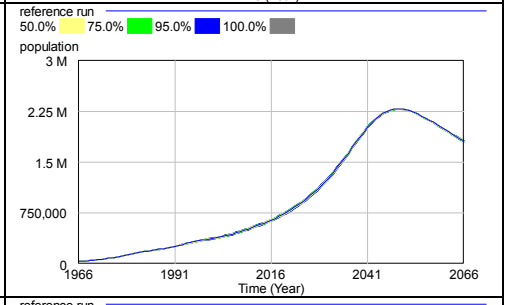
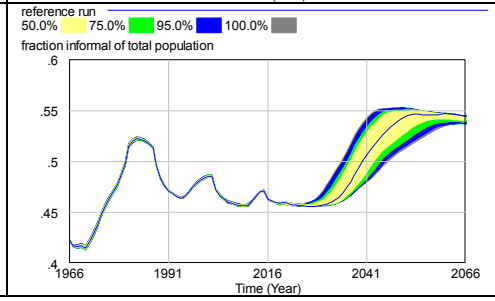
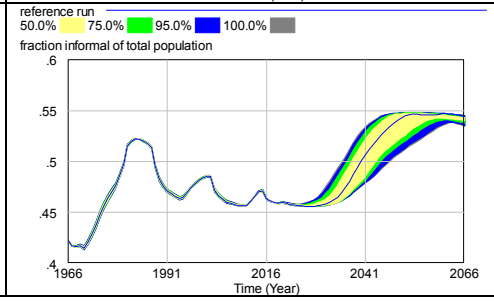
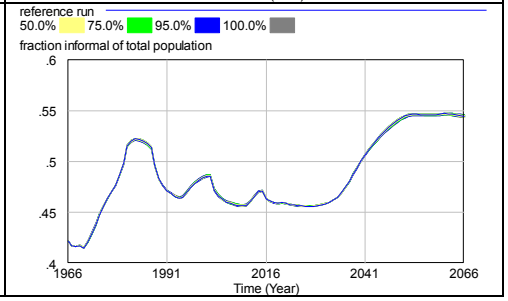
Parameter	labor arrival multiplier perception time	labor arrival factor	labor birth rate
Units	Year	-	1/year
Nominal value	15	1	0.017
Minimum plausible	5	0.8	0.0136 (-20%)
Maximum plausible	20	1.2	0.0204 (+20%)

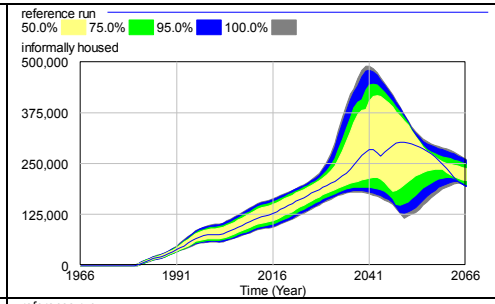
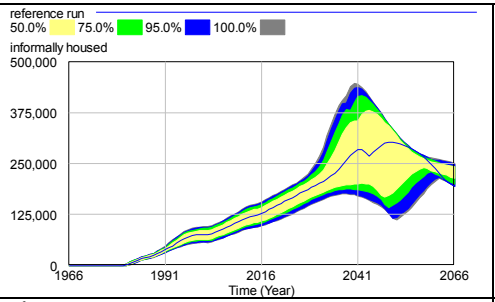
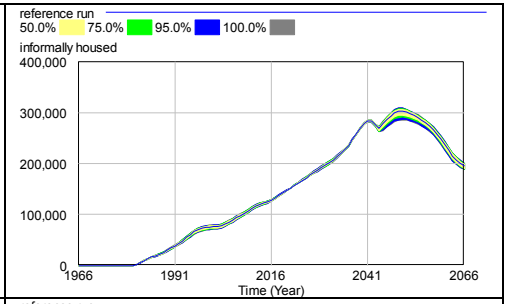
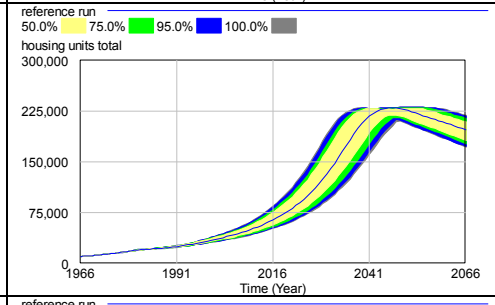
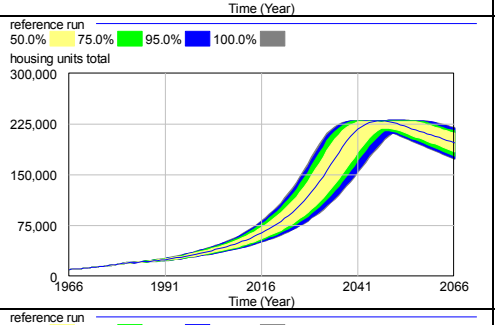
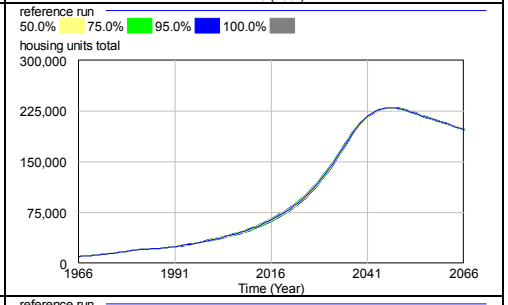
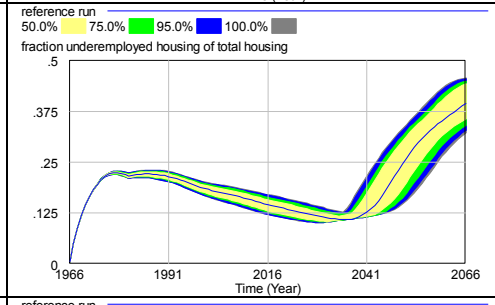
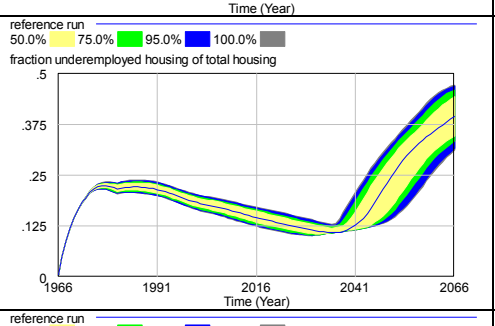
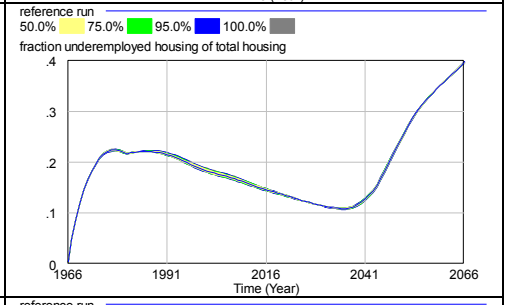
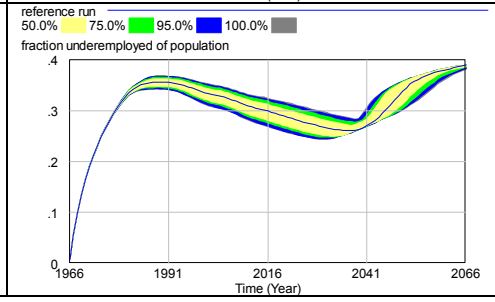
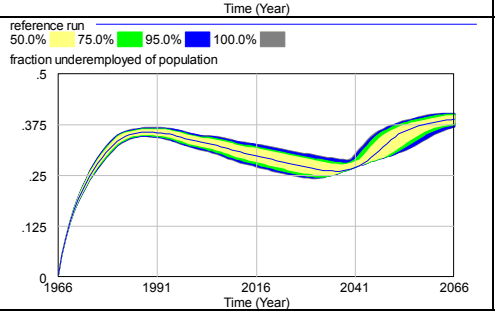
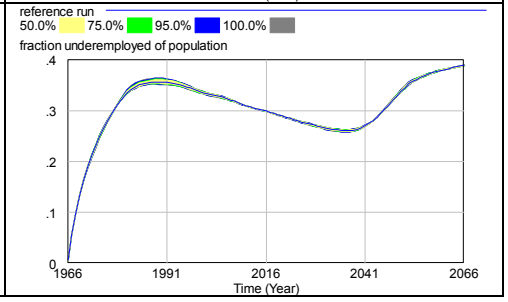
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

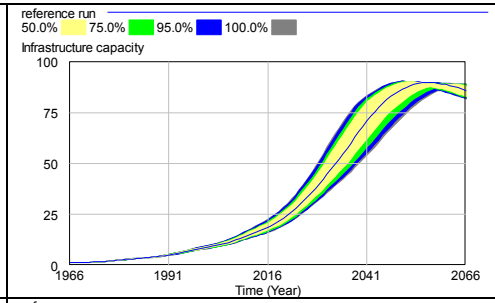
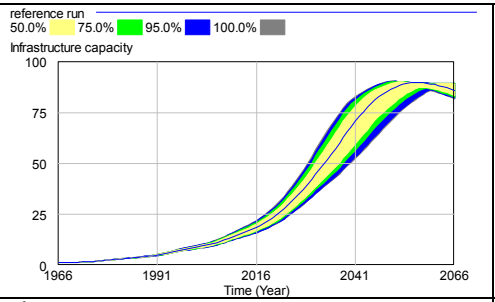
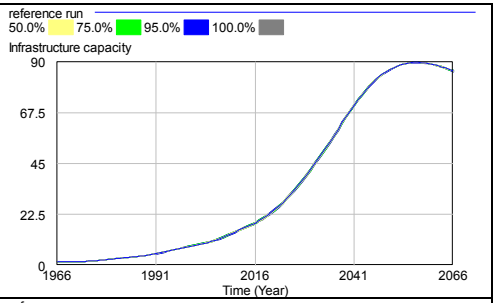
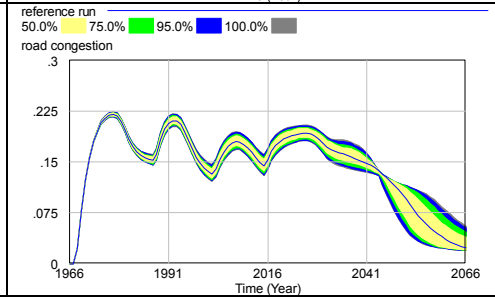
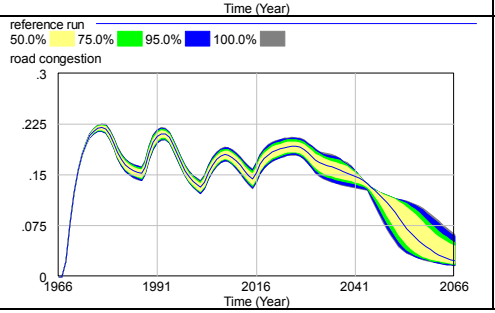
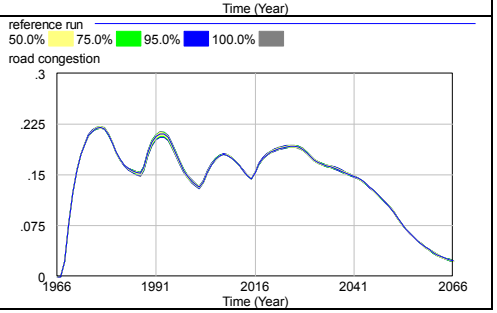
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

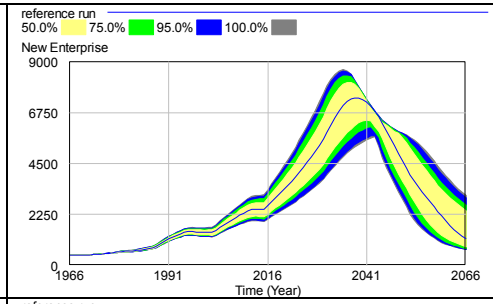
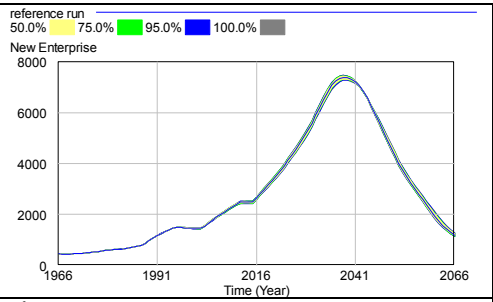
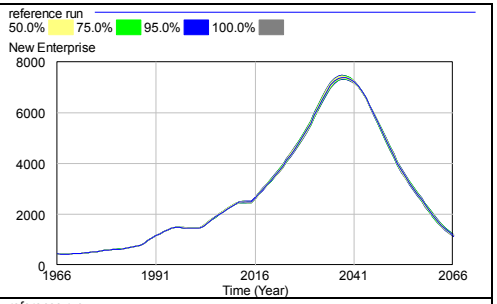
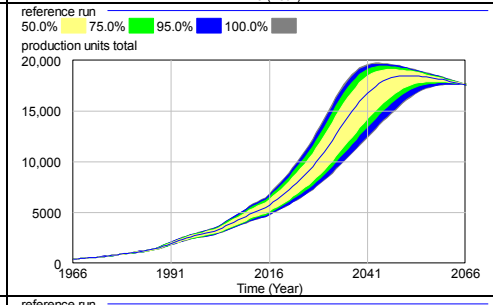
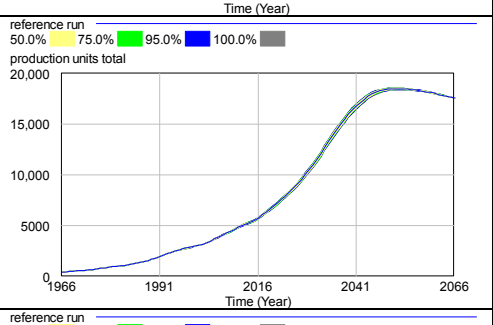
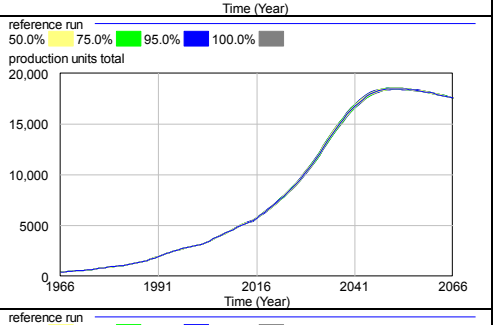
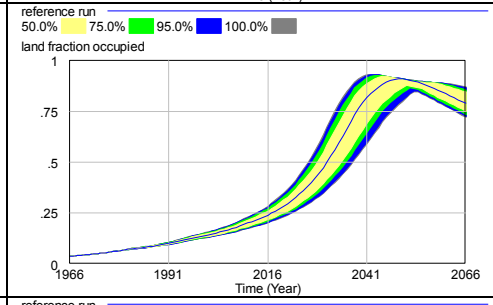
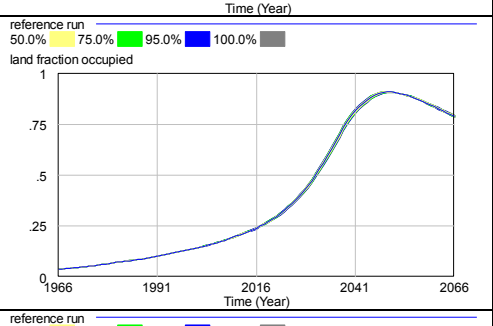
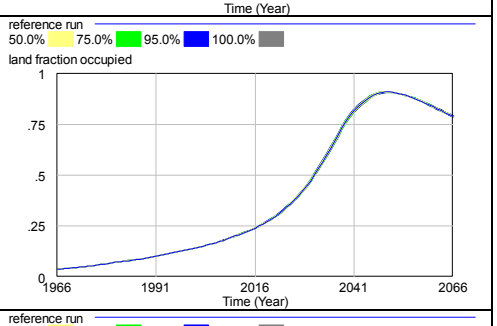
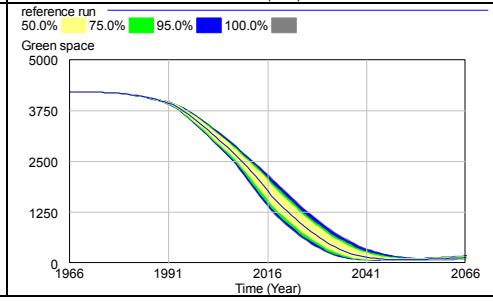
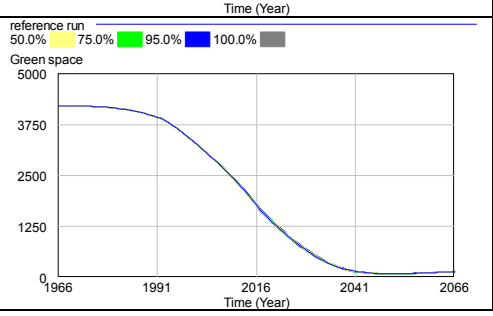
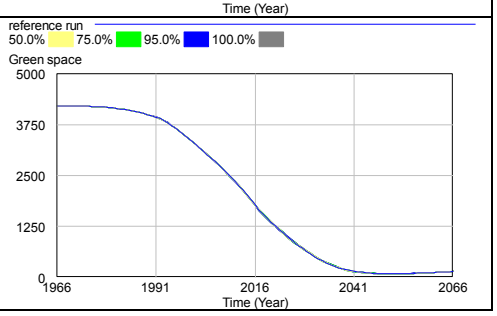
Parameter	labor departures normal	underemployed mobility normal	underemployed mobility perception time
Units	1/year	1/year	Year
Nominal value	0.02	0.1	10
Minimum plausible	0.01 (-50%)	0.08 (-20%)	5
Maximum plausible	0.03 (+50%)	0.12 (+20%)	15
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			

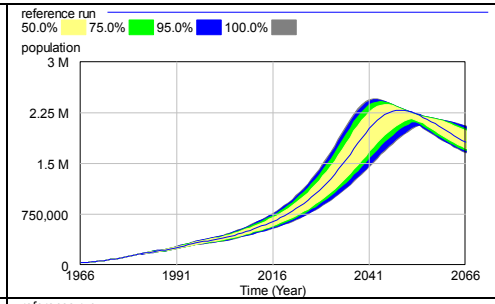
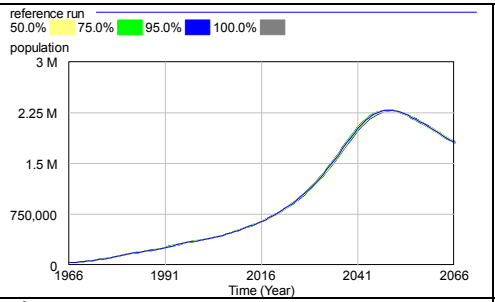
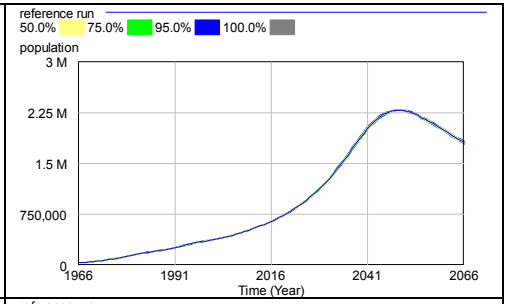
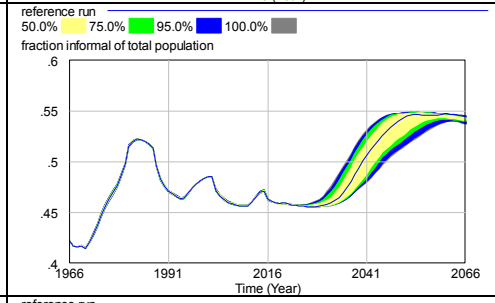
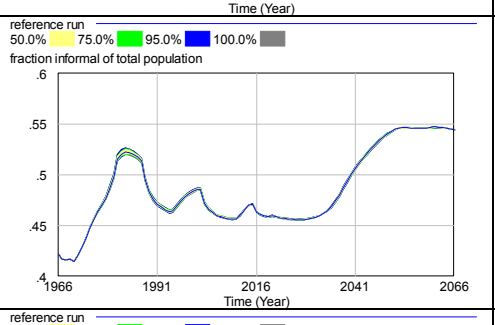
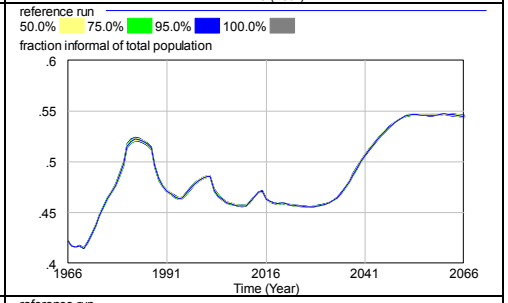
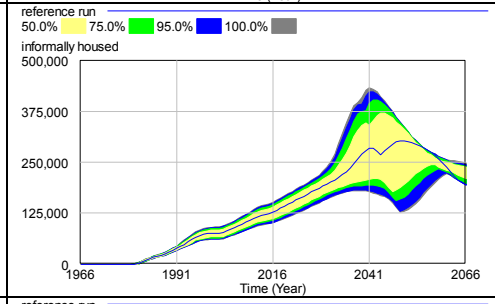
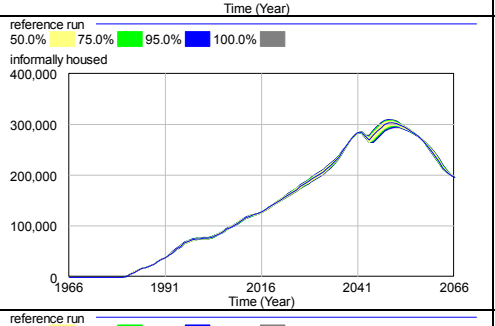
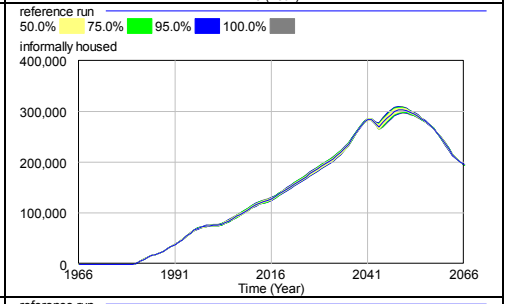
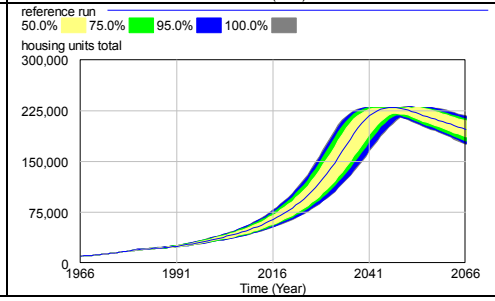
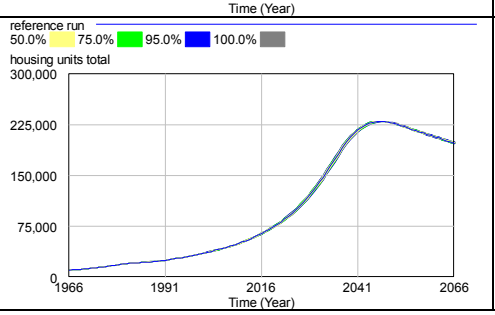
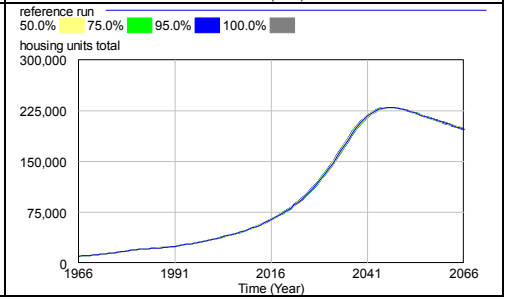
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			

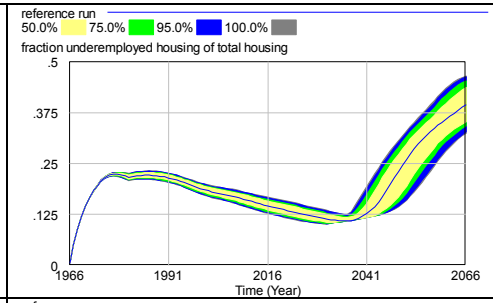
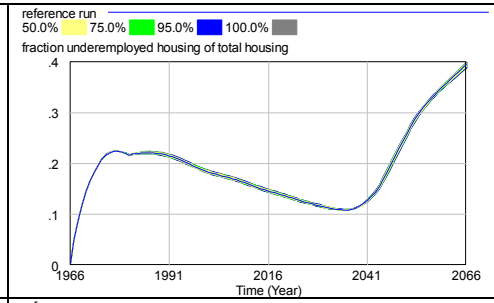
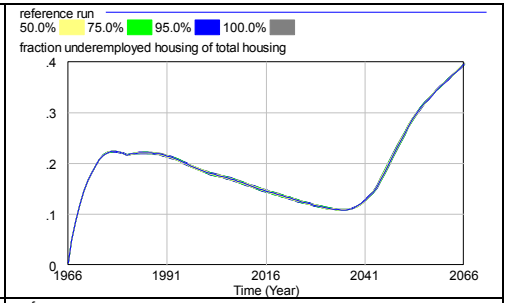
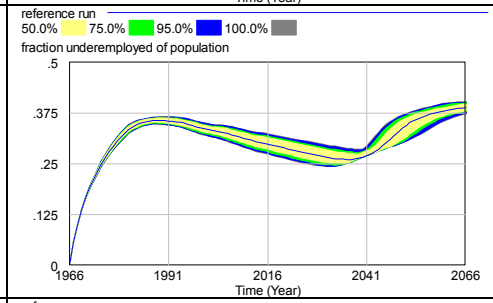
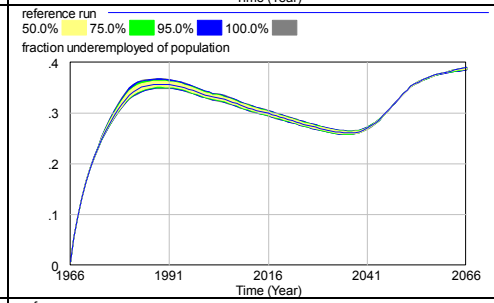
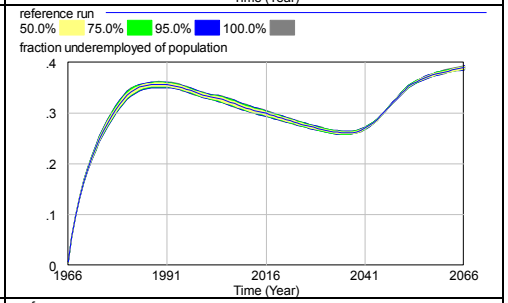
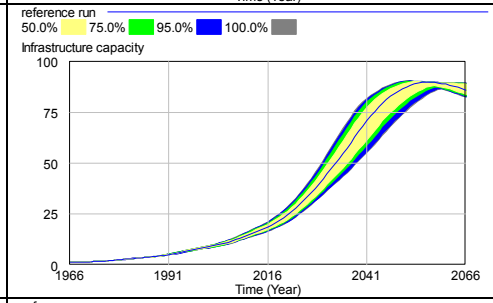
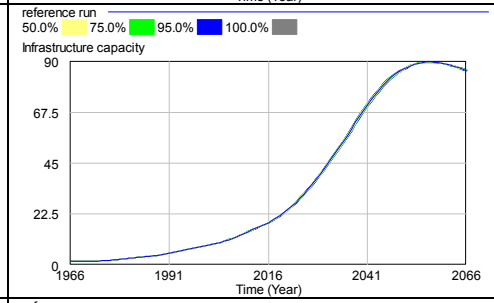
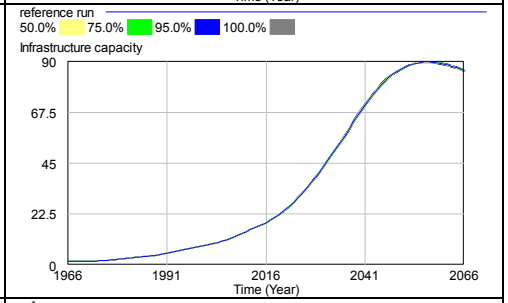
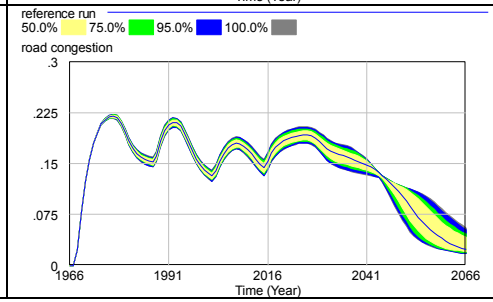
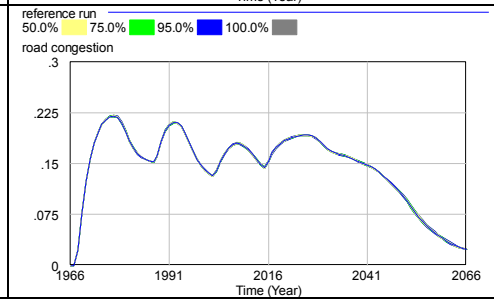
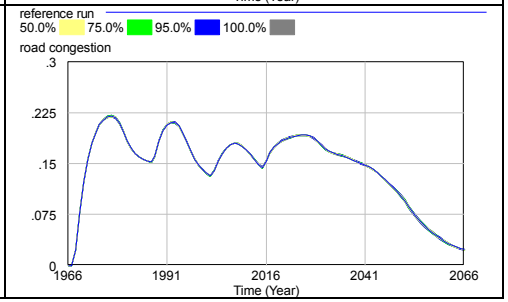
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			

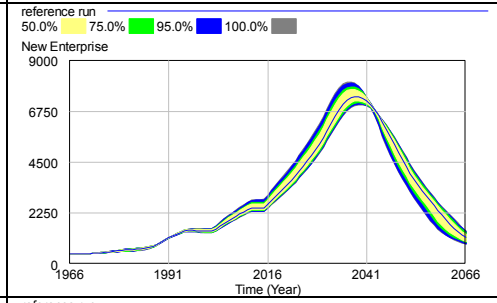
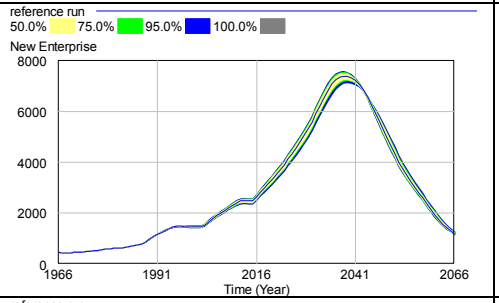
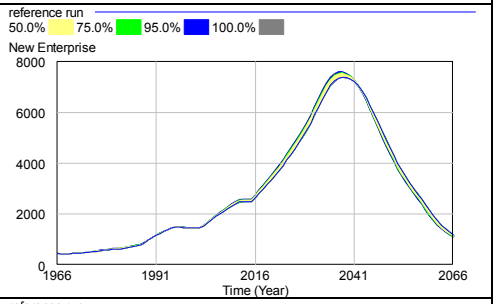
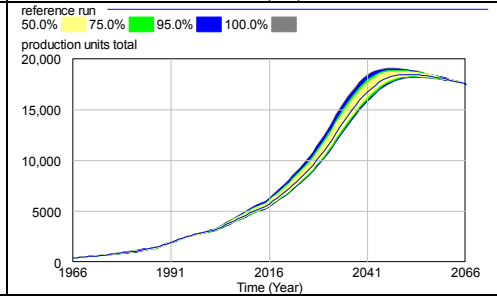
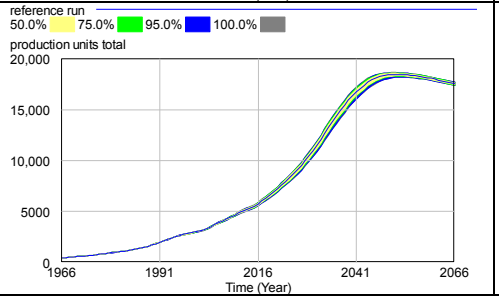
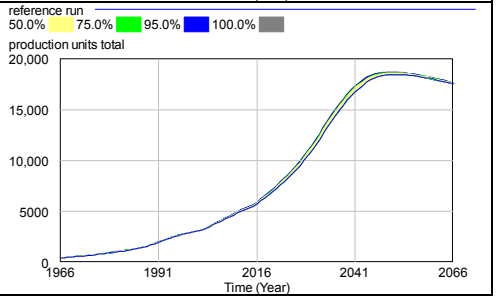
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

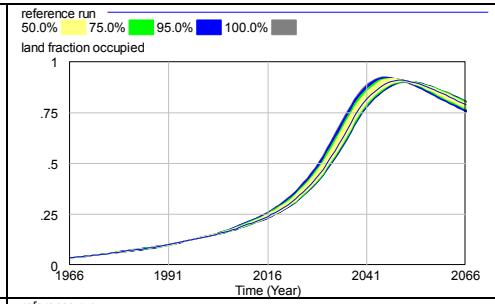
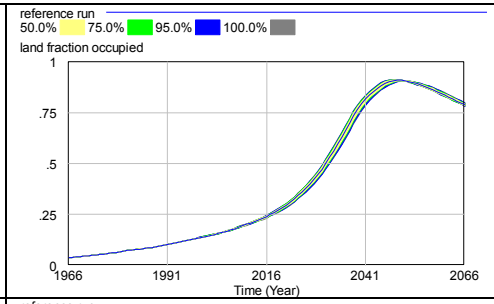
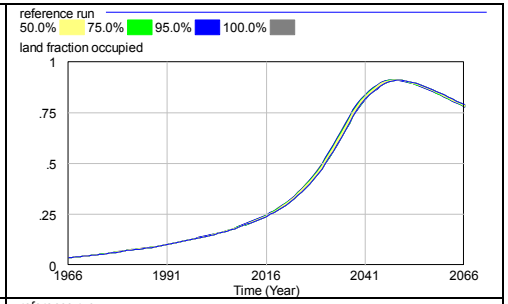
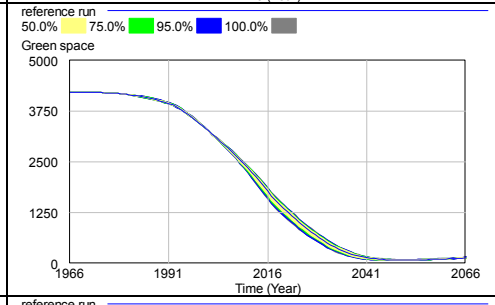
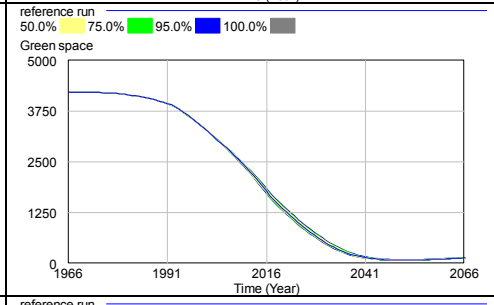
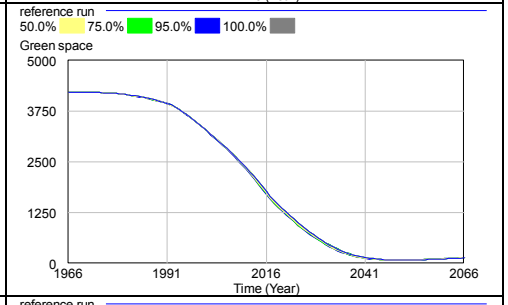
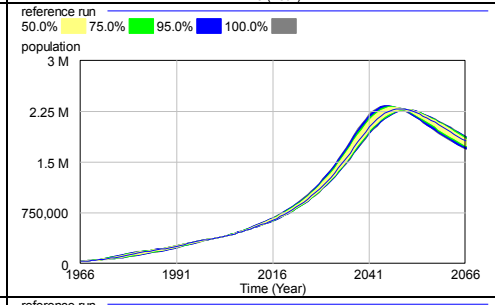
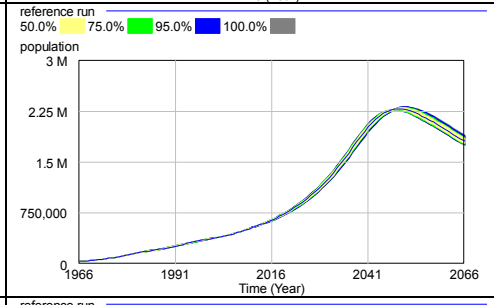
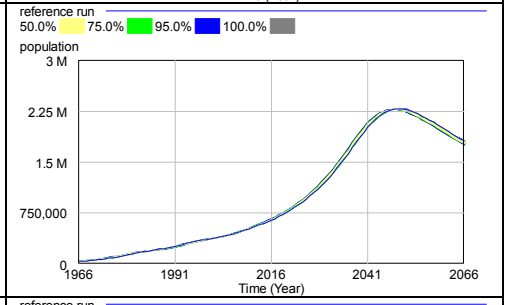
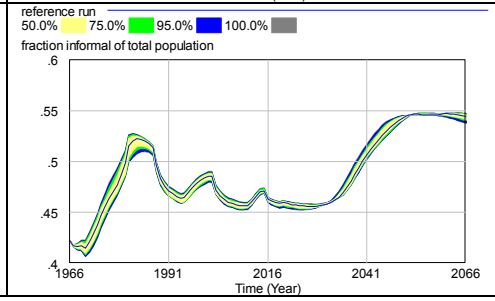
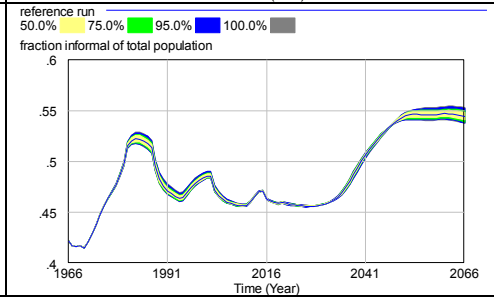
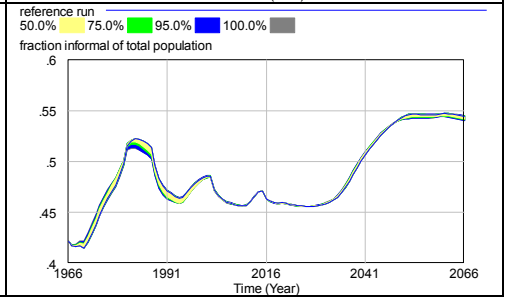
Parameter	underemployed mobility factor	underemployed to labor perception time	underemployed birth rate
Units	-	Year	1/year
Nominal value	1	10	0.02
Minimum plausible	0.8 (-20%)	5	0.01 (-50%)
Maximum plausible	1.2 (+20%)	15	0.03 (+50%)

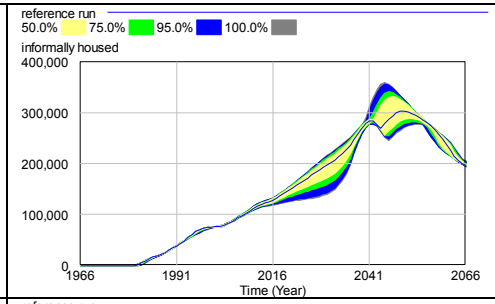
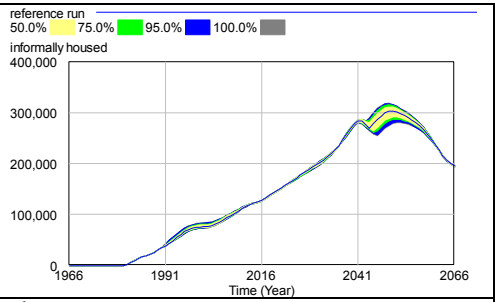
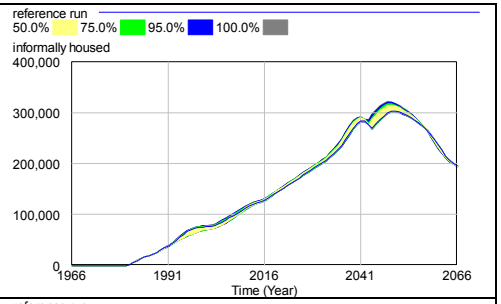
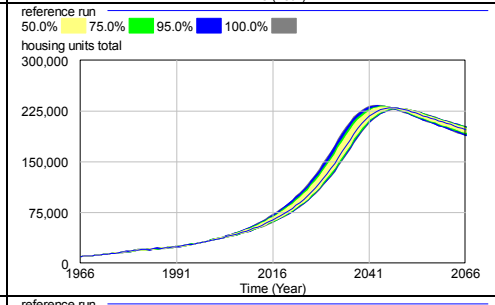
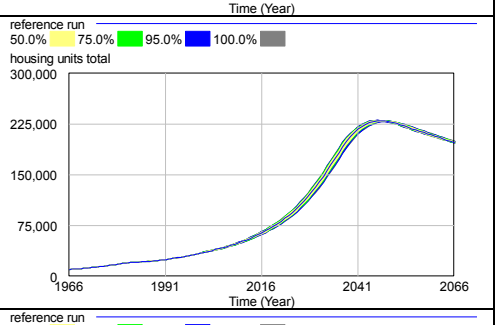
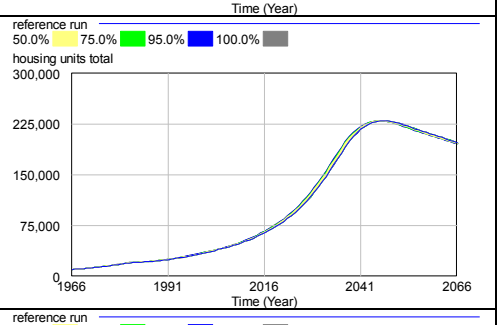
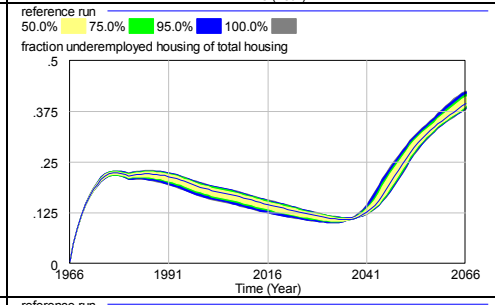
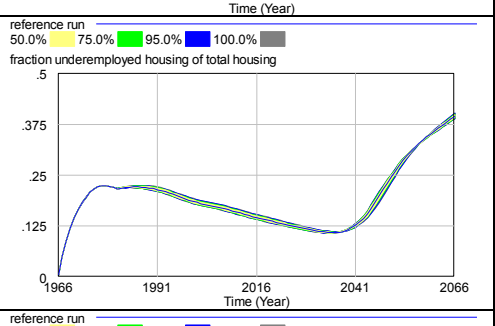
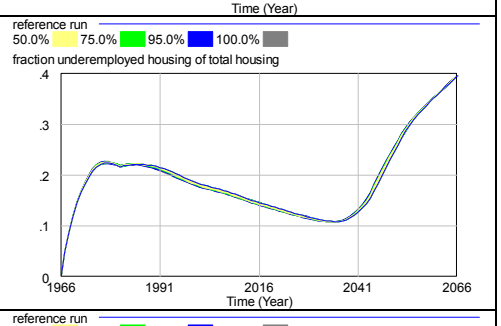
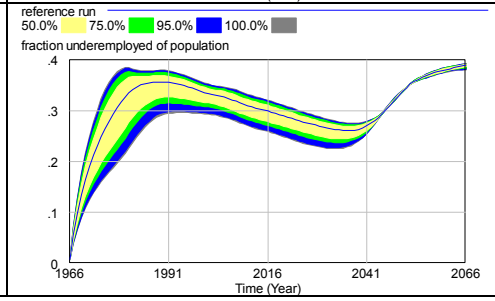
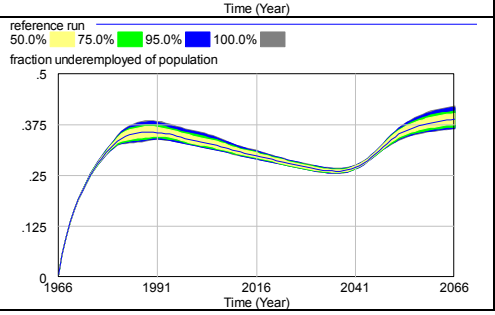
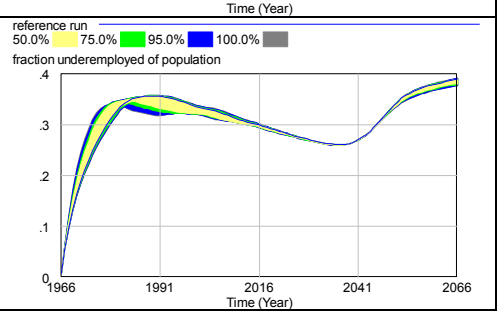
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

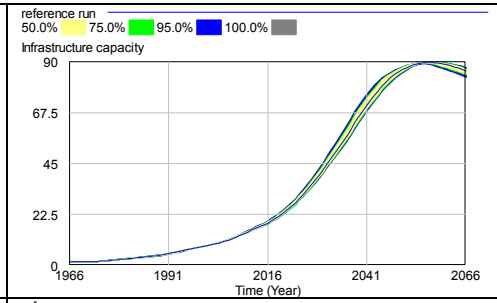
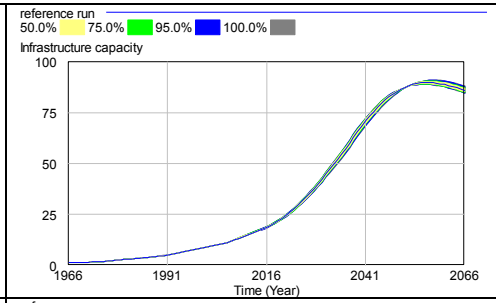
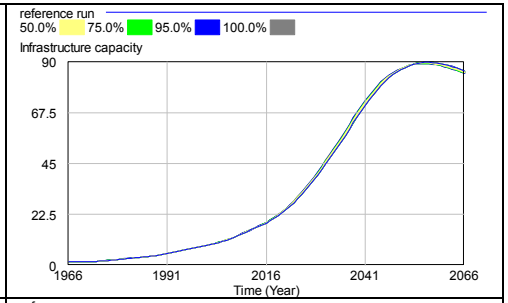
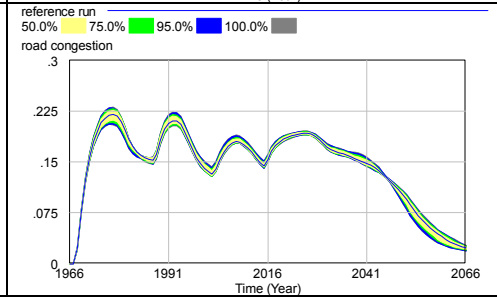
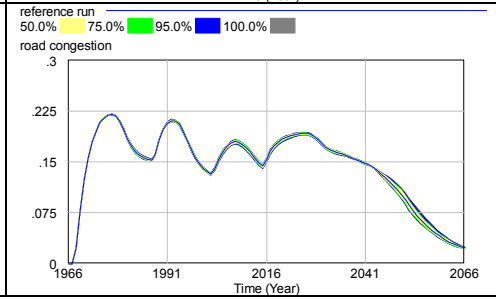
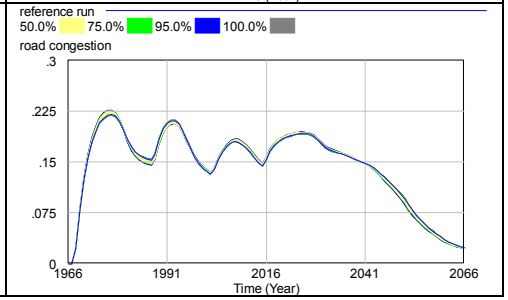
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

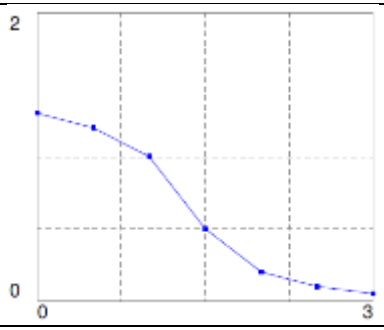
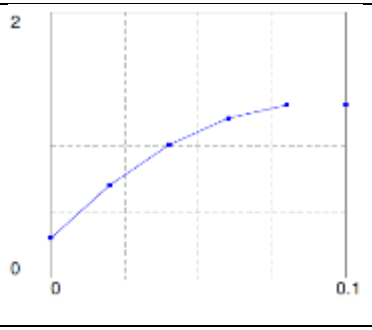
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

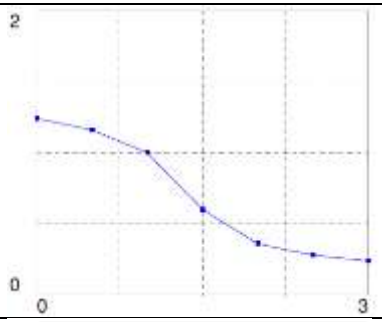
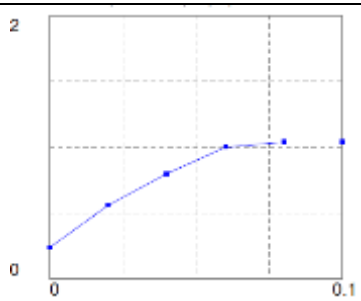
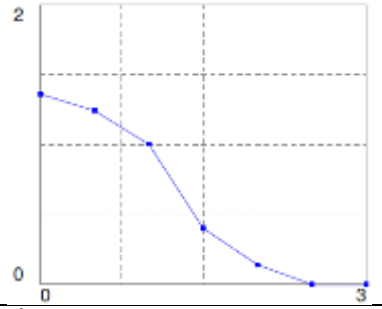
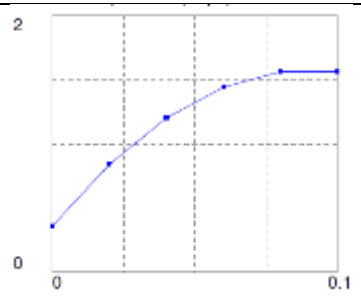
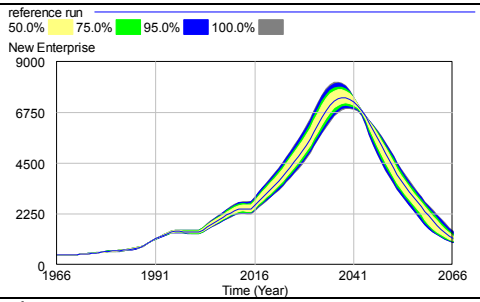
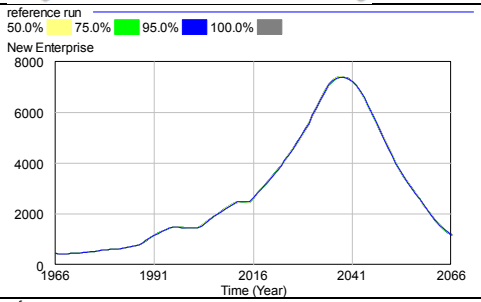
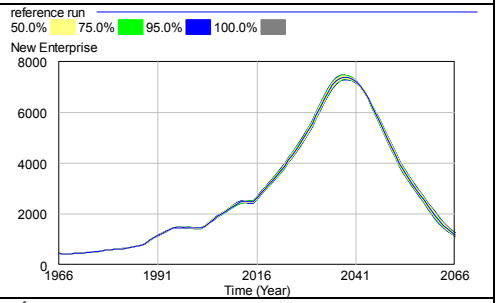
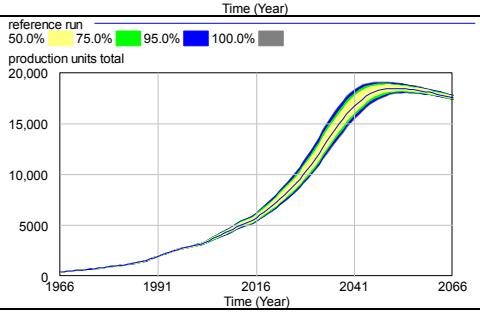
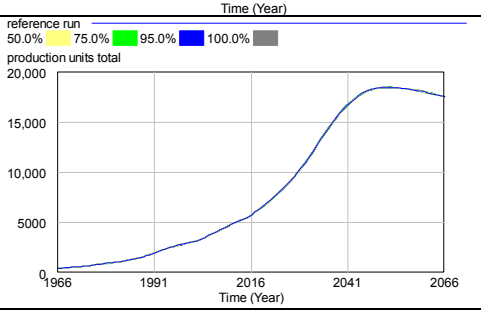
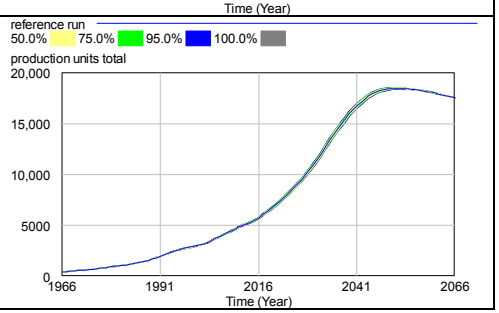
Parameter	underemployed arrivals normal	underemployed departures normal	attractiveness for migration multiplier perception time
Units	1/year	1/year	Year
Nominal value	0.05	0.02	20
Minimum plausible	0.025	0.01 (-50%)	5
Maximum plausible	0.075	0.03 (+50%)	25
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			

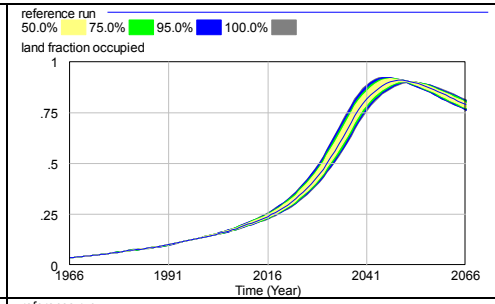
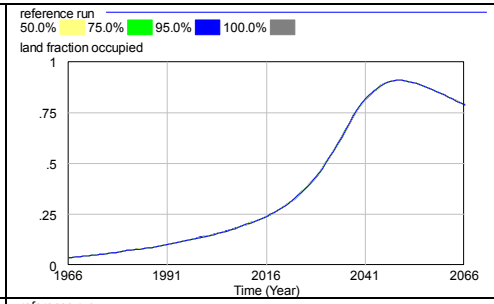
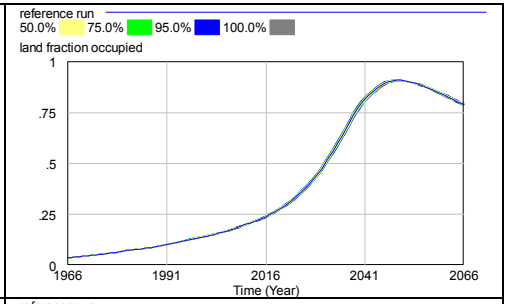
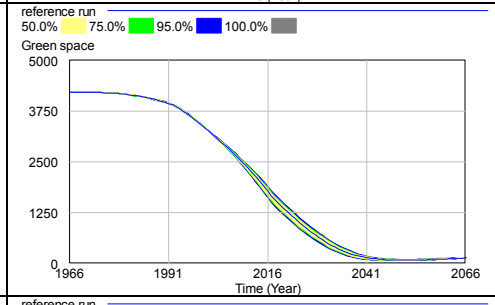
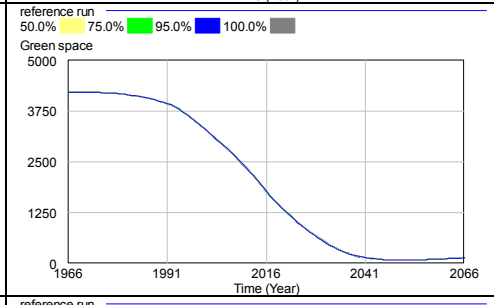
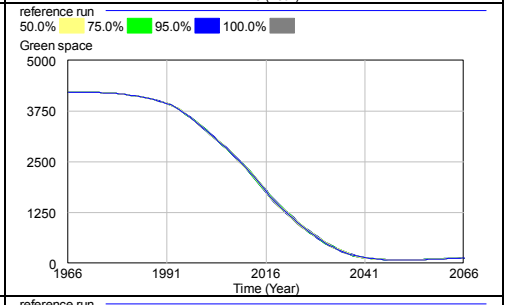
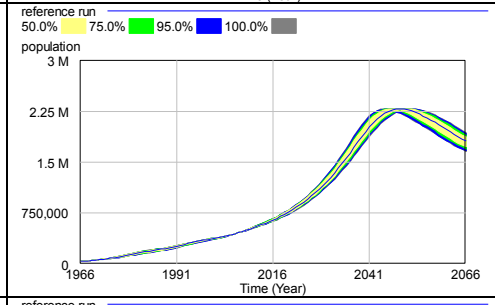
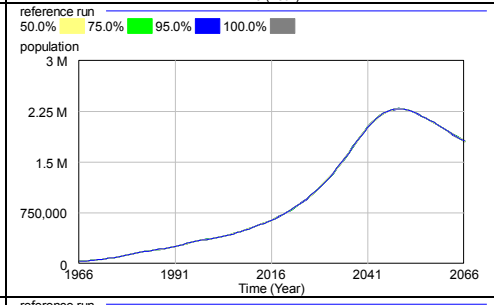
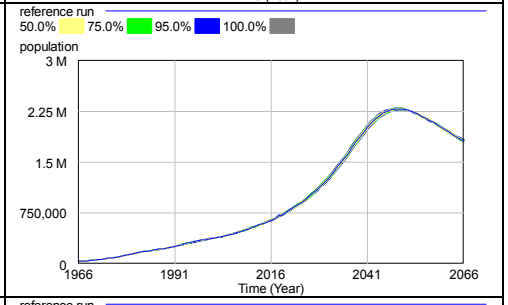
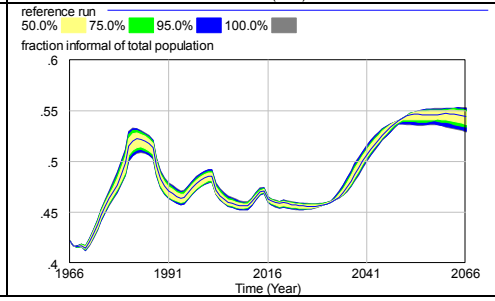
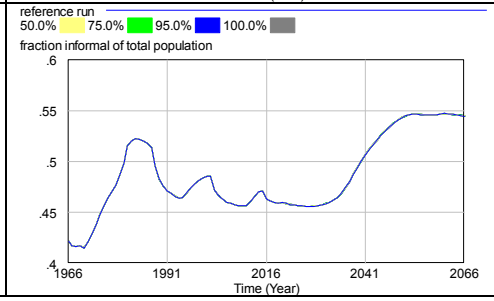
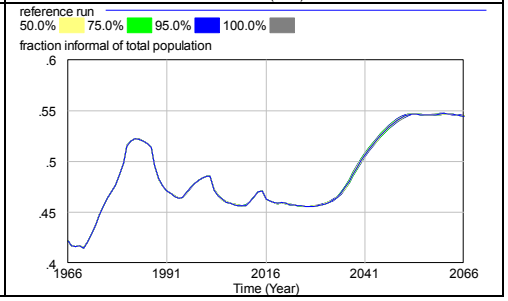
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			

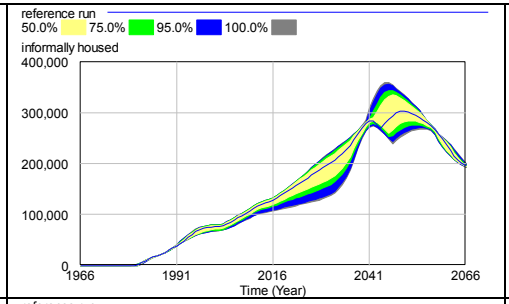
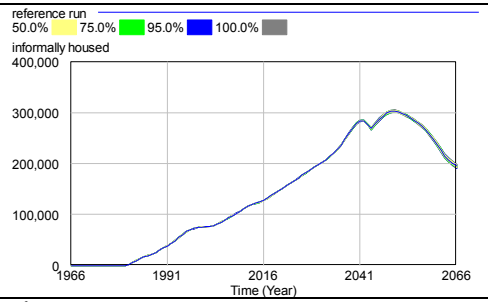
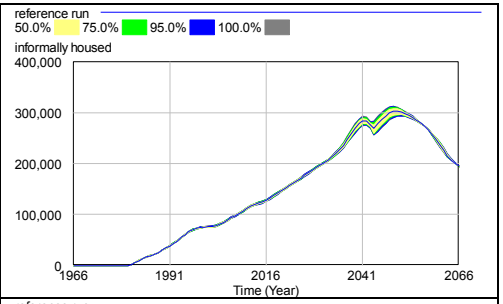
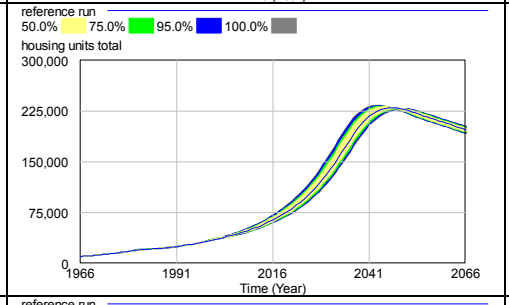
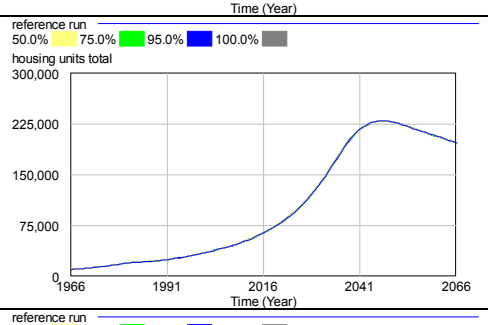
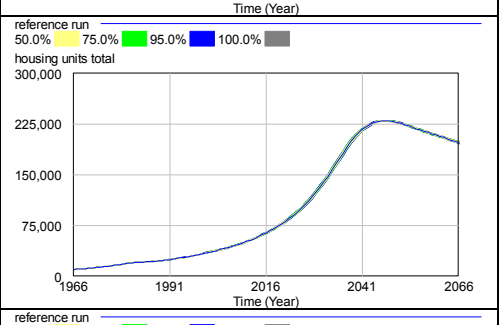
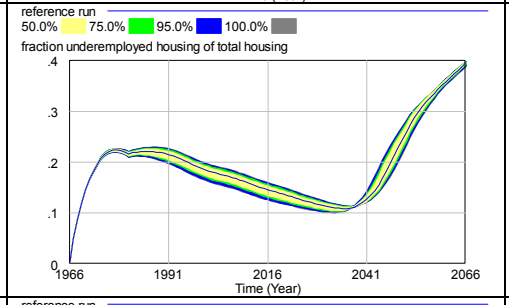
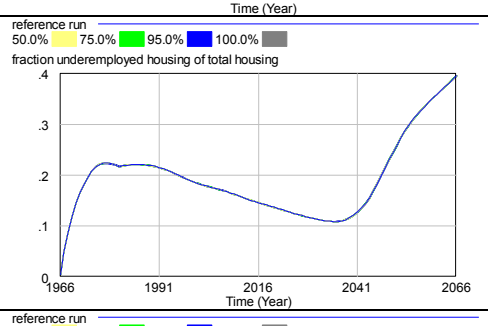
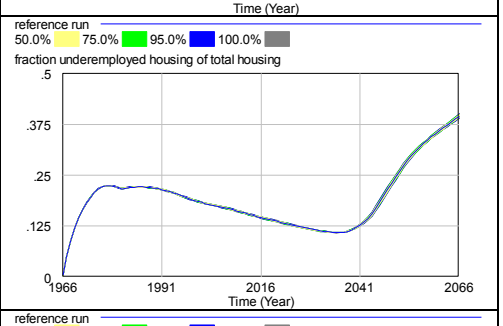
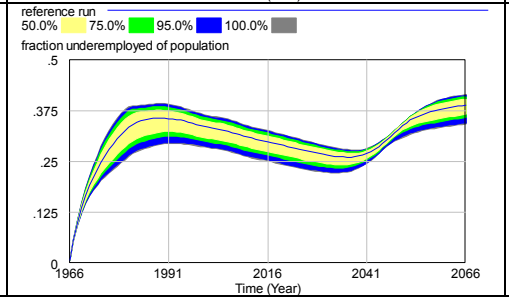
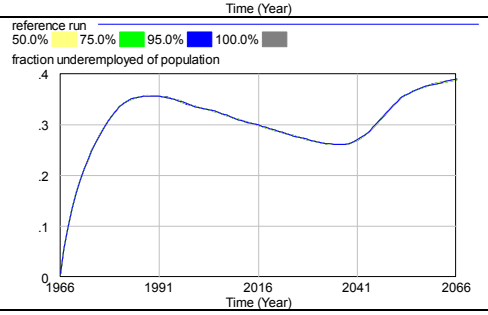
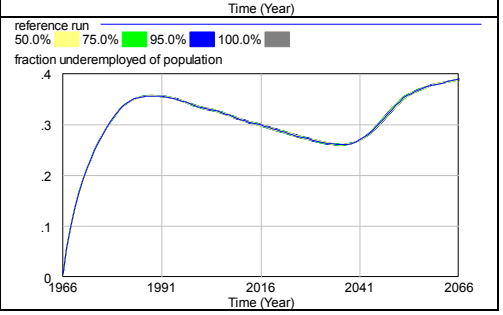
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			

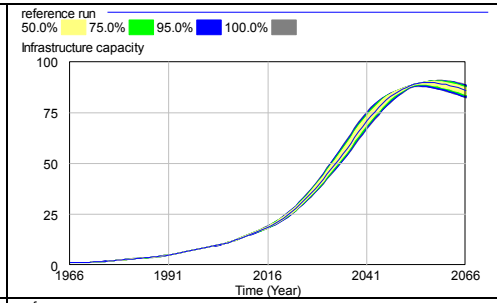
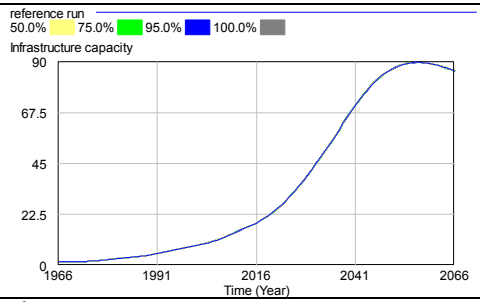
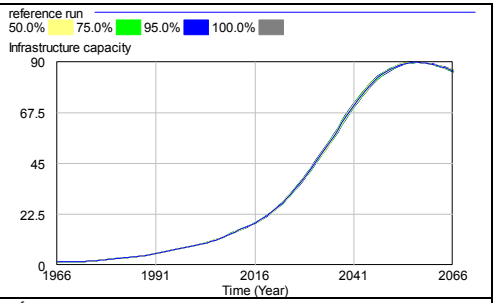
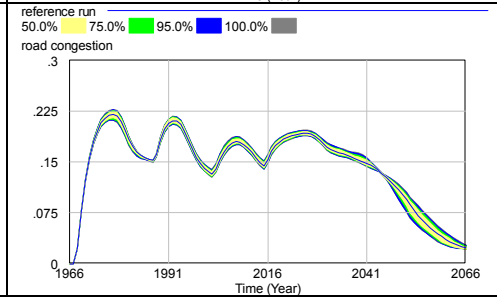
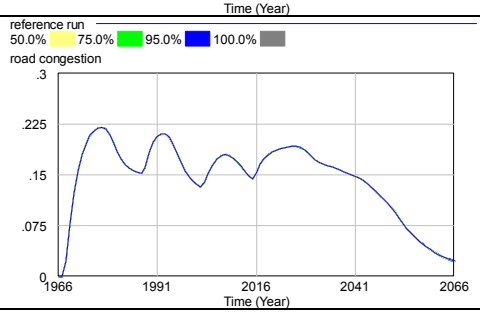
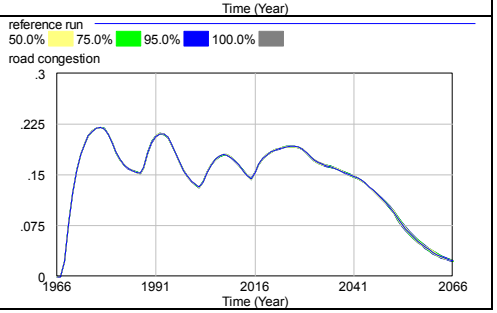
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

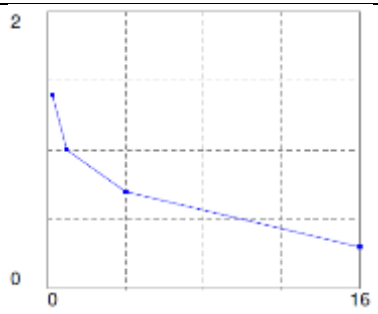
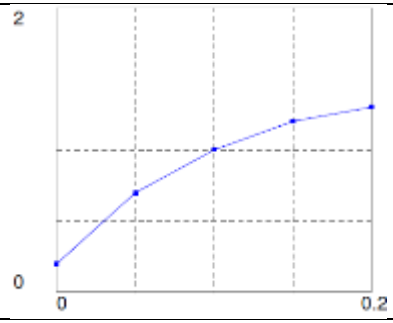
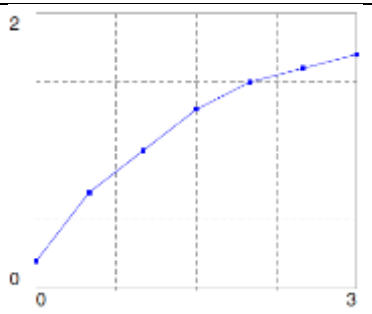
Parameter	attractiveness for migration factor	manager-arrival housing multiplier (lookup)	manager-arrival population multiplier (lookup)
Units	-	-	-
Nominal value	1		

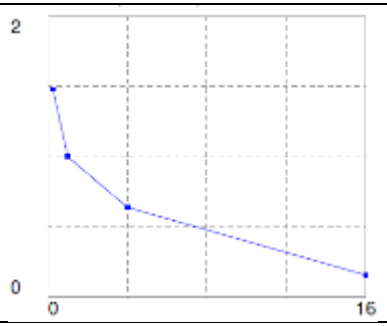
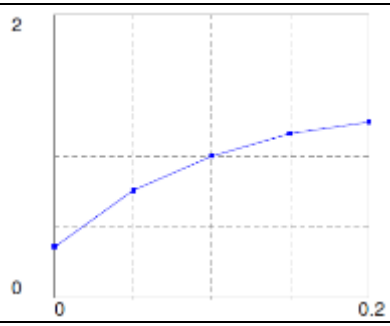
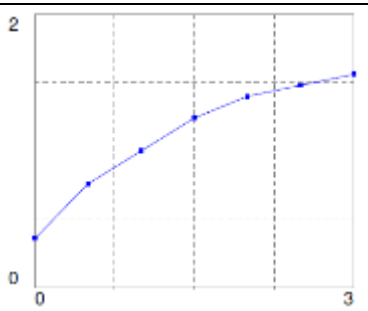
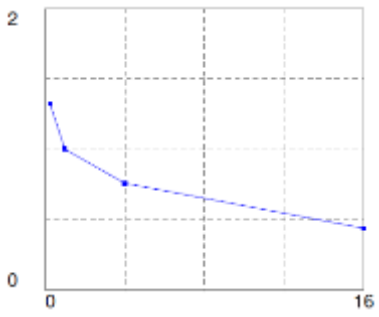
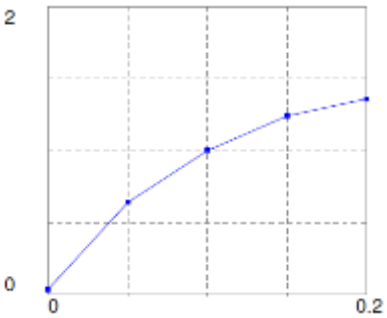
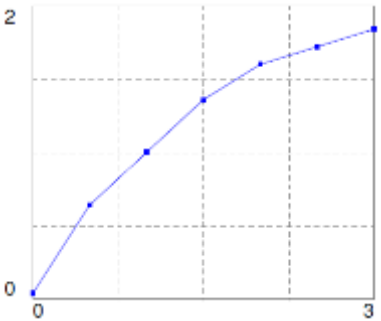
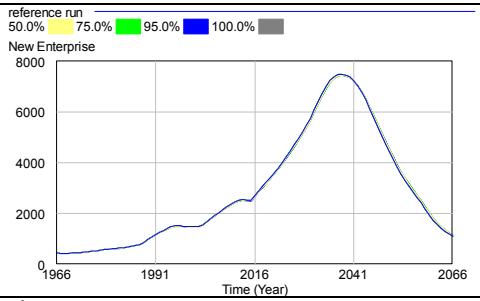
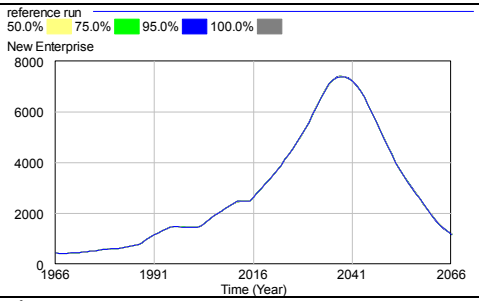
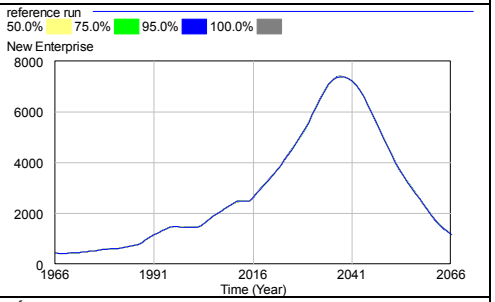
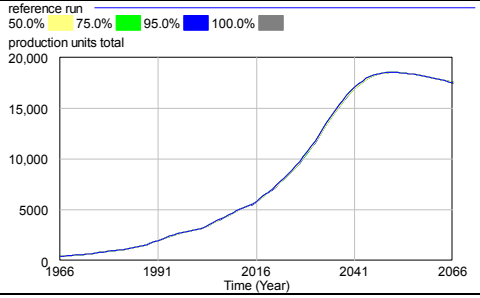
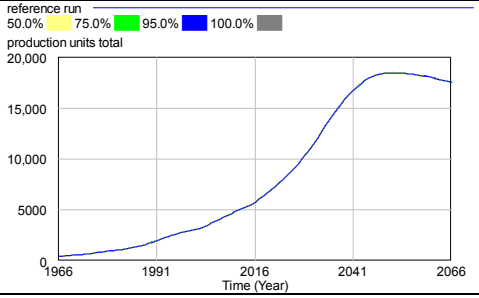
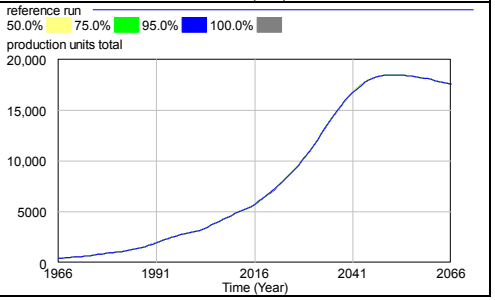
Minimum plausible	0.5 (-50%)		
Maximum plausible	1.5 (+50%)		
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			

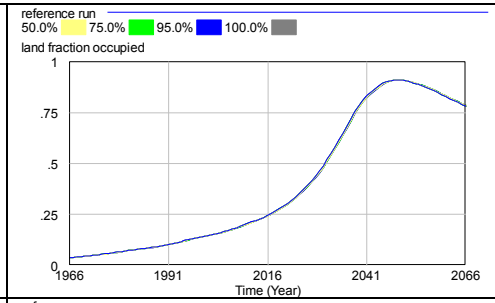
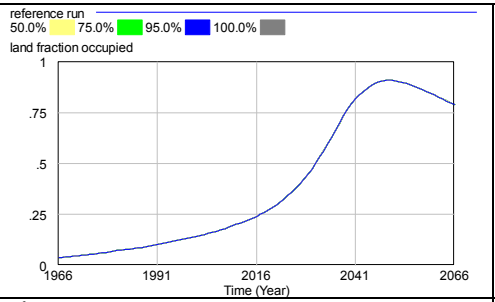
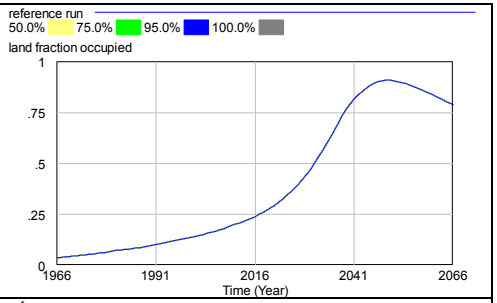
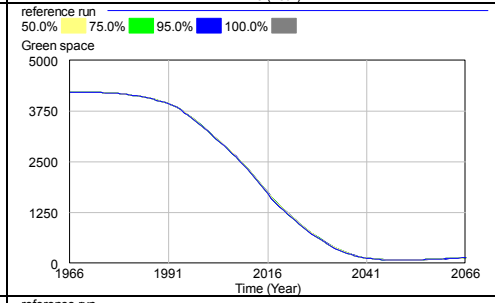
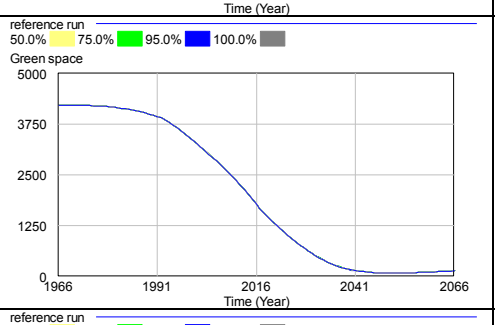
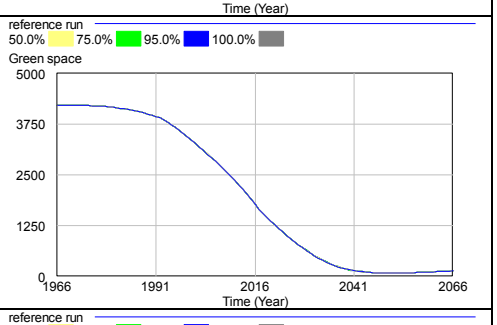
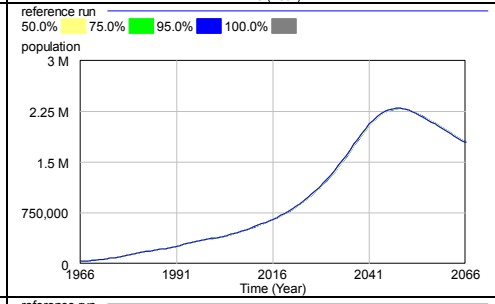
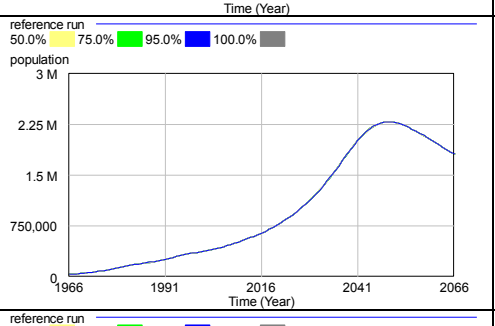
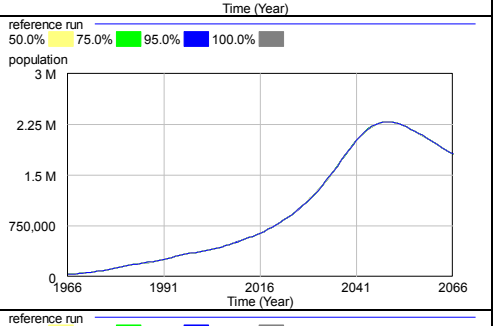
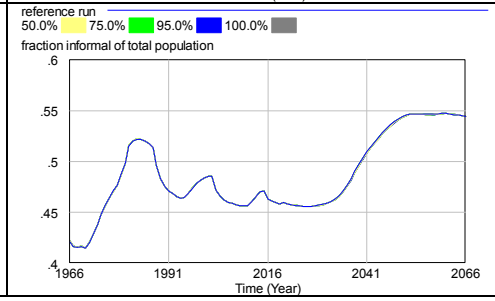
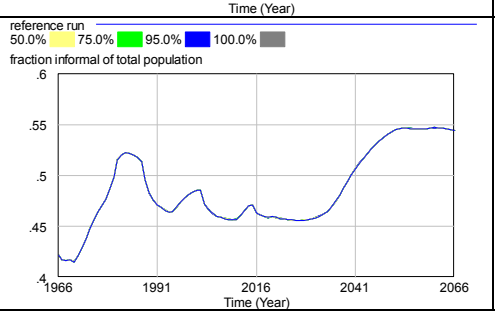
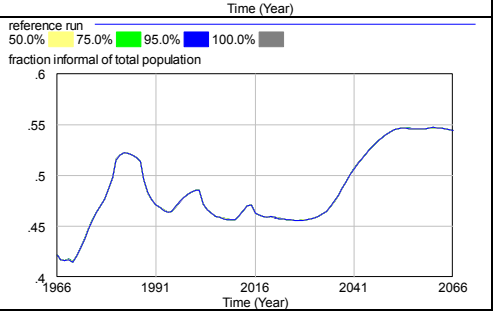
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			

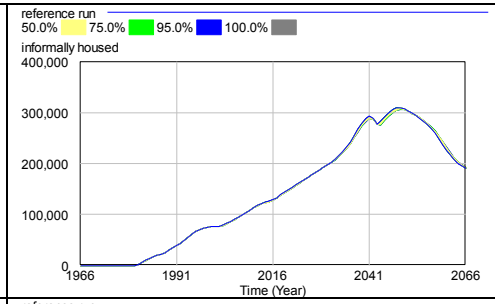
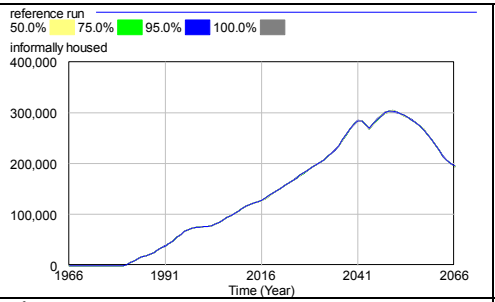
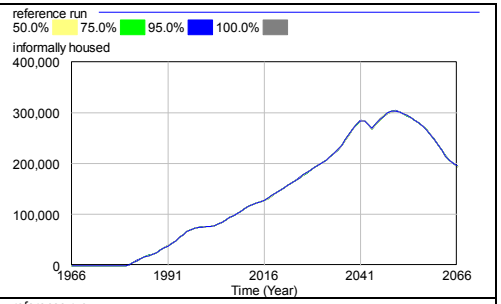
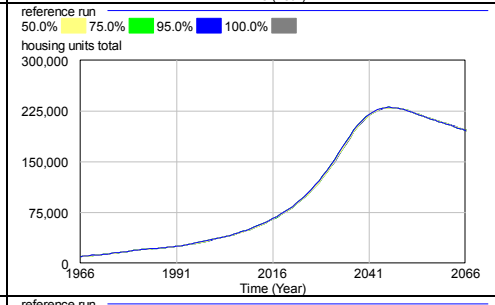
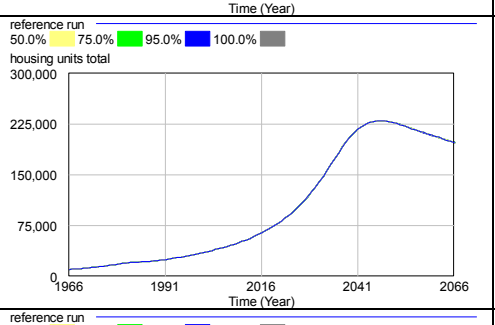
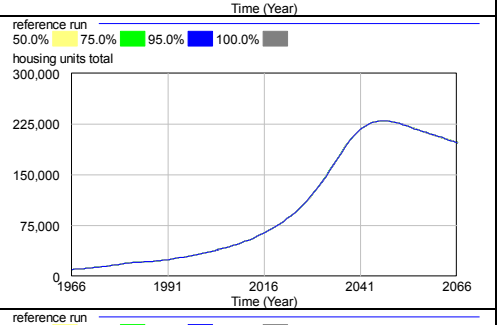
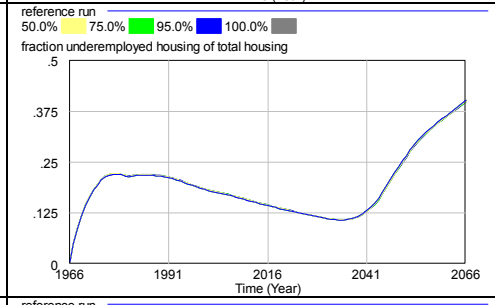
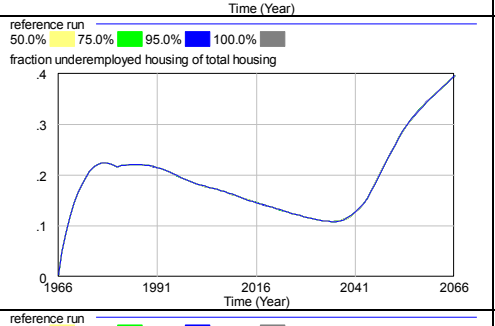
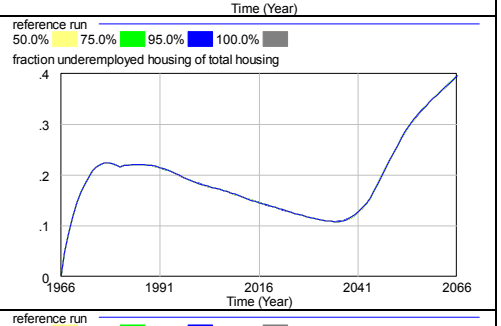
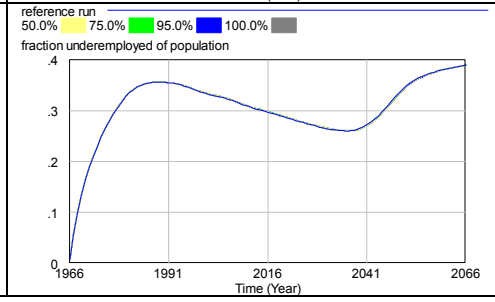
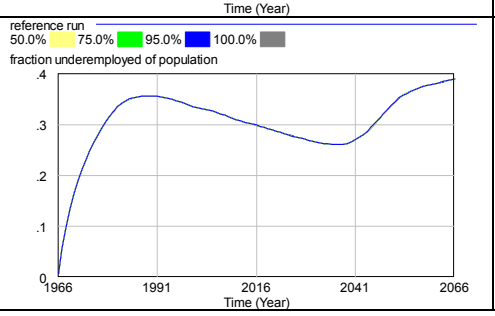
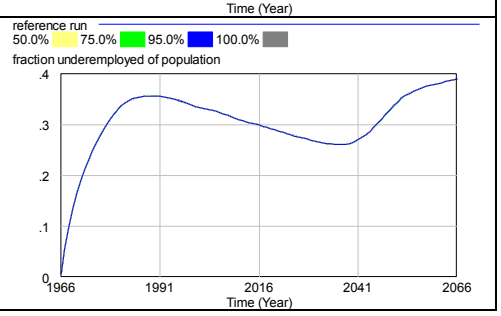
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			

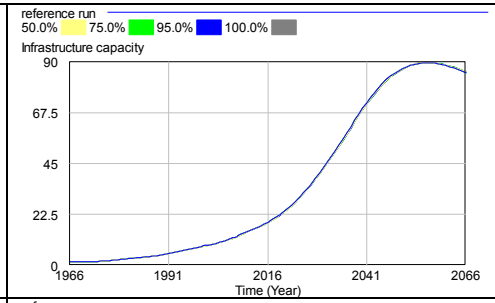
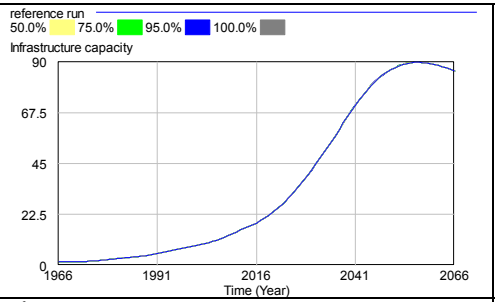
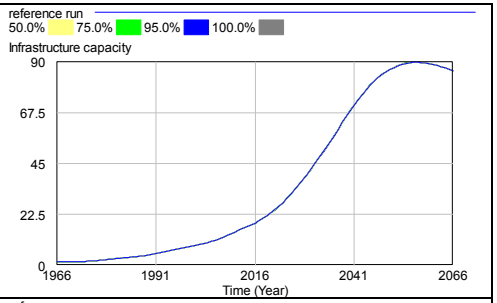
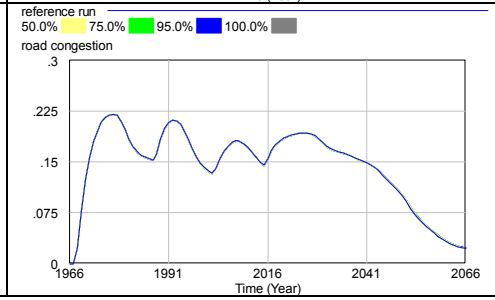
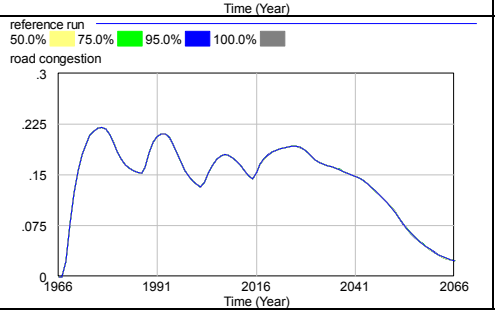
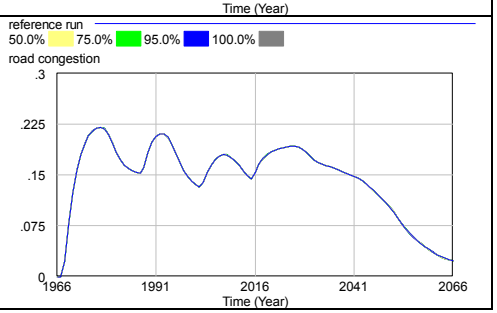
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

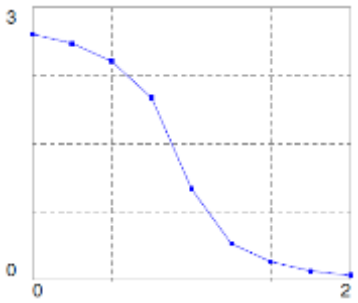
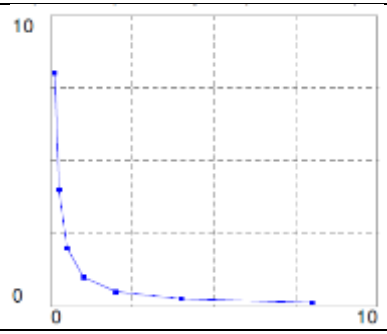
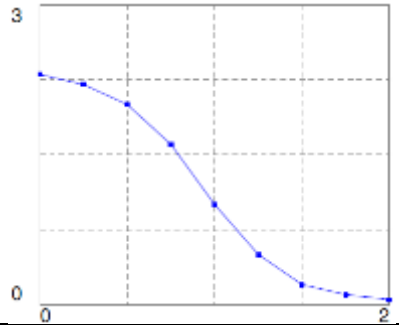
Parameter	manager-arrival tax multiplier (lookup)	manager/labor multiplier (lookup)	labor educational multiplier (lookup)
Units	-	-	-
Nominal value			

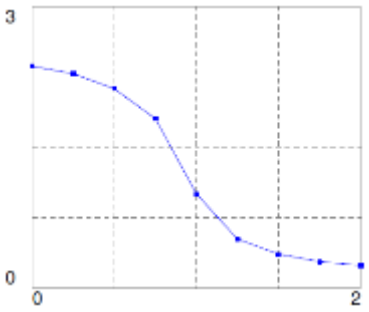
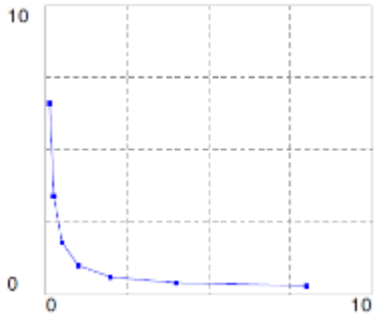
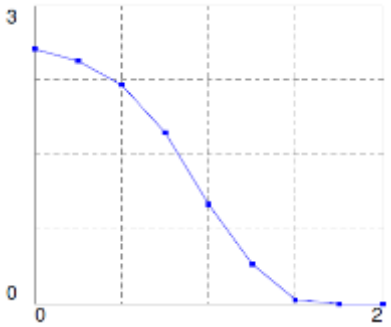
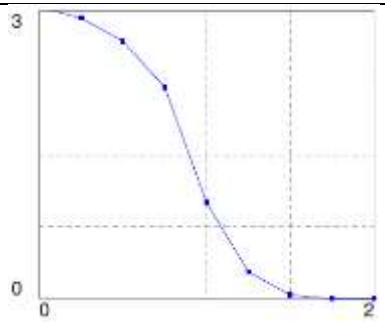
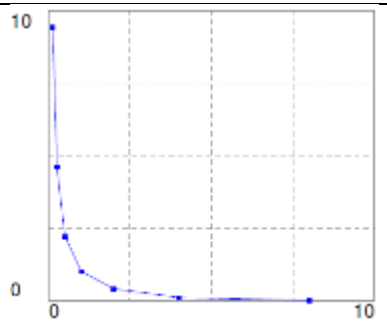
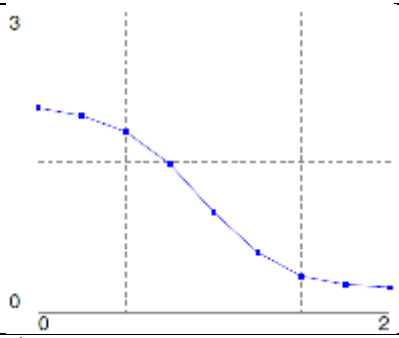
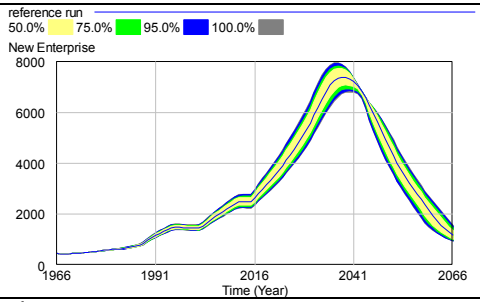
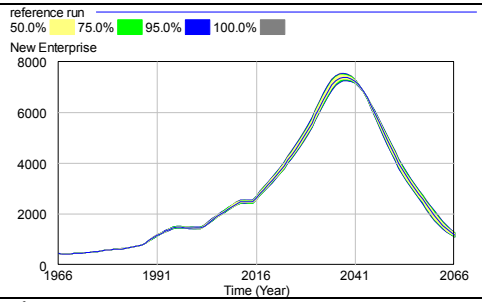
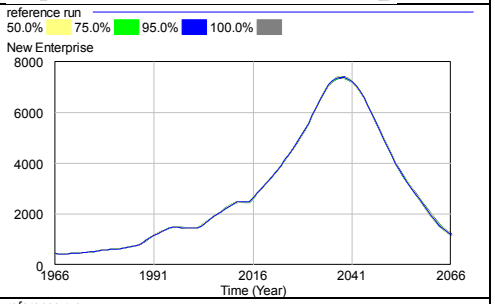
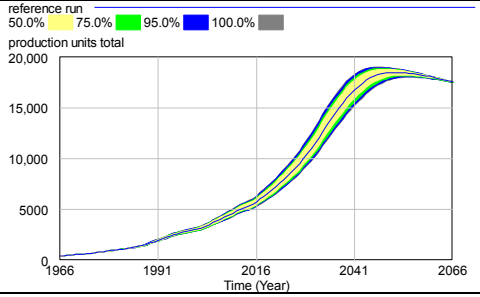
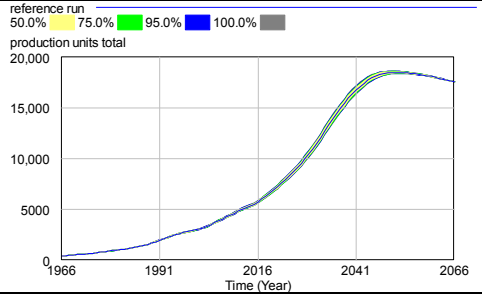
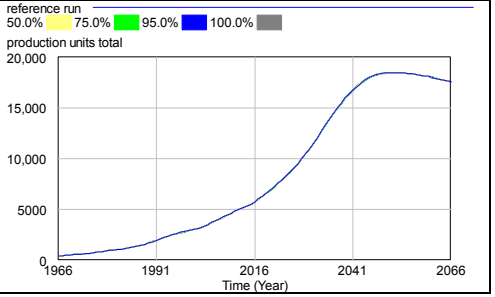
Minimum plausible			
Maximum plausible			
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			

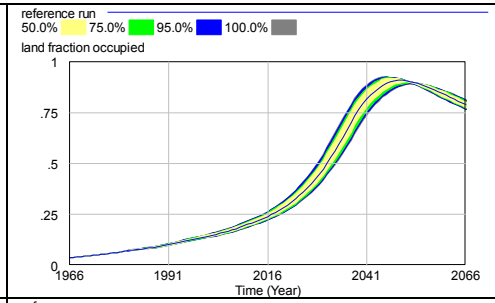
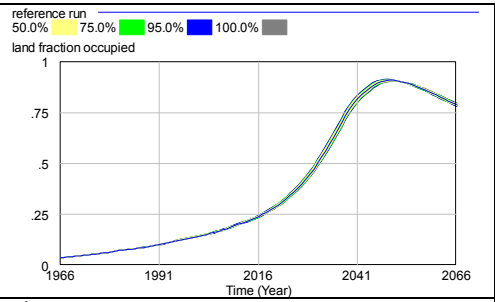
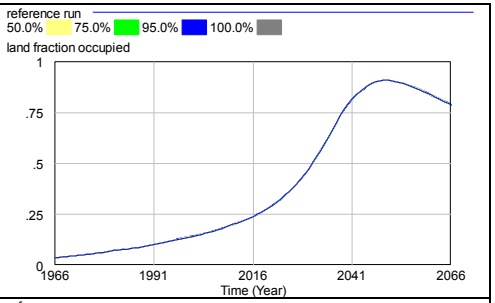
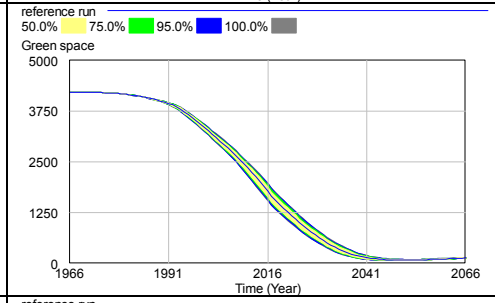
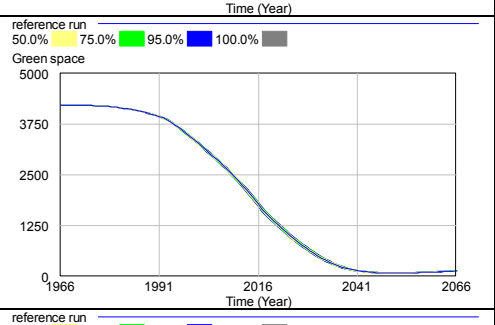
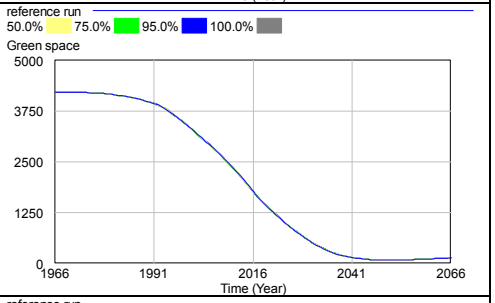
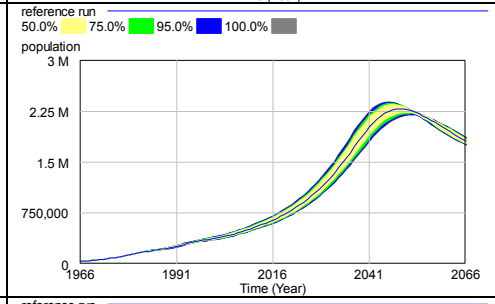
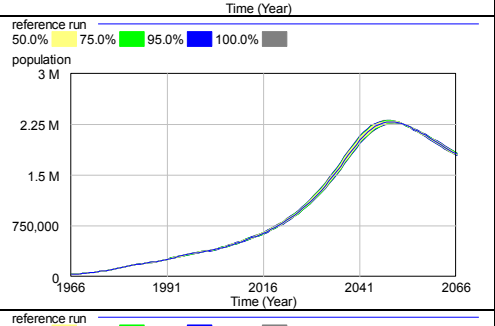
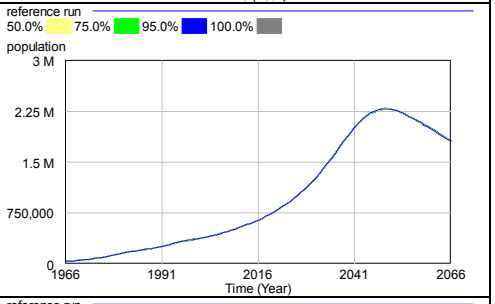
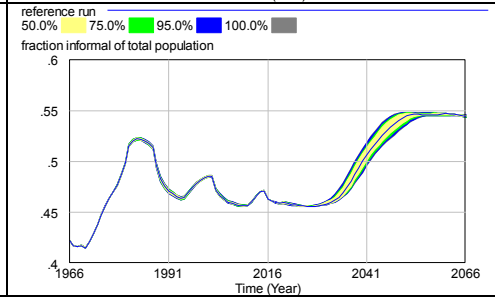
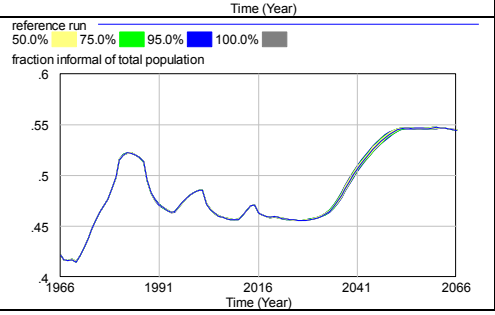
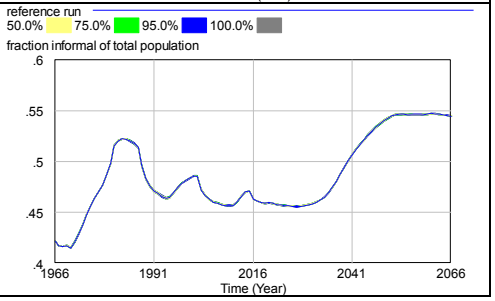
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			

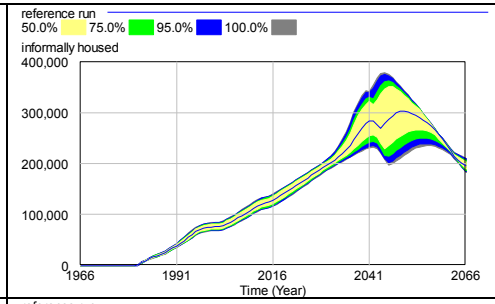
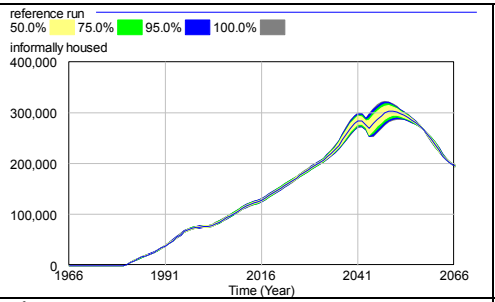
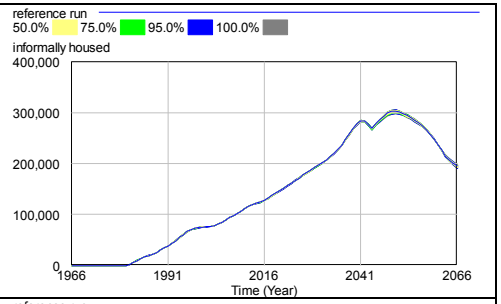
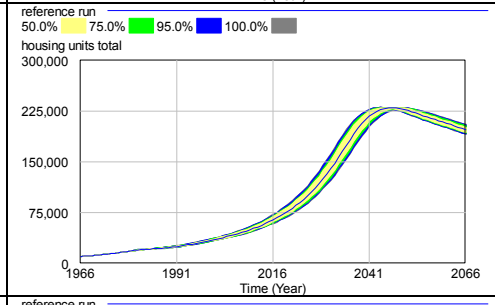
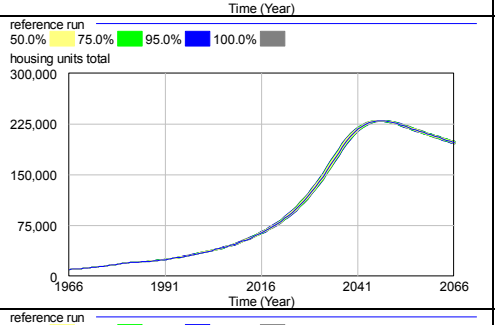
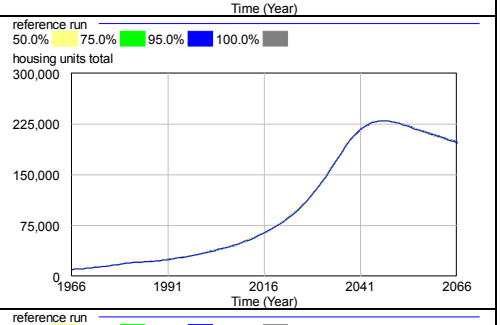
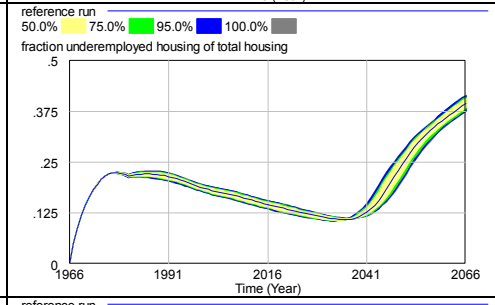
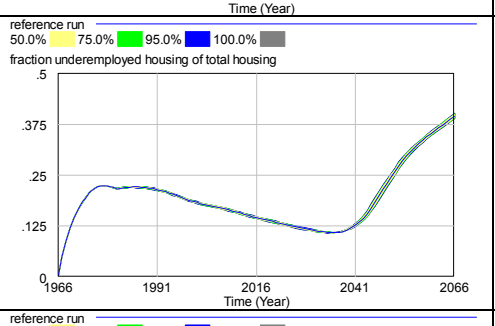
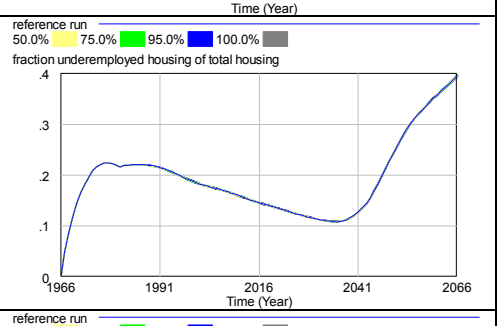
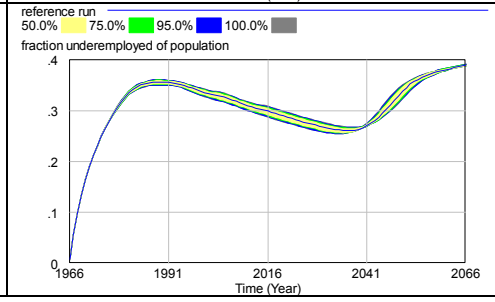
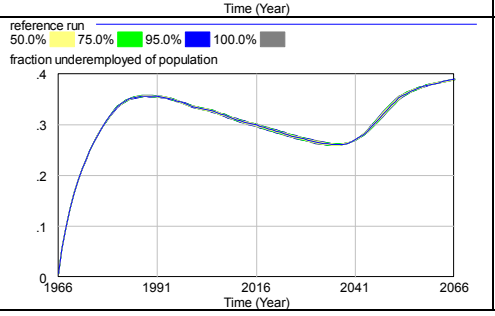
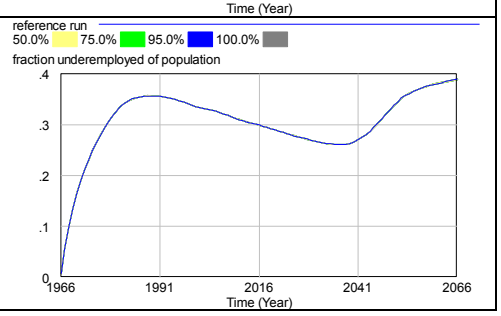
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			

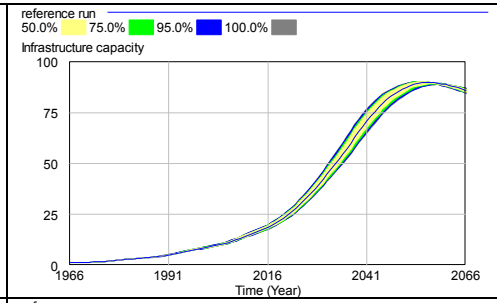
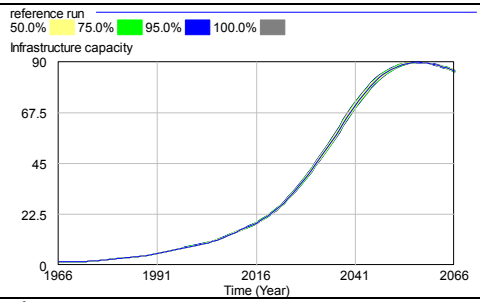
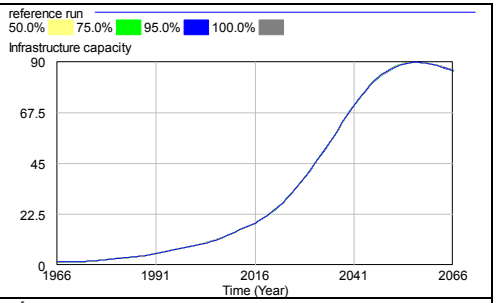
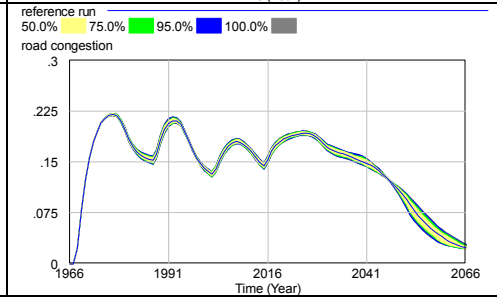
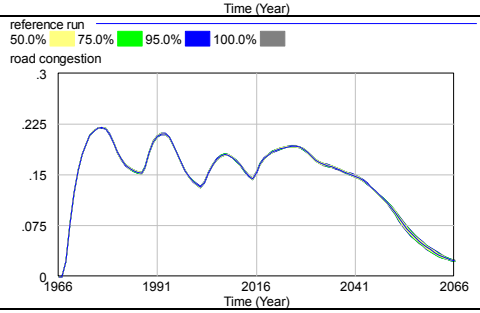
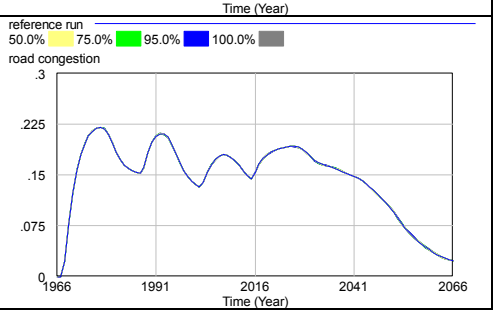
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

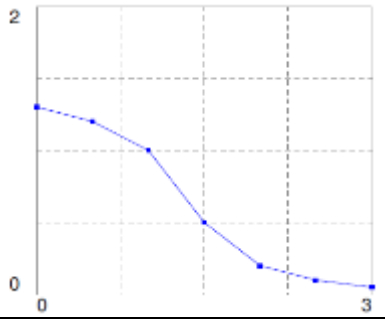
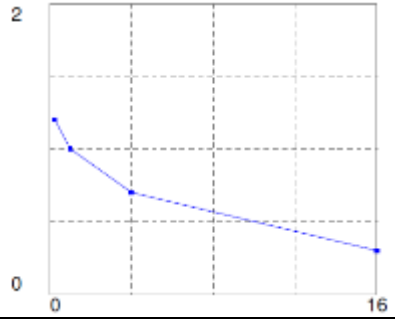
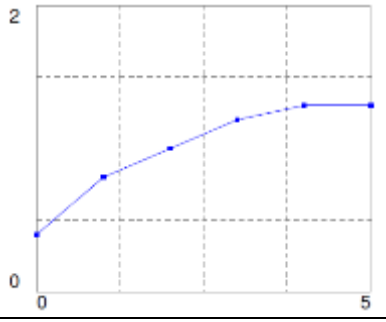
Parameter	manager-arrival job multiplier (lookup	manager departure multiplier (lookup)	manager supply multiplier (lookup)
Units	-	-	-
Nominal value			

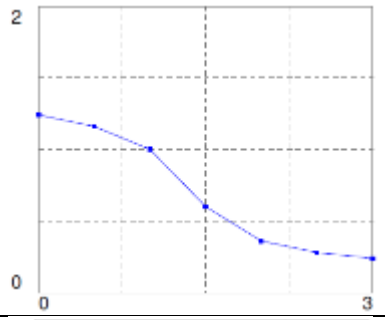
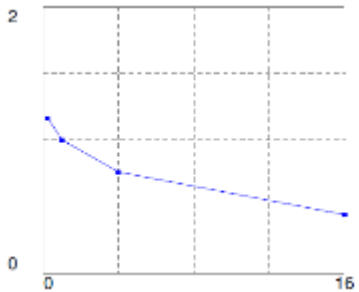
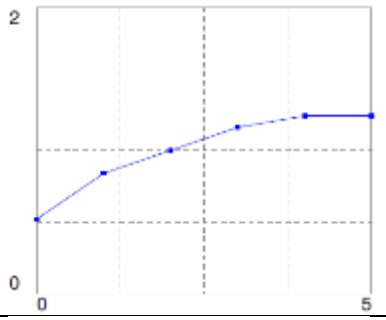
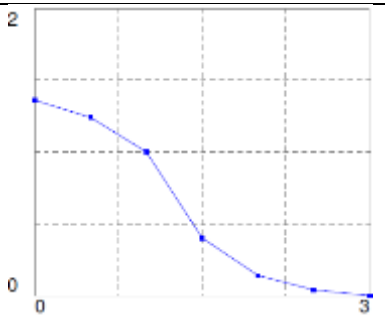
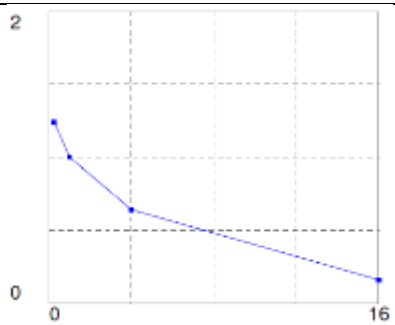
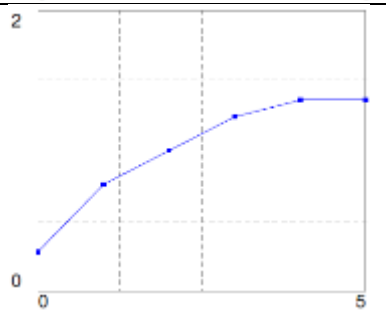
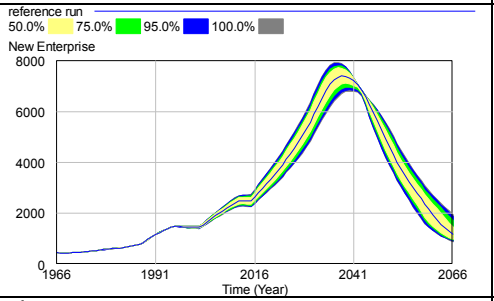
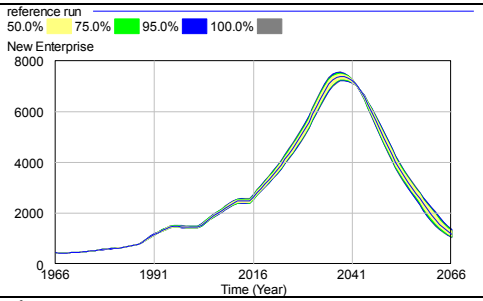
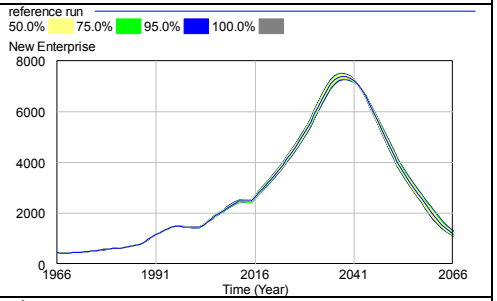
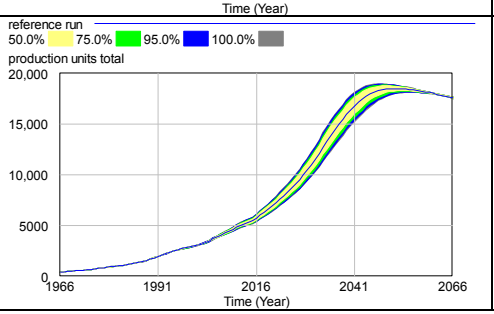
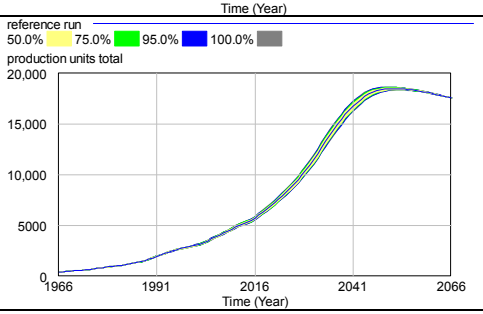
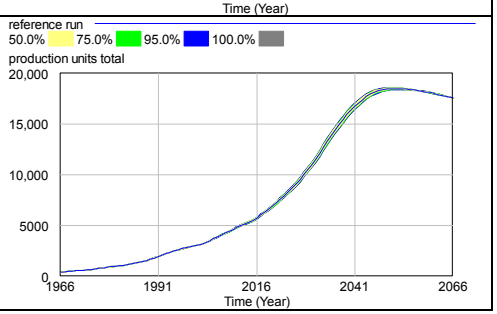
Minimum plausible			
Maximum plausible			
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			

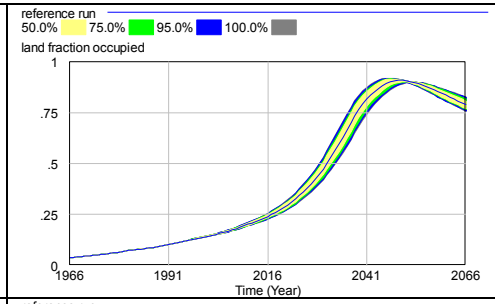
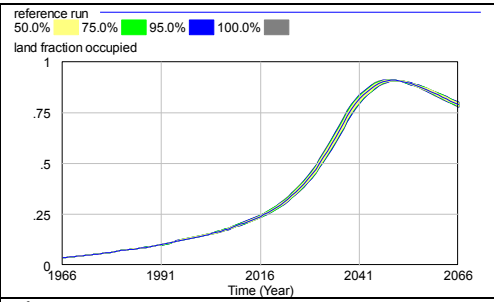
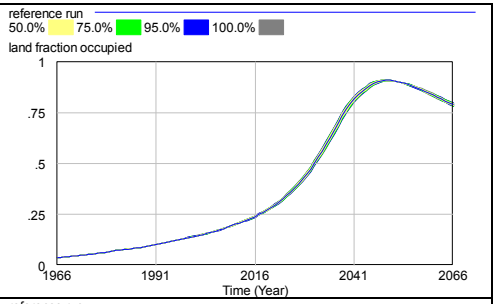
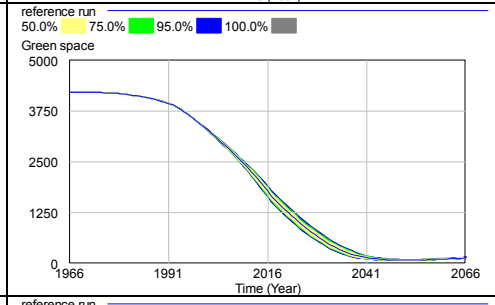
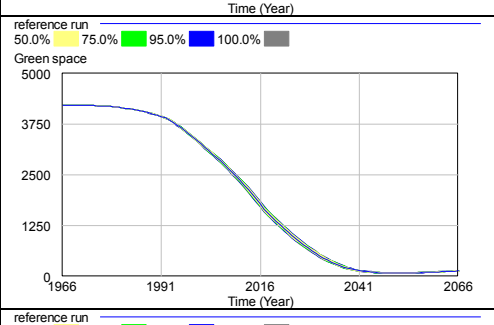
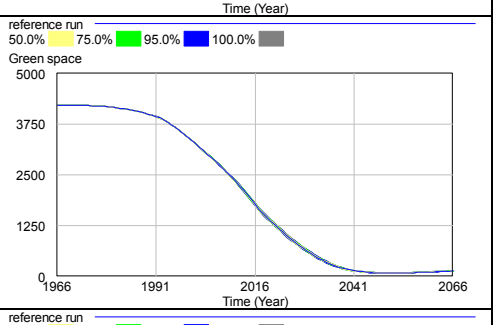
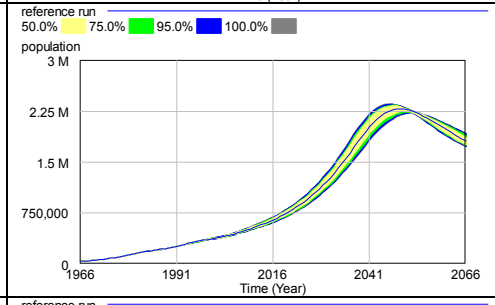
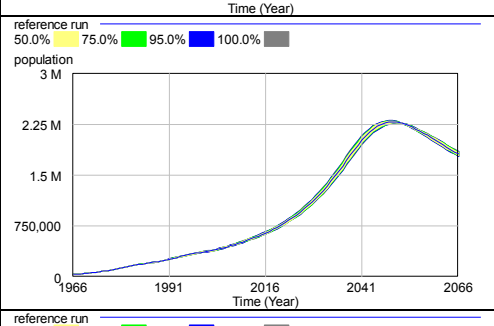
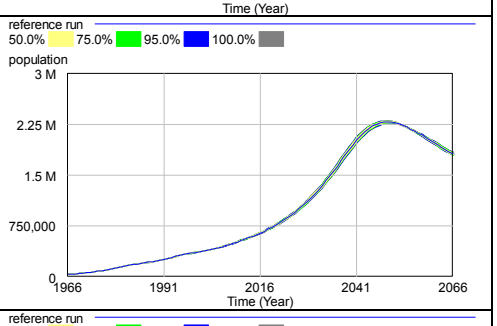
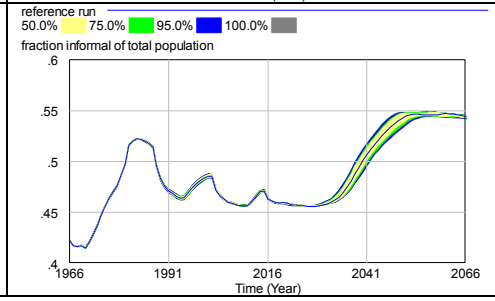
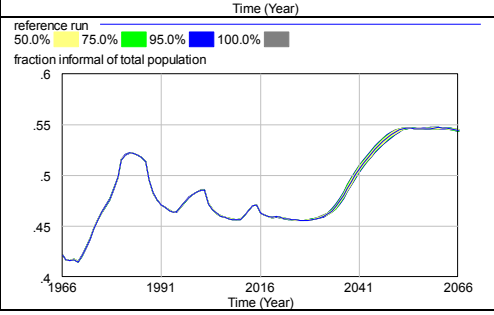
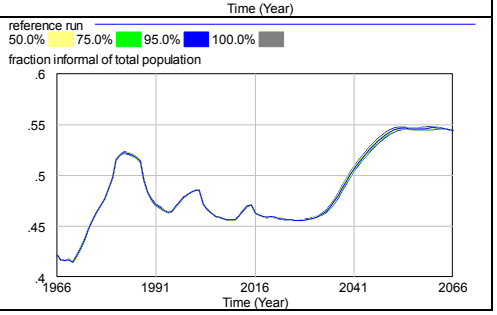
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			

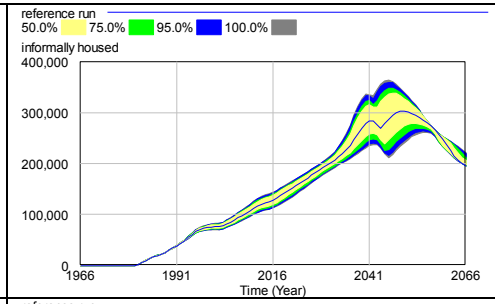
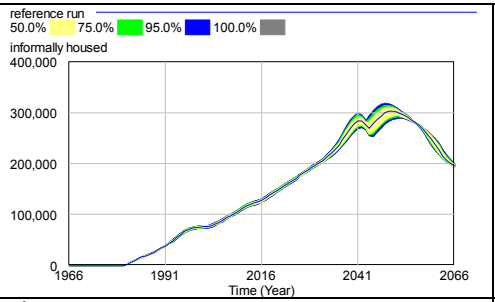
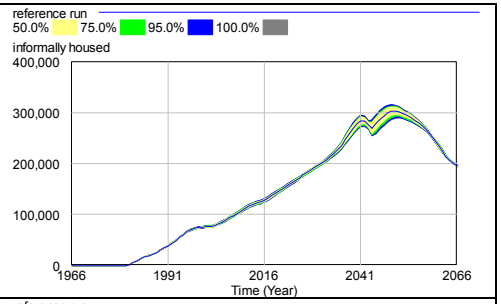
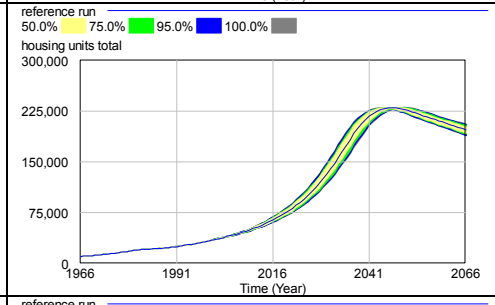
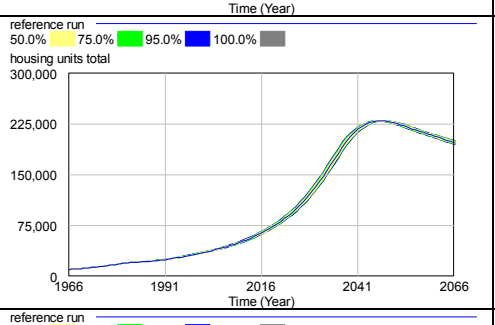
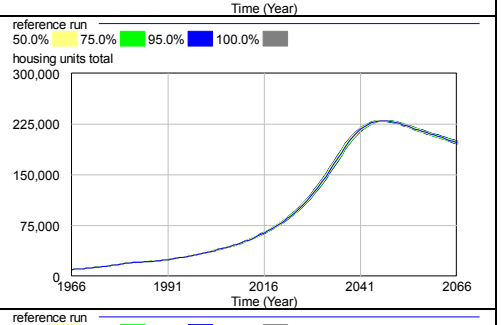
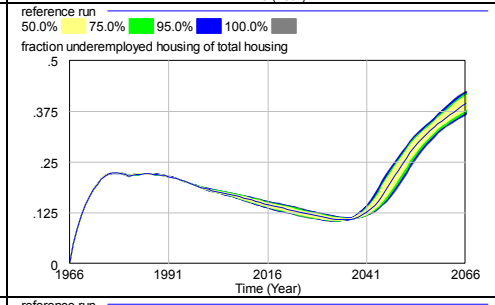
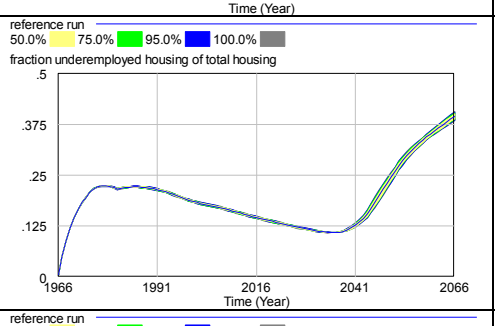
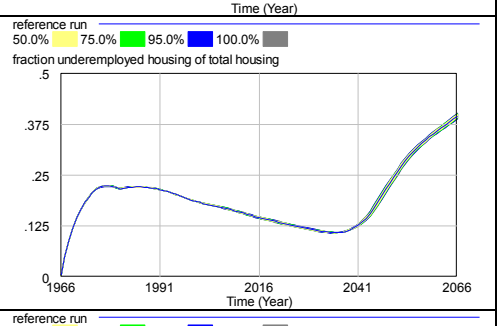
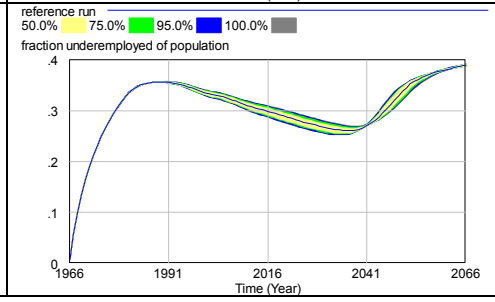
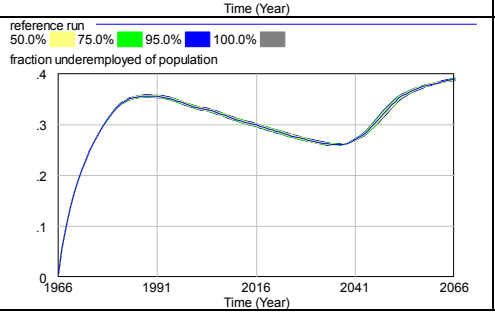
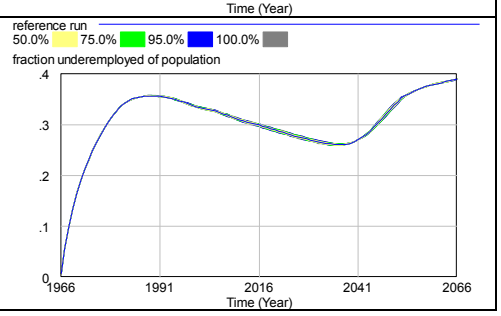
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			

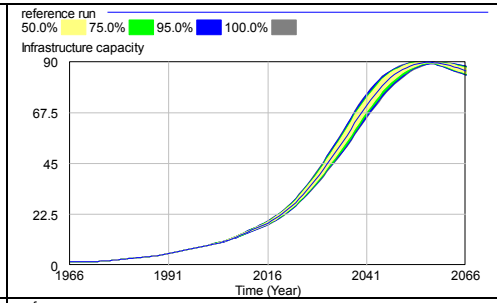
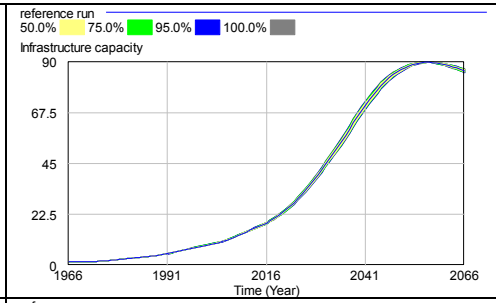
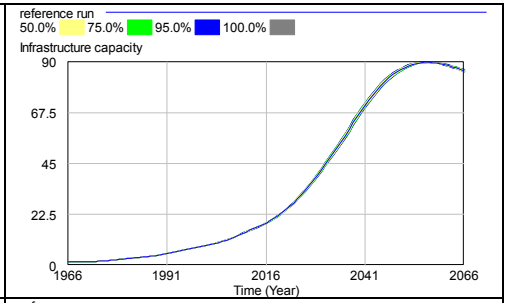
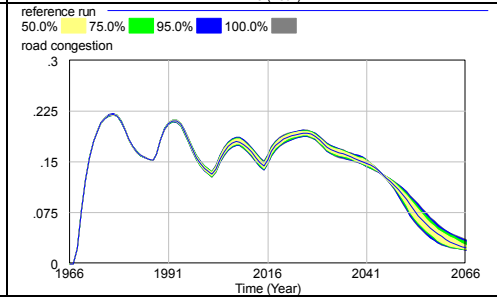
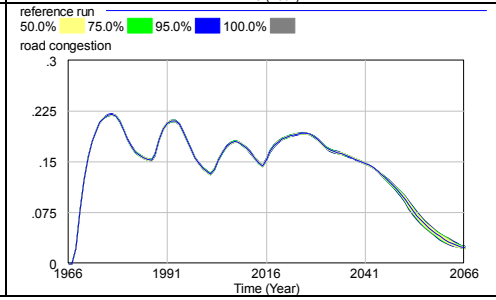
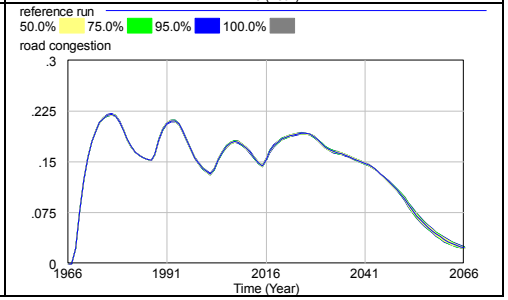
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

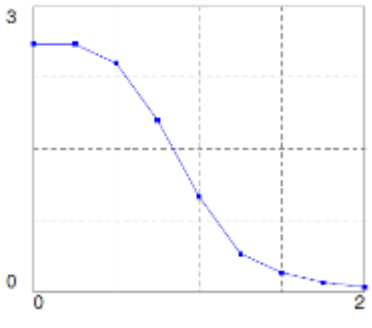
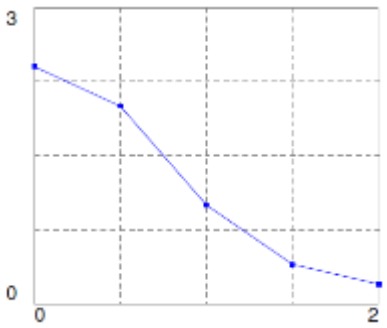
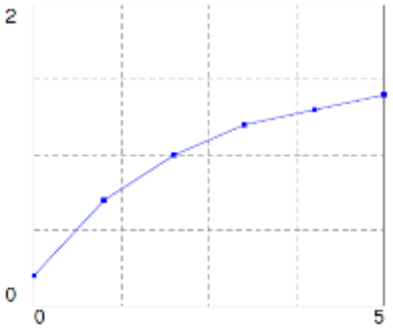
Parameter	labor arrival housing multiplier	labor arrival tax multiplier	labor arrival underemployed multiplier
Units	-	-	-
Nominal value			

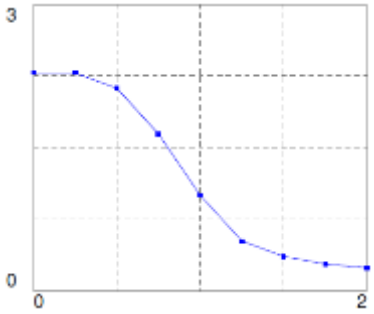
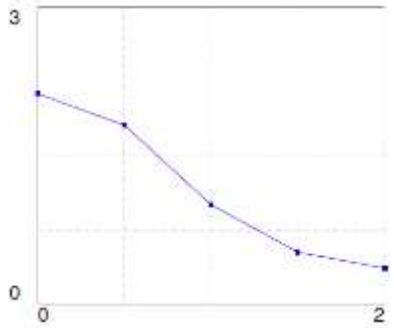
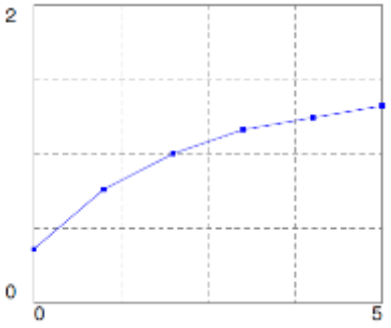
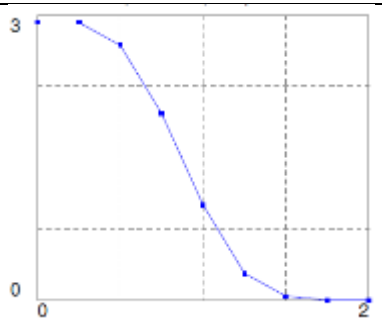
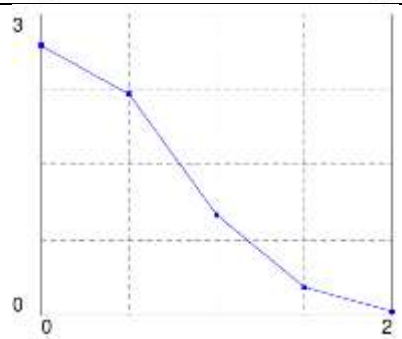
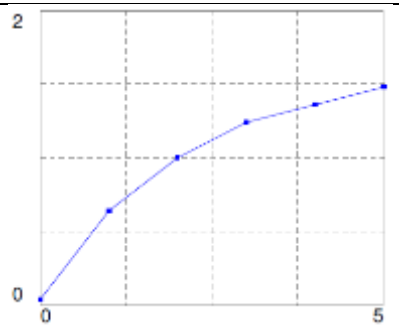
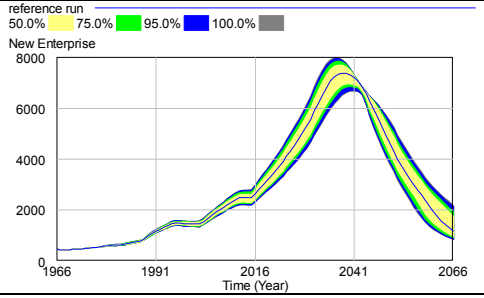
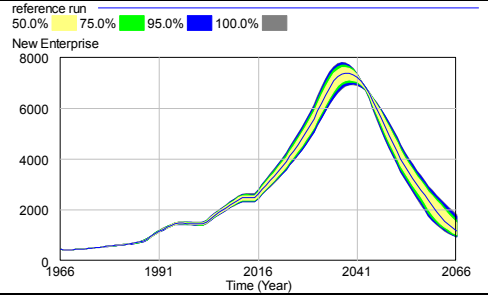
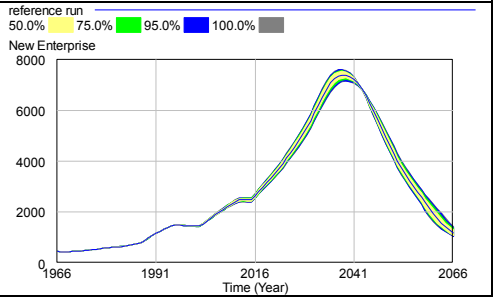
Minimum plausible			
Maximum plausible			
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			

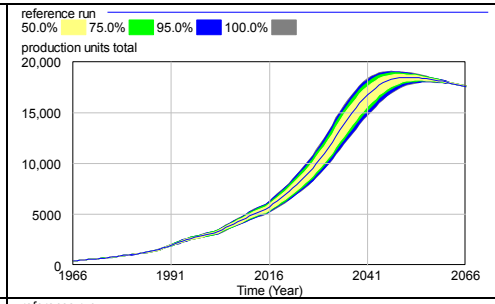
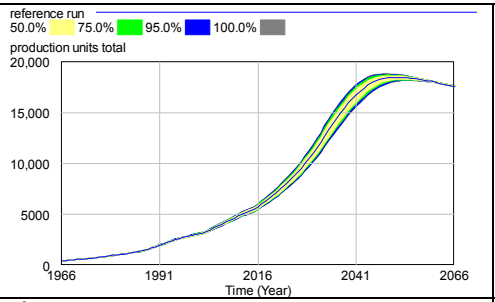
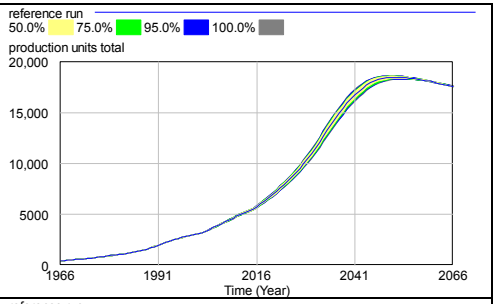
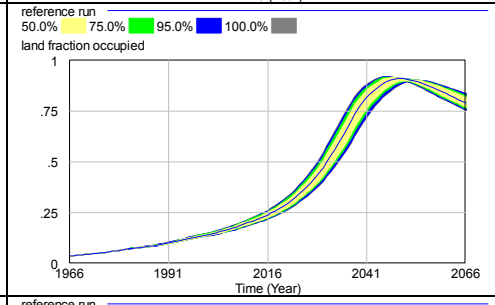
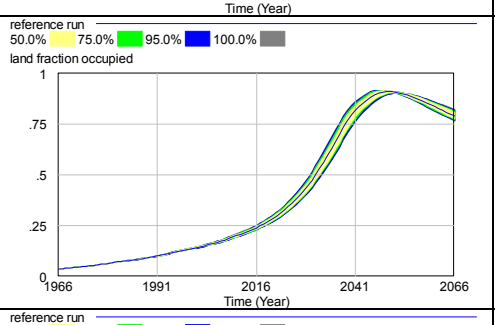
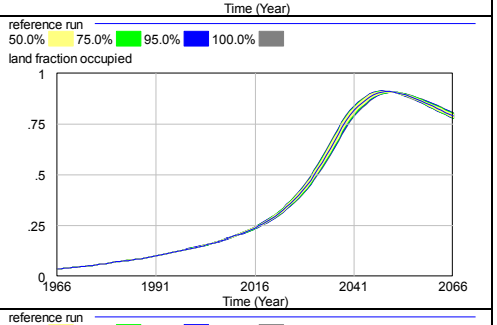
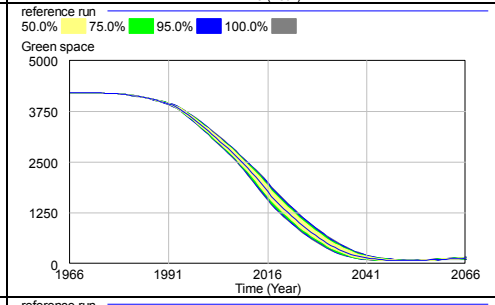
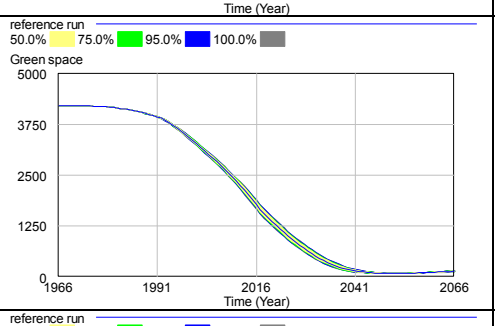
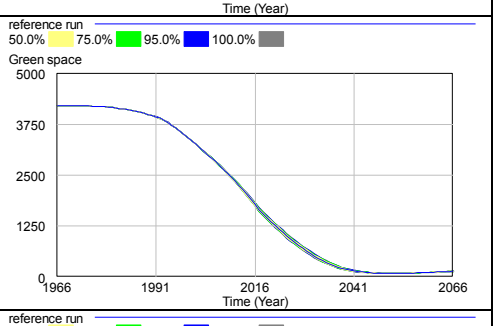
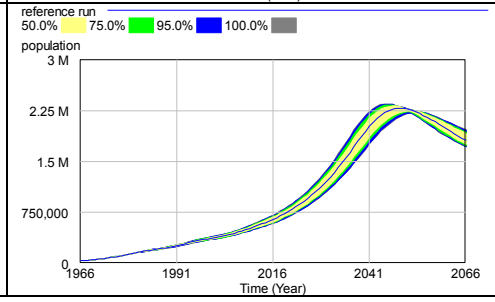
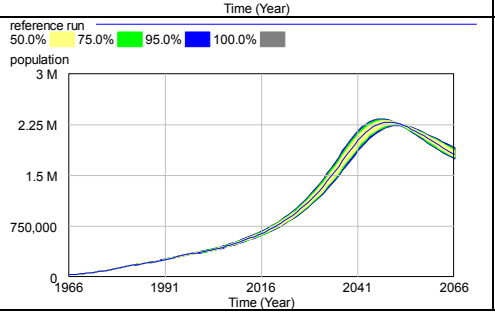
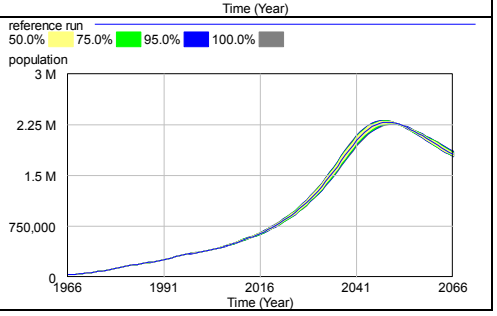
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			

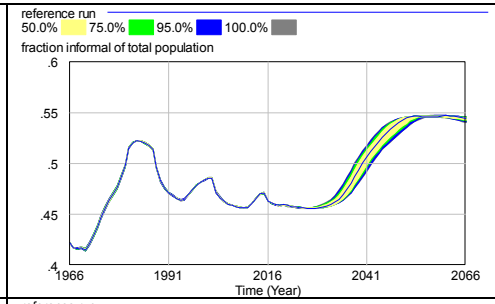
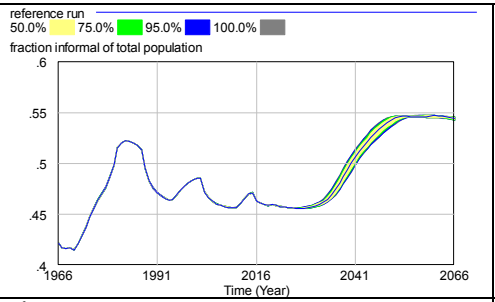
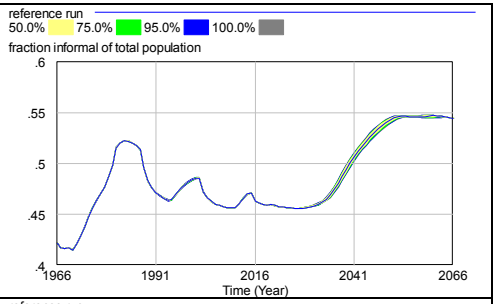
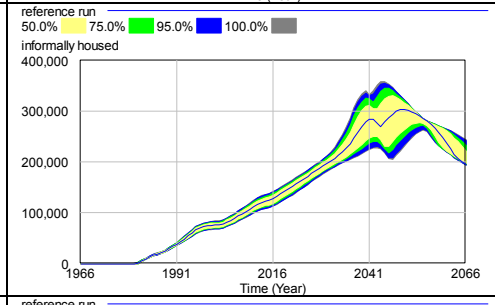
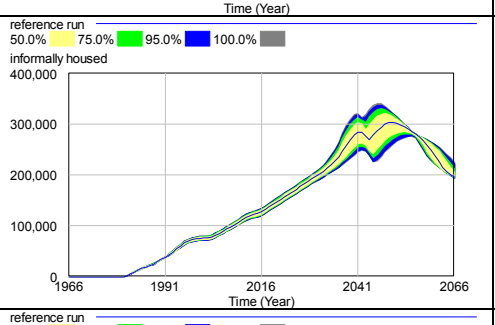
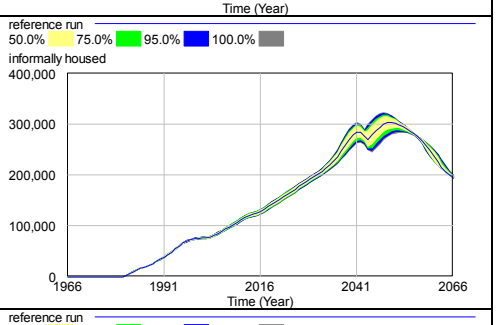
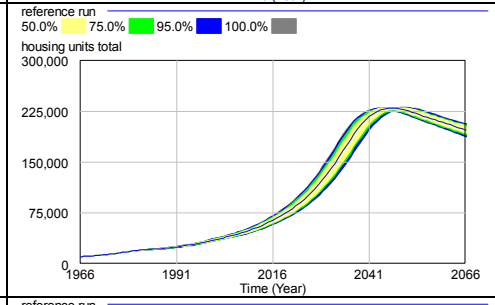
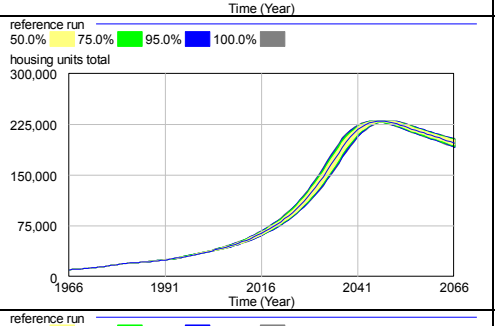
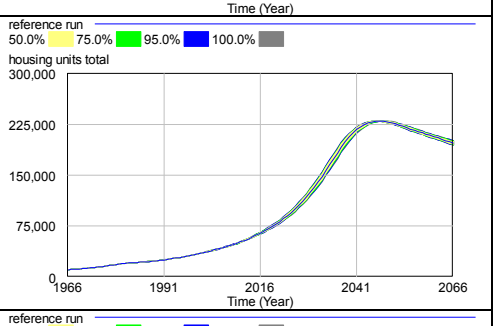
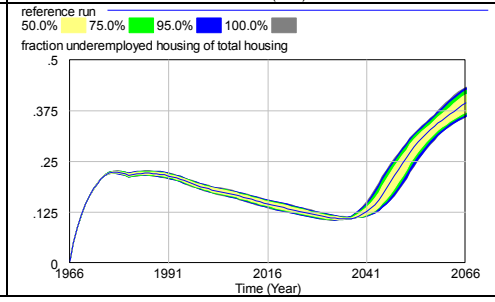
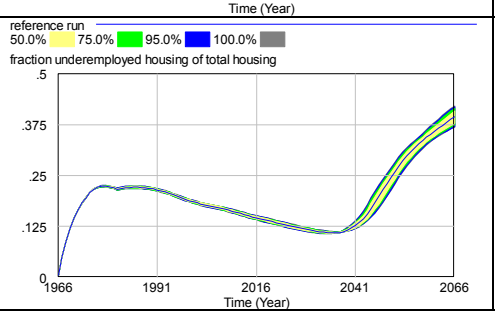
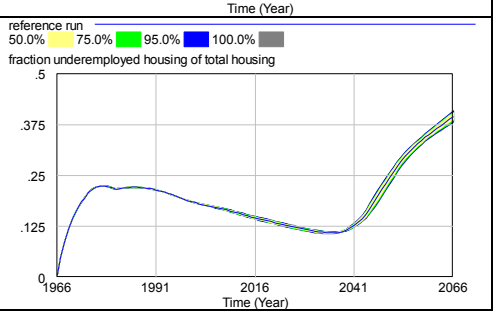
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			

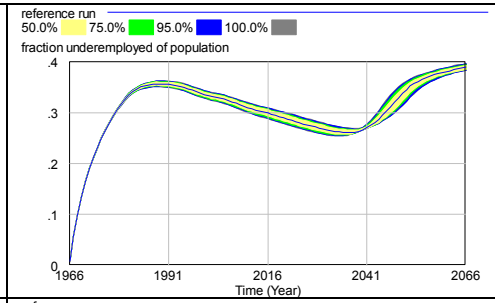
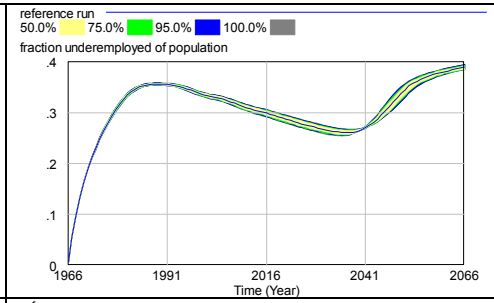
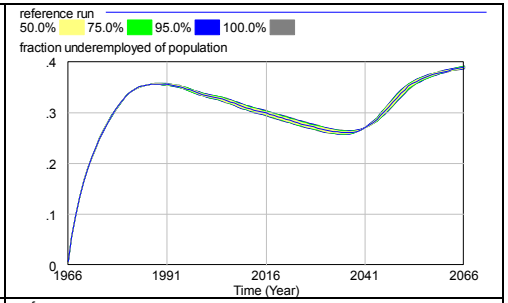
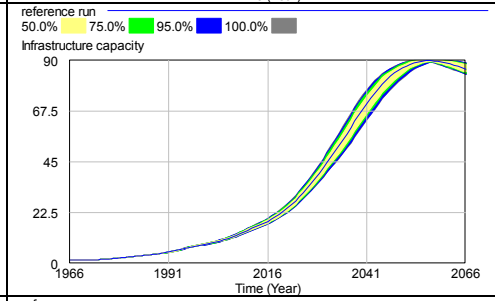
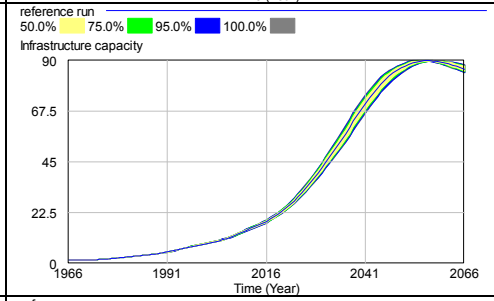
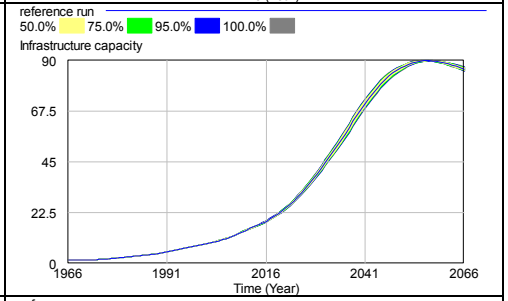
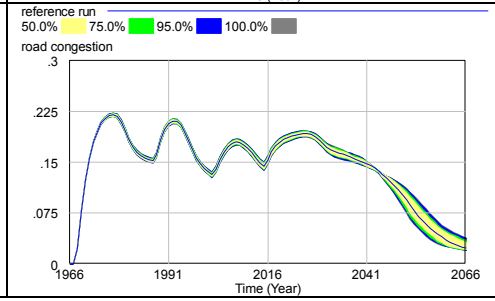
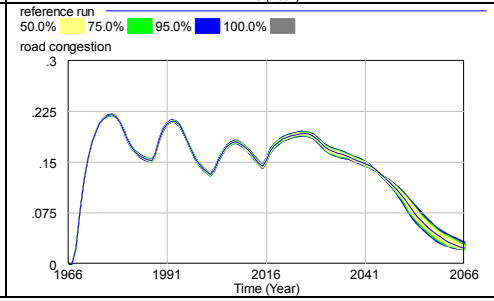
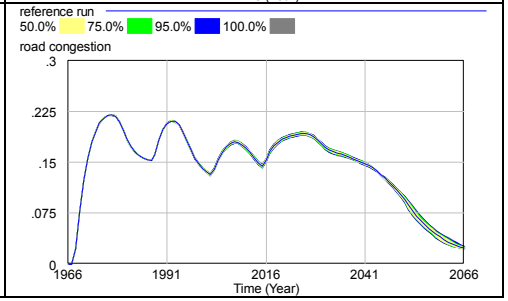
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

Parameter	labor arrival job multiplier	labor supply multiplier (lookup)	labor/underemployed multiplier (lookup)
Units	-	-	-
Nominal value			

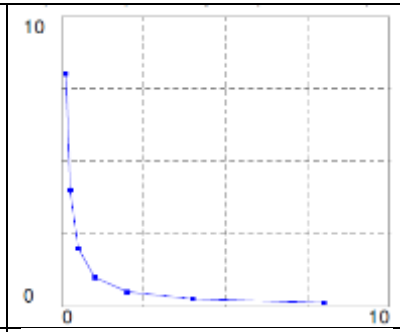
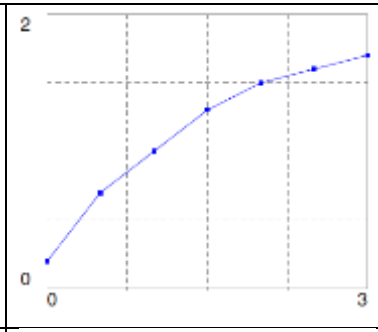
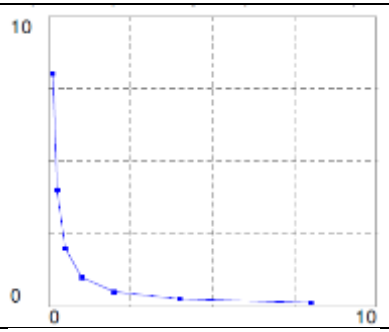
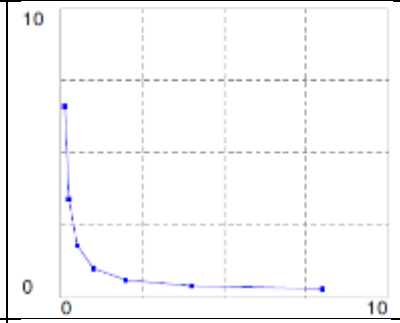
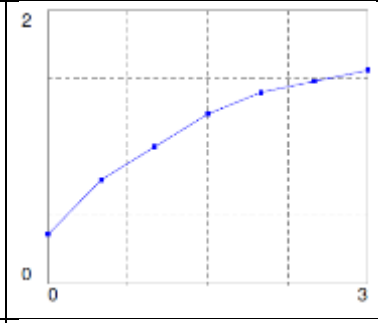
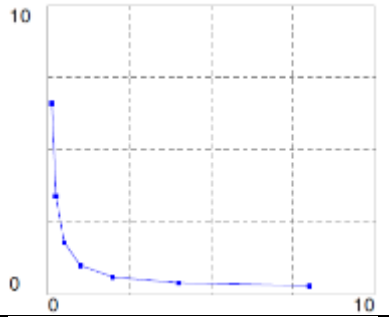
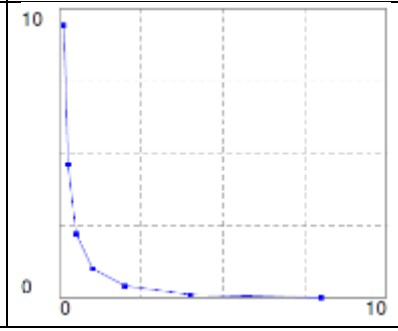
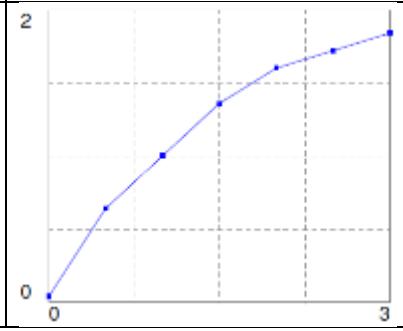
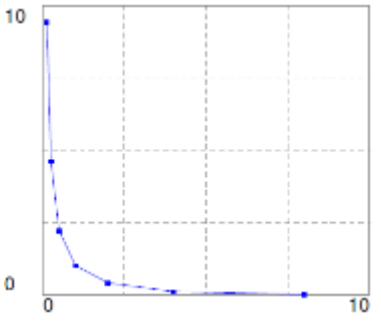
Minimum plausible			
Maximum plausible			
Sensitivity plot: New Enterprise			

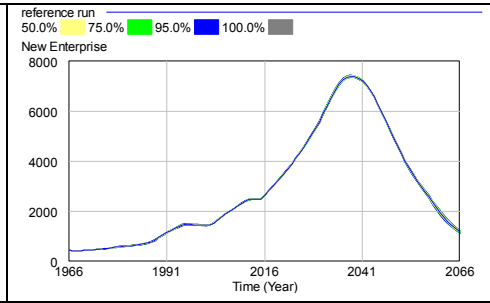
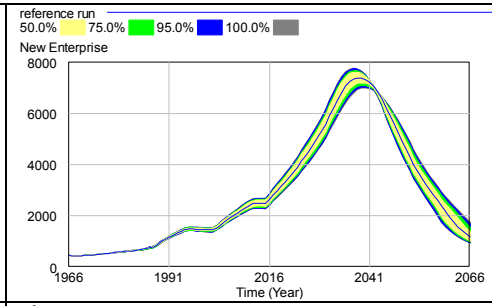
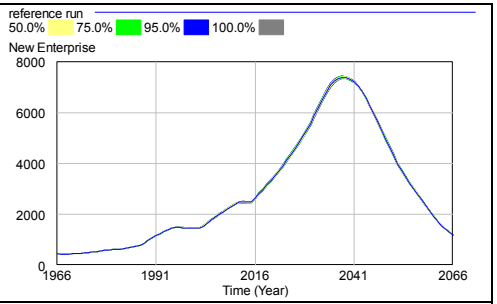
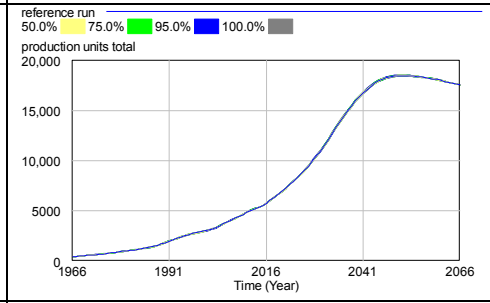
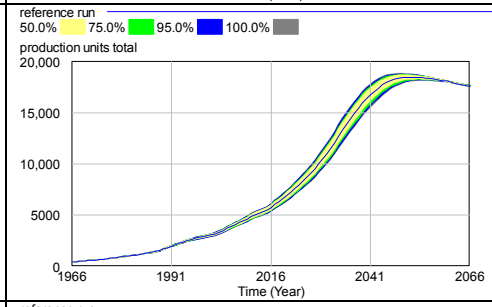
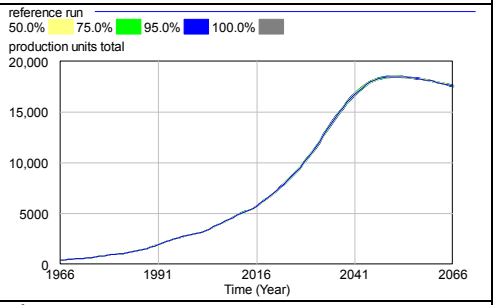
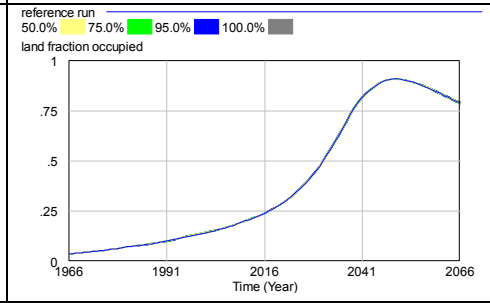
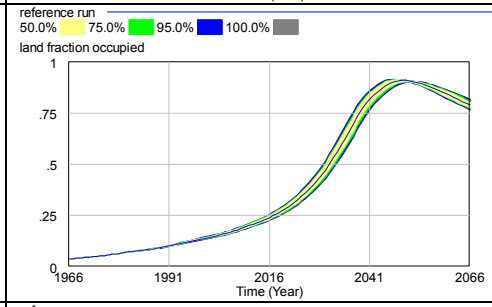
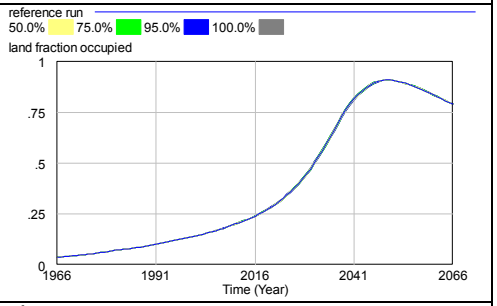
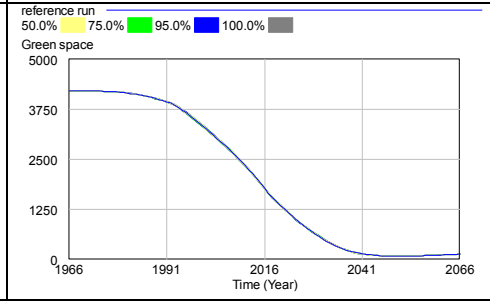
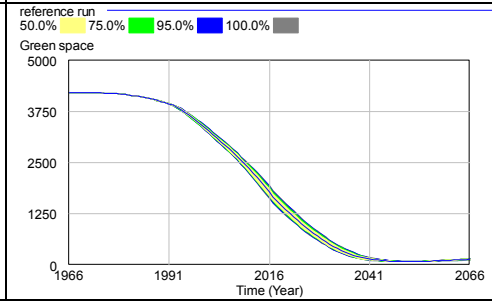
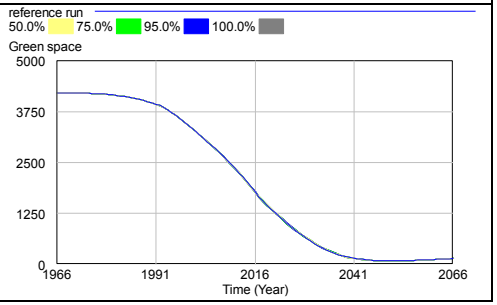
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

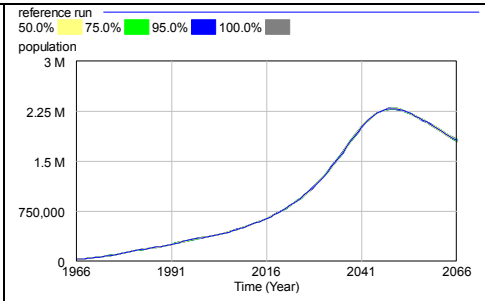
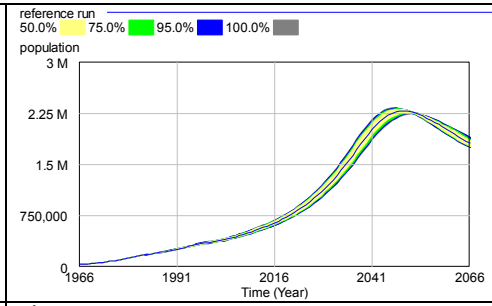
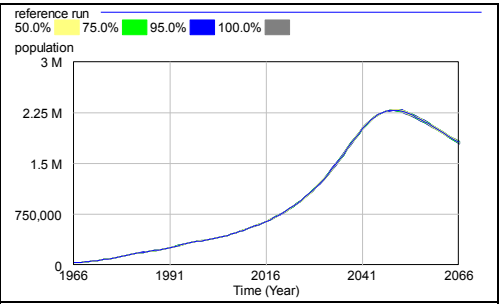
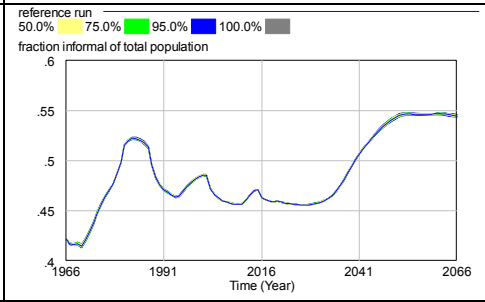
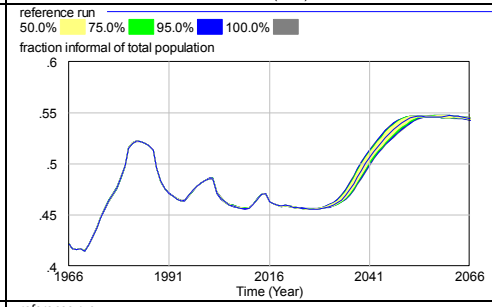
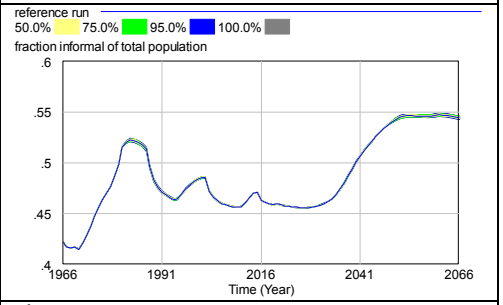
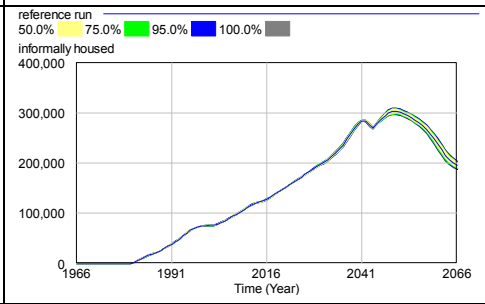
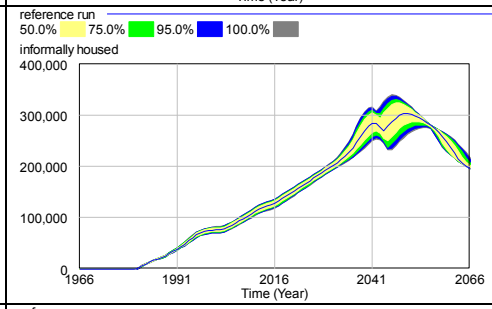
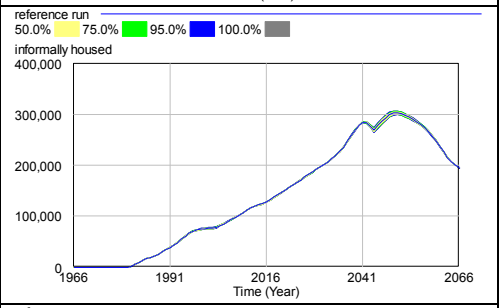
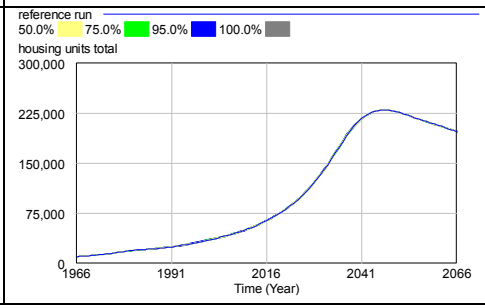
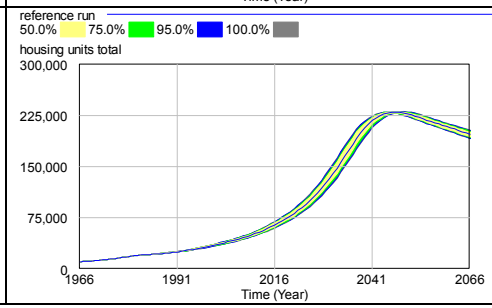
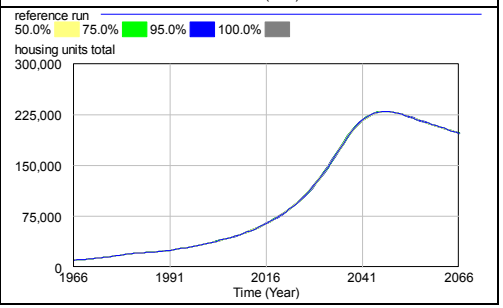
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

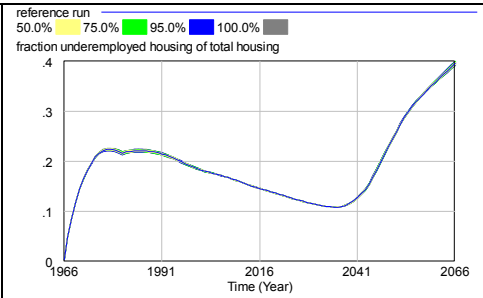
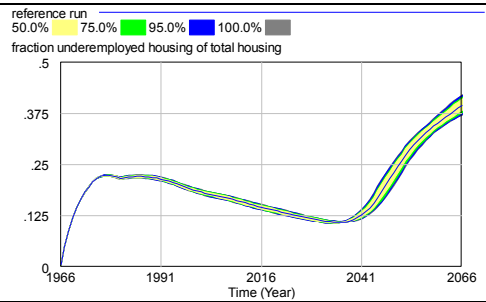
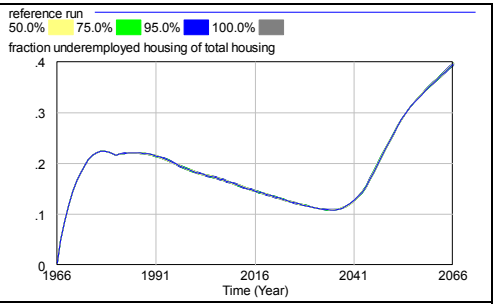
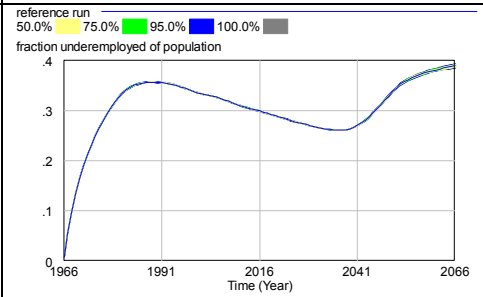
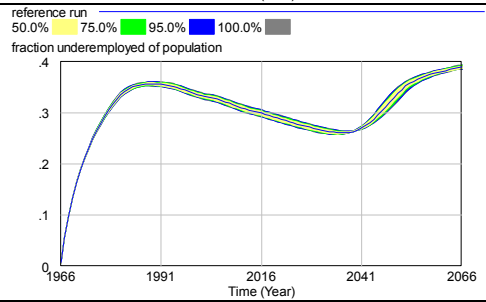
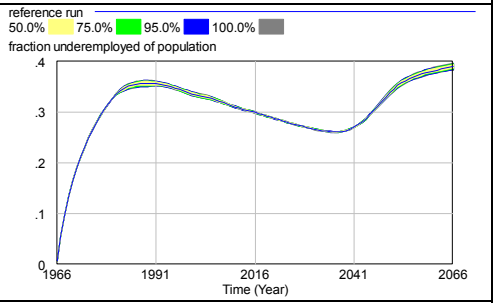
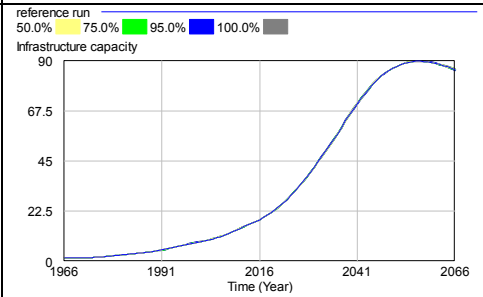
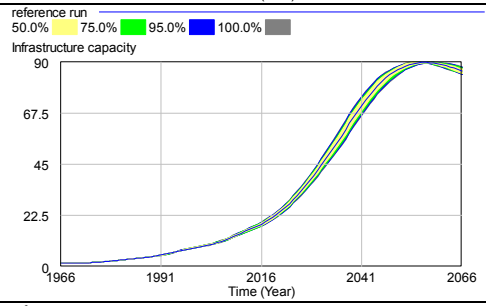
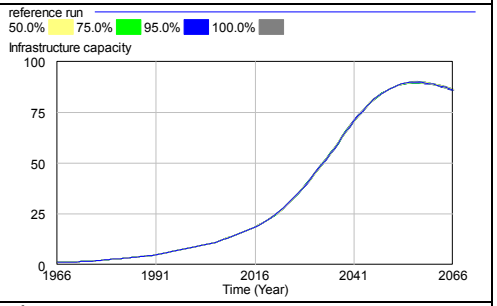
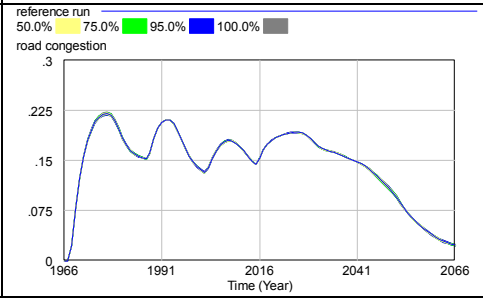
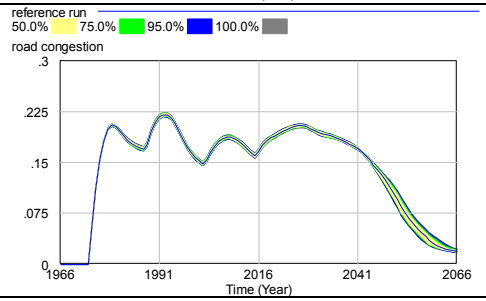
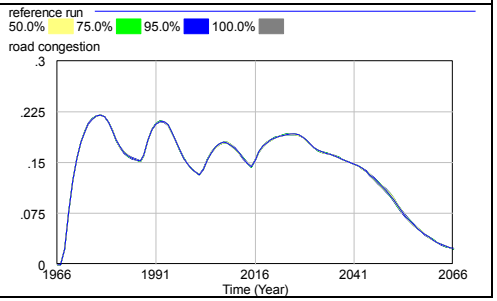
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

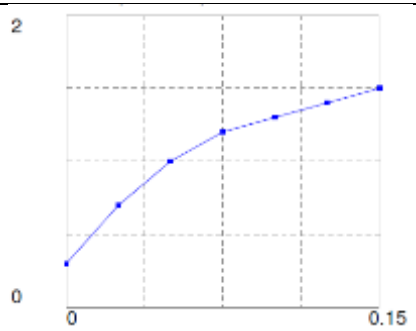
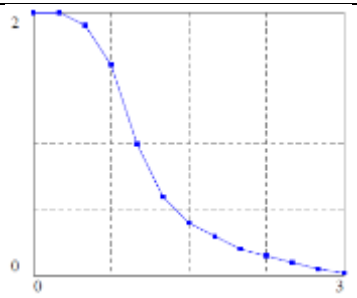
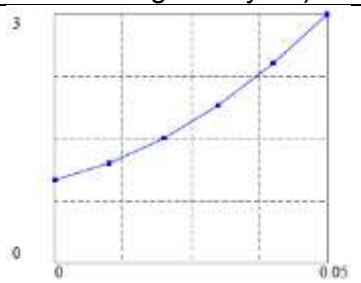
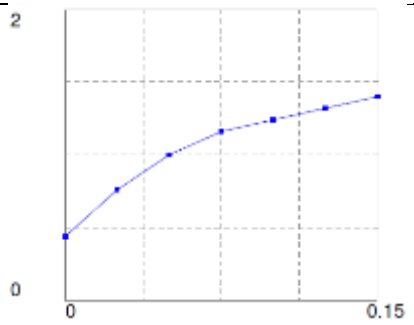
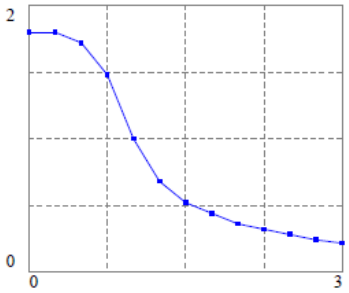
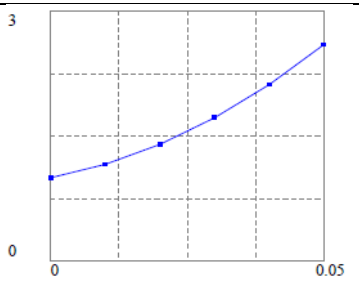
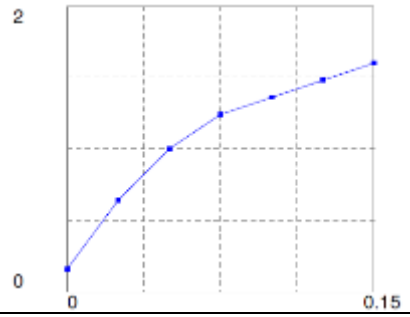
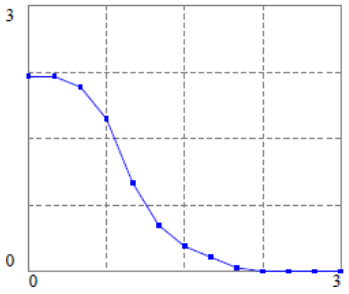
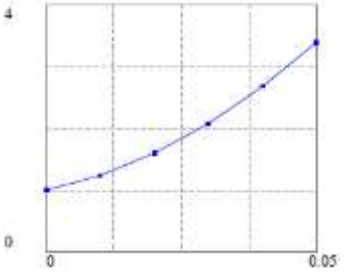
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Units	-	-	-

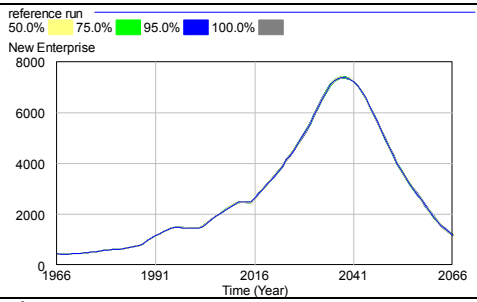
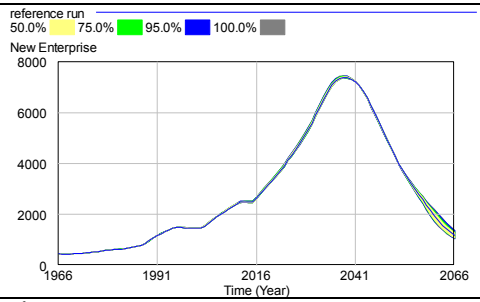
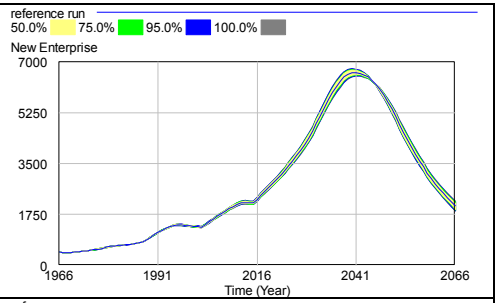
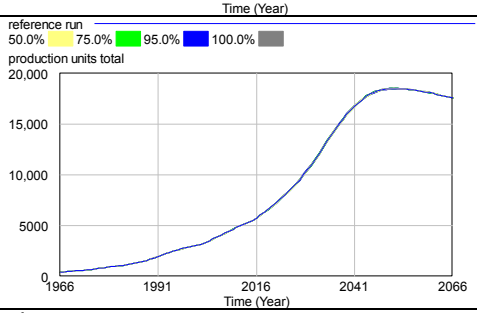
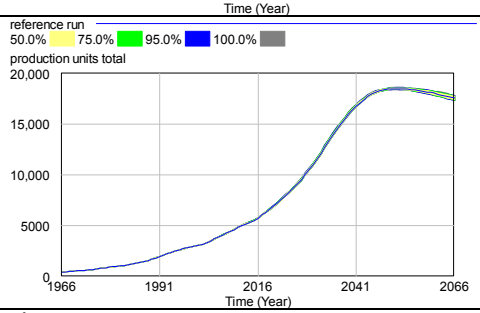
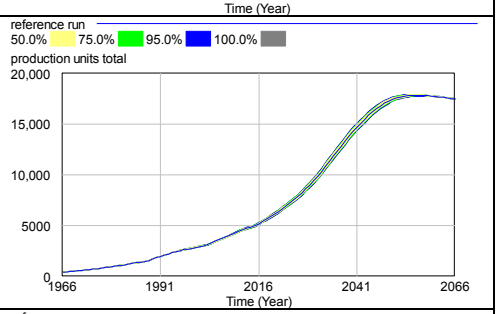
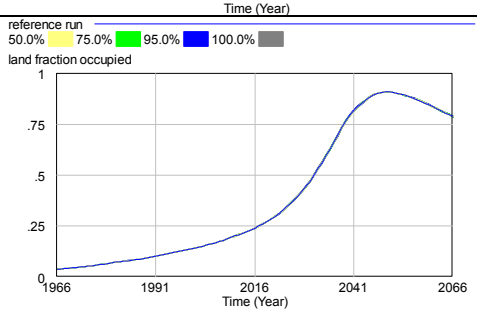
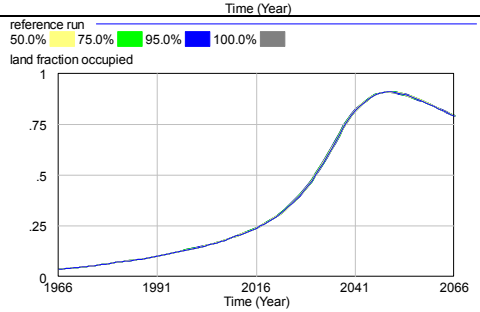
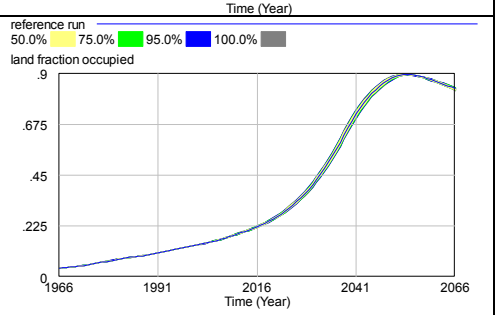
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Maximum plausible			

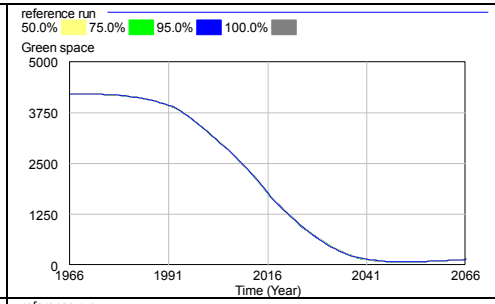
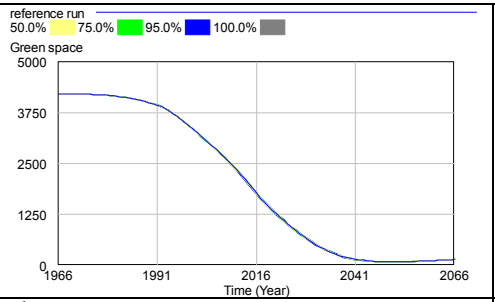
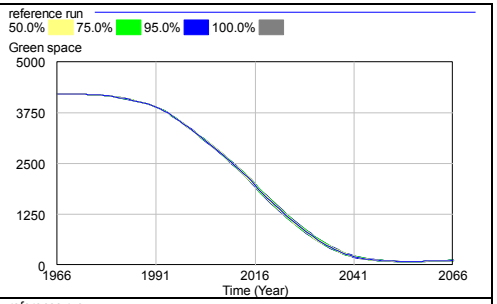
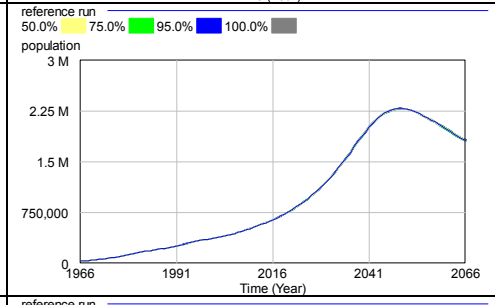
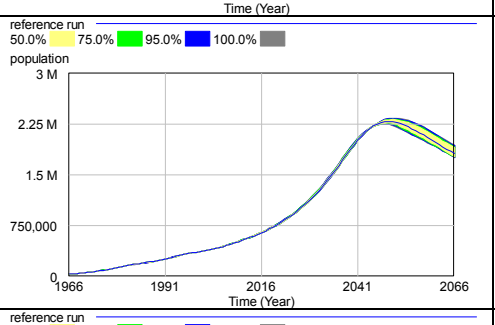
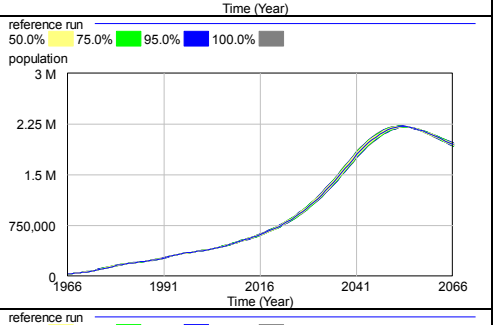
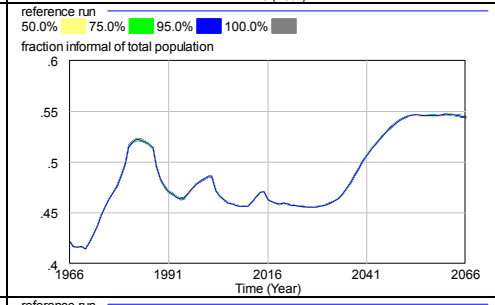
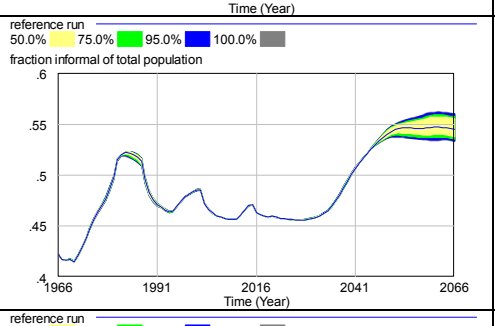
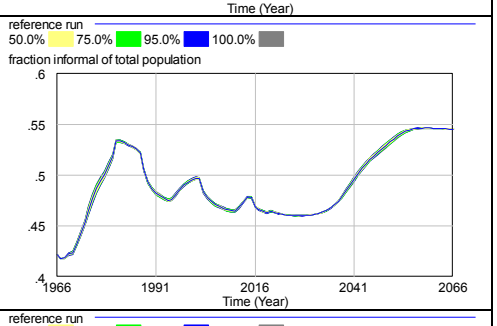
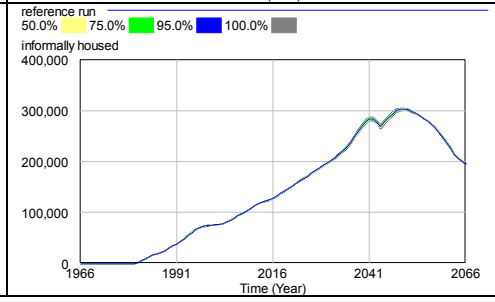
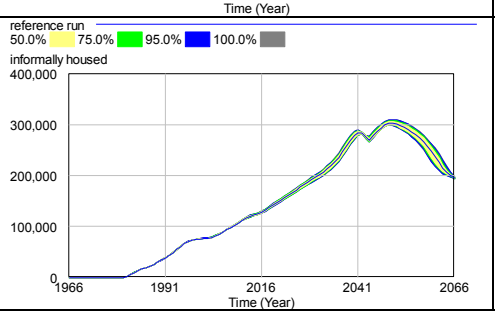
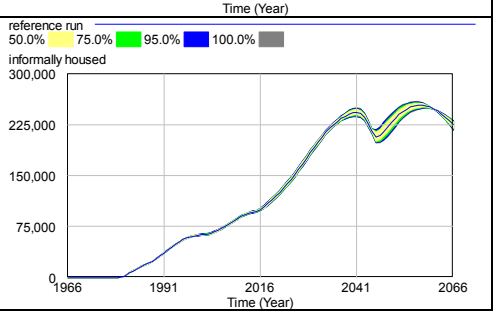
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

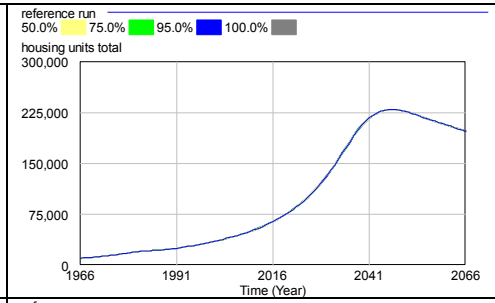
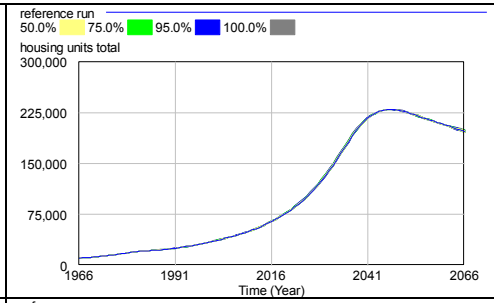
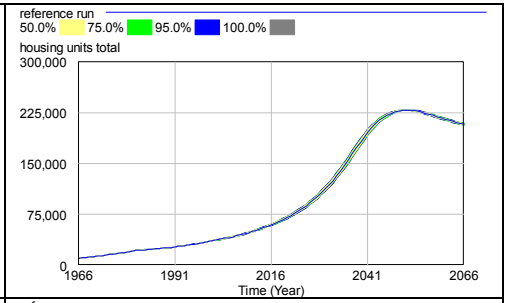
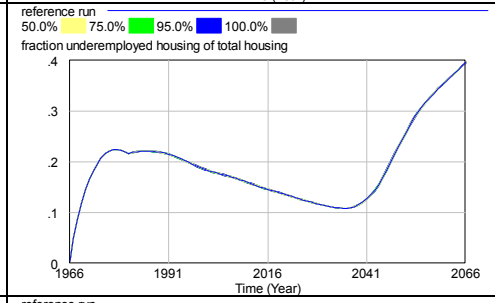
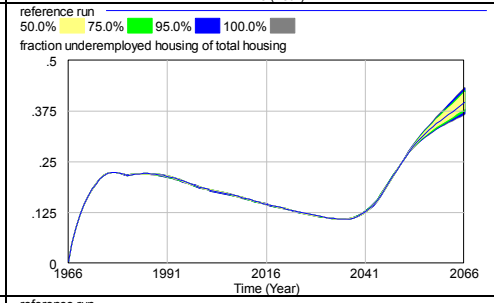
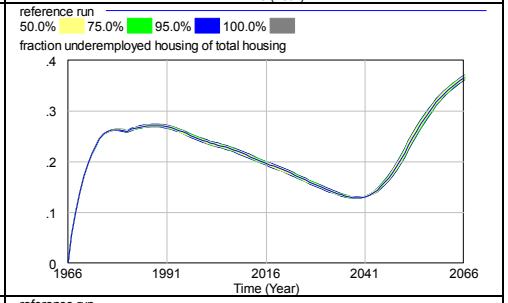
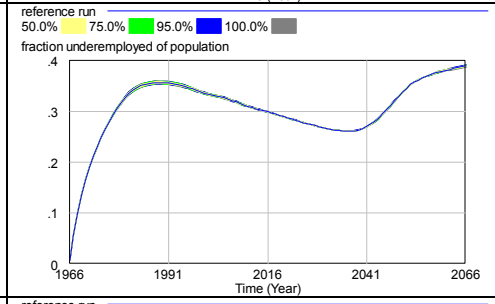
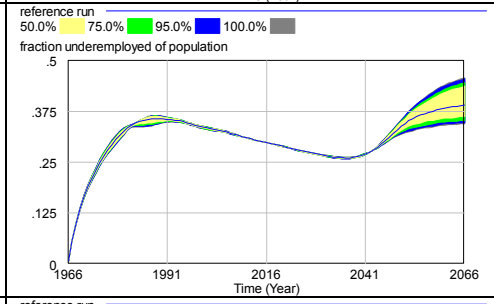
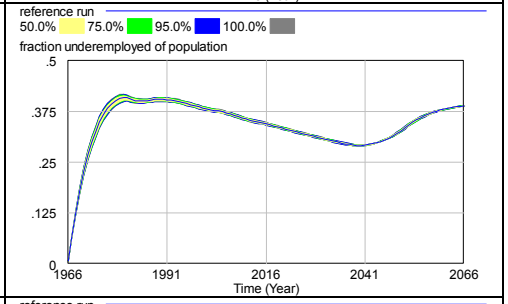
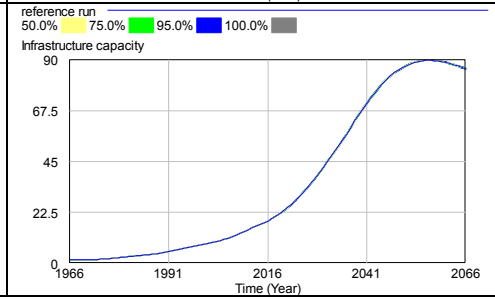
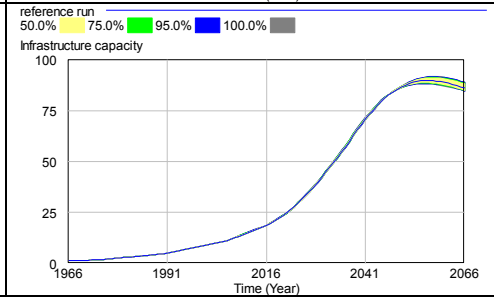
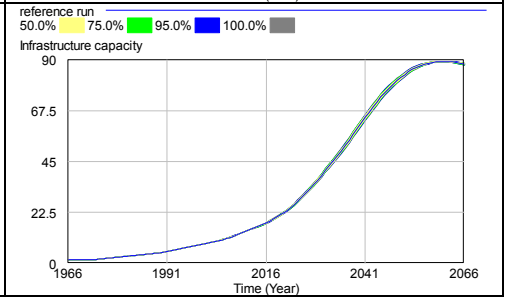
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

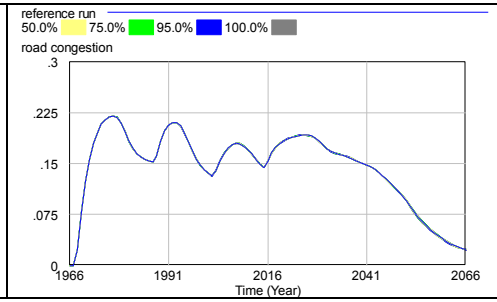
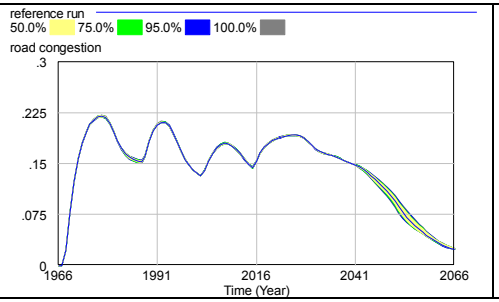
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

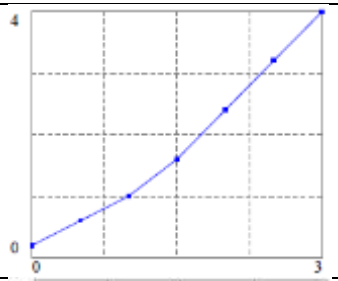
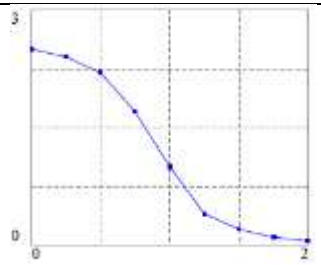
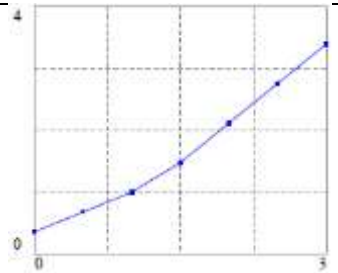
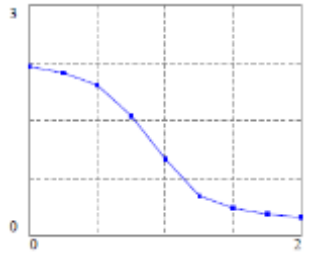
Parameter	underemployed arrivals mobility multiplier (lookup)	underemployed/job multiplier	underemployed housing program multiplier
Units	-	-	- (@ *low-cost housing program* = 100 housing units/year)
Nominal value			
Minimum plausible			
Maximum plausible			

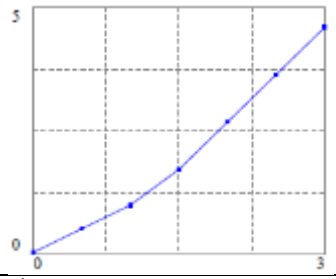
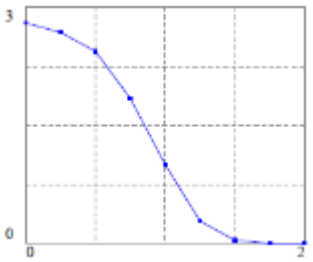
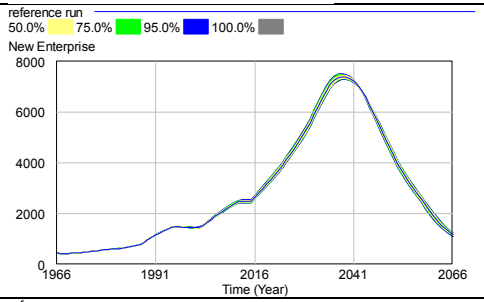
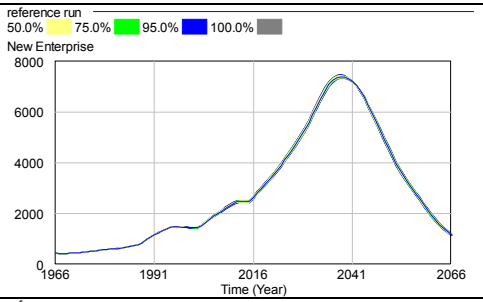
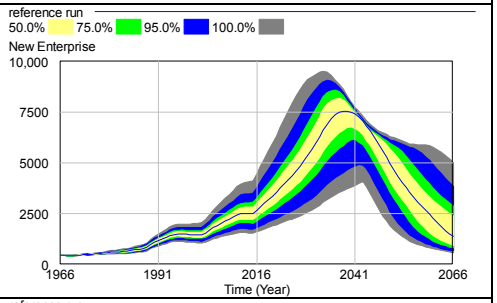
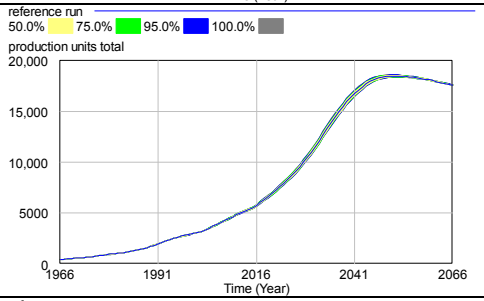
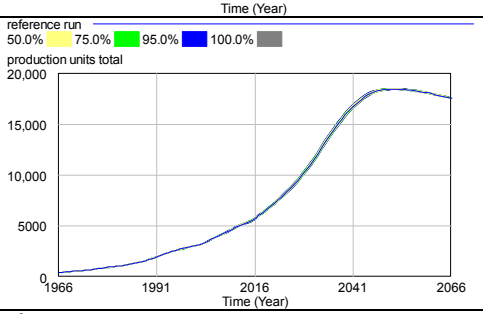
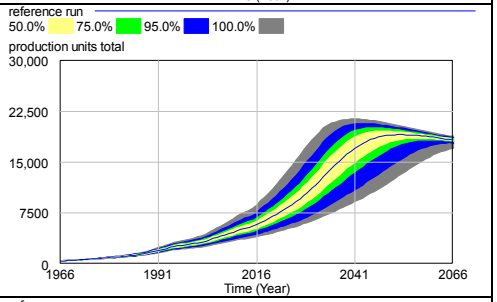
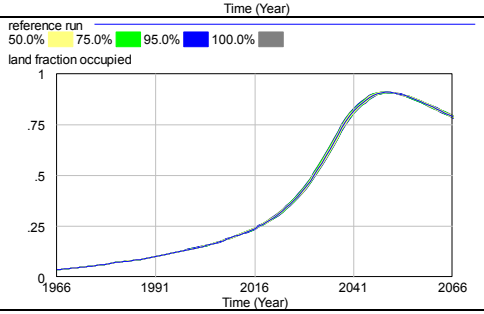
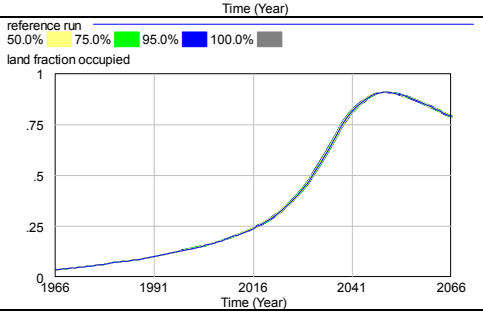
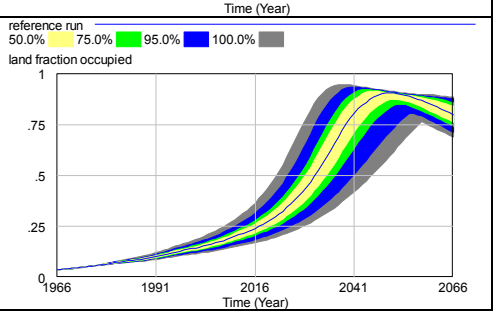
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			

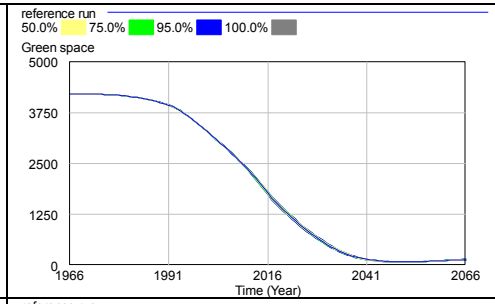
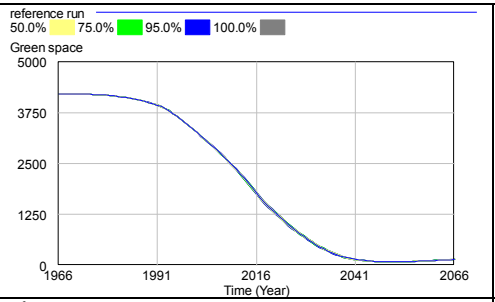
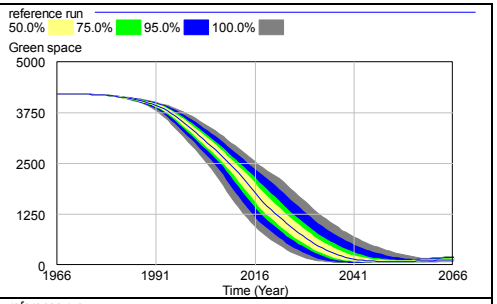
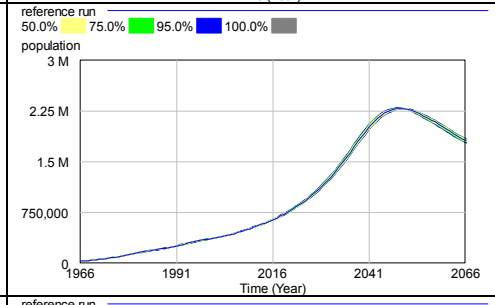
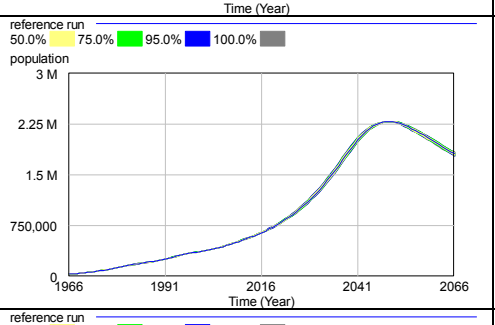
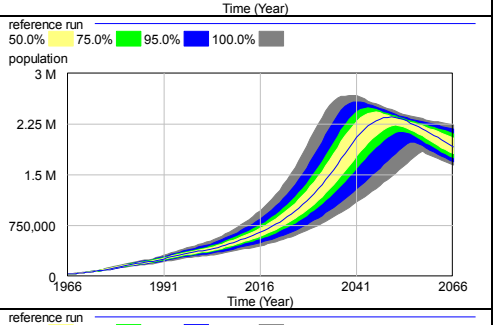
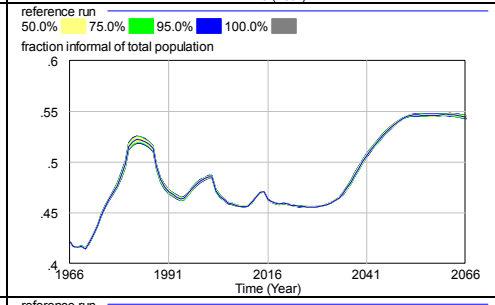
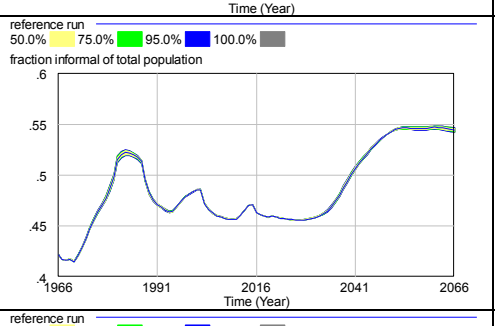
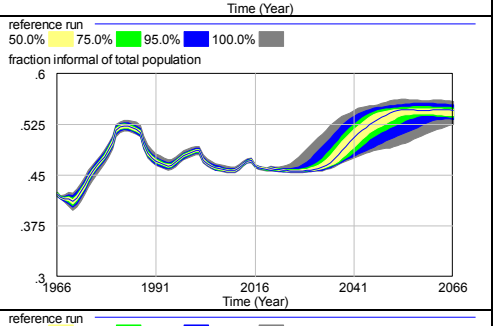
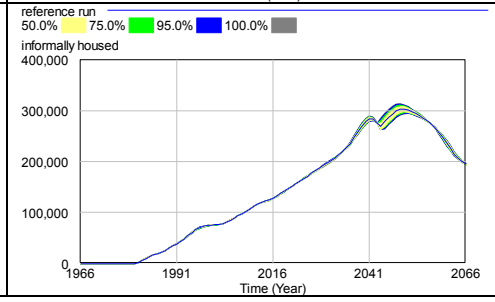
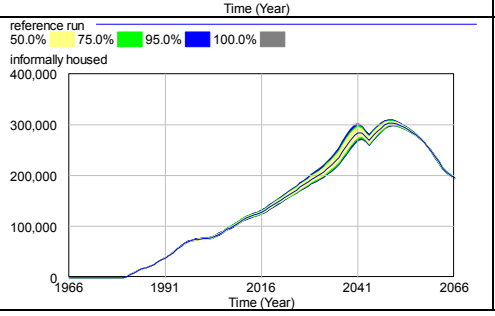
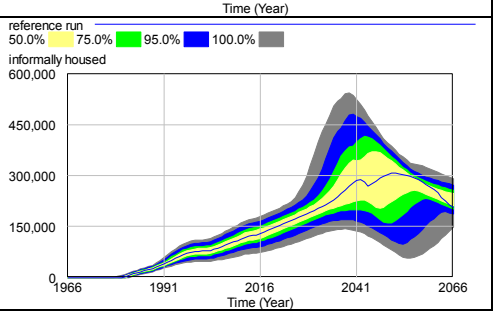
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			

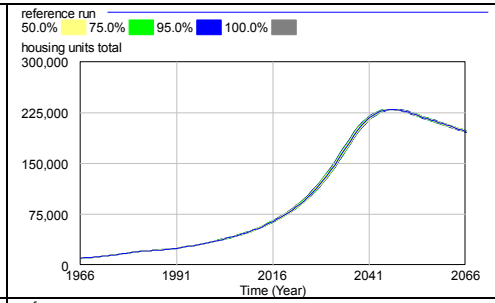
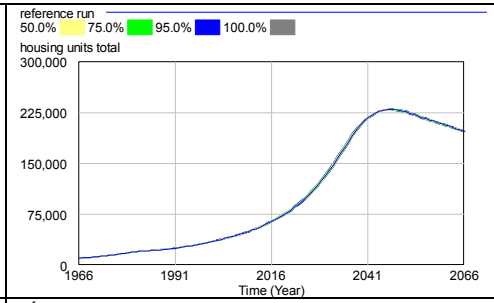
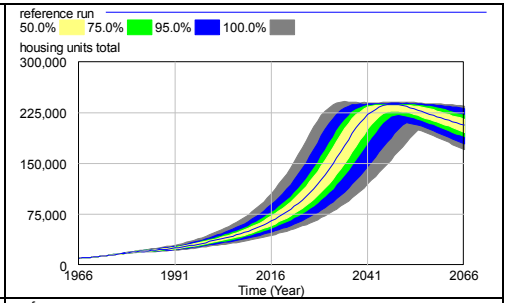
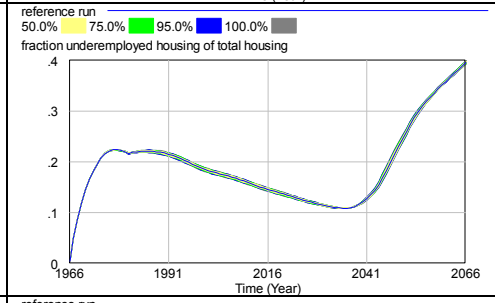
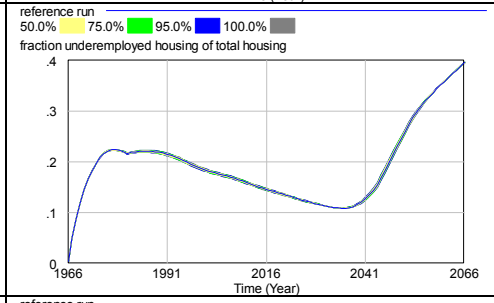
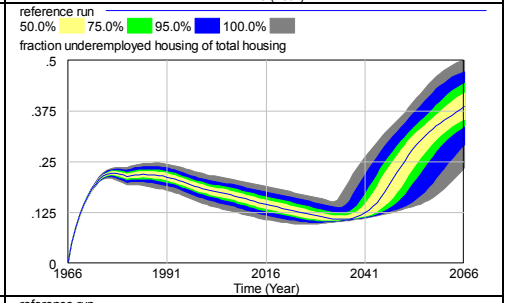
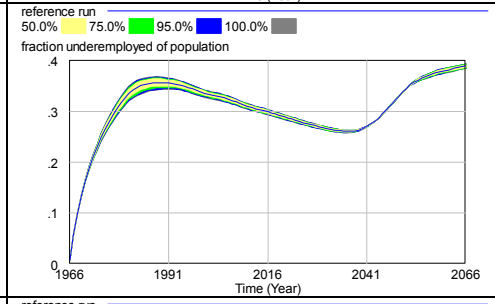
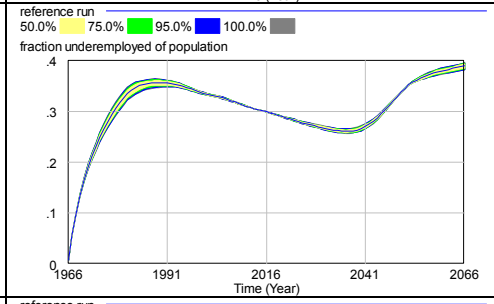
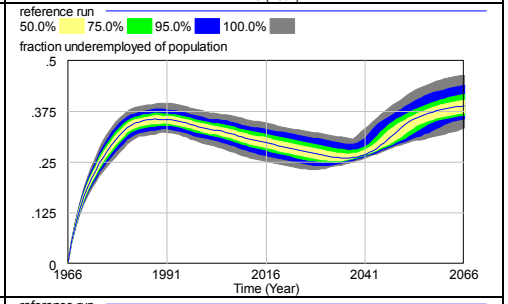
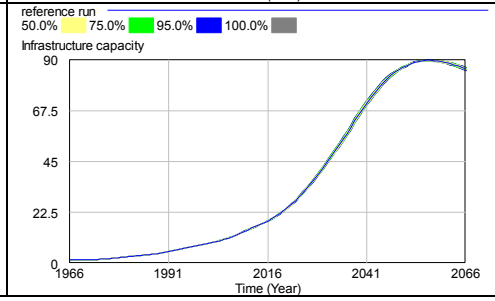
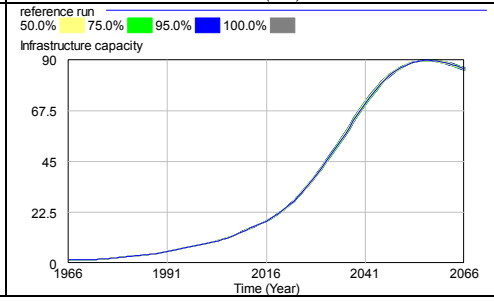
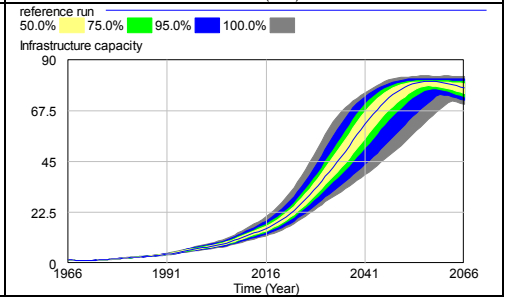
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			

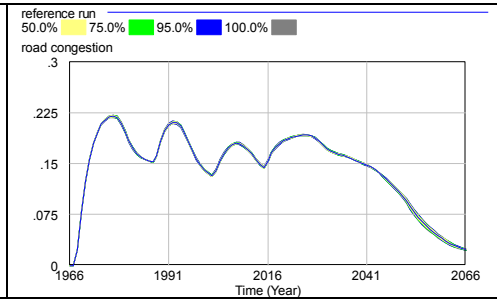
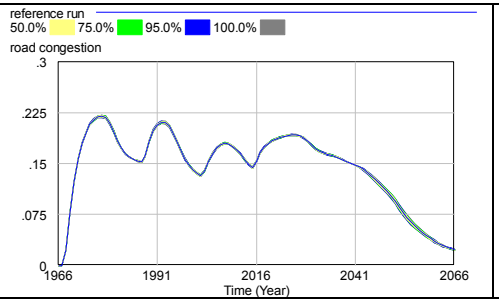
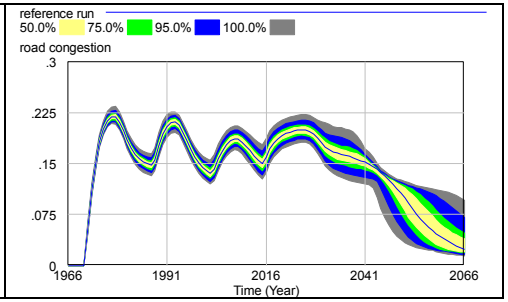
Sensitivity plot: road congestion			

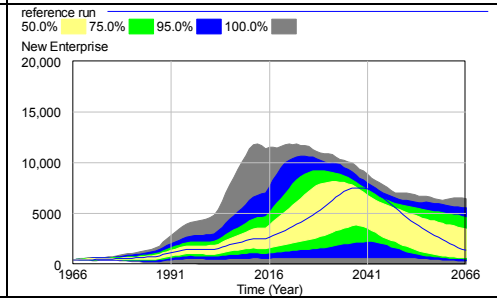
Parameter	public expenditure multiplier	underemployed/housing multiplier	Multivariate, all parameters and lookups except housing program-related
Units	-	-	-
Nominal value			-
Minimum plausible			-10%

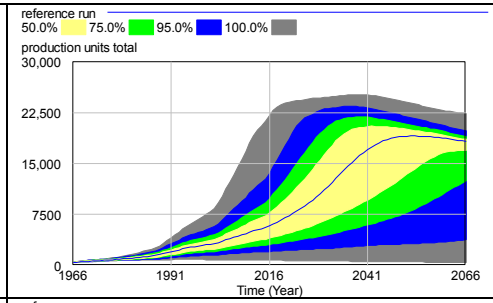
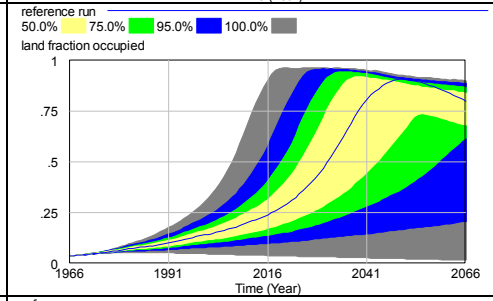
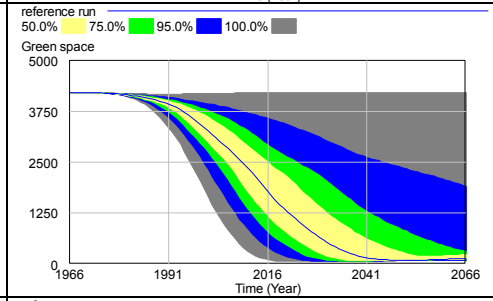
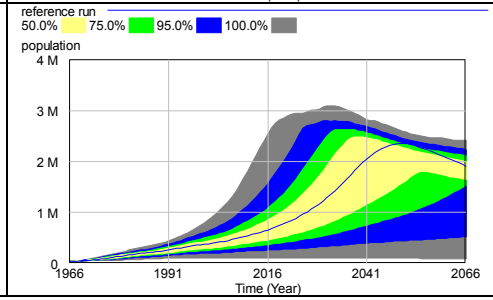
Maximum plausible			+10%
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			

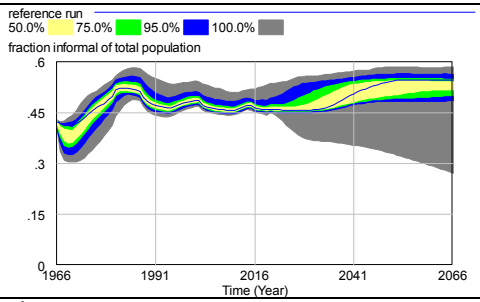
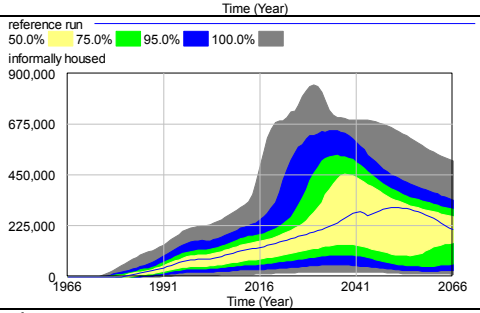
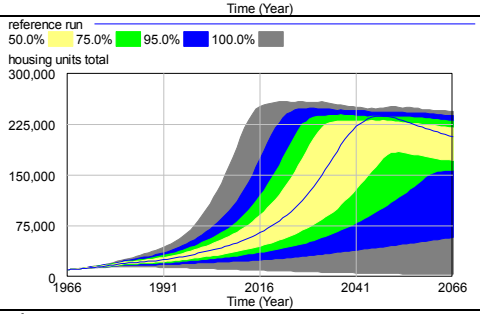
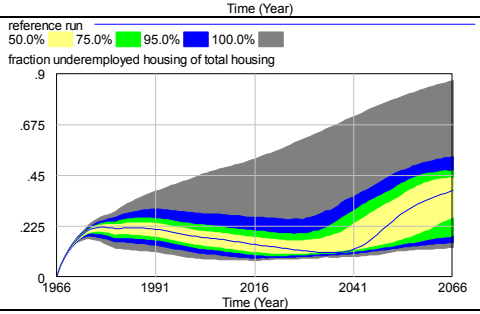
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			

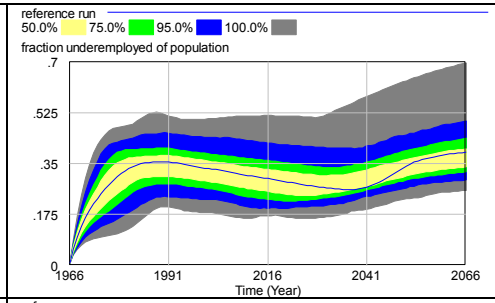
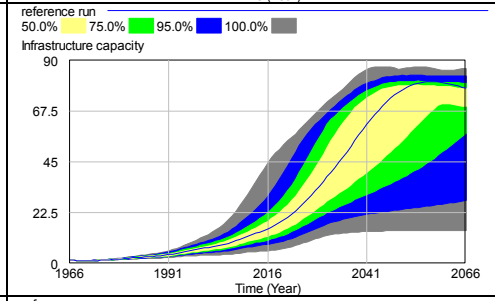
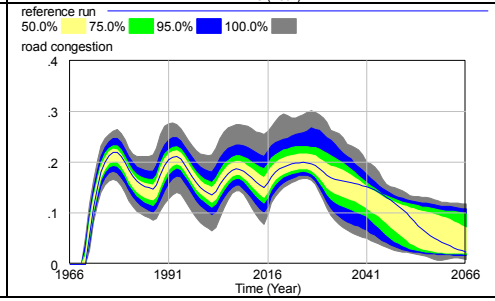
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			

Sensitivity plot: road congestion			

Parameter	Multivariate, all parameters		
Units	-		
Nominal value	-		
Minimum plausible	Respective minimum plausible values		
Maximum plausible	Respective maximum plausible values		
Sensitivity plot: New Enterprise			

Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			

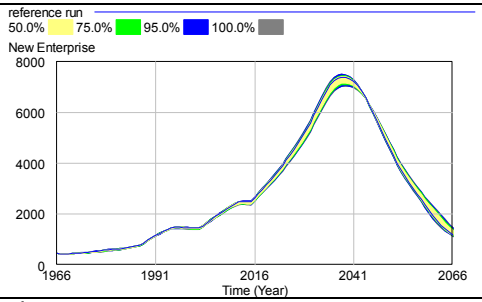
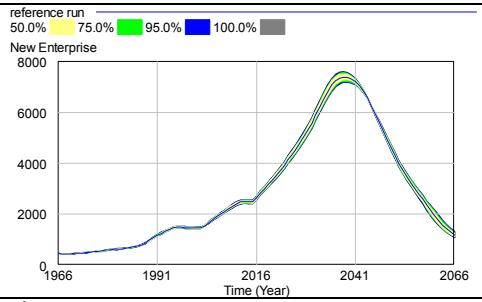
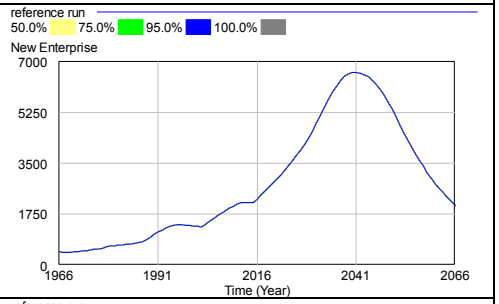
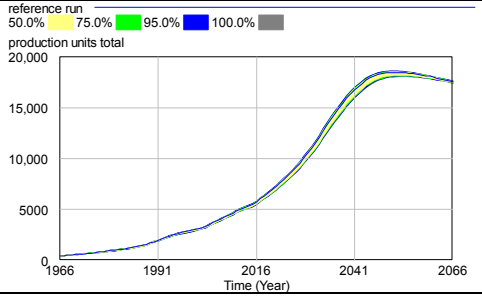
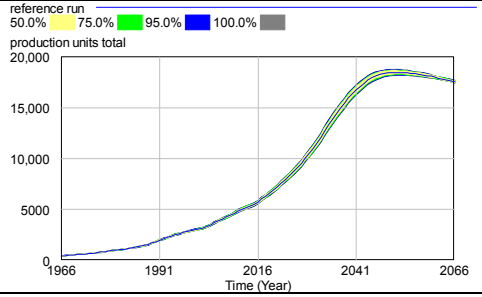
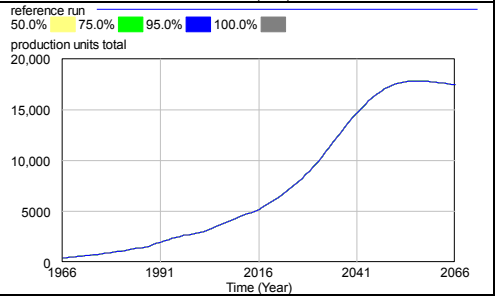
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			

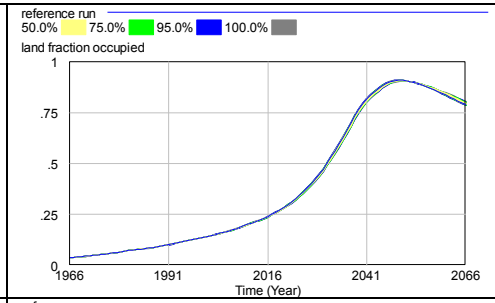
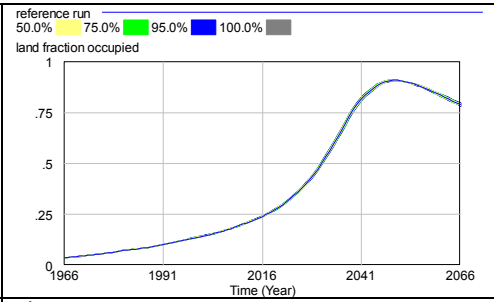
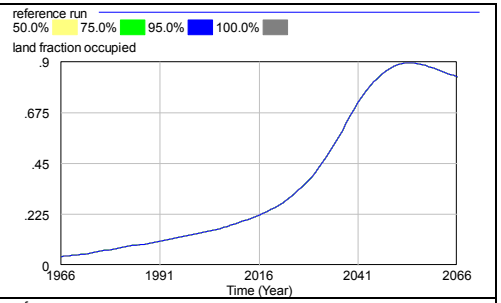
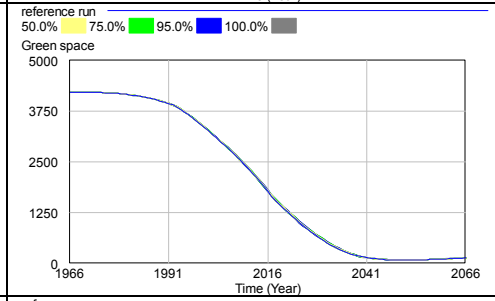
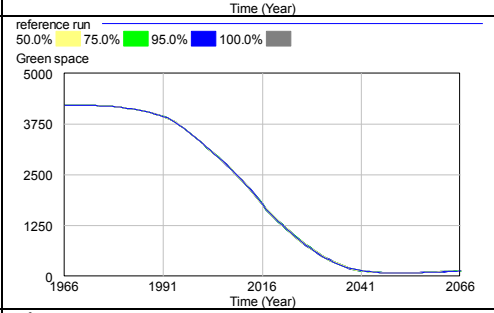
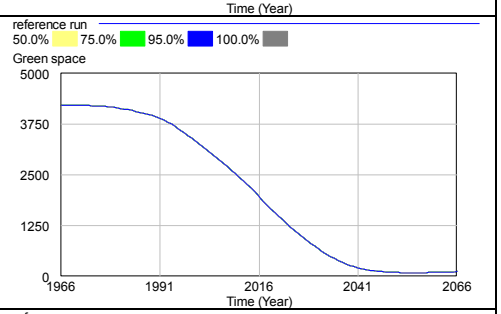
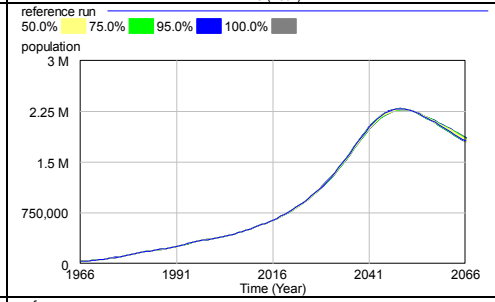
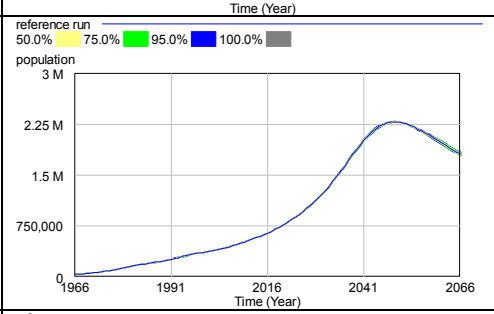
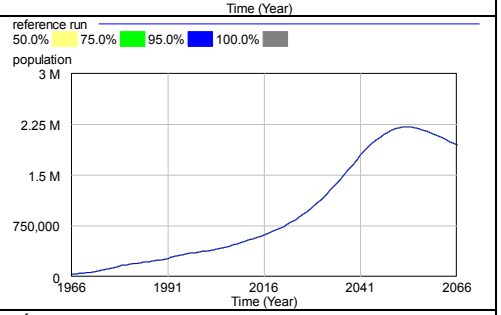
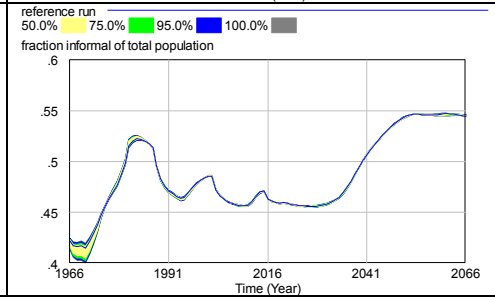
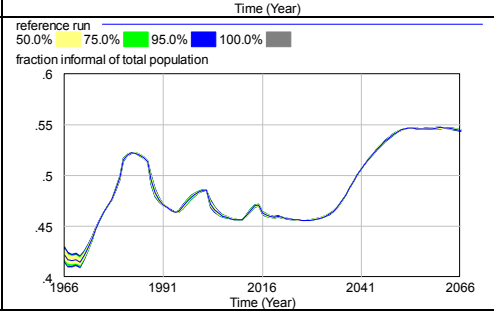
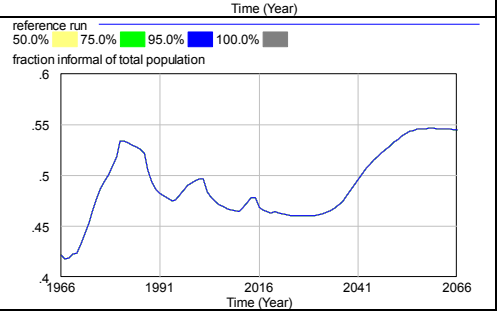
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

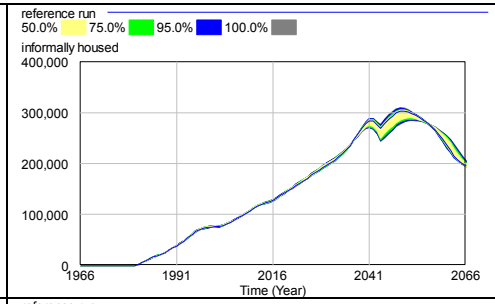
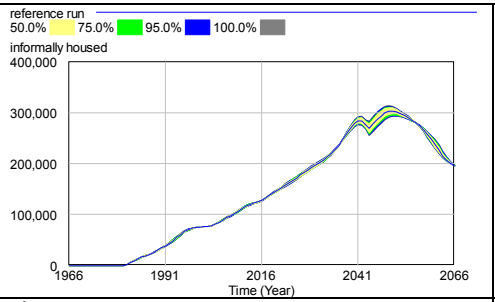
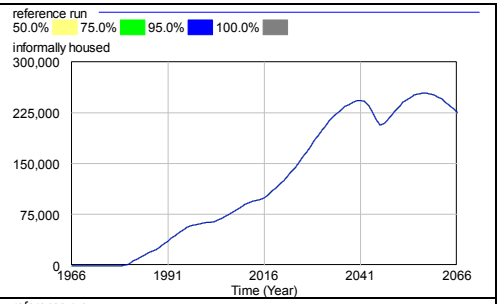
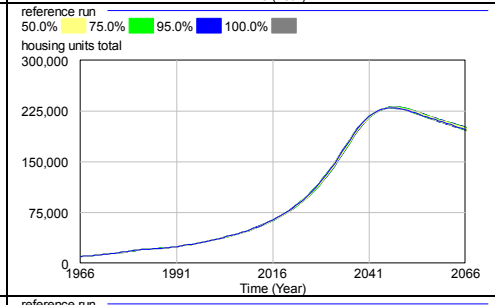
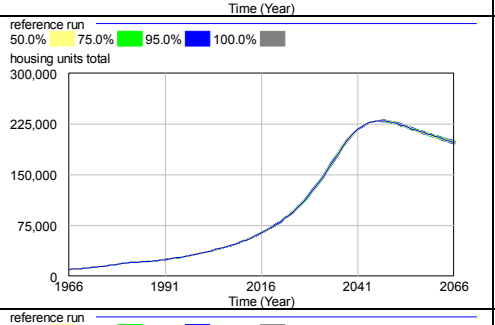
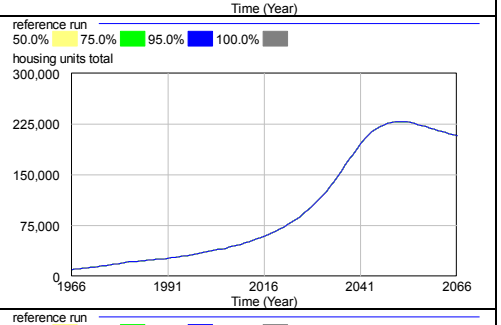
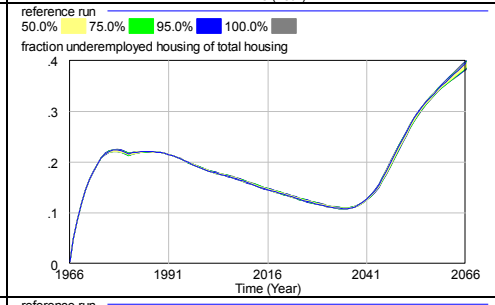
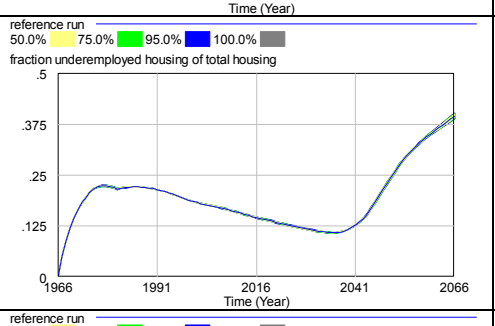
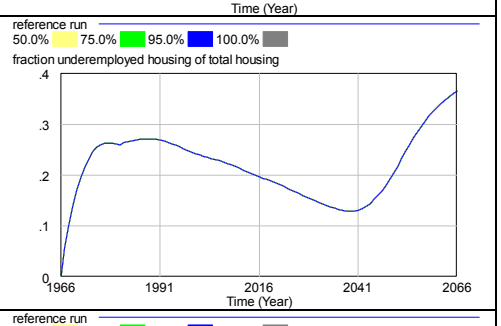
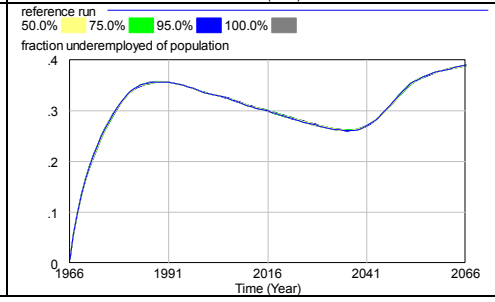
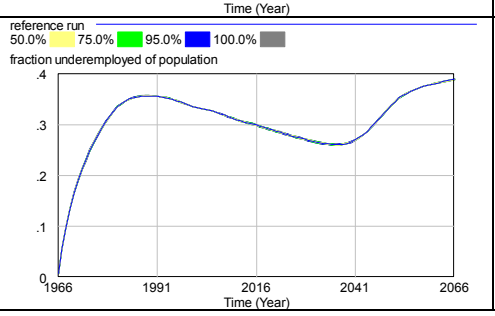
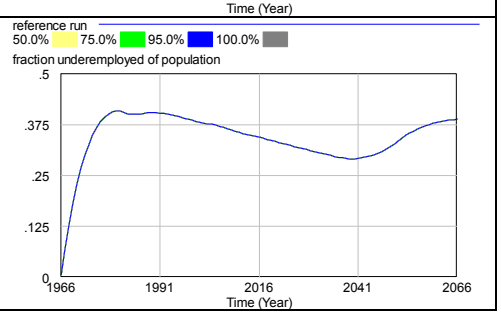
4.7 Job section sensitivity

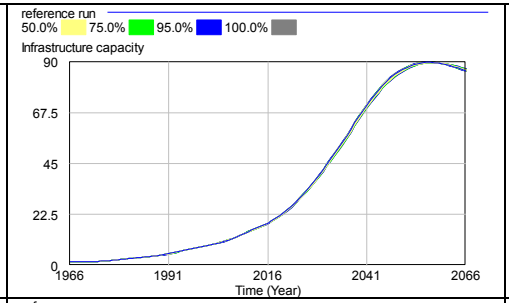
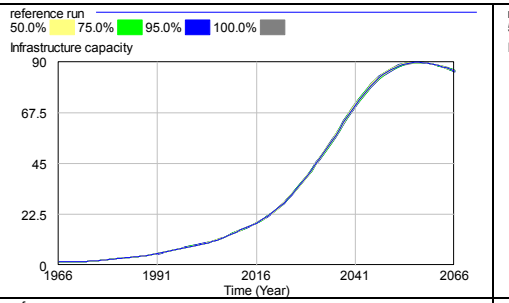
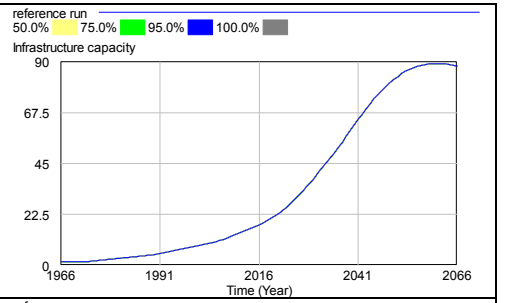
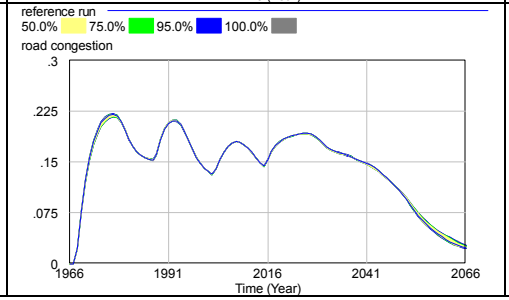
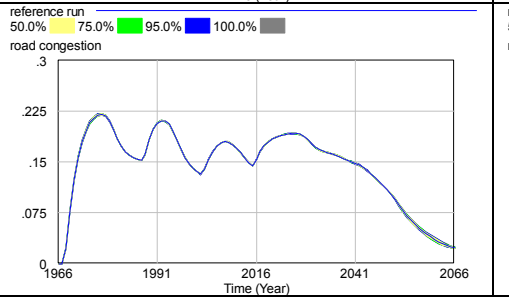
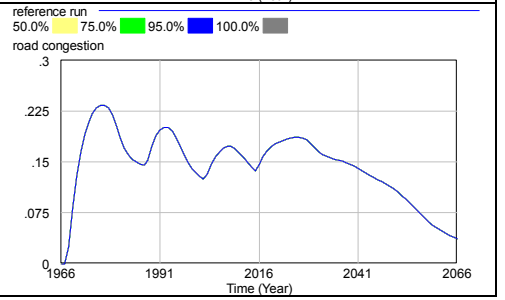
Parameters:

- premium housing construction labor
- new enterprise construction labor
- low cost housing construction labor
- low cost housing construction desired
- worker housing construction labor
- new enterprise labor
- mature business labor
- declining industry labor
- industry automation level
- underemployed job program
- labor/job perception time
-

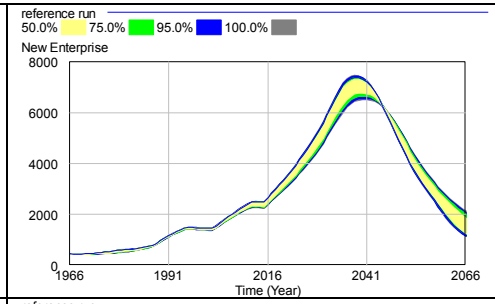
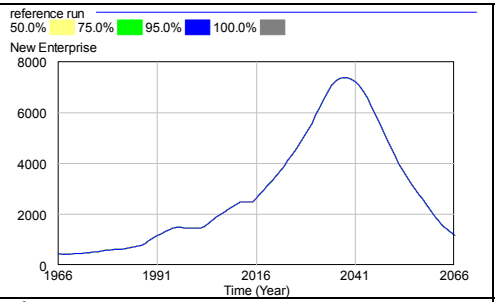
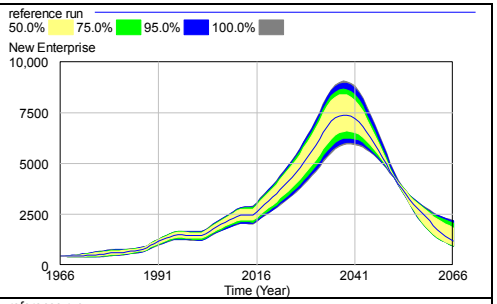
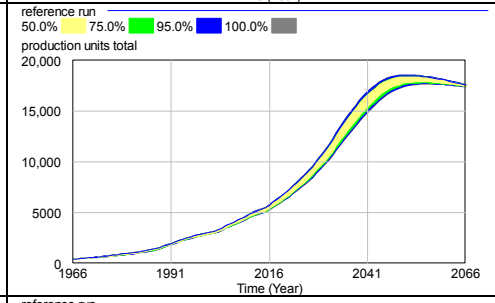
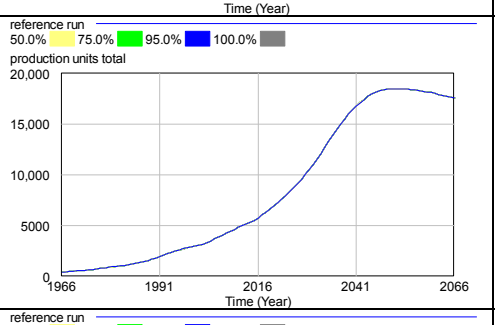
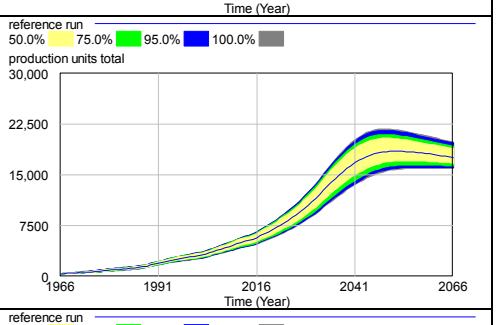
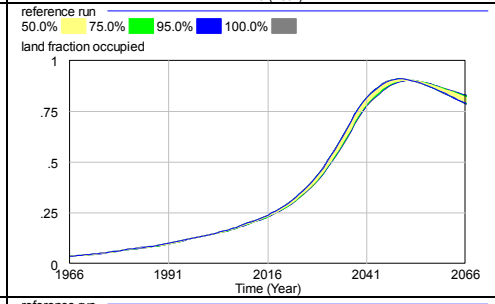
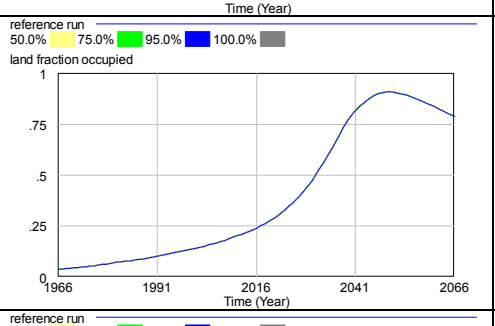
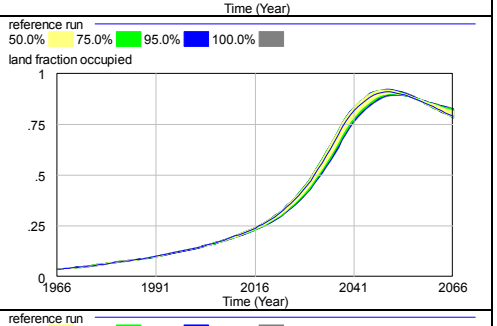
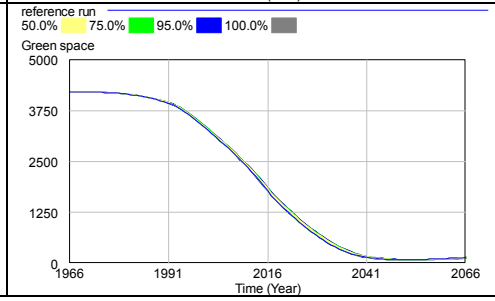
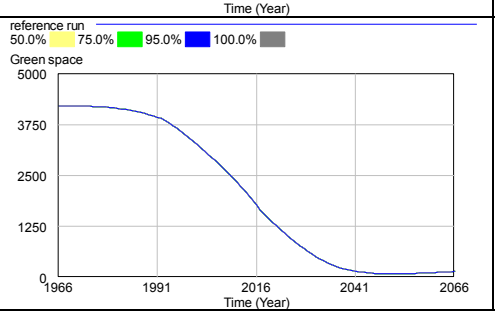
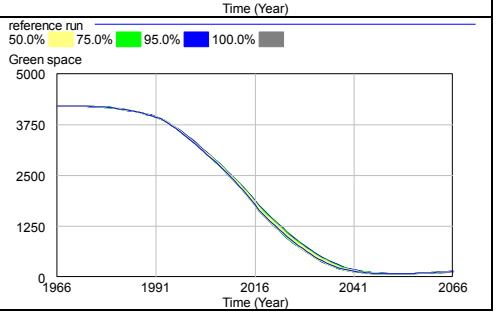
Parameter	premium housing construction labor	new enterprise construction labor	low cost housing construction labor
Units	worker*Year/housing unit	worker*Year/housing unit	worker*Year/housing unit
Nominal value	2	20	0.6
Minimum plausible	1	10	0.1
Maximum plausible	5	30	1 (low cost housing program @ 100)
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			

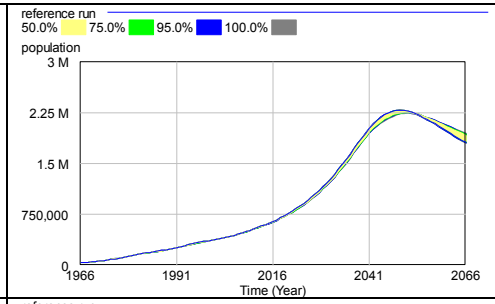
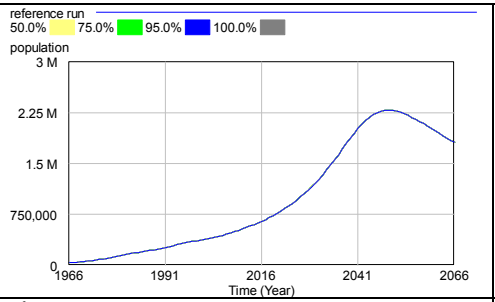
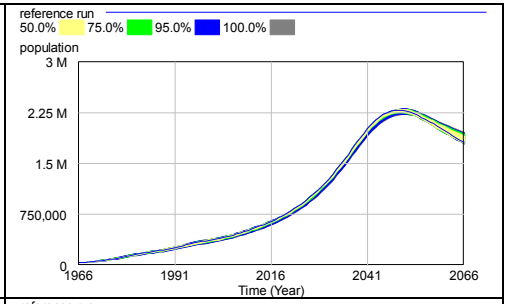
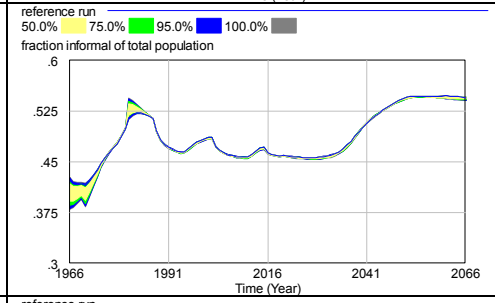
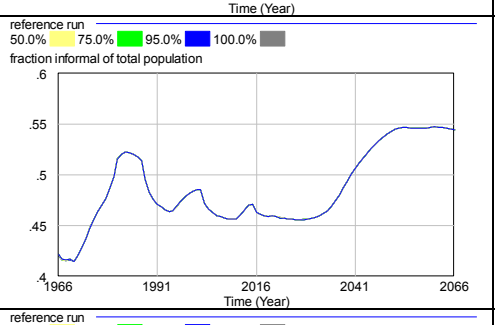
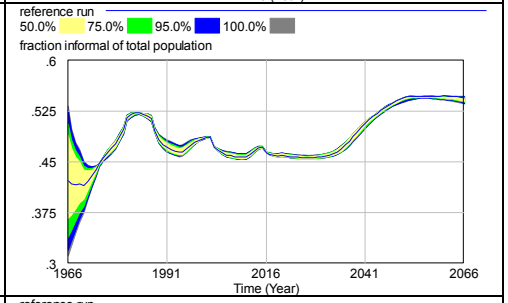
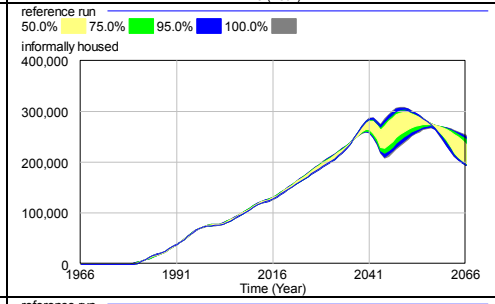
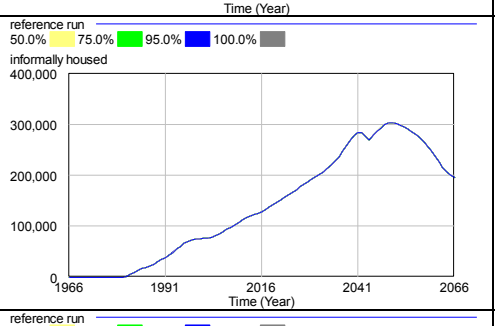
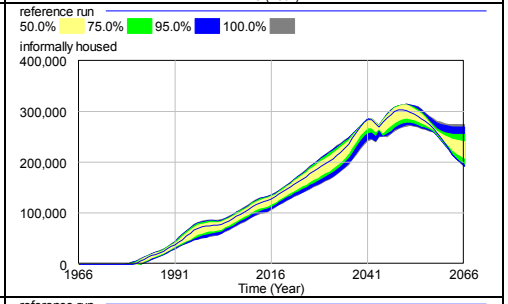
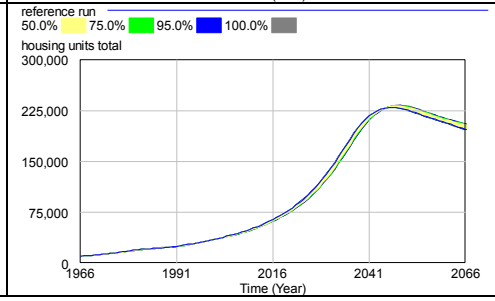
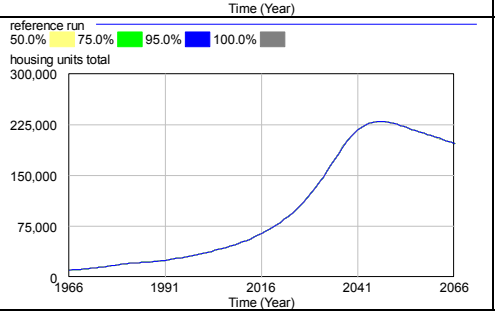
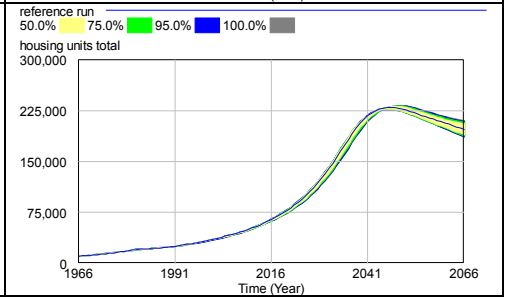
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			

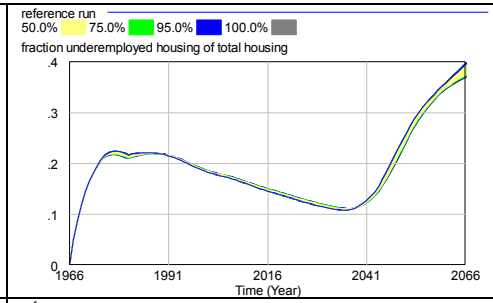
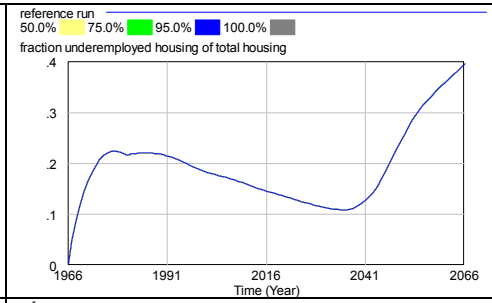
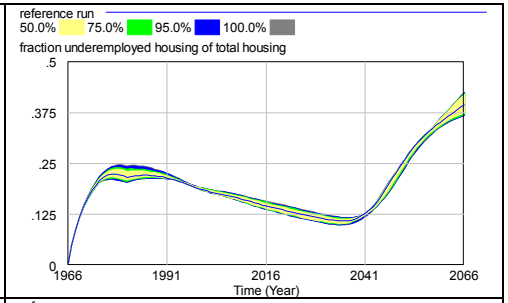
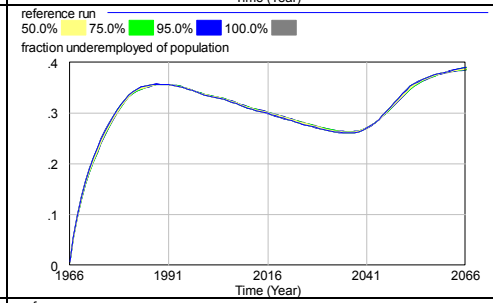
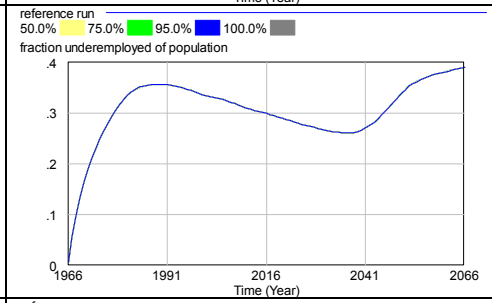
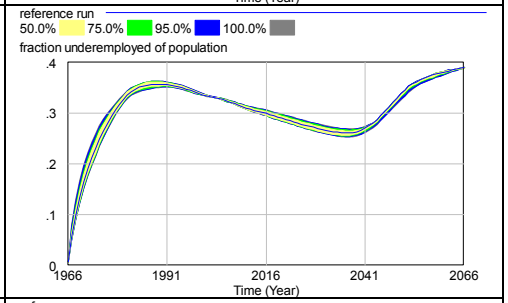
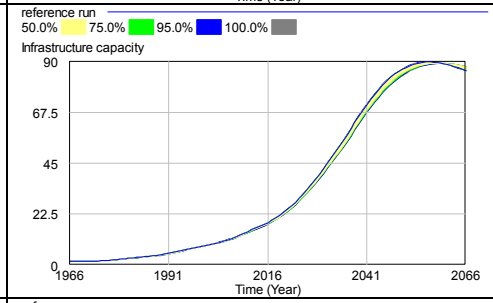
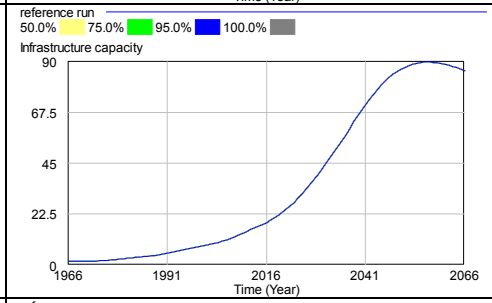
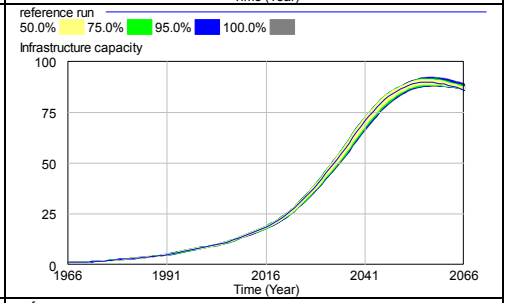
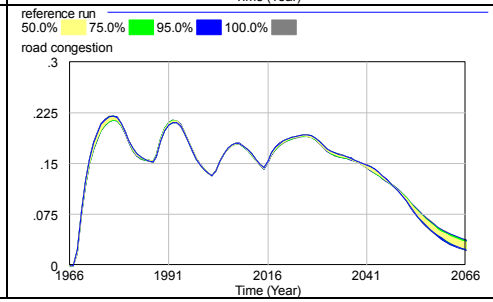
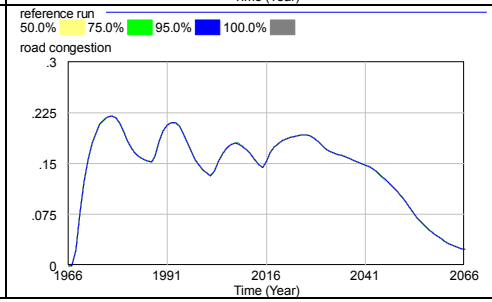
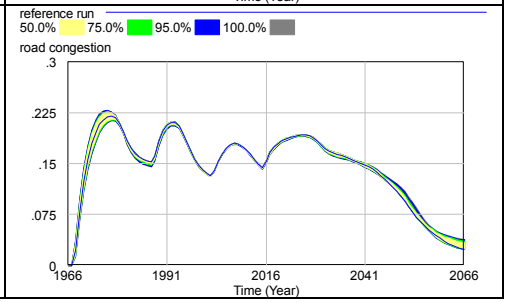
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			

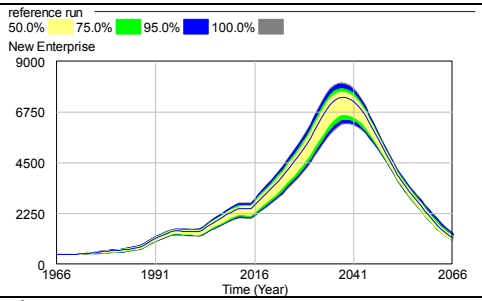
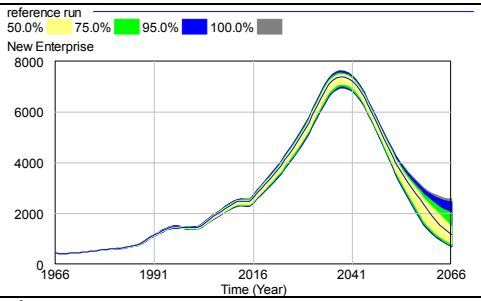
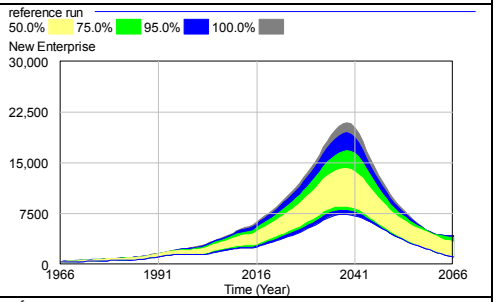
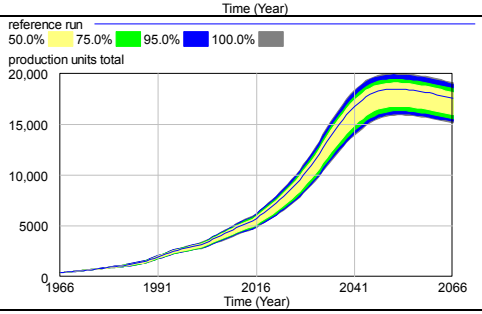
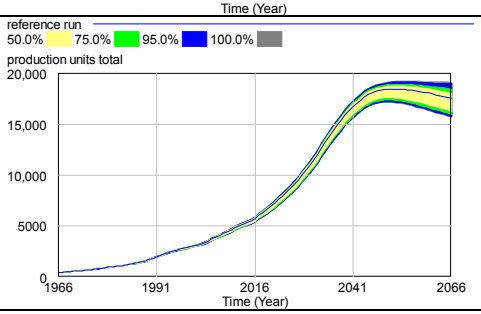
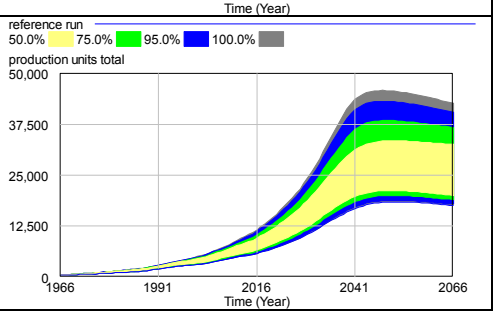
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

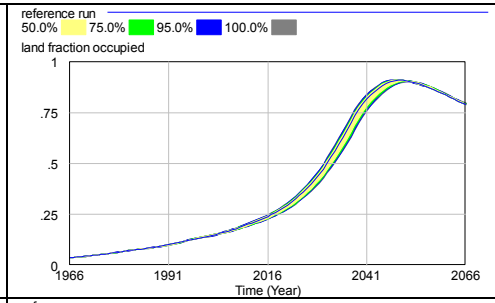
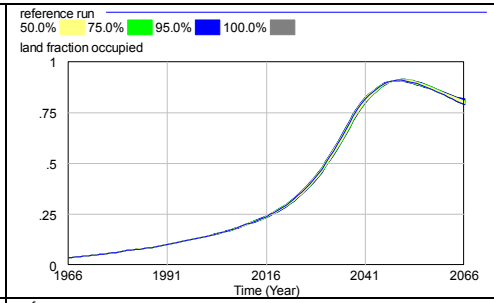
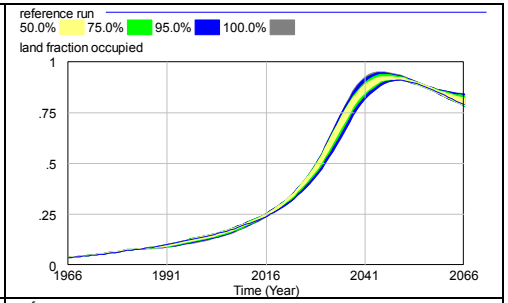
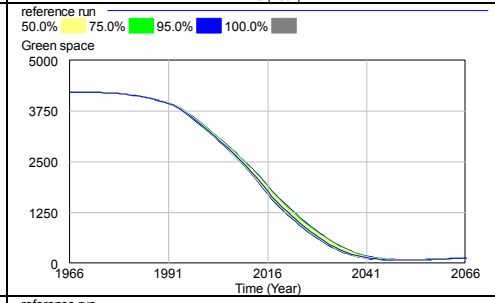
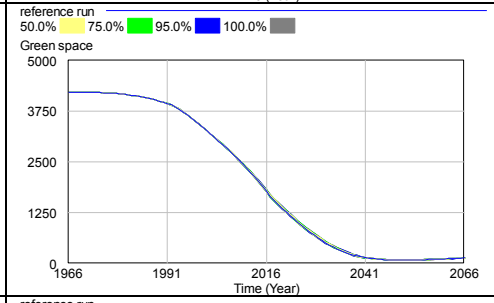
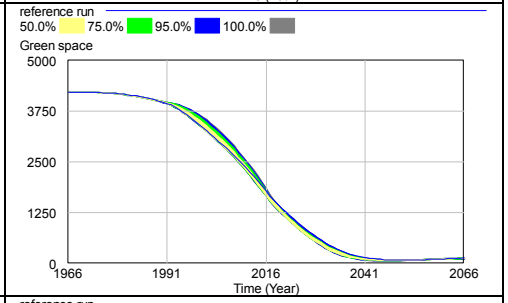
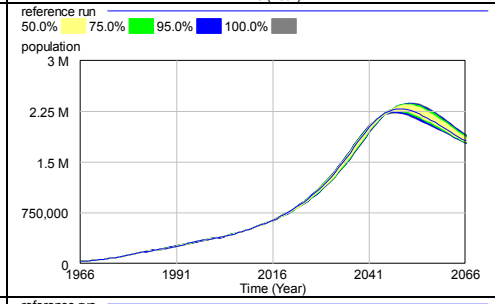
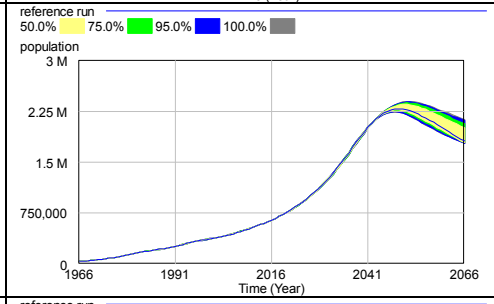
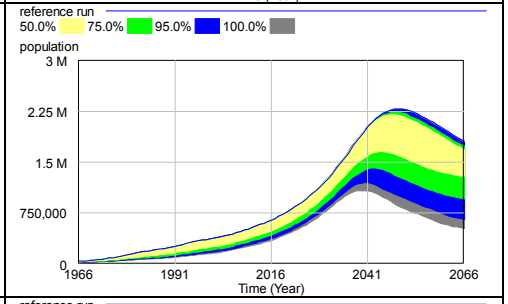
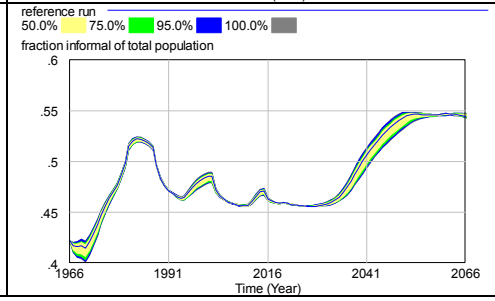
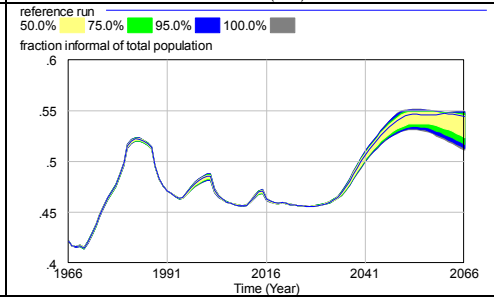
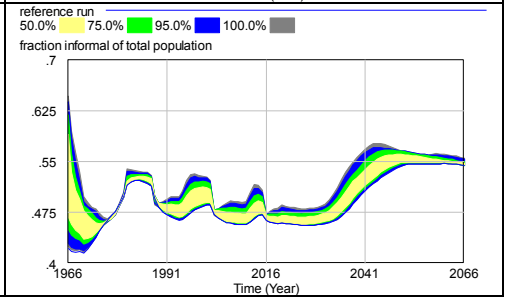
Parameter	worker housing construction labor	low cost housing construction desired	new enterprise labor
Units	worker*Year/housing unit	Housing unit/year	worker/productive unit
Nominal value	1	0	20
Minimum plausible	0.5	0	10 (-50%)
Maximum plausible	5	100	30 (+50%)

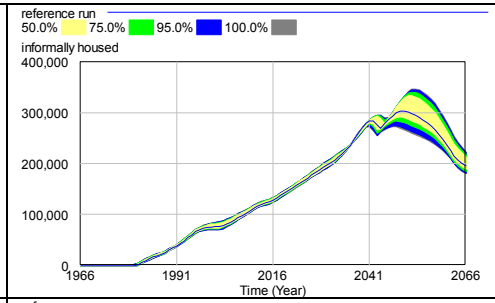
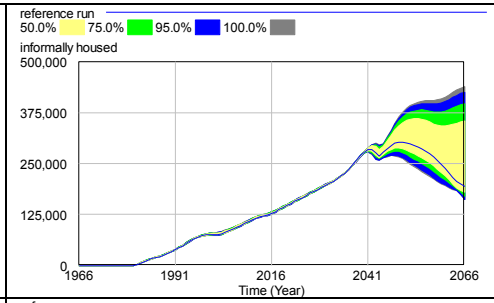
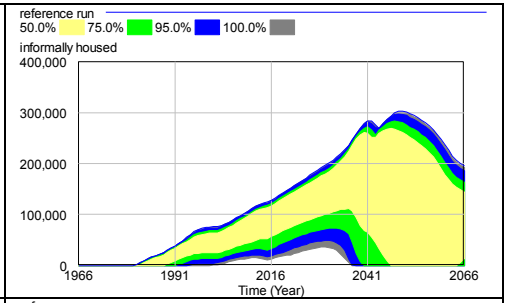
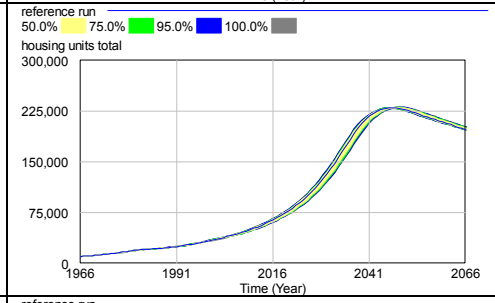
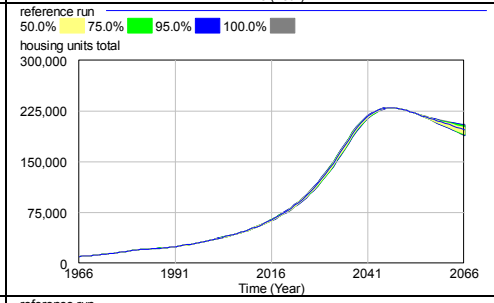
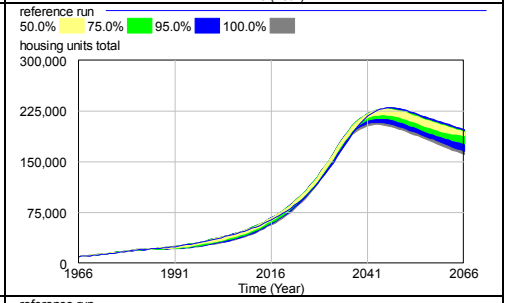
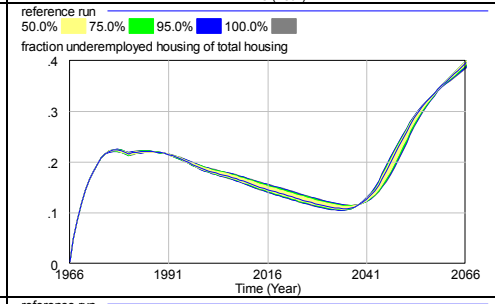
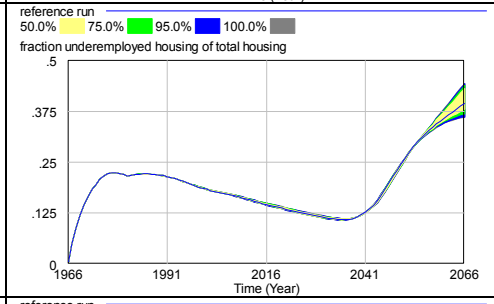
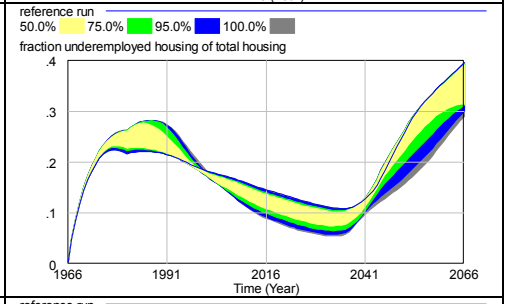
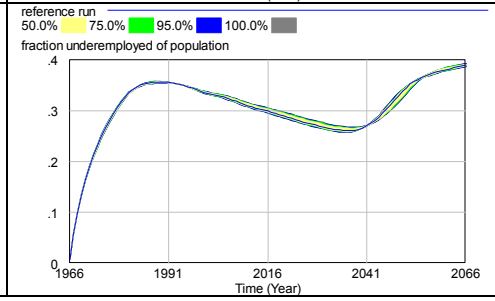
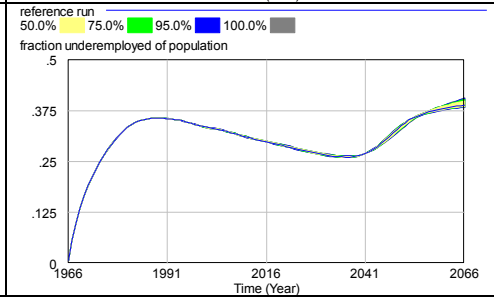
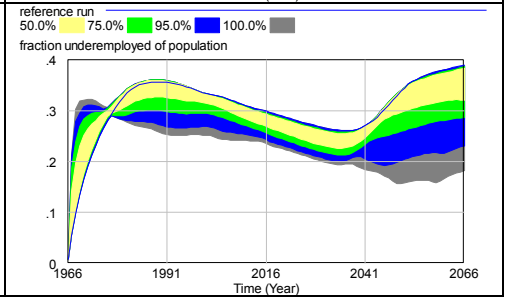
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

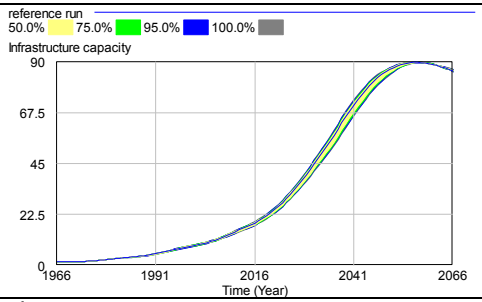
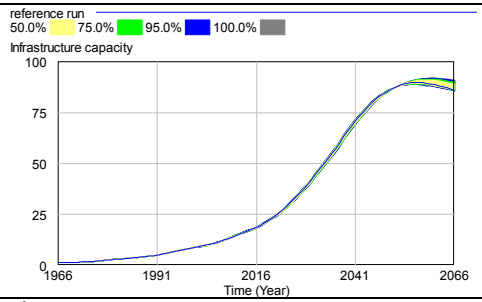
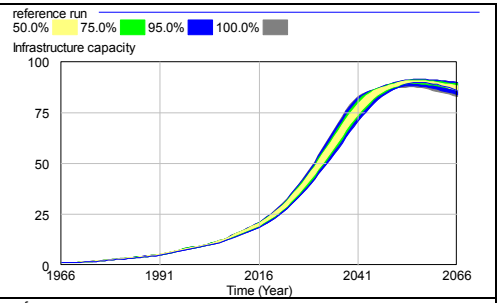
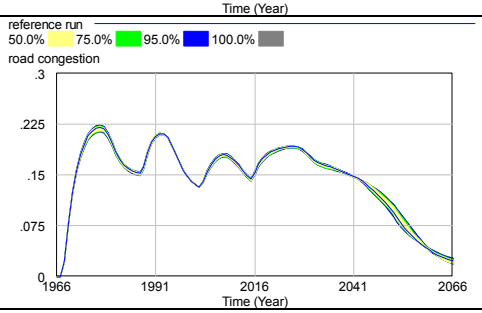
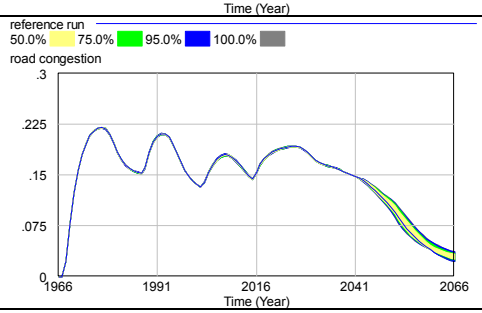
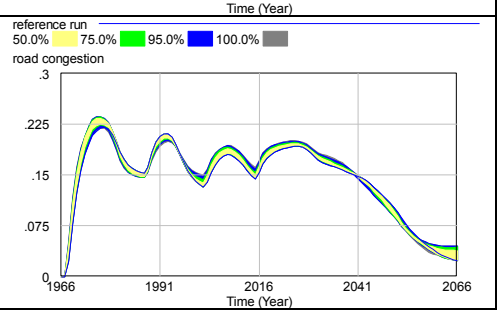
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

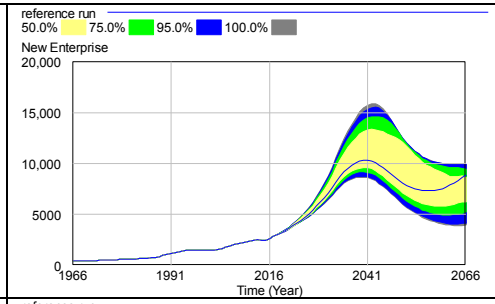
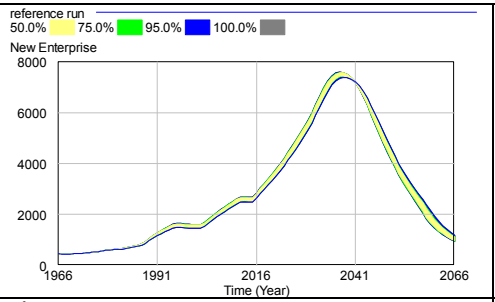
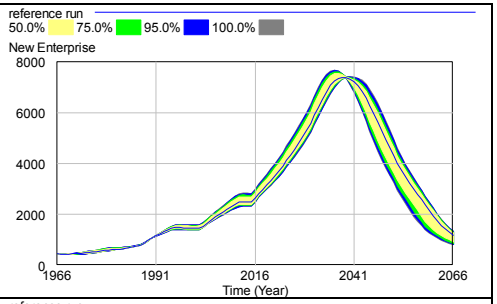
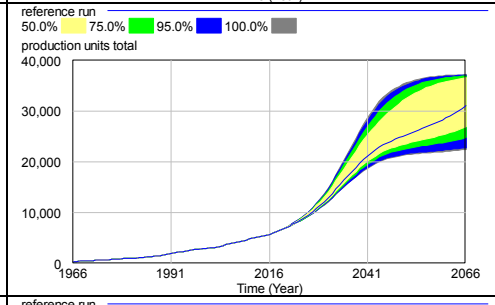
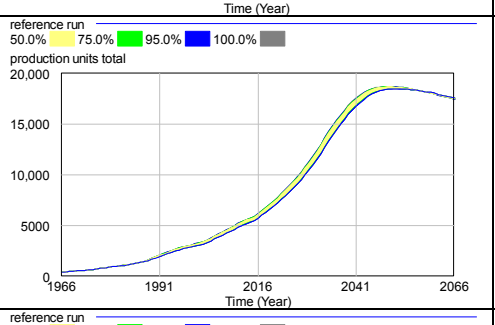
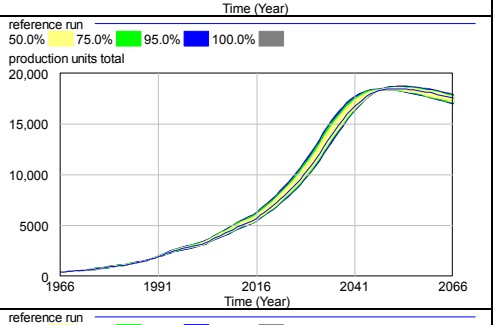
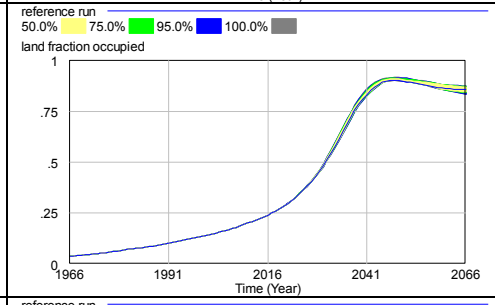
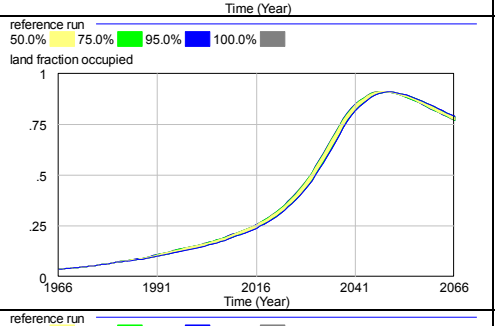
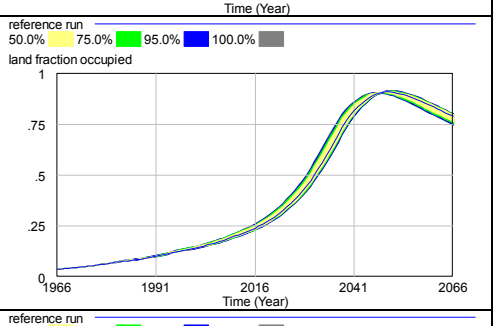
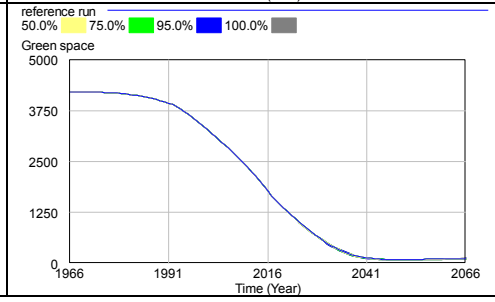
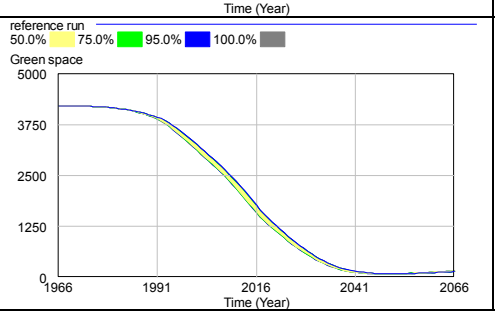
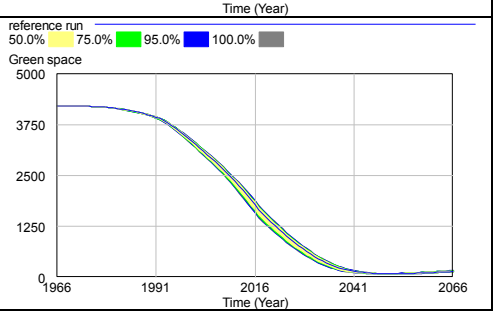
Parameter	mature business labor	declining industry labor	industry automation level
Units	worker/productive unit	worker/productive unit	-
Nominal value	15	10	0
Minimum plausible	10	5	0
Maximum plausible	25	20	1
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			

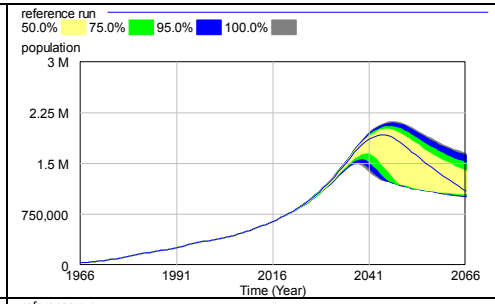
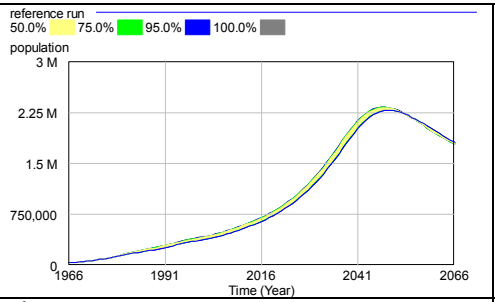
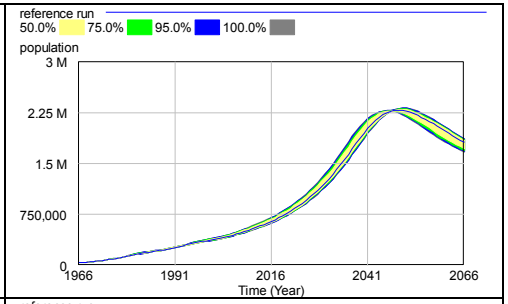
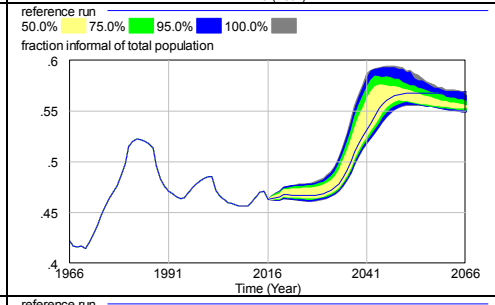
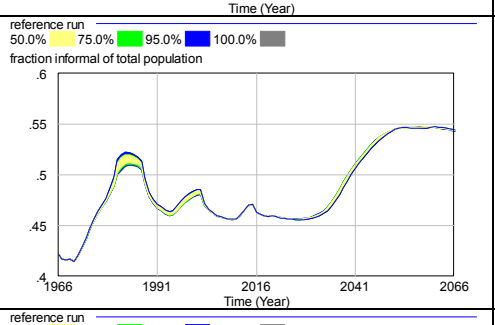
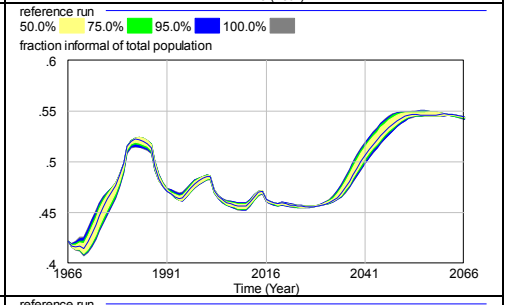
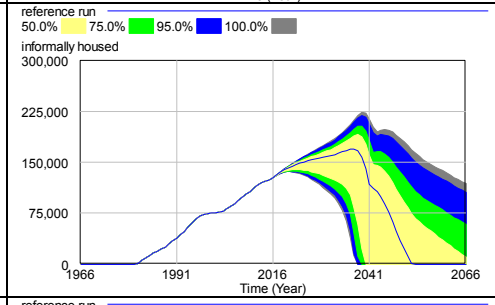
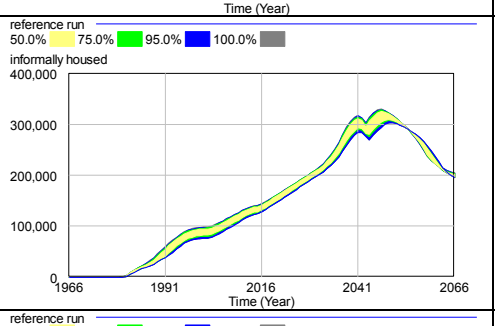
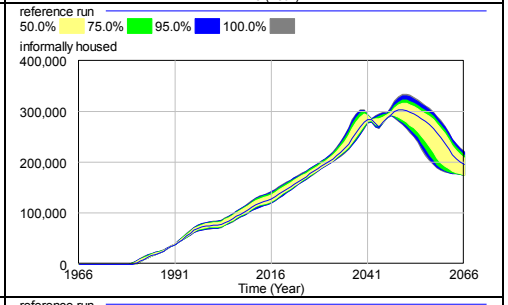
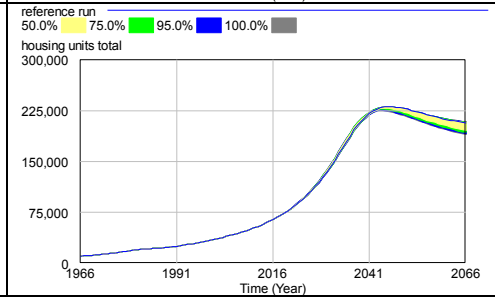
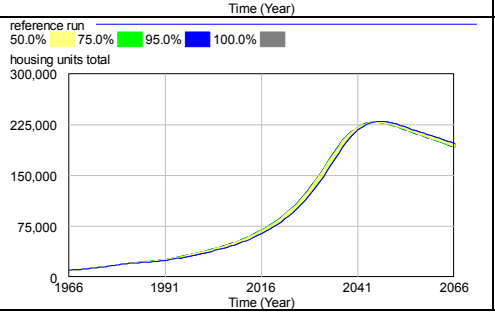
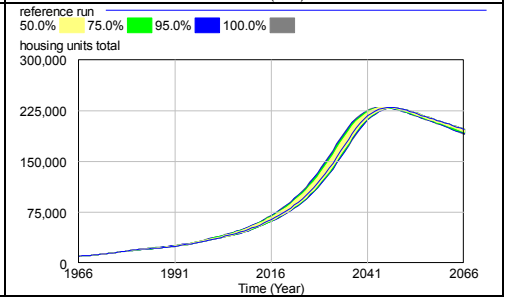
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			

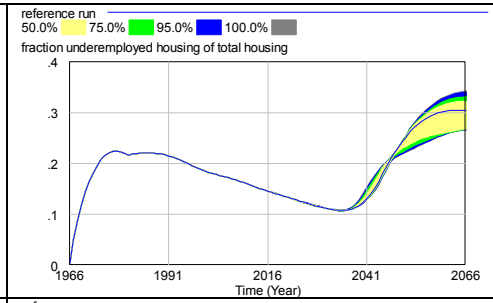
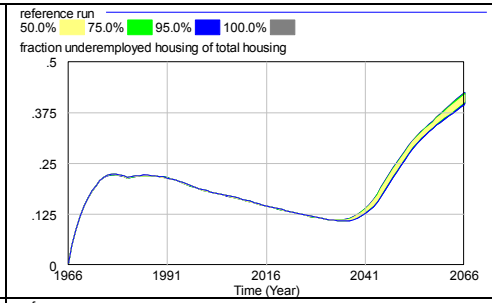
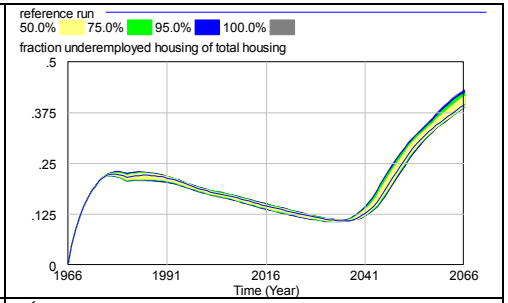
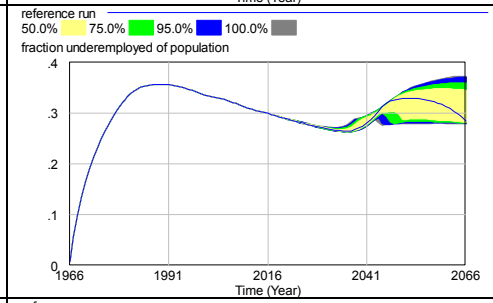
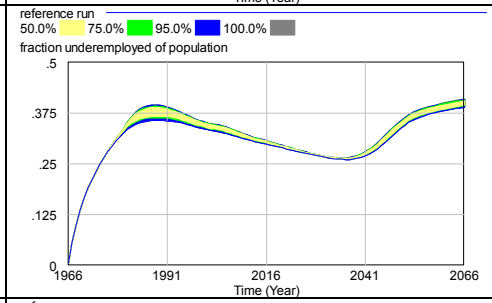
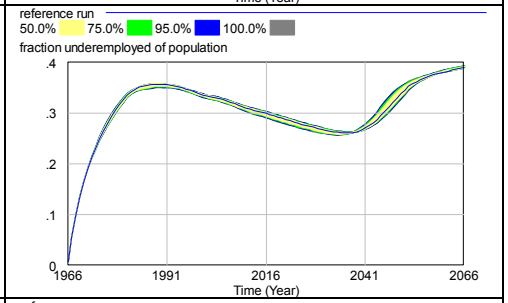
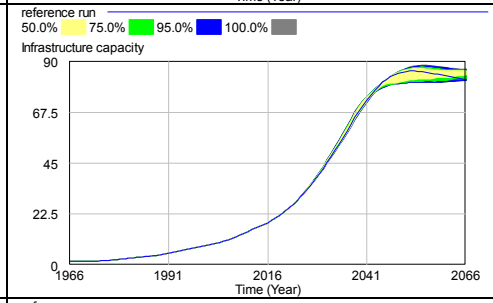
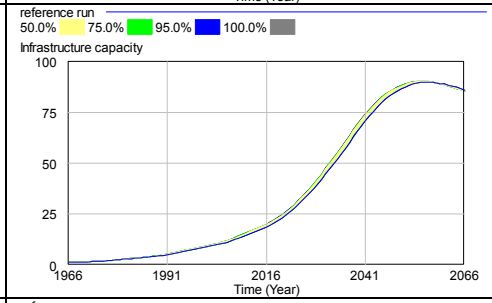
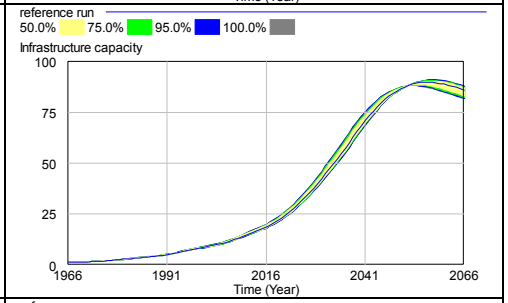
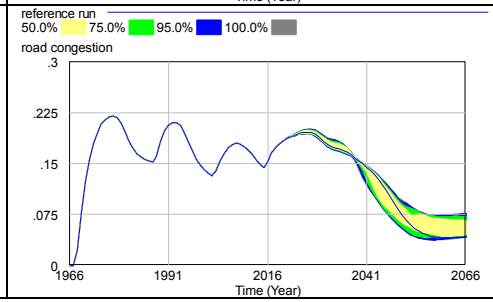
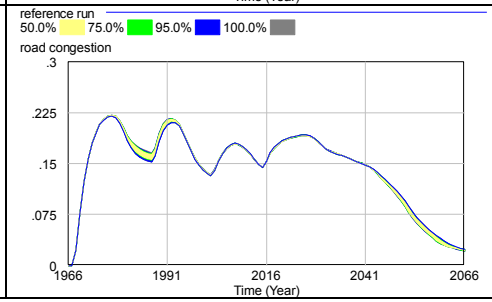
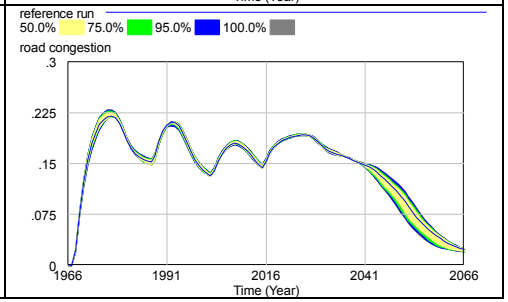
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			

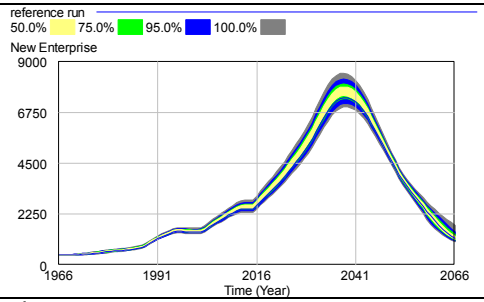
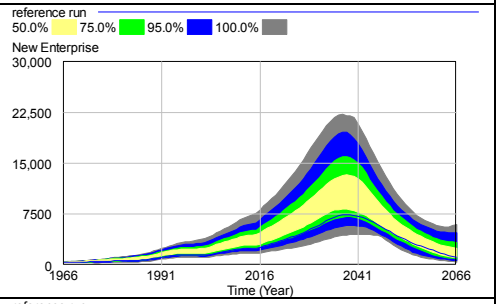
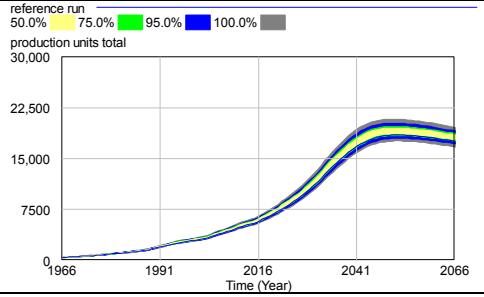
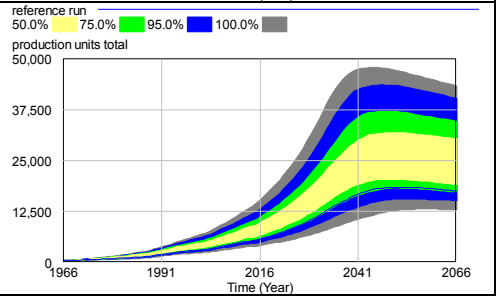
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

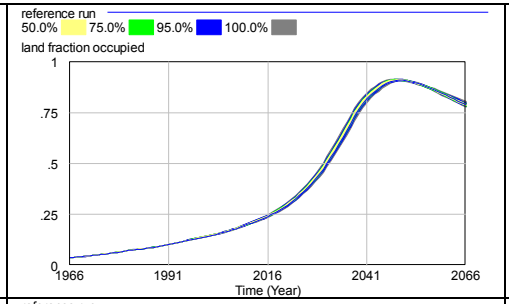
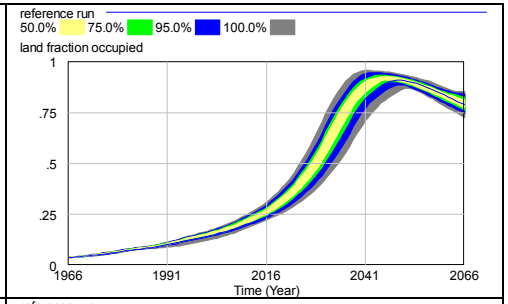
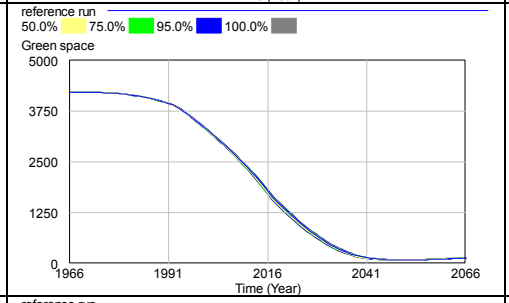
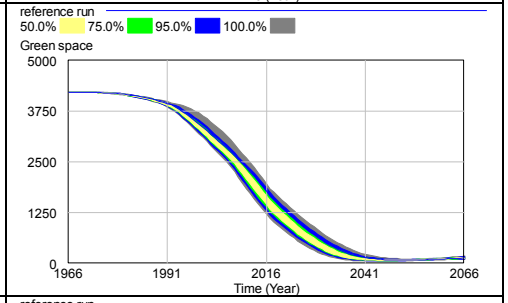
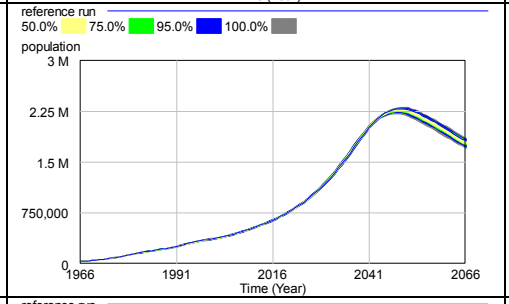
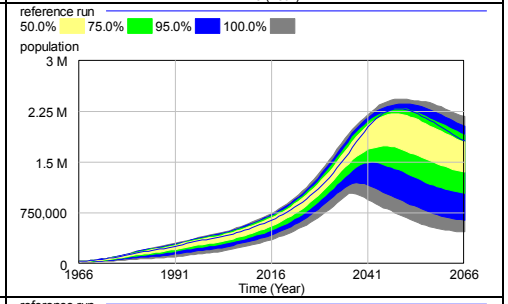
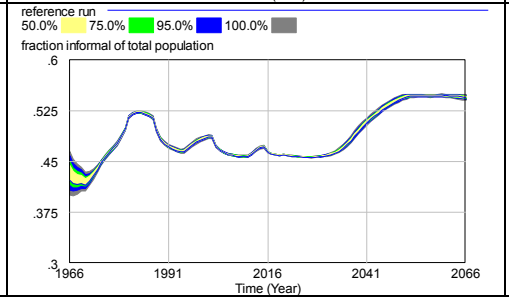
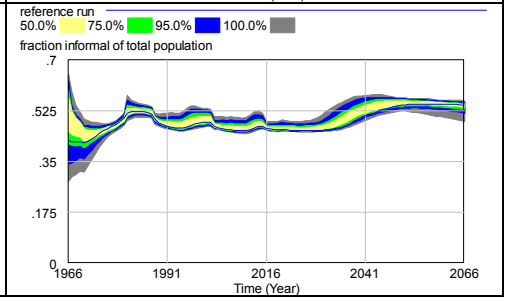
Parameter	industry automation level rate	underemployed job program	labor/job ratio perception time
Units	-	worker	year
Nominal value	0.02 (within 50 years after 2016, up to 90% automation)	0	5
Minimum plausible	0.01 (within 100 years after 2016, up to 90% automation)	0	2
Maximum plausible	0.04 (within 25 years after 2016, up to 90% automation)	10000	10

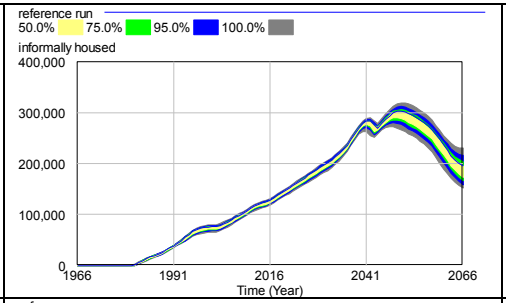
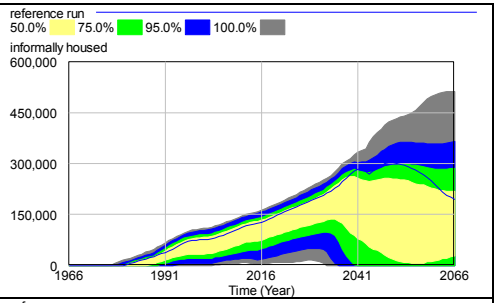
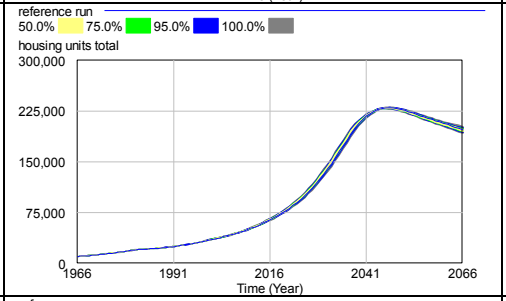
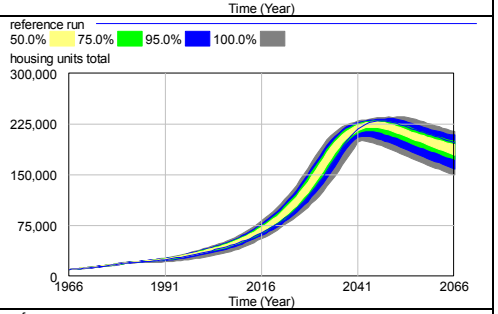
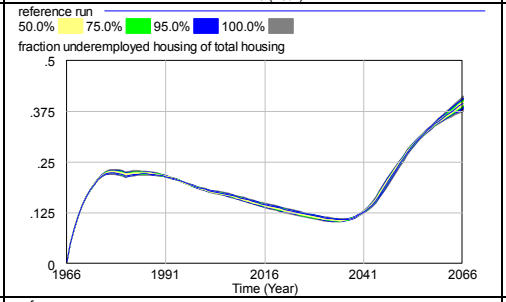
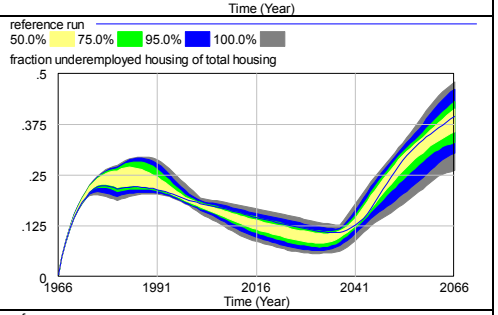
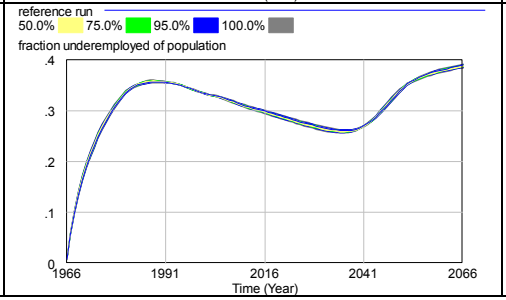
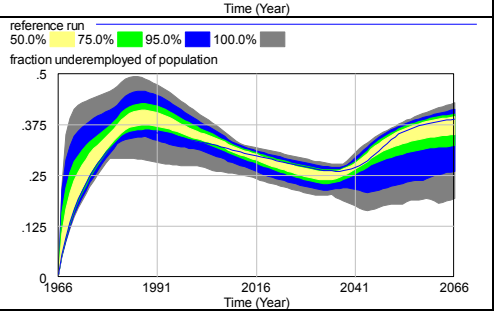
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

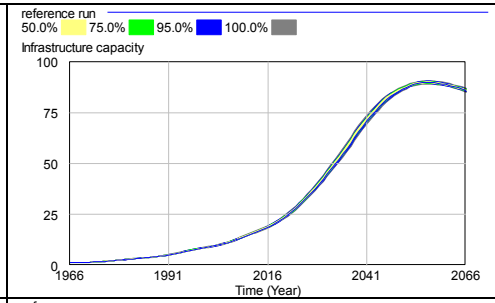
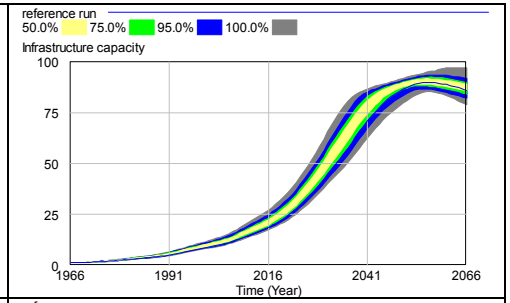
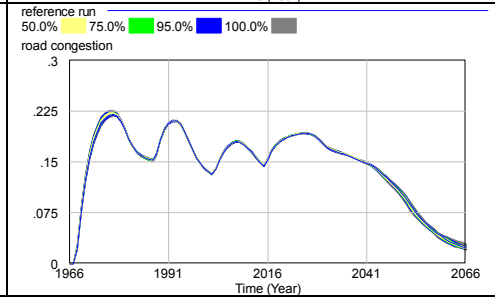
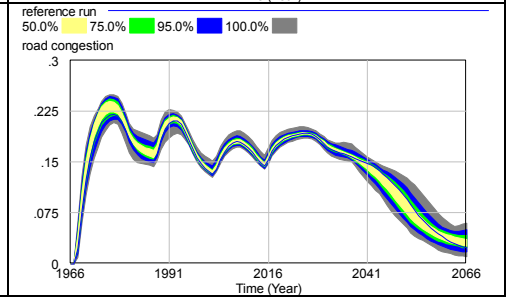
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

Parameter	Multivariate, all parameters except programs	Multivariate, all parameters
Units	-	-
Nominal value	-	-
Minimum plausible	-10%	Respective plausible minimum for each parameter
Maximum plausible	+10%	Respective plausible maximum for each parameter
Sensitivity plot: New Enterprise		
Sensitivity plot: production units total		

Sensitivity plot: land fraction occupied		
Sensitivity plot: Green space		
Sensitivity plot: Population		
Sensitivity plot: fraction informal of total population		

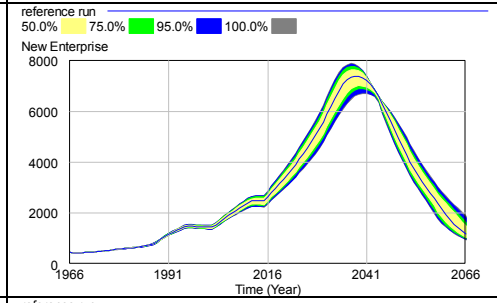
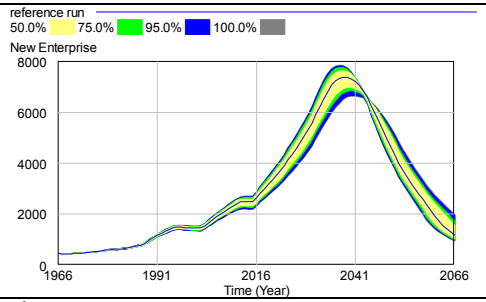
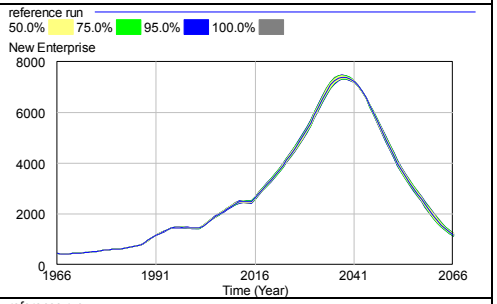
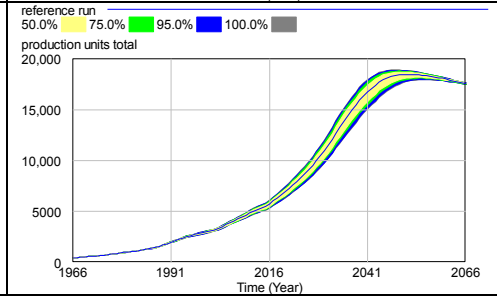
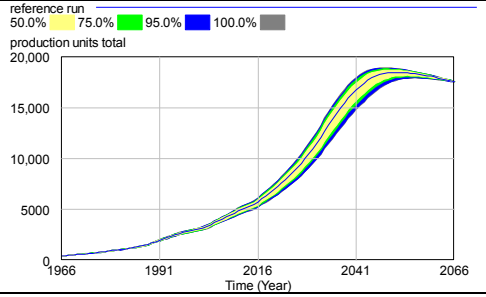
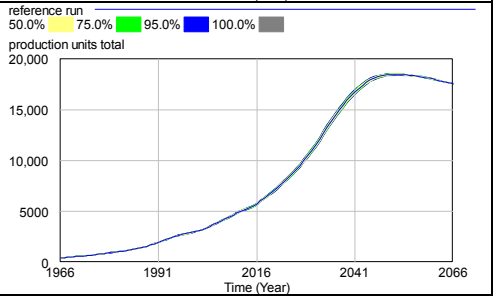
Sensitivity plot: informally housed		
Sensitivity plot: housing units total		
fraction under-employed housing of total housing		
Sensitivity plot: fraction under-employed of population		

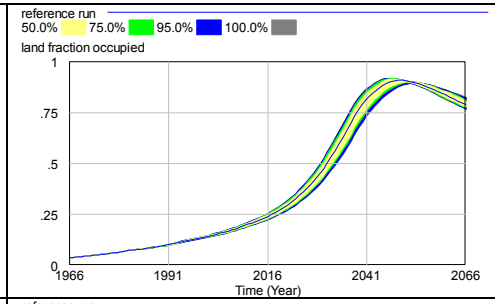
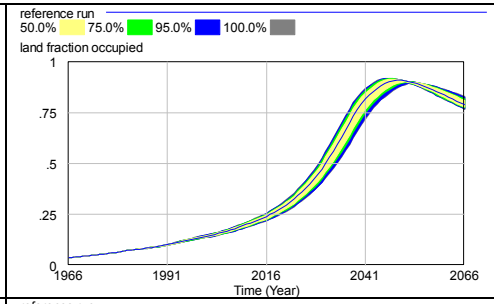
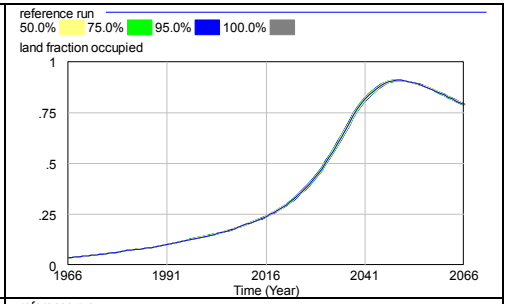
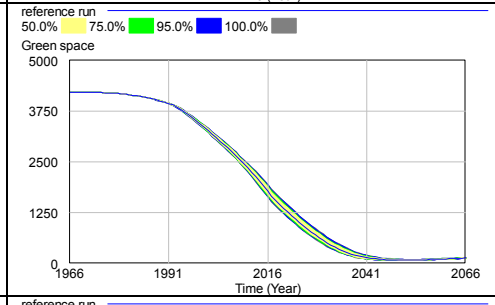
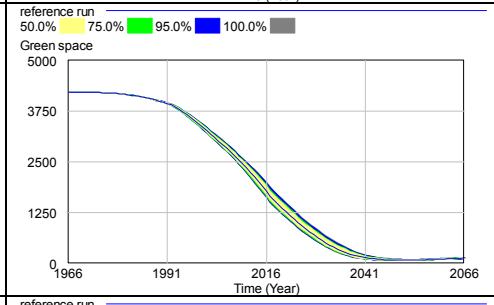
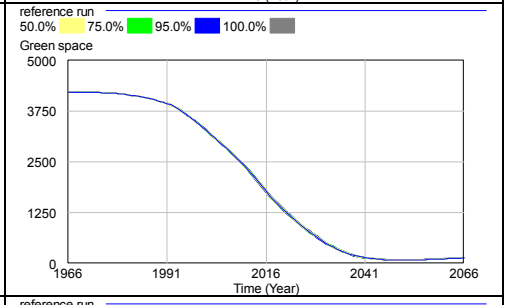
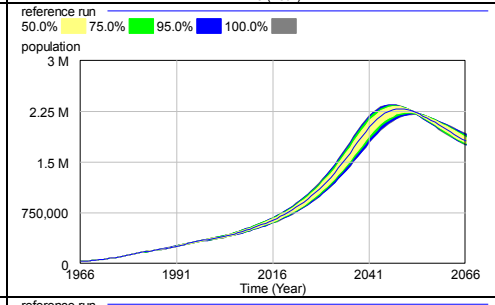
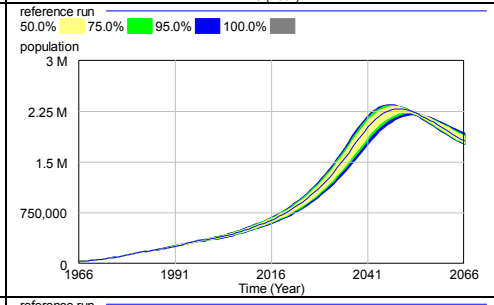
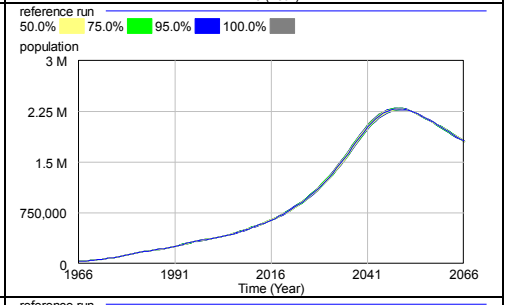
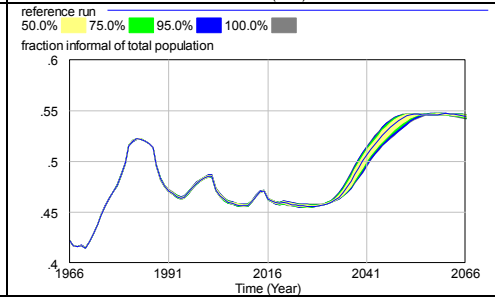
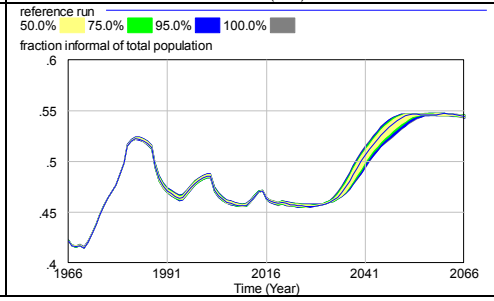
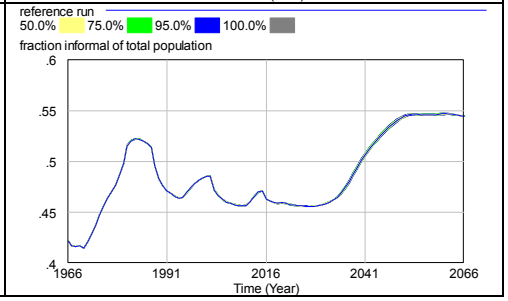
Sensitivity plot: Infra-structure capacity		
Sensitivity plot: road congestion		

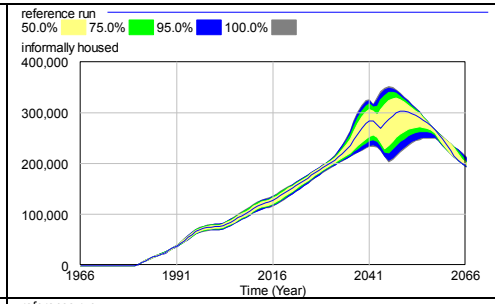
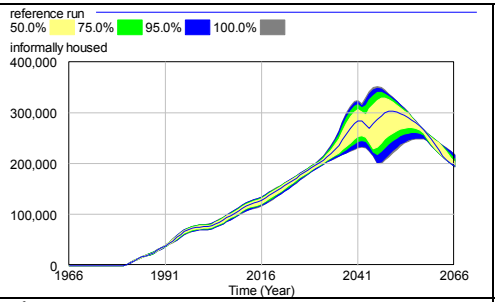
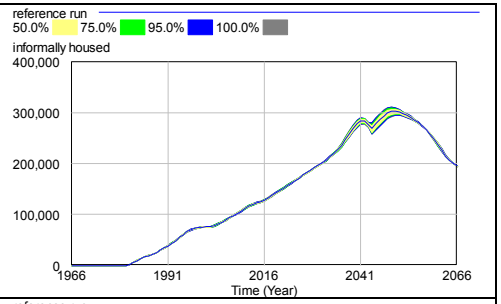
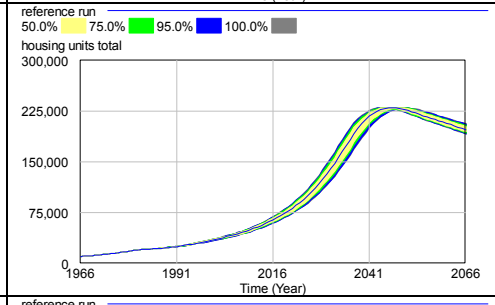
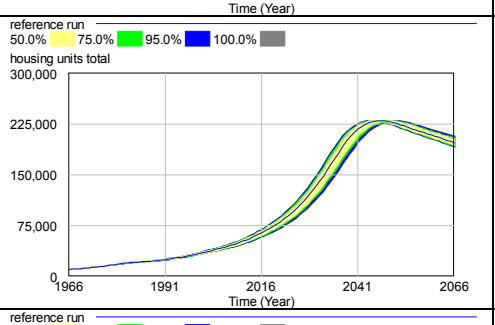
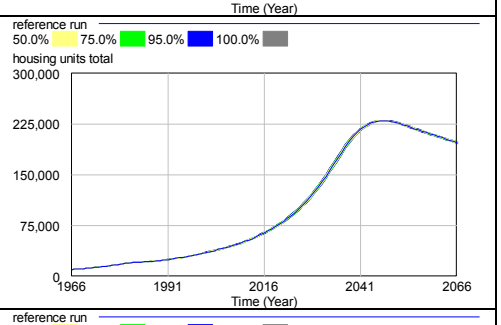
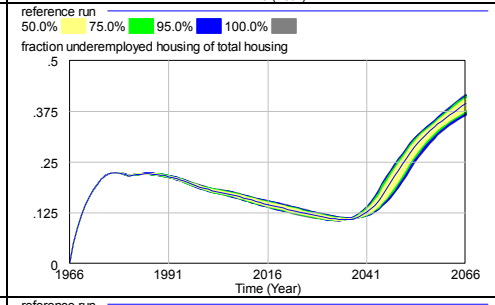
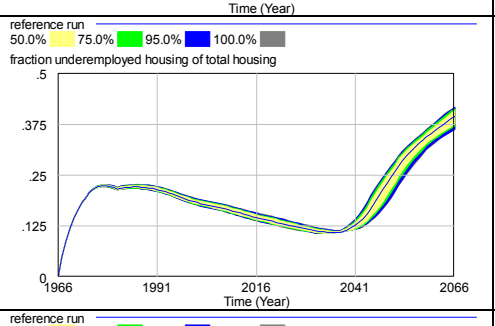
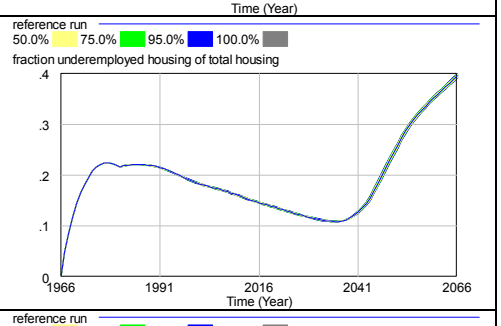
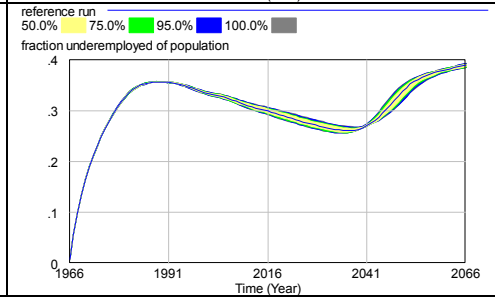
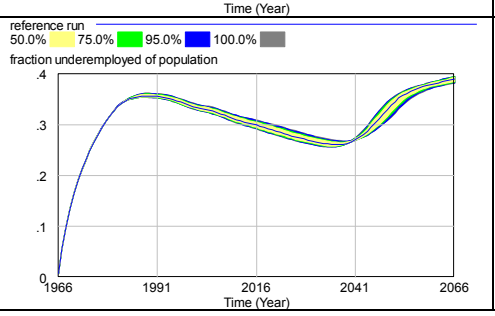
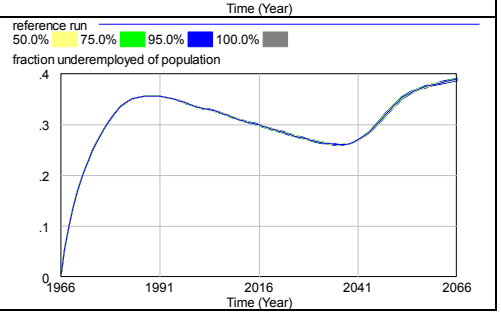
4.8 Tax section sensitivity

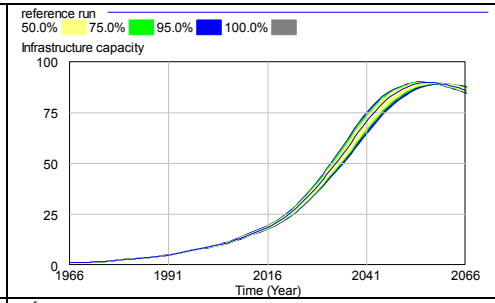
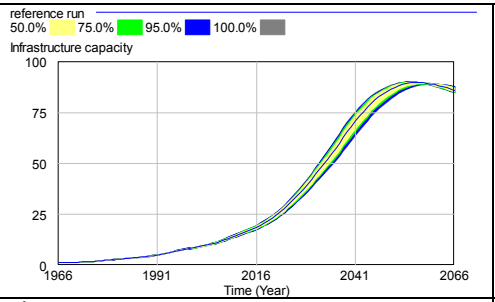
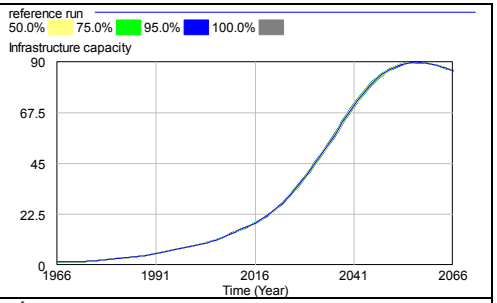
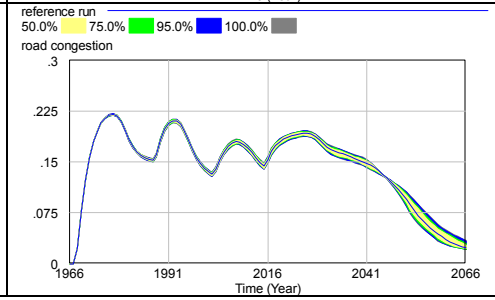
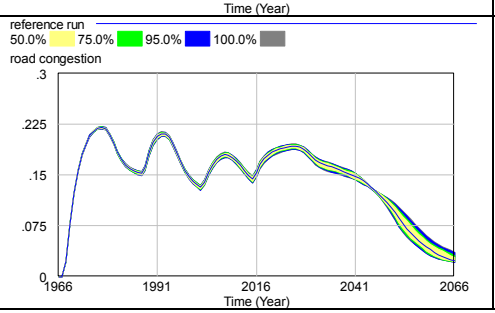
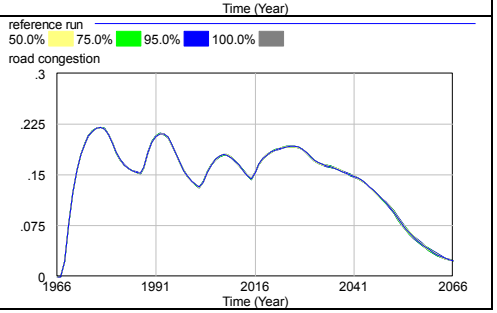
Parameters

- premium-housing assessed value
- worker-housing assessed value
- underemployed-housing assessed value
- new-enterprise assessed value
- mature-business assessed value
- declining-industry assessed value
- tax per labor person
- tax per management person
- tax per underemployed person
- tax ratio needed perception time
- tax assessment normal
- managerial professional family size
- labor family size
- tax per capita subsidy program
- tax per capita normal
- tax ratio (lookup)

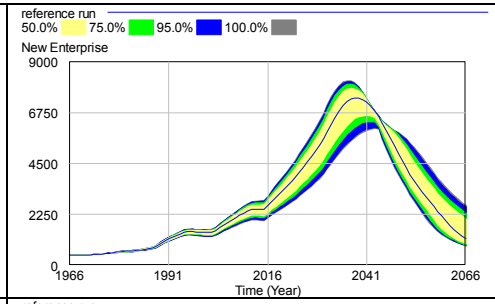
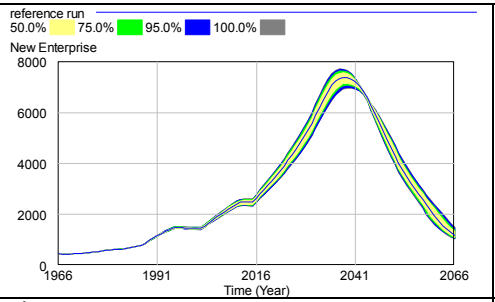
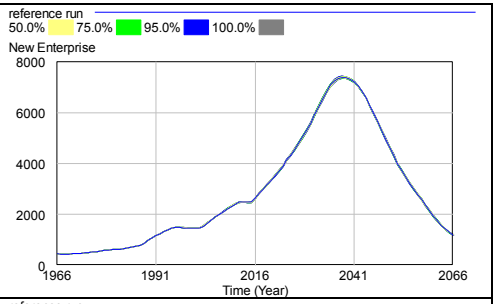
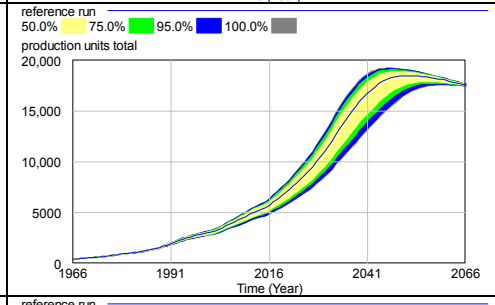
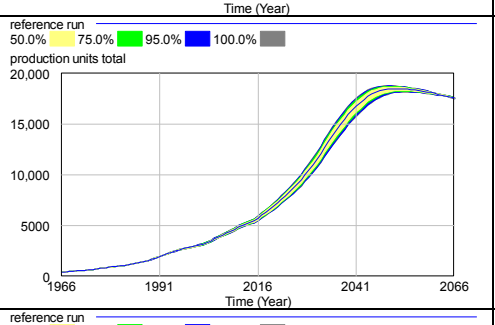
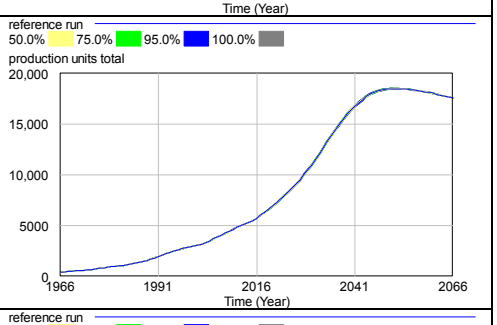
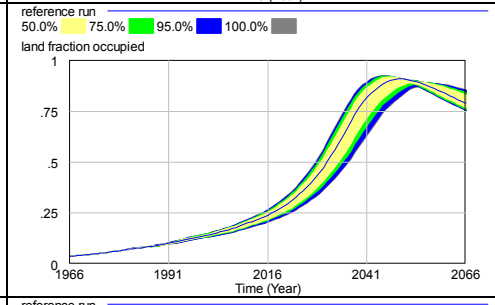
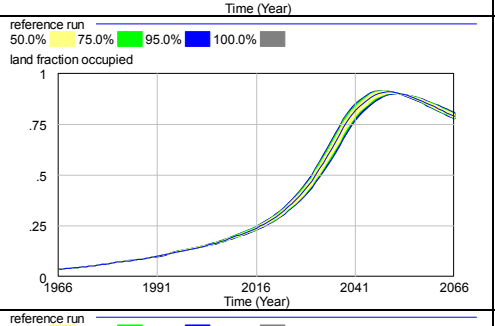
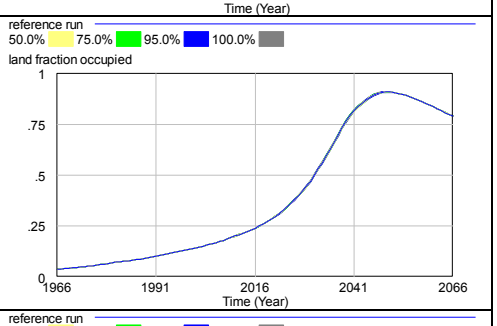
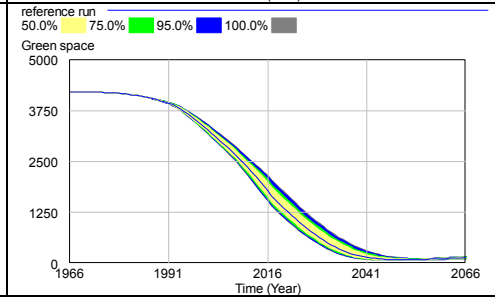
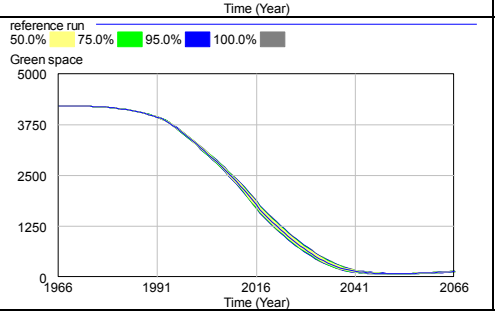
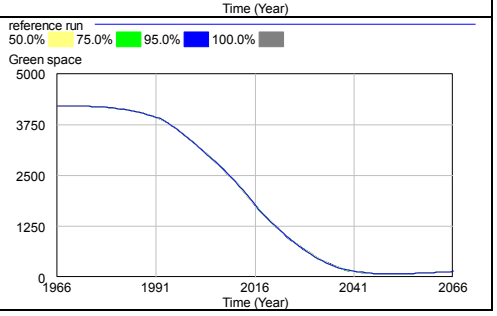
Parameter	premium-housing assessed value	worker-housing assessed value	underemployed-housing assessed value
Units	thousand dollars/housing unit	thousand dollars/housing unit	thousand dollars/housing unit
Nominal value	30	15	5
Minimum plausible	10	5	0
Maximum plausible	50	25	10
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			

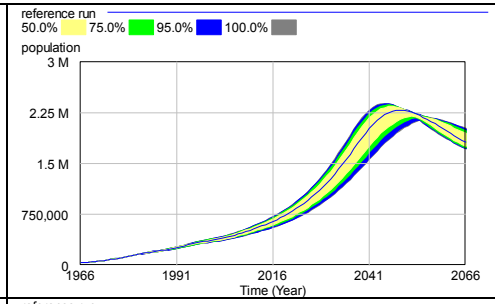
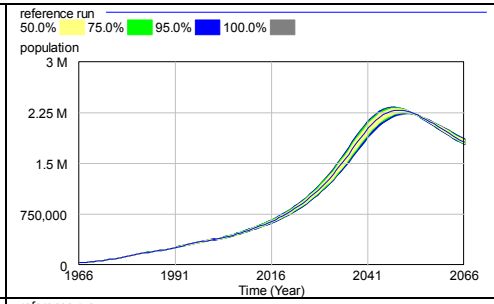
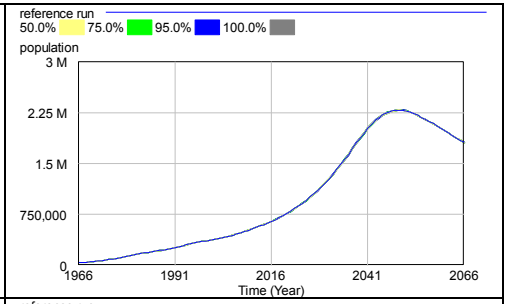
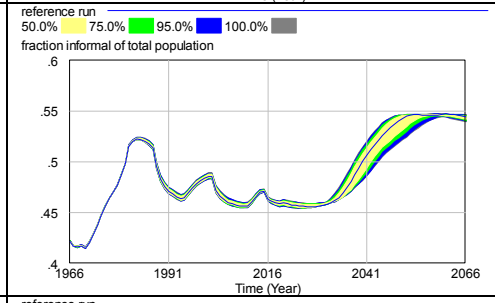
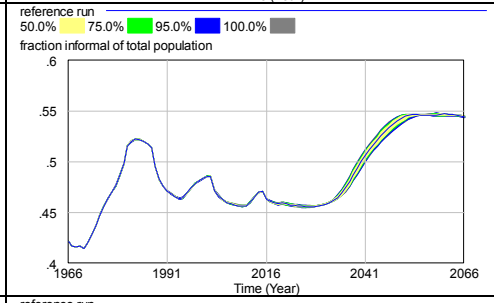
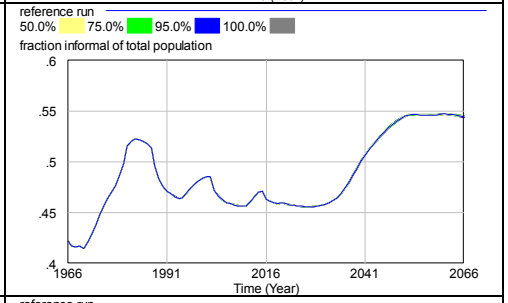
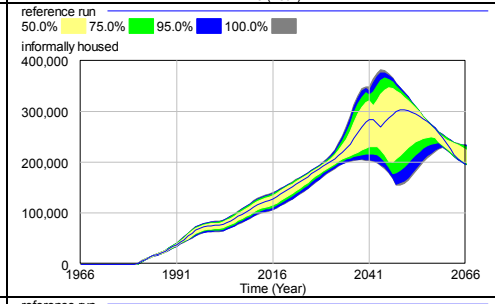
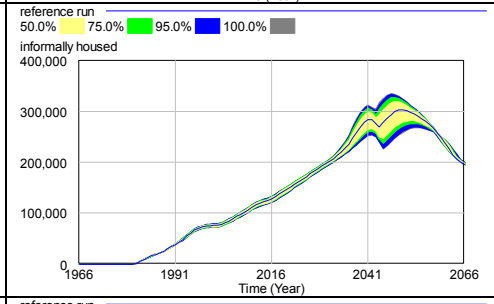
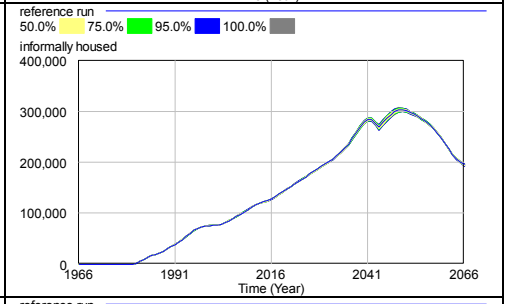
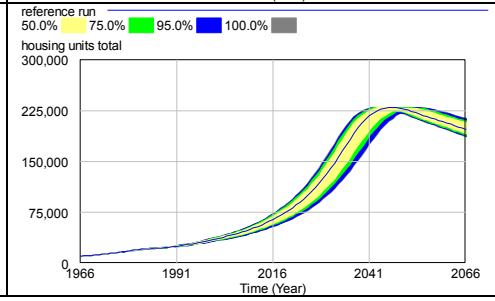
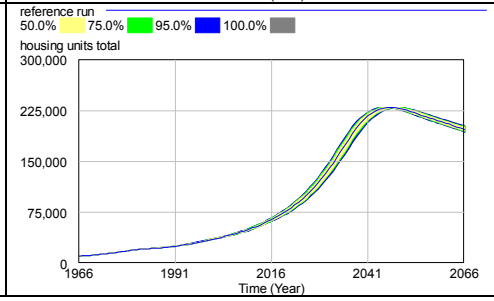
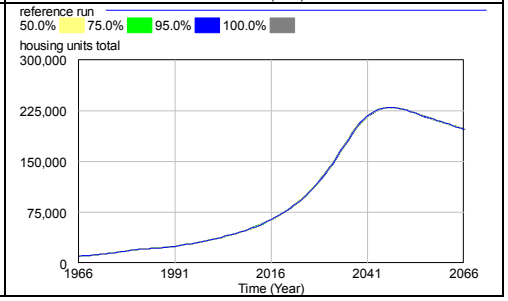
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			

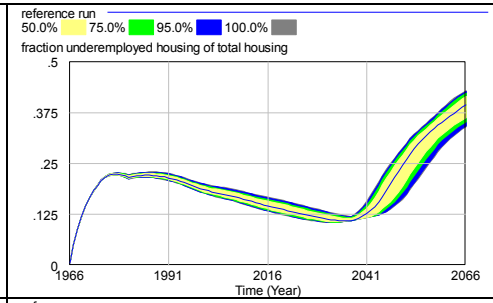
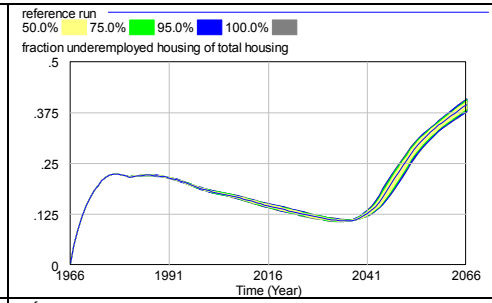
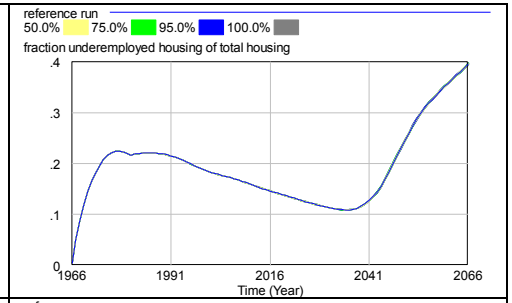
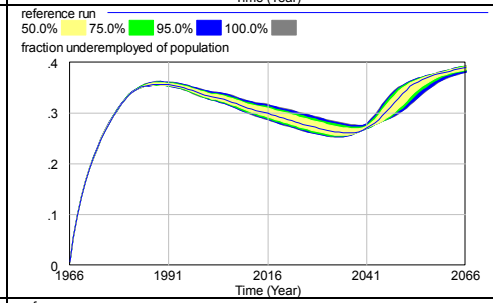
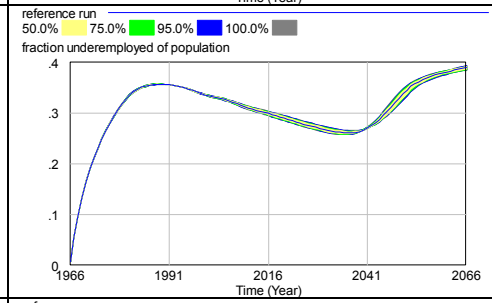
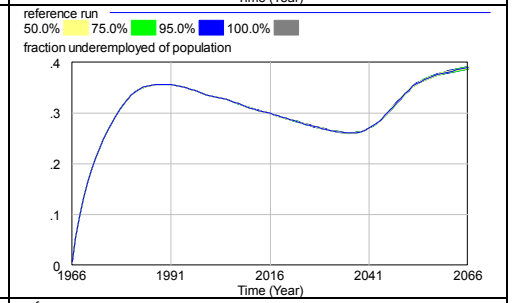
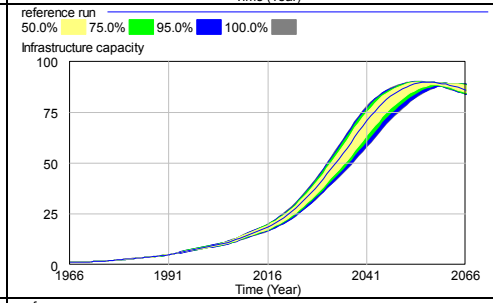
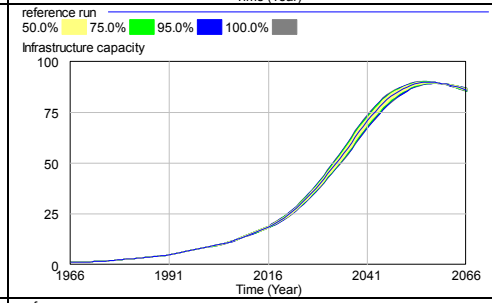
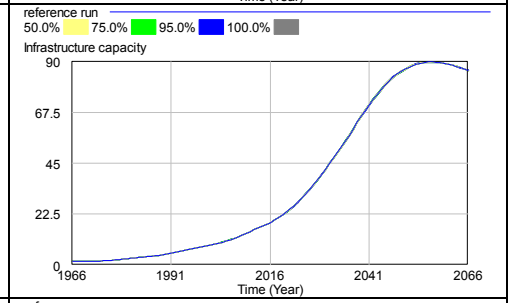
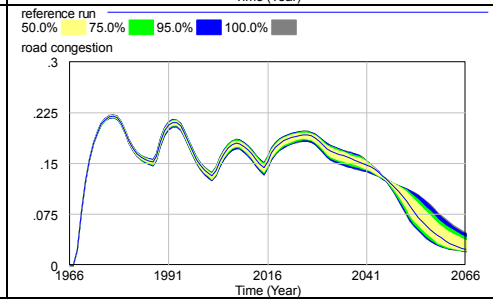
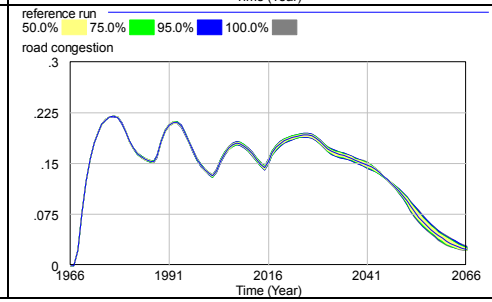
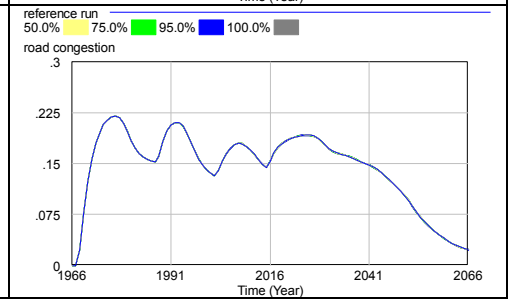
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			

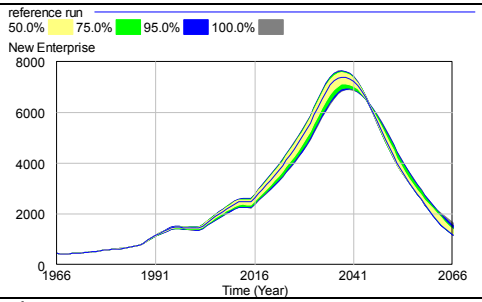
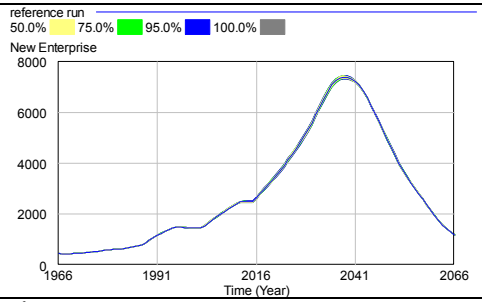
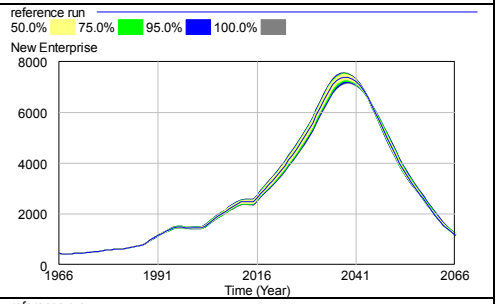
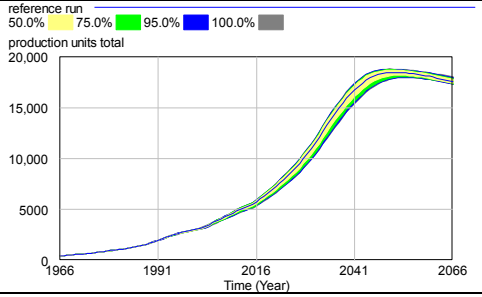
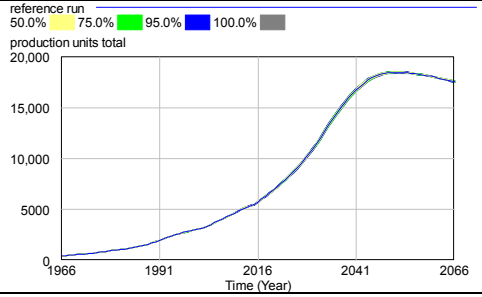
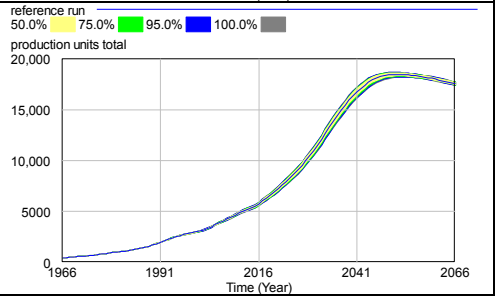
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

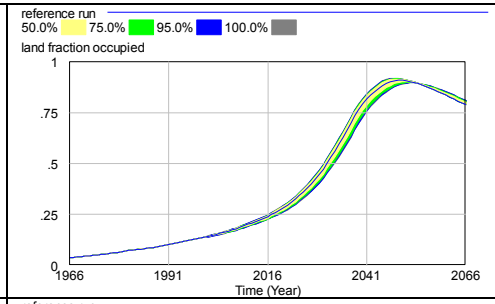
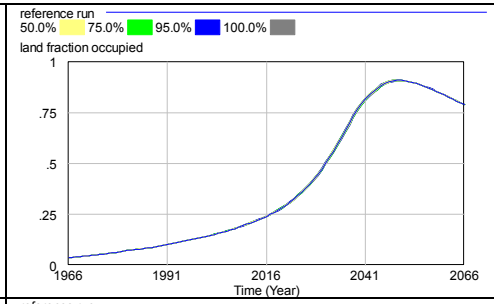
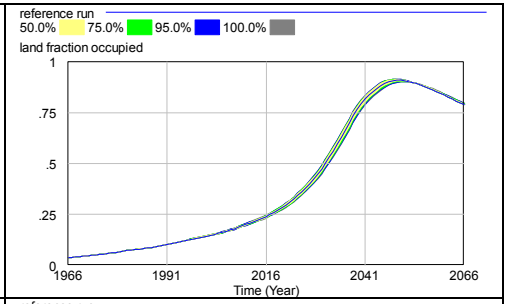
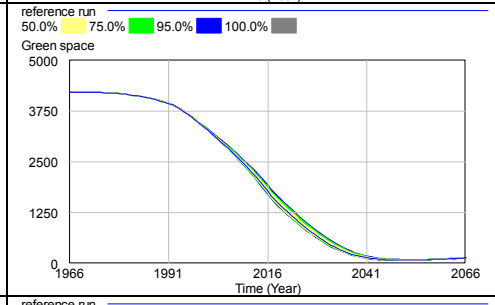
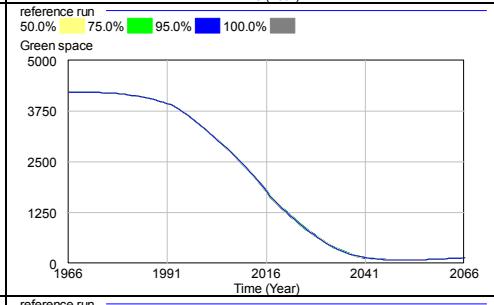
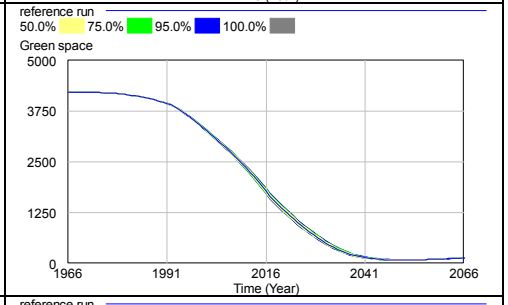
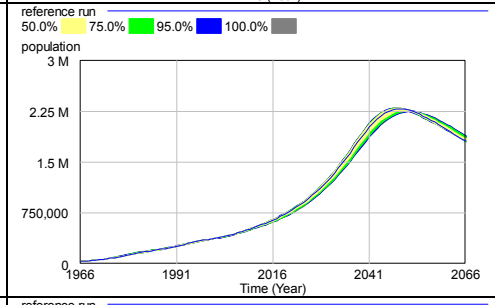
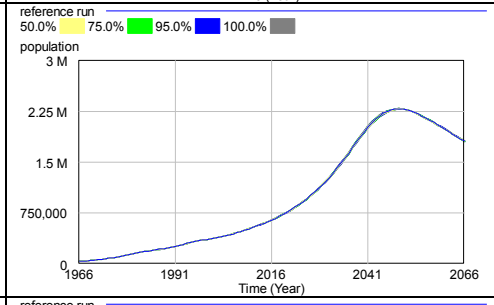
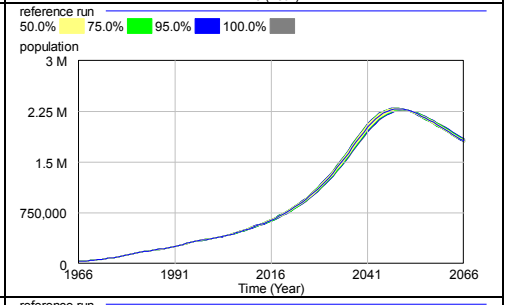
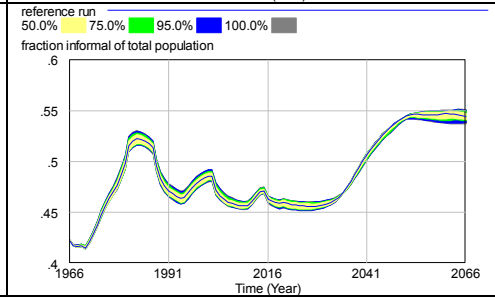
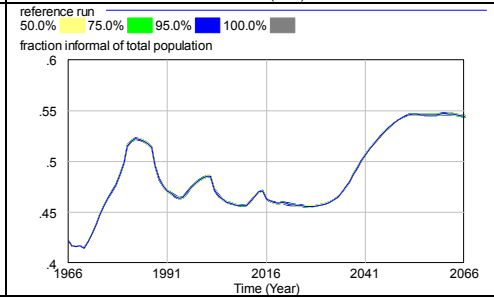
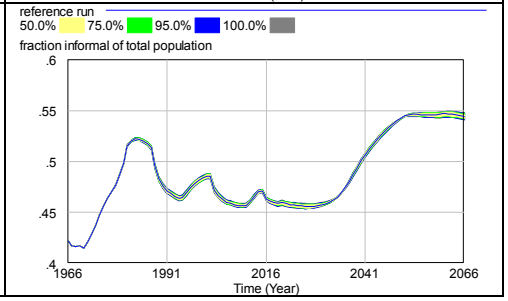
Parameter	new-enterprise assessed value	mature-business assessed value	declining-industry assessed value
Units	thousand dollars/productive unit	thousand dollars/productive unit	thousand dollars/productive unit
Nominal value	500	300	100
Minimum plausible	250	150	50
Maximum plausible	750	450	150

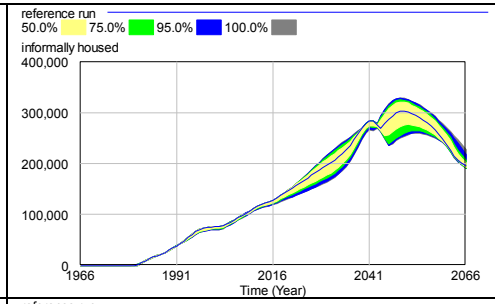
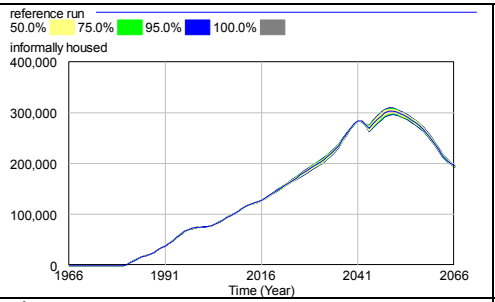
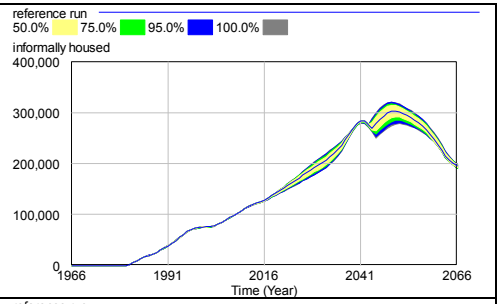
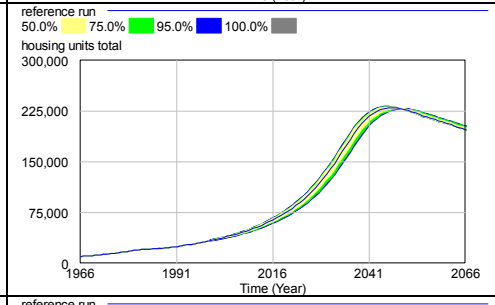
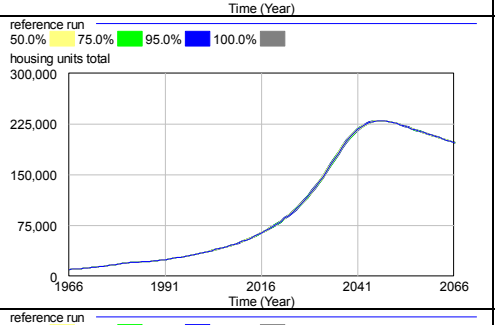
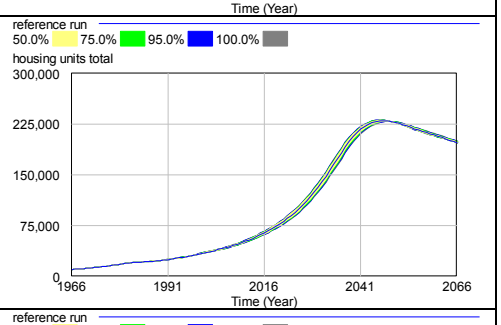
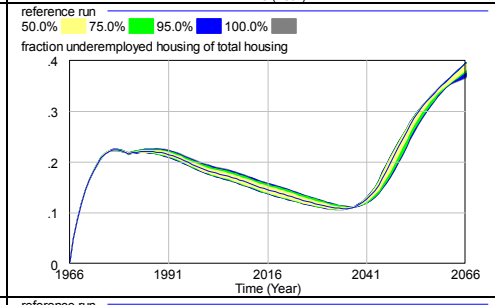
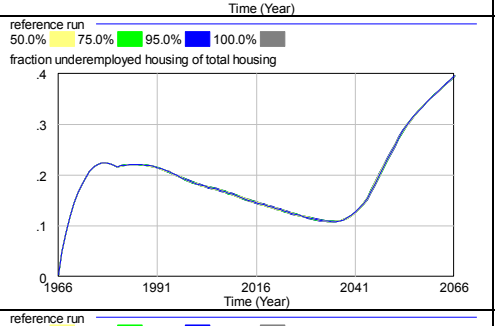
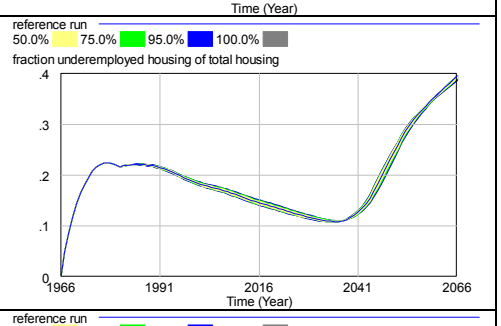
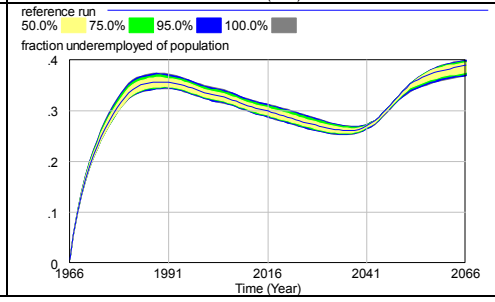
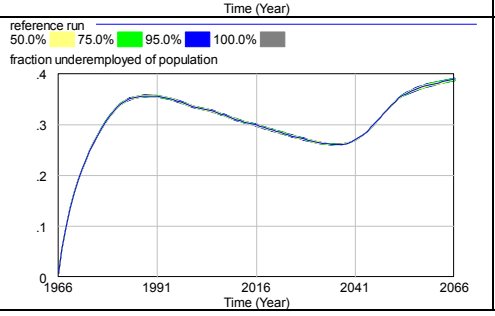
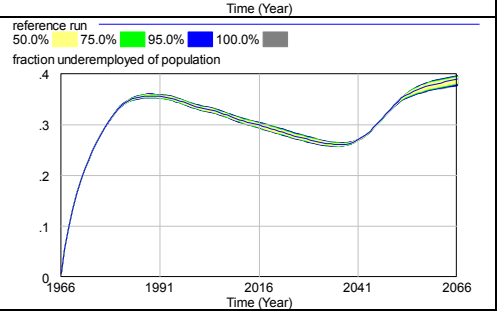
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

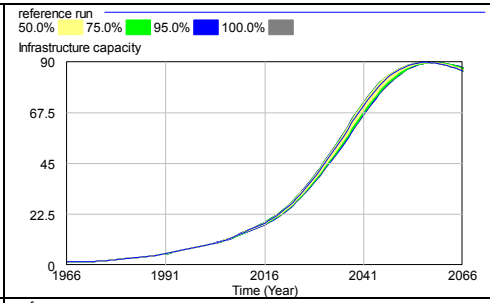
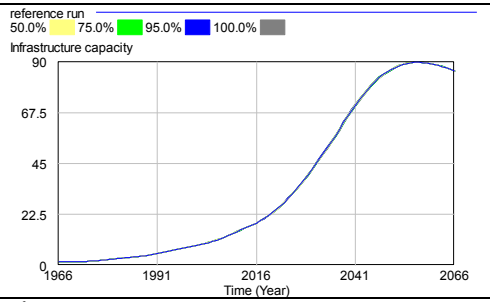
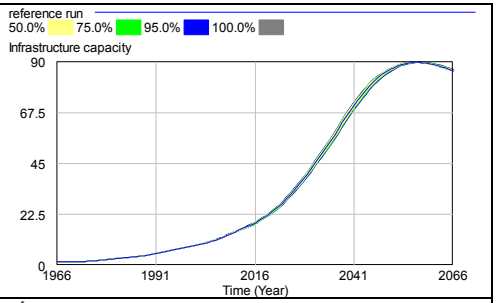
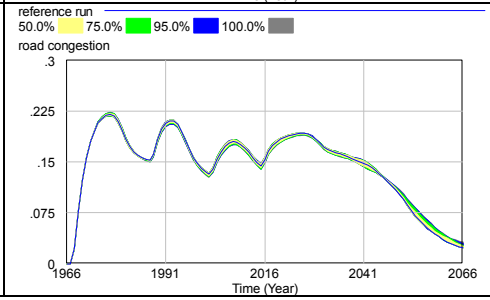
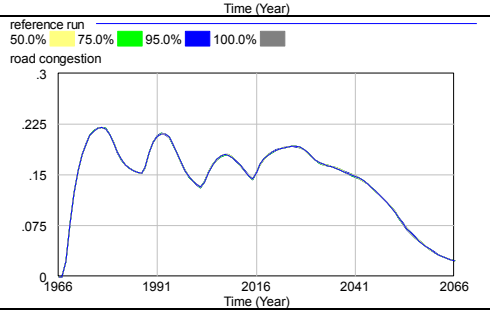
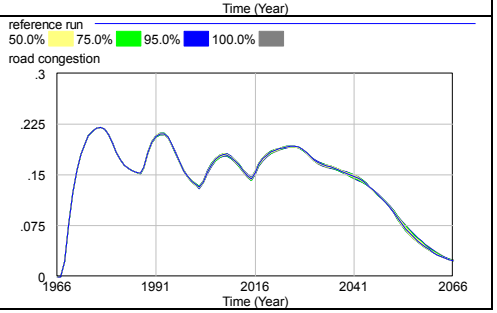
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

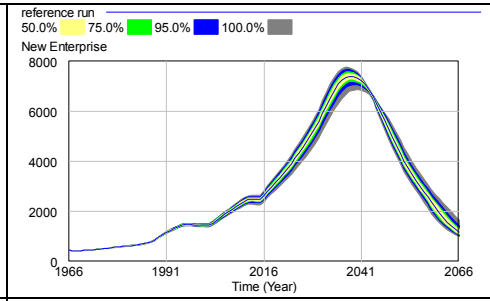
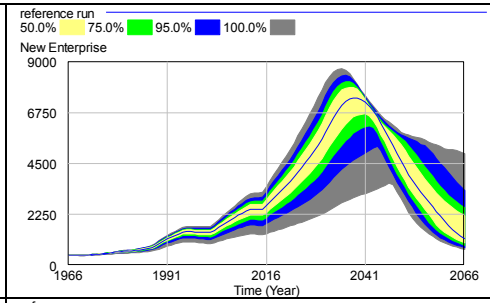
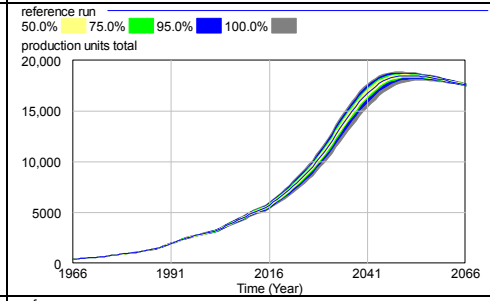
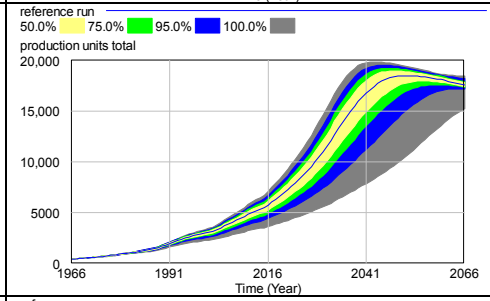
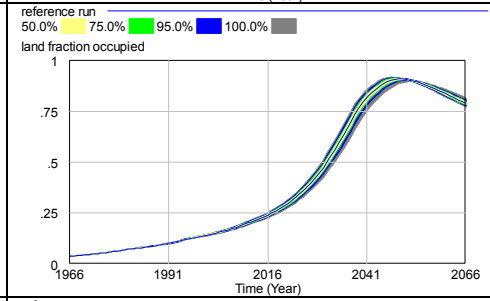
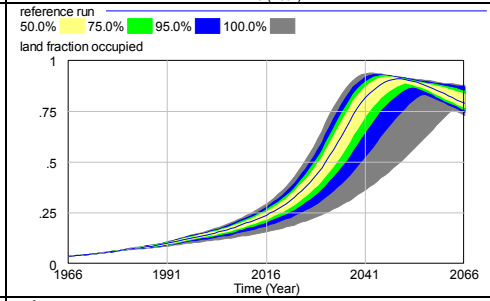
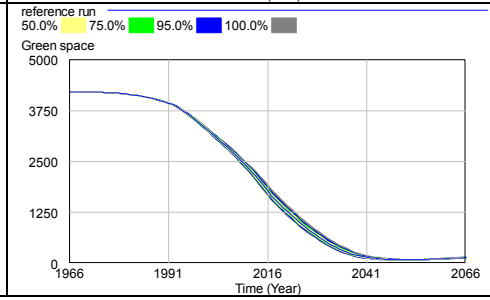
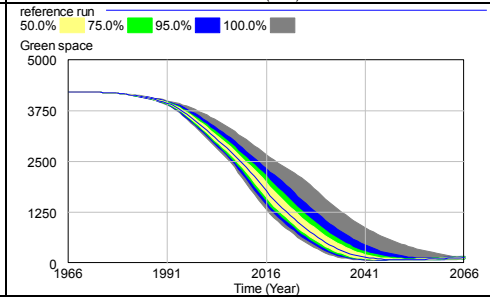
Parameter	tax per labor person	tax per management person	tax per underemployed person
Units	dollars/person/Year	dollars/person/Year	dollars/person/Year
Nominal value	200	150	200
Minimum plausible	100 (-50%)	75	100
Maximum plausible	300 (+50%)	225	300
Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			

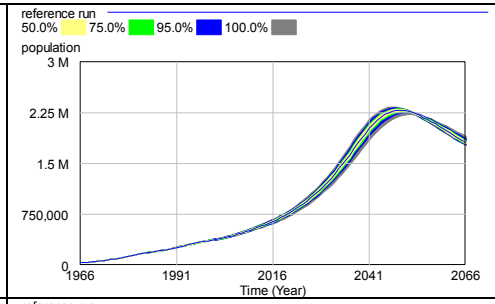
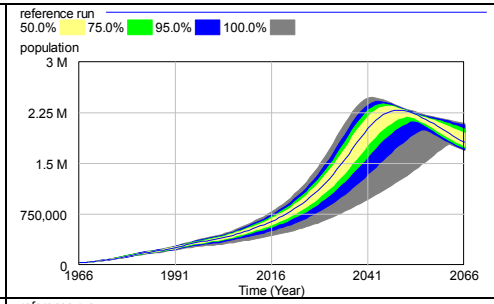
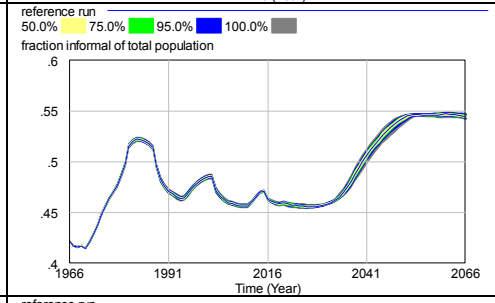
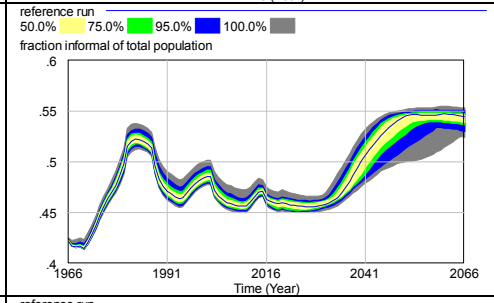
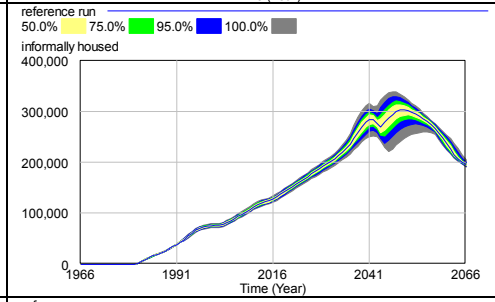
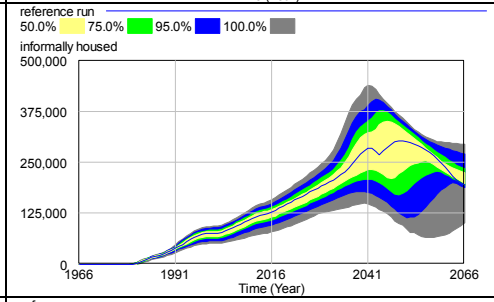
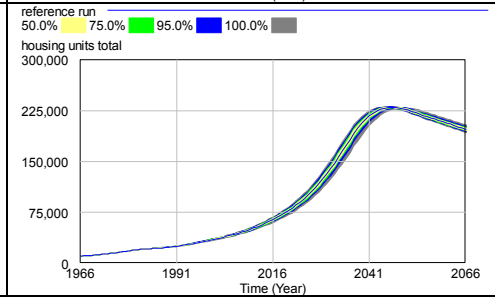
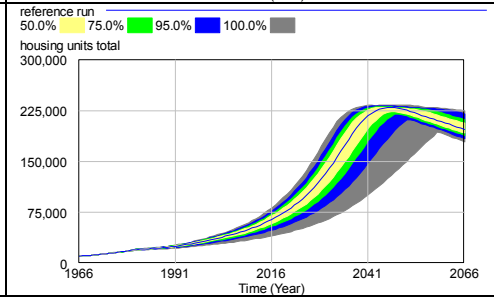
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			
Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			

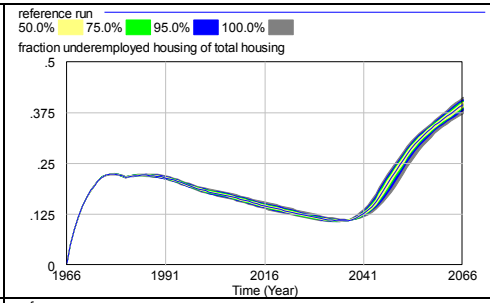
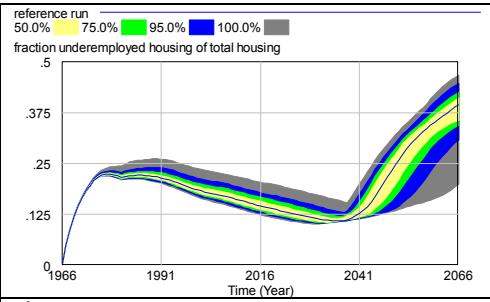
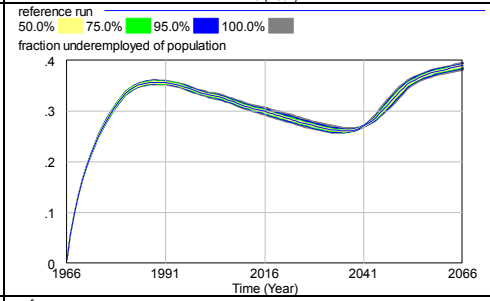
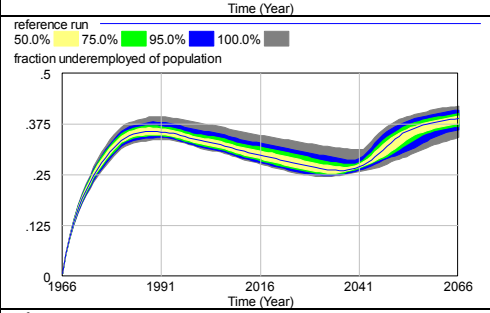
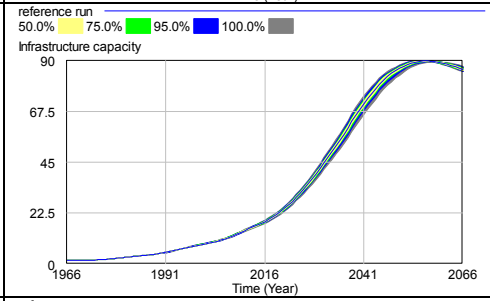
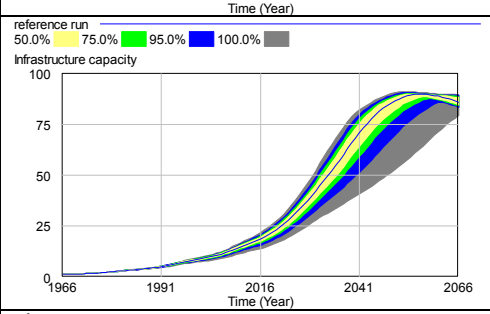
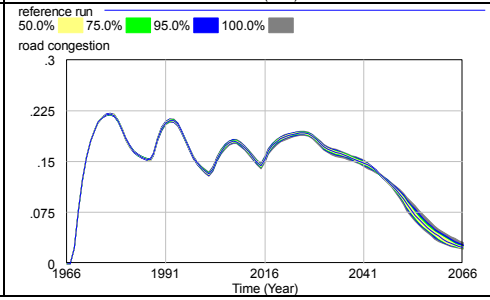
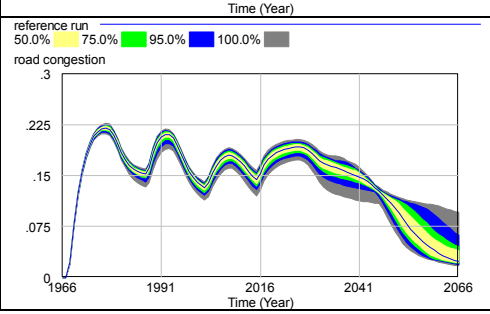
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			
fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			

Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

Parameter	Multivariate, all parameters	Multivariate, all parameters	
Units	-	-	
Nominal value	-	-	
Minimum plausible	-10%	Respective plausible minimum per variable	
Maximum plausible	+10%	Respective plausible maximum per variable	

Sensitivity plot: New Enterprise			
Sensitivity plot: production units total			
Sensitivity plot: land fraction occupied			
Sensitivity plot: Green space			

Sensitivity plot: Population			
Sensitivity plot: fraction informal of total population			
Sensitivity plot: informally housed			
Sensitivity plot: housing units total			

fraction under-employed housing of total housing			
Sensitivity plot: fraction under-employed of population			
Sensitivity plot: Infra-structure capacity			
Sensitivity plot: road congestion			

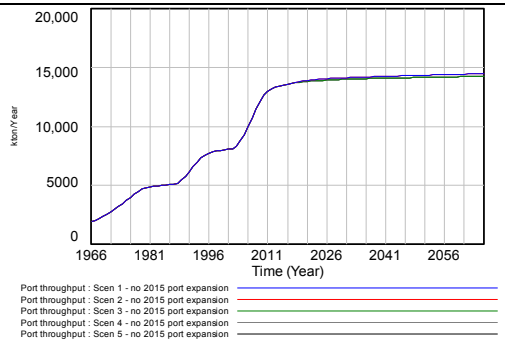
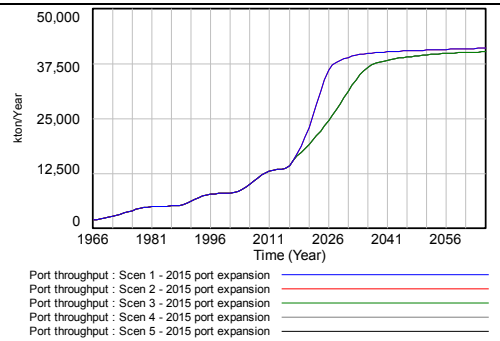
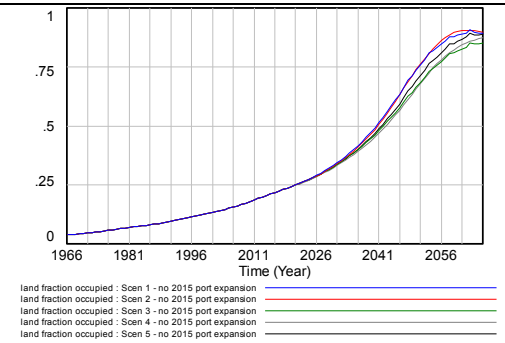
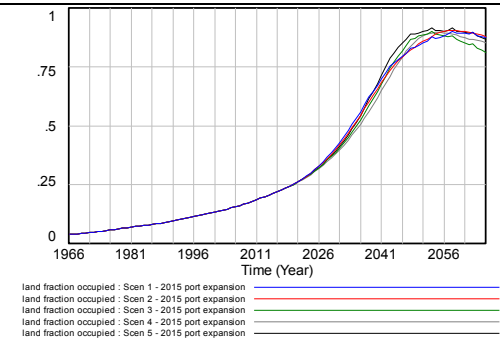
5 Policy runs

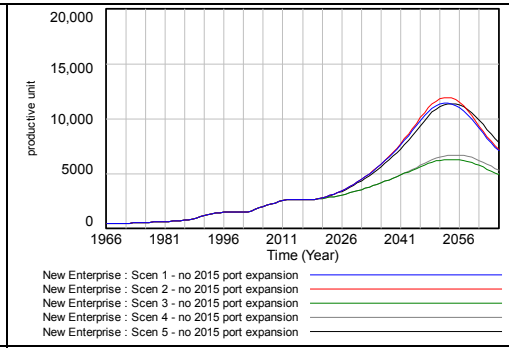
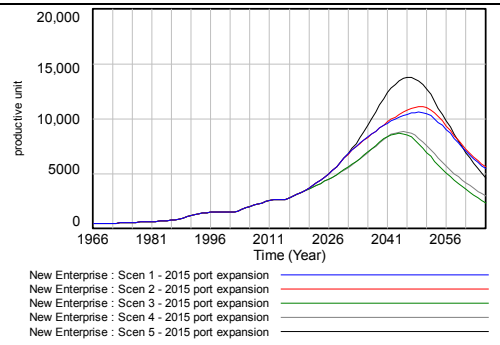
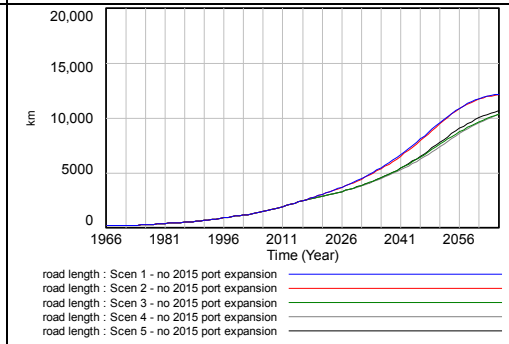
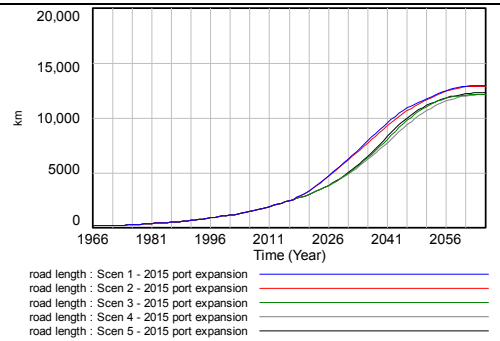
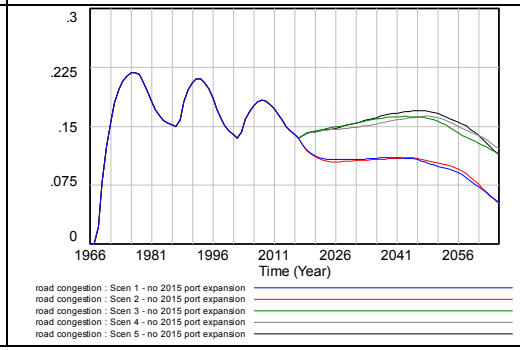
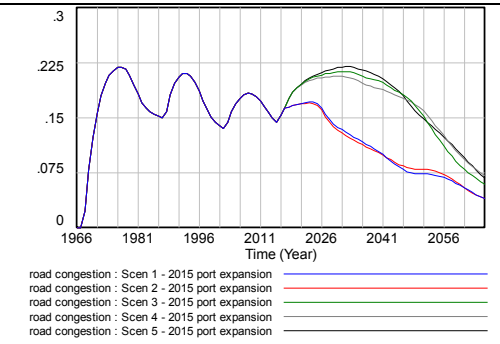
In this section some results of policy runs that have been performed are compiled.

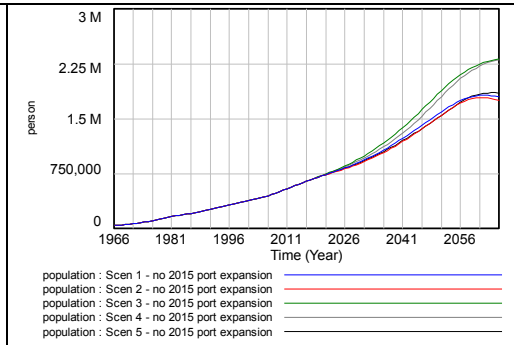
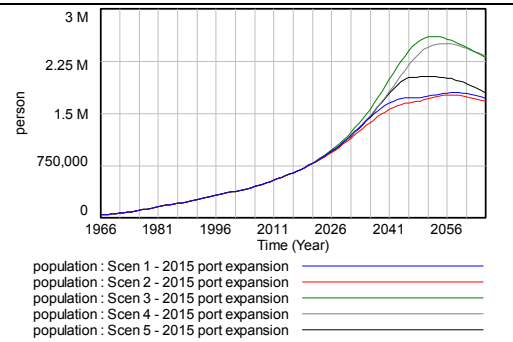
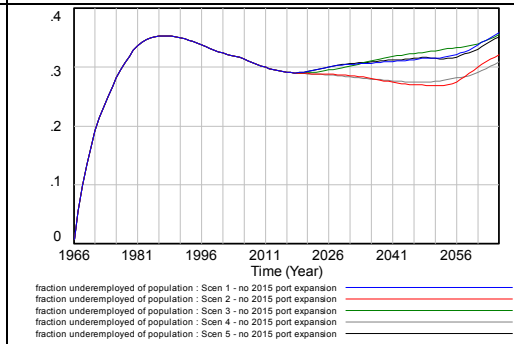
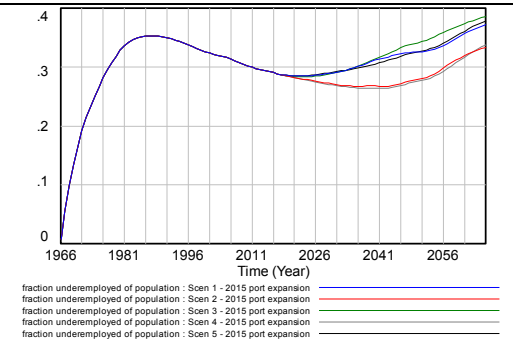
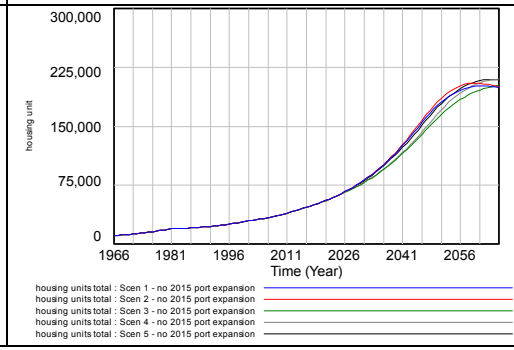
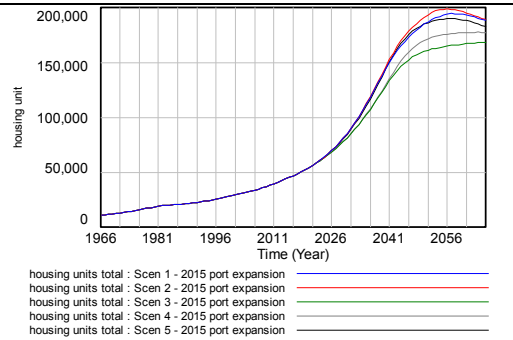
5.1 Port infrastructure impacts on city

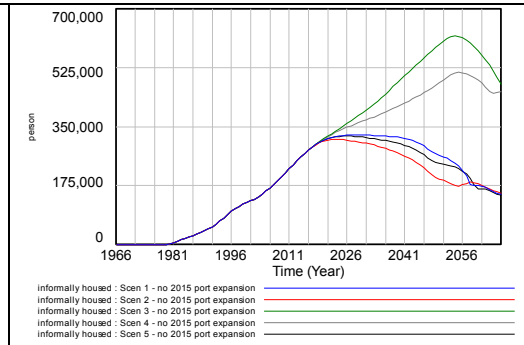
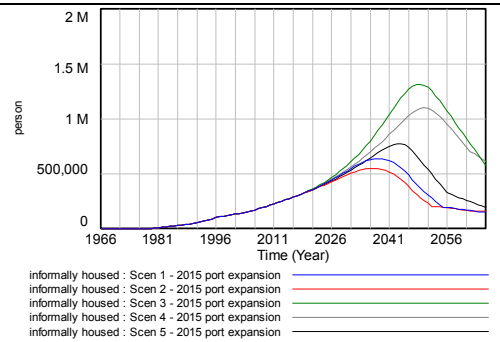
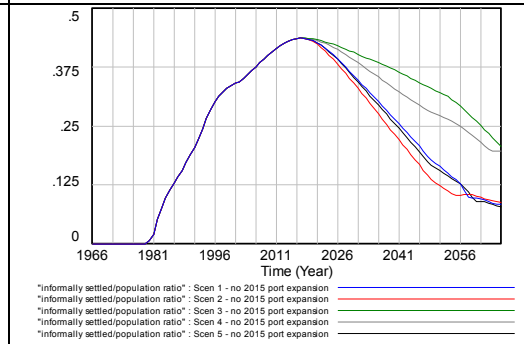
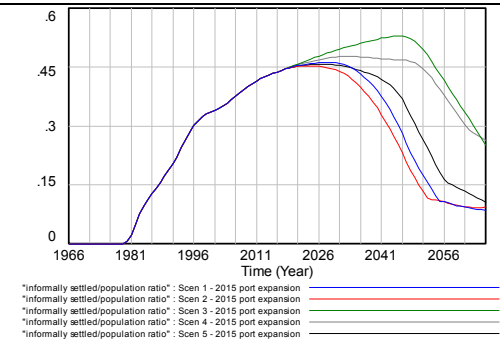
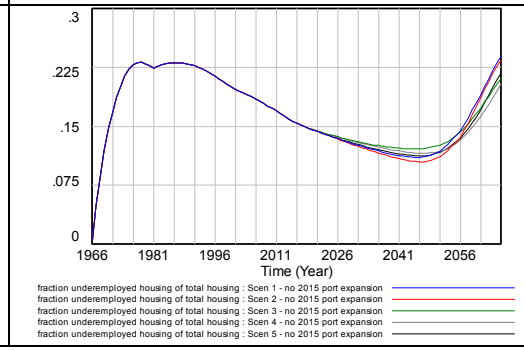
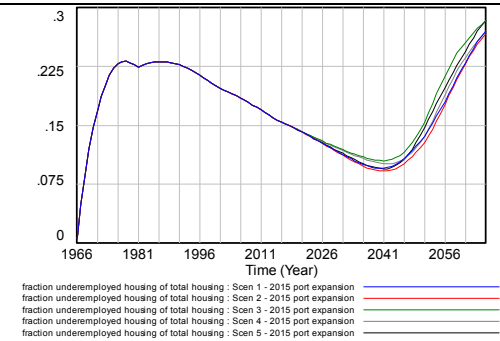
5.1.1 No 2015 port expansion vs. 2015 port expansion (=reference run)

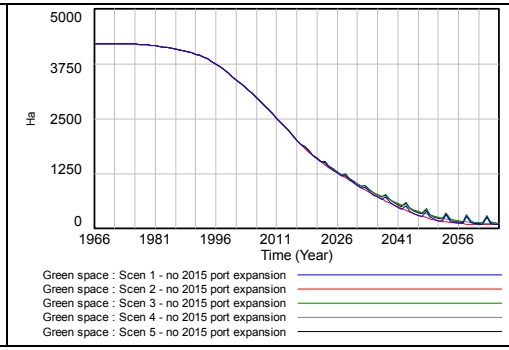
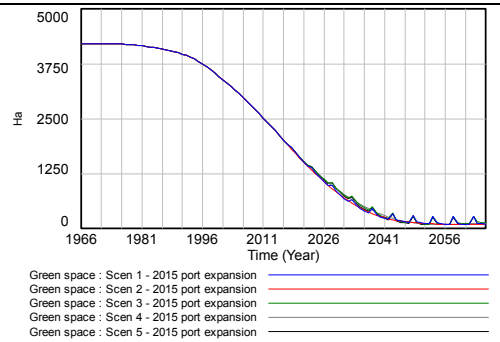
Comparison of port infrastructure impacts in different scenarios of uncertain factors (scenario 1: blue, scenario 2: red, scenario 3: green, scenario 4: grey, scenario 5: black)

KPI	No 2015 port expansion	2015 port expansion
Port throughput		
Land fraction occupied		

New enterprise		
Road length		
Road congestion		

Population		
Fraction underemployed of population		
Housing units total		

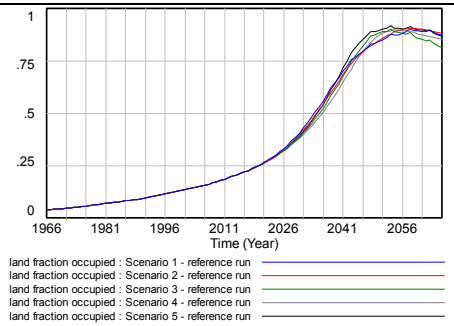
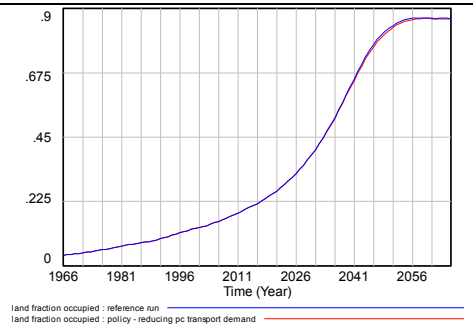
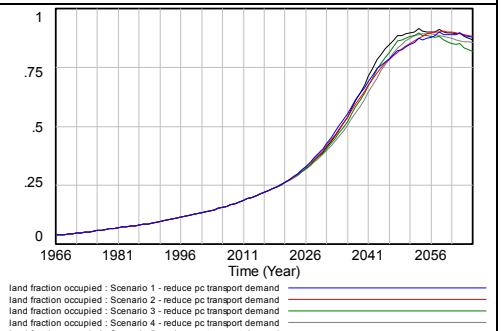
Informally housed		
Informally settled/population ratio		
Fraction underemployed housing of total housing		

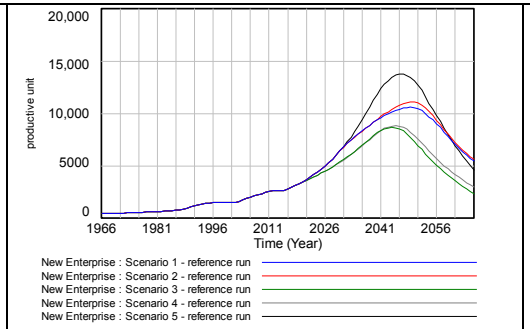
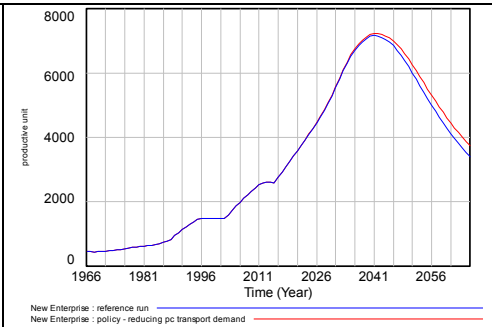
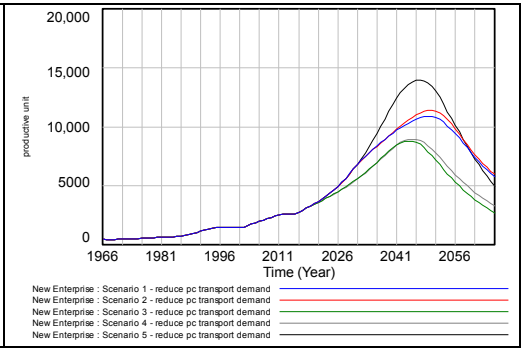
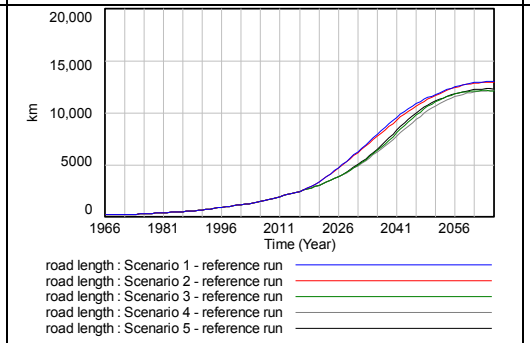
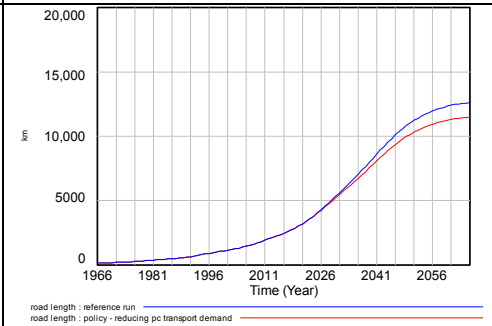
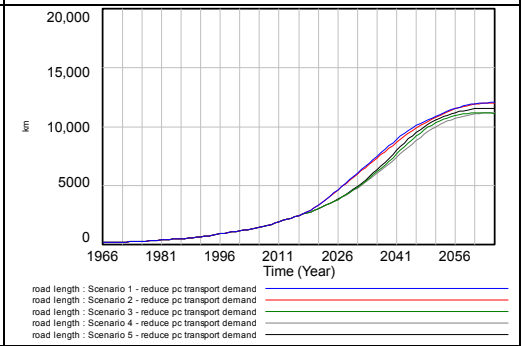
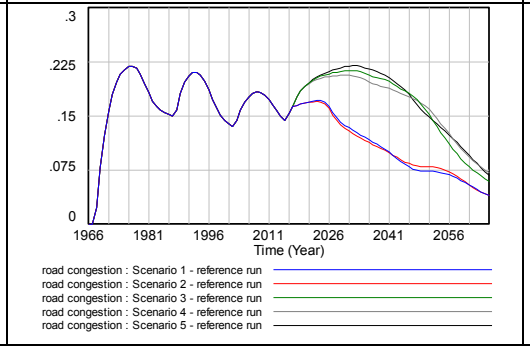
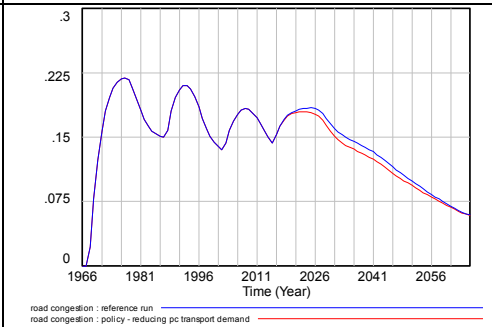
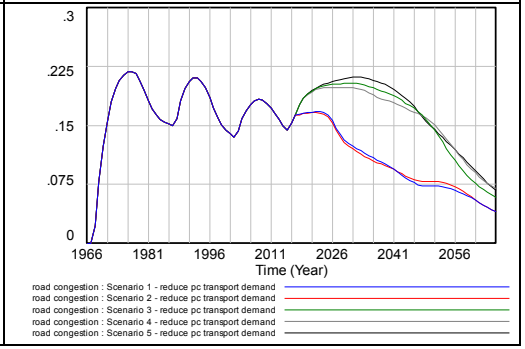
Green space		

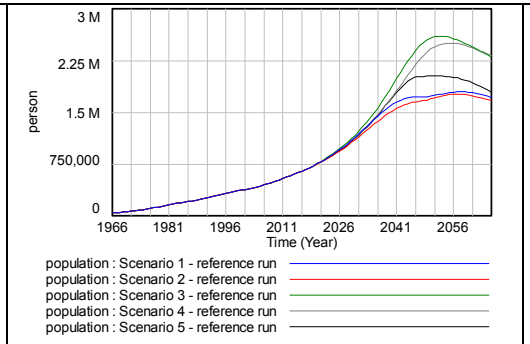
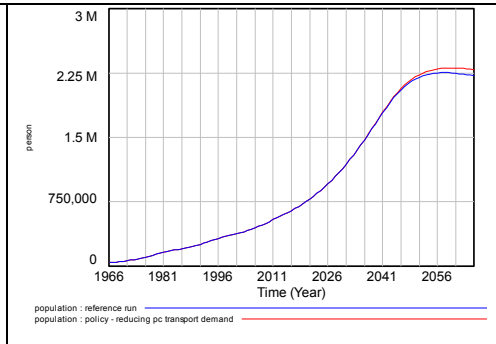
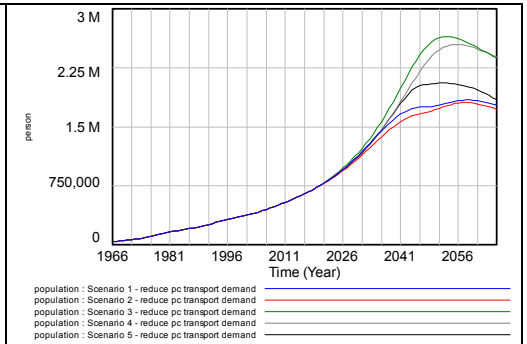
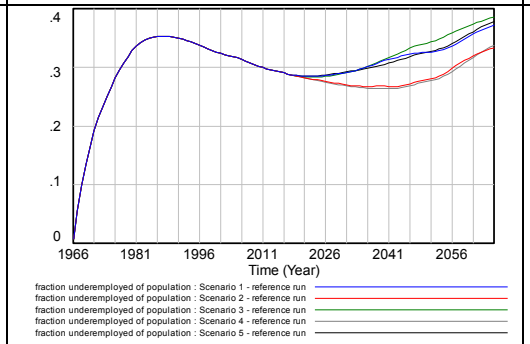
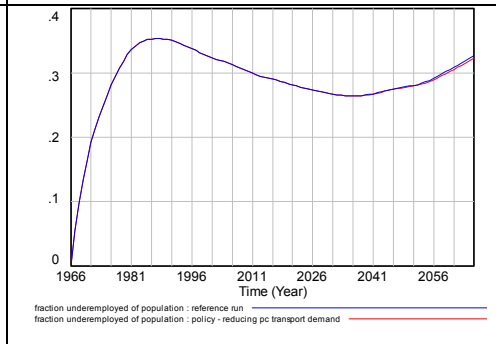
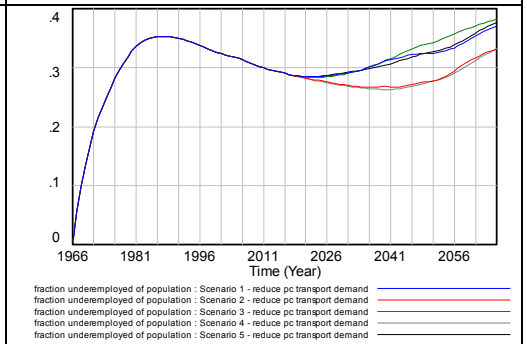
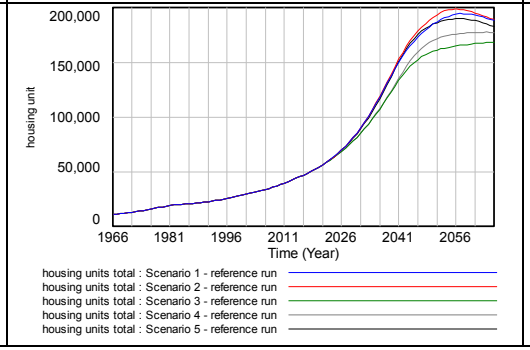
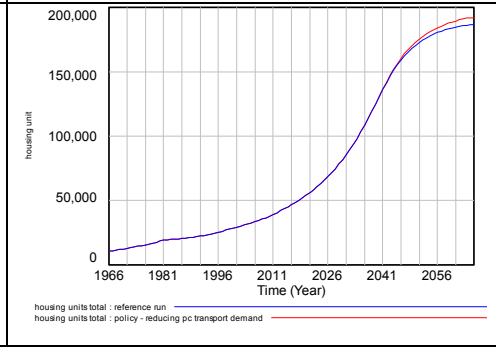
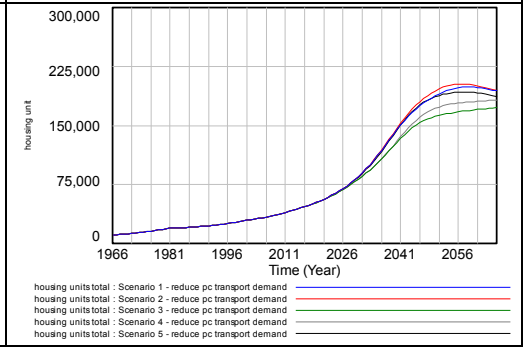
5.2 Transport sub-model

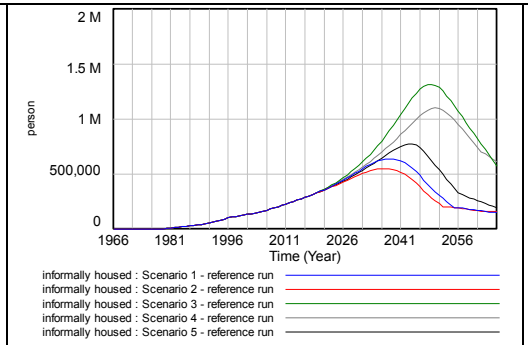
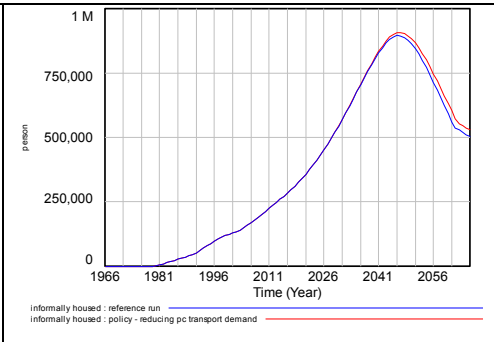
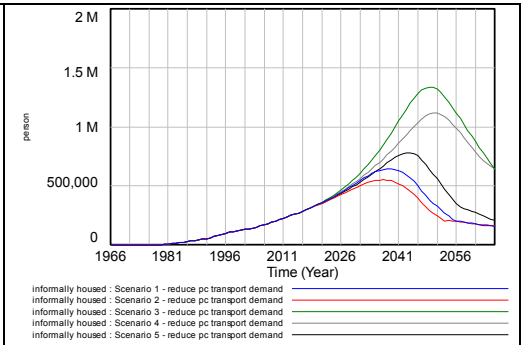
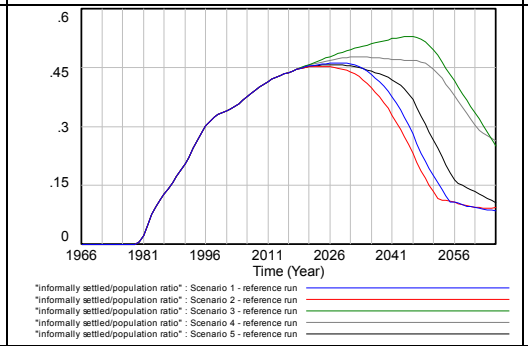
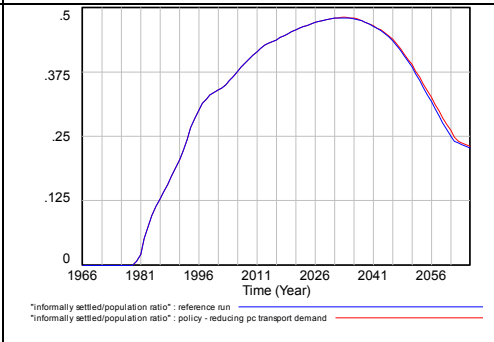
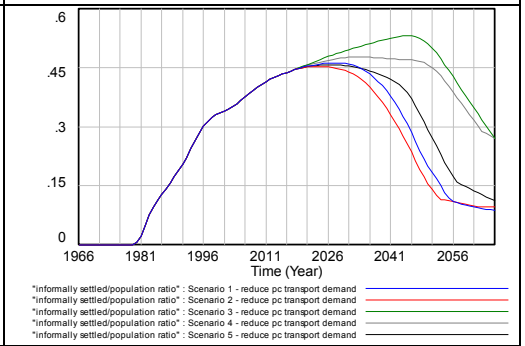
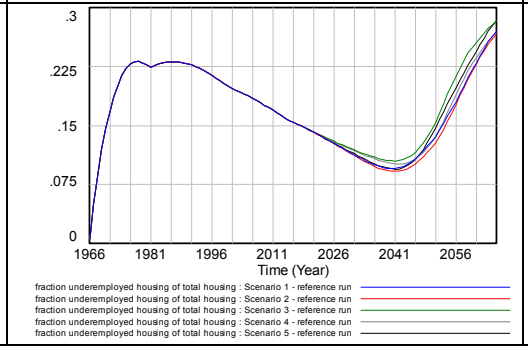
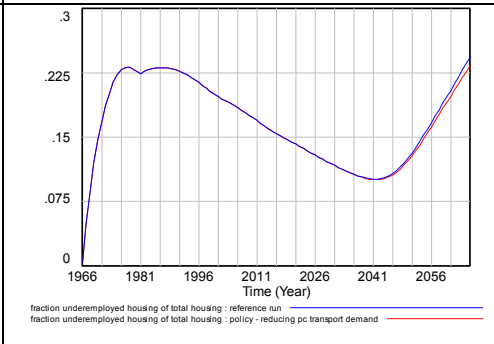
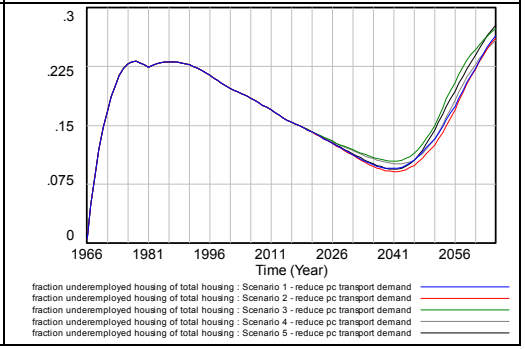
5.2.1 Reducing per capita transport demand

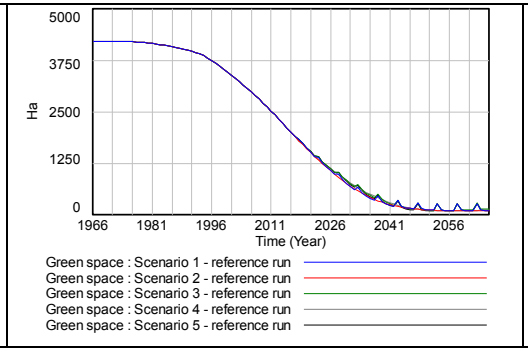
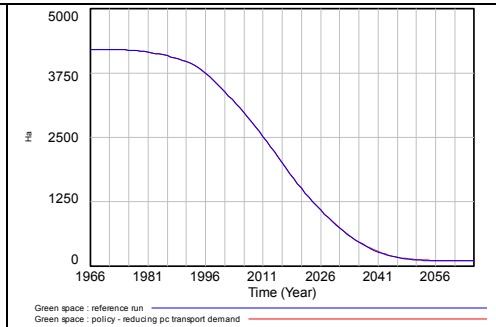
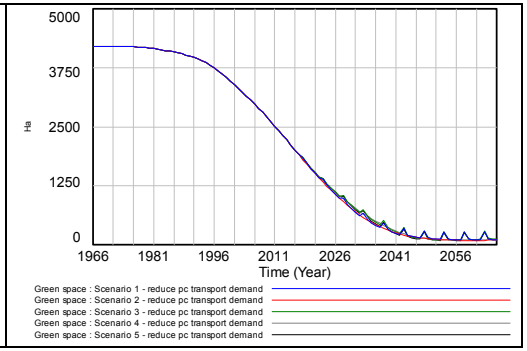
Variable	**Specification**
pc transport demand growth rate	0.05 - RAMP(0.01/10,2017,2027)
max per capita transport demand	2-RAMP(0.4/10,2017,2027)

KPI	Reference run	Reference vs. policy run	Reducing per capita transport demand
Land fraction occupied			

New enterprise			
Road length			
Road congestion			

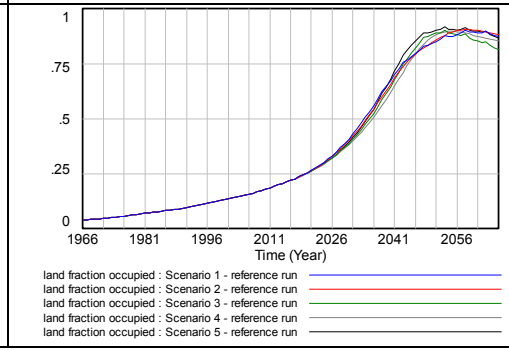
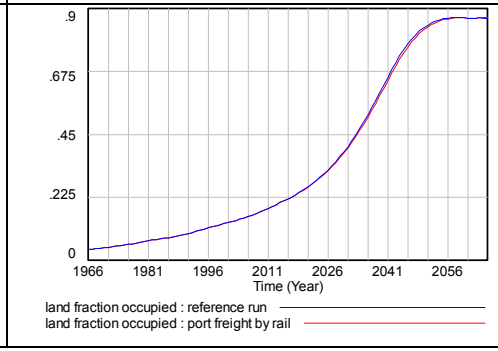
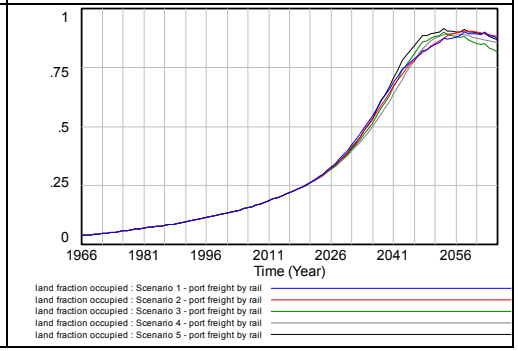
Population			
Fraction underemployed of population			
Housing units total			

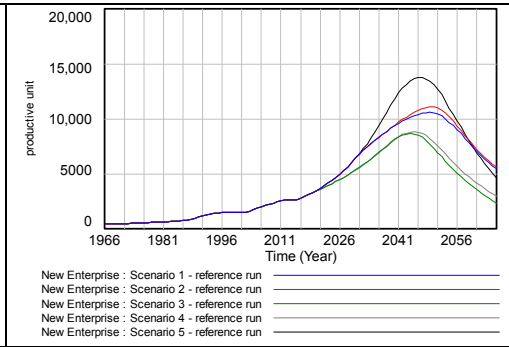
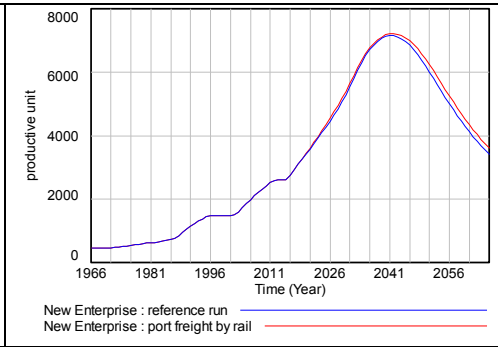
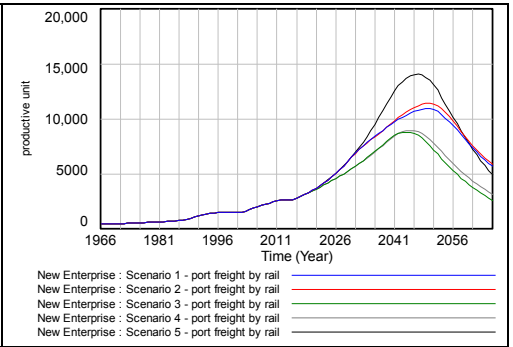
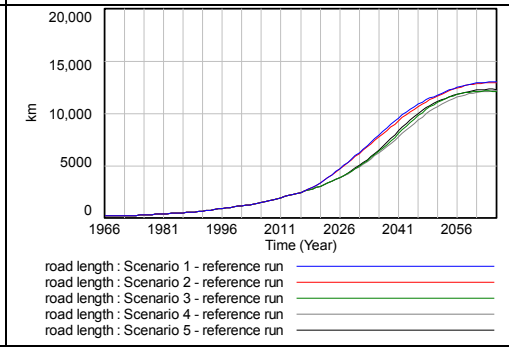
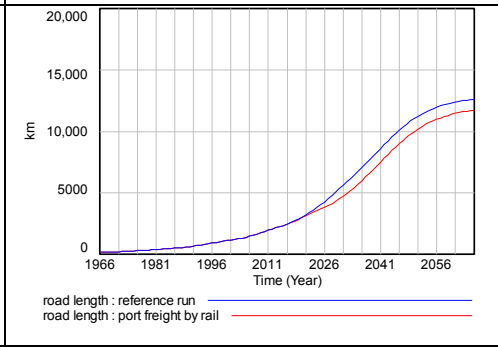
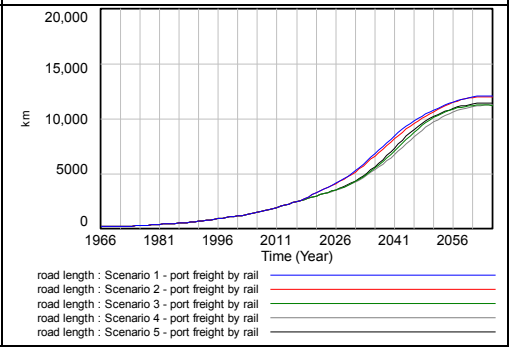
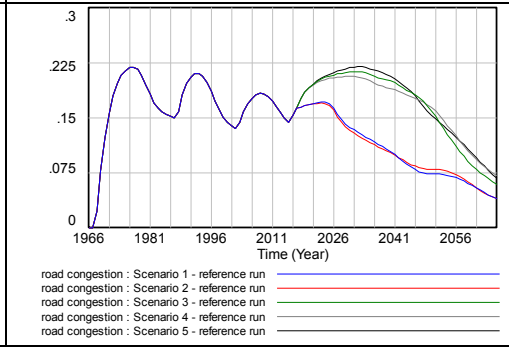
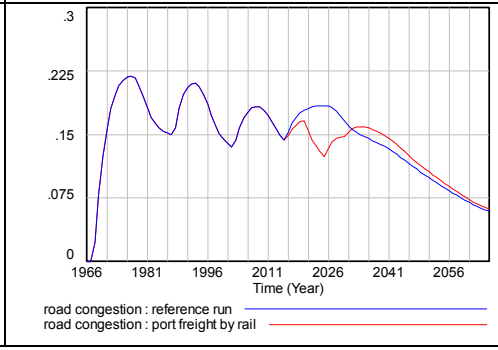
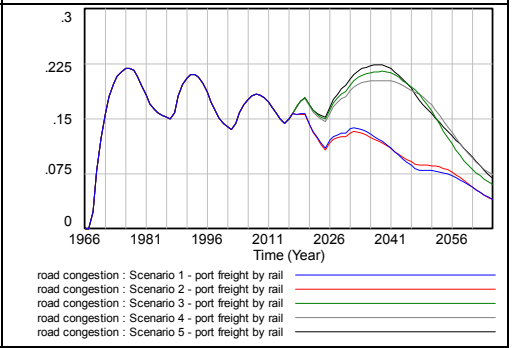
Informally housed			
Informally settled/population ratio			
Fraction underemployed housing of total housing			

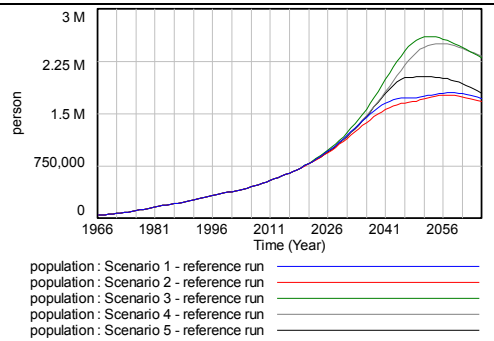
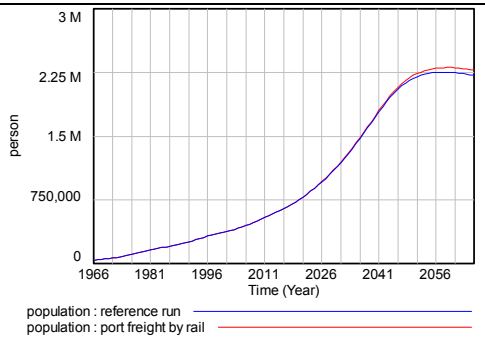
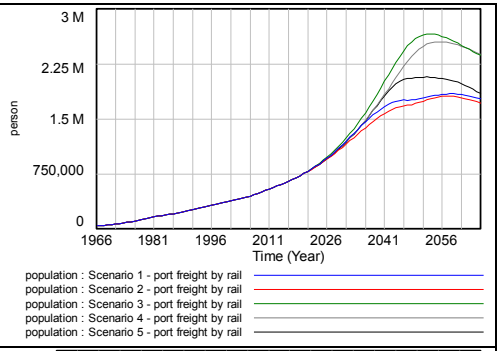
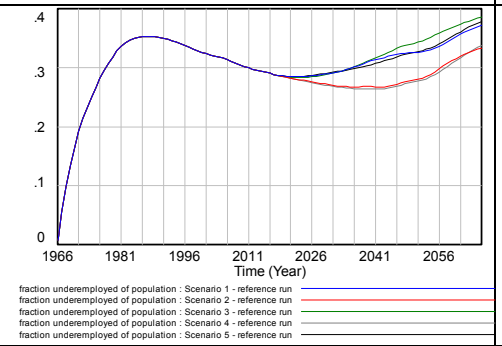
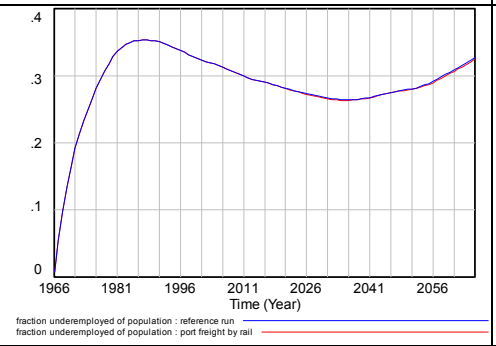
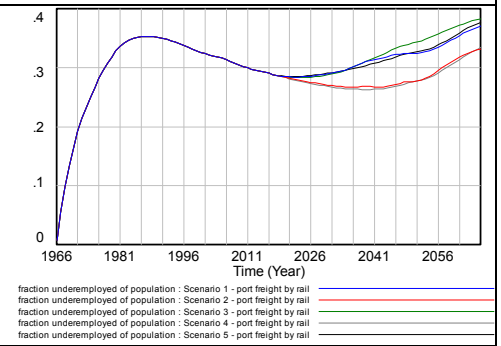
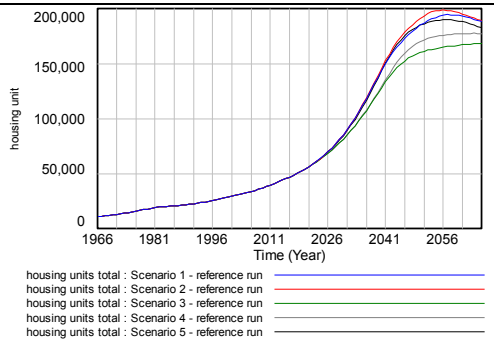
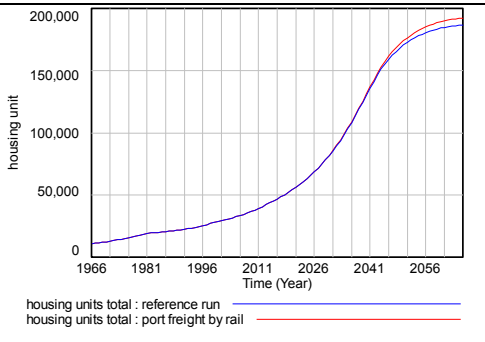
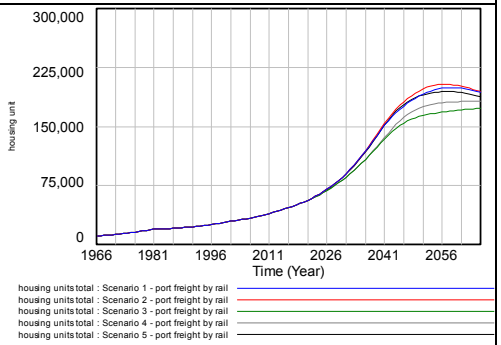
Green space			

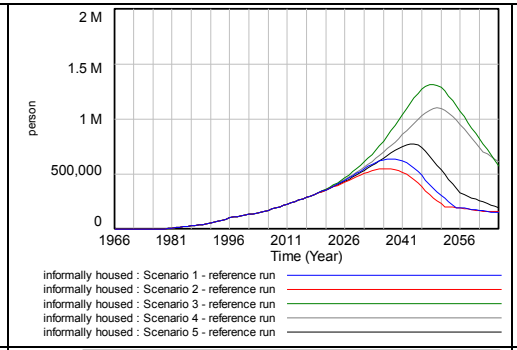
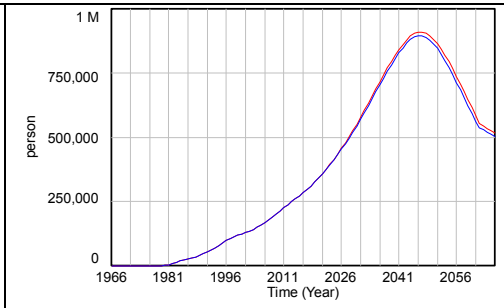
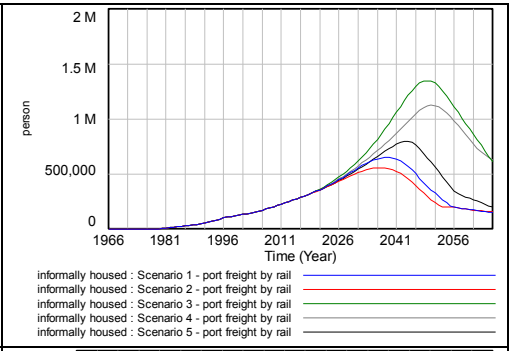
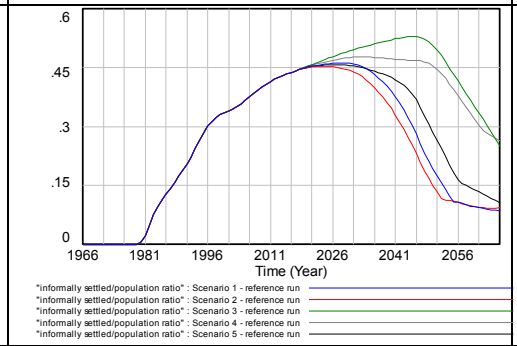
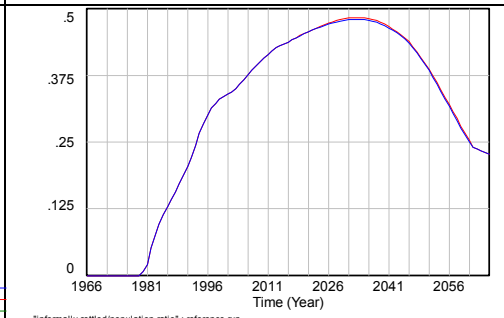
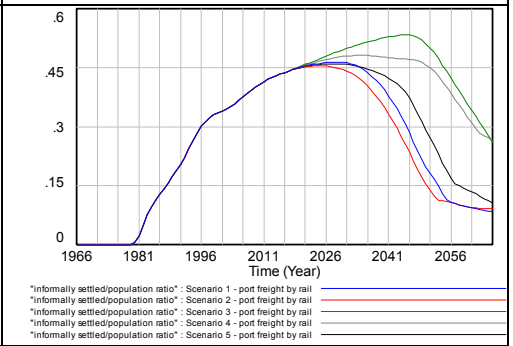
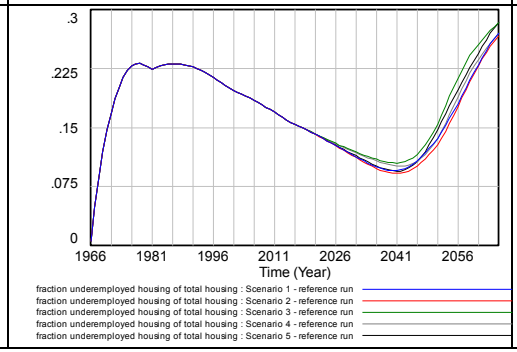
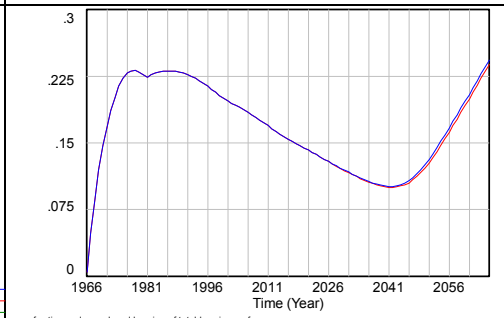
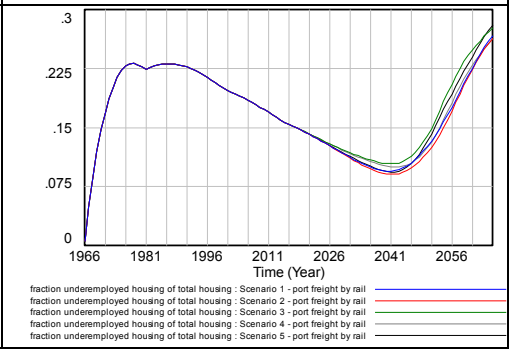
5.2.2 Reducing port freight by road (e.g. rail infrastructure)

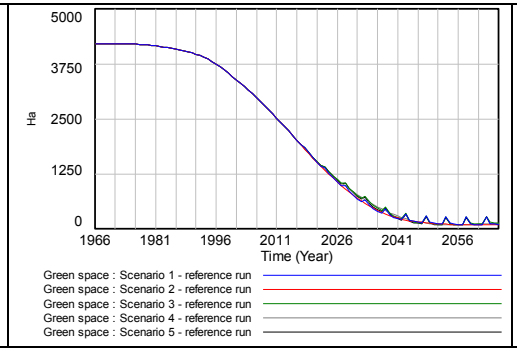
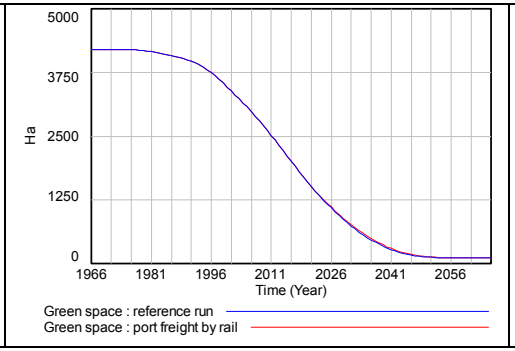
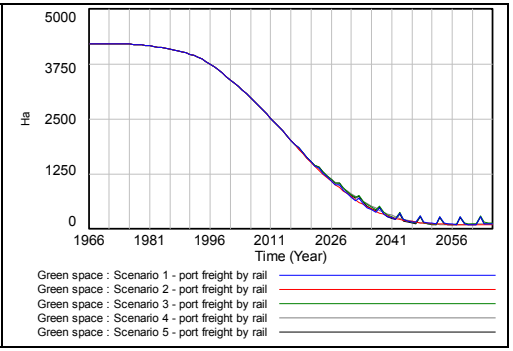
Intervention variable	Specification
road transport change	-0.75
fraction of port freight by road	0.95+RAMP(road transport change/30, 2015 , 2030) +RAMP(road transport change/10, 2020 , 2025)

KPI	Reference run	Reference vs. policy	+0.75 port freight by rail
Land fraction occupied			

New enterprise			
Road length			
Road congestion			

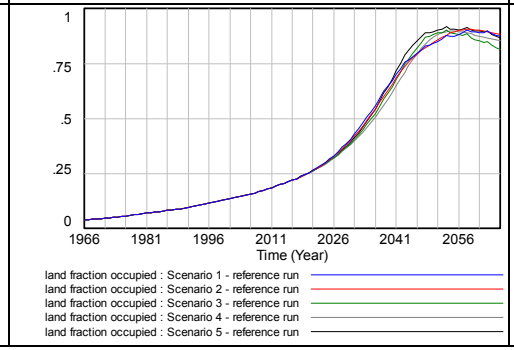
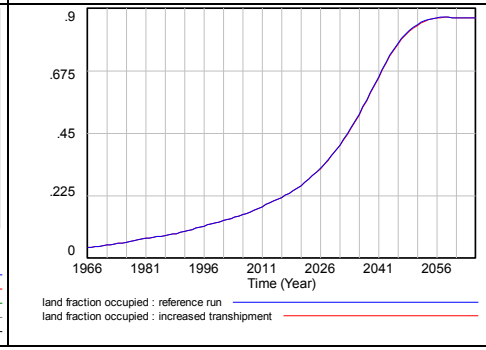
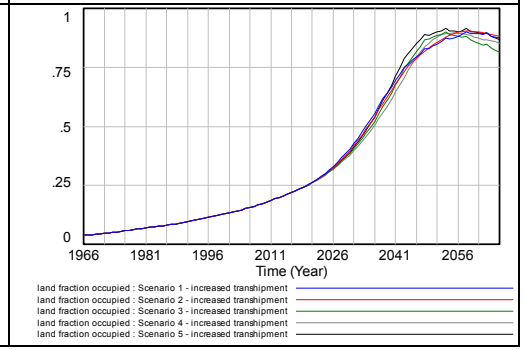
Population			
Fraction underemployed of population			
Housing units total			

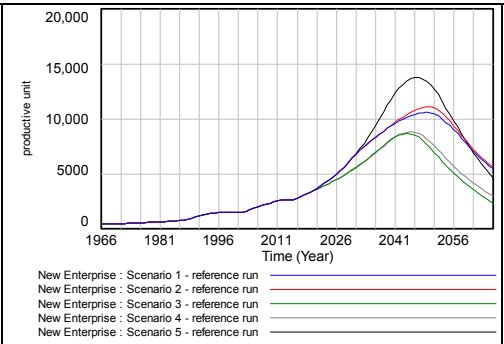
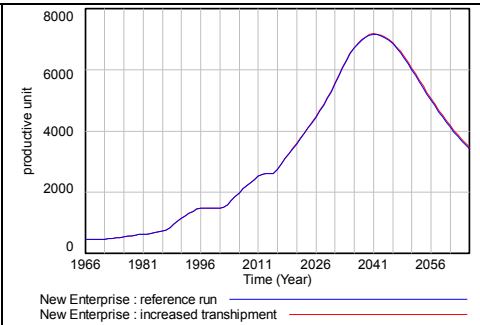
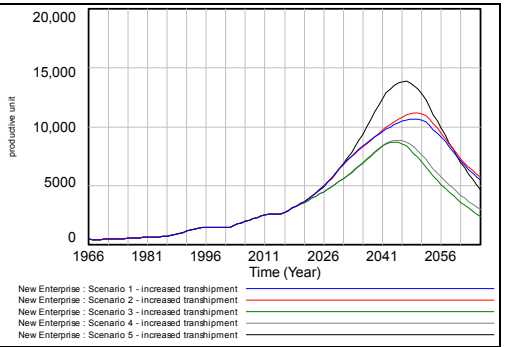
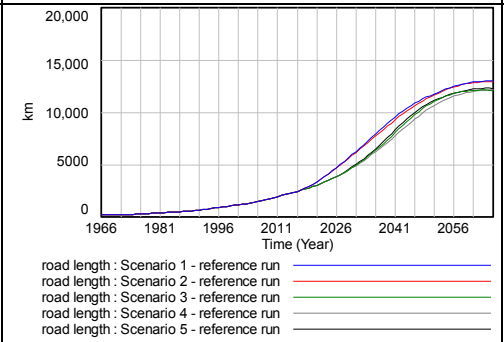
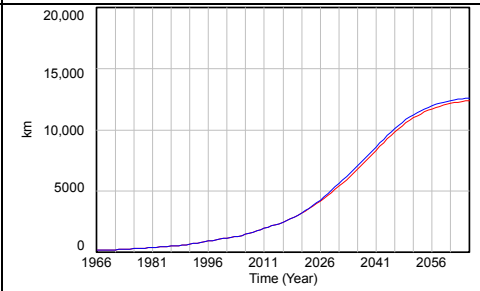
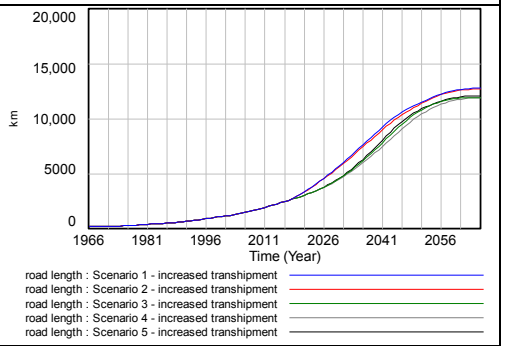
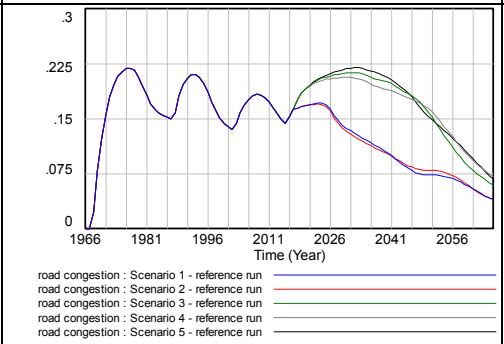
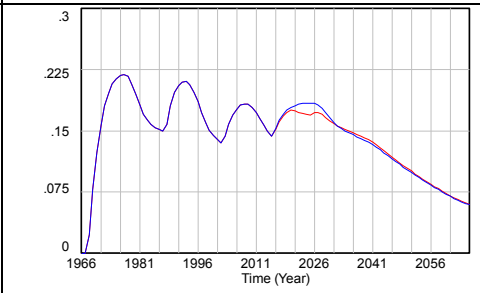
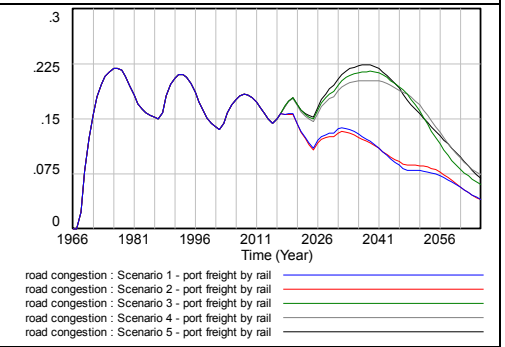
Informally housed			
Informally settled/population ratio			
Fraction underemployed housing of total housing			

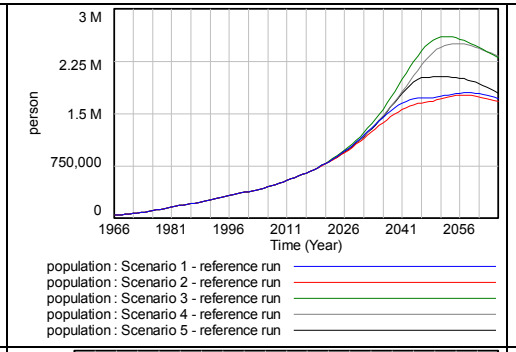
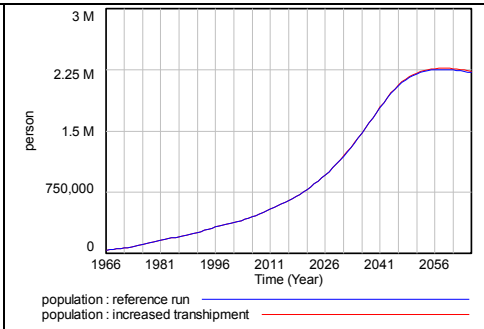
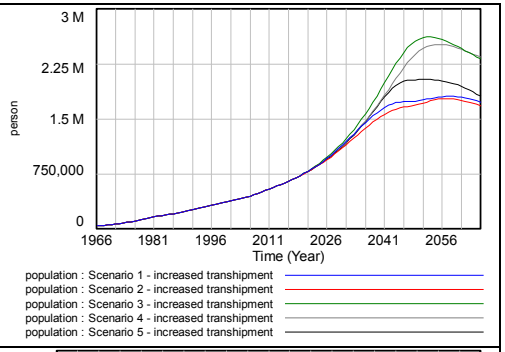
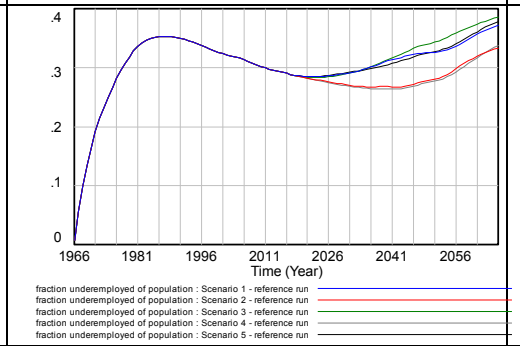
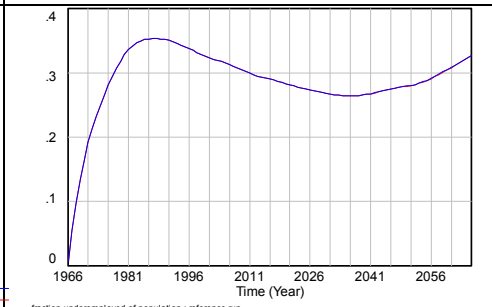
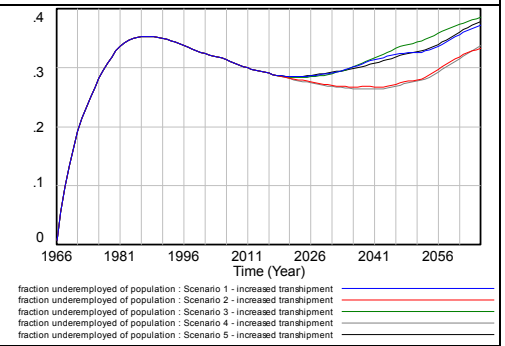
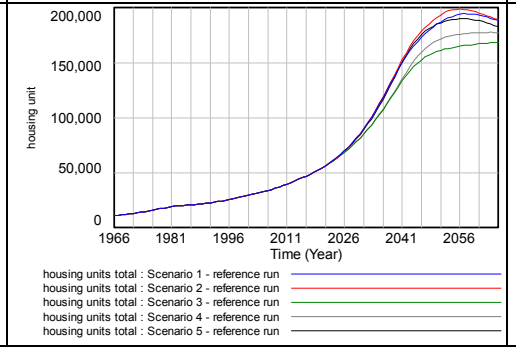
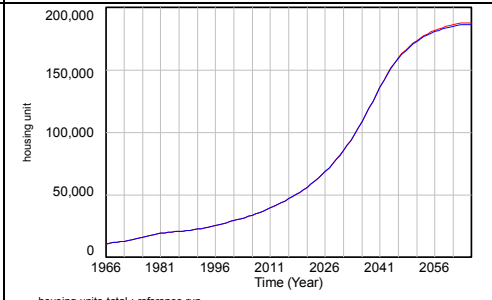
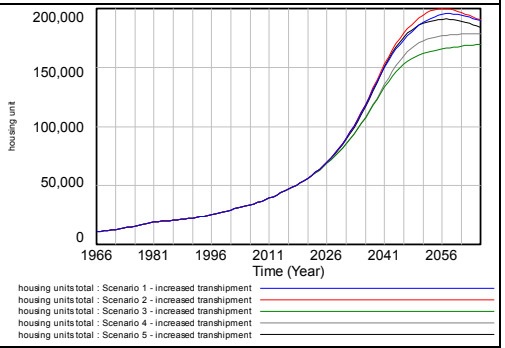
Green space			

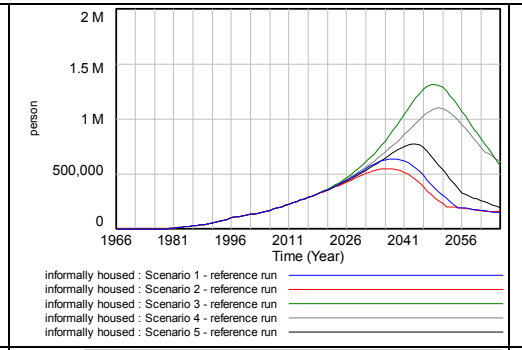
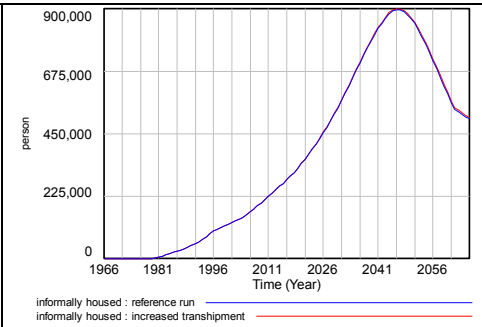
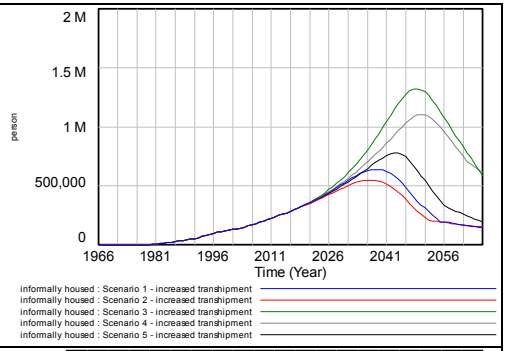
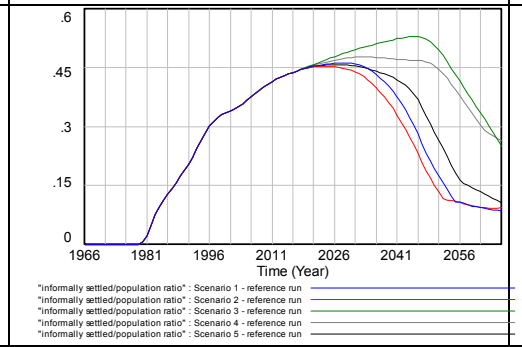
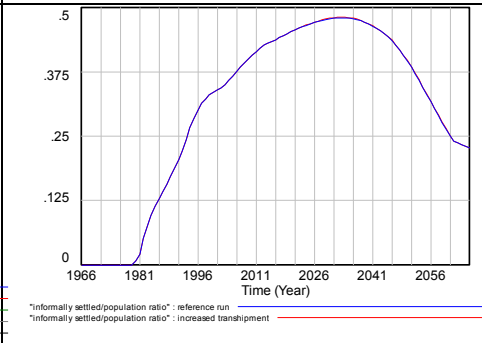
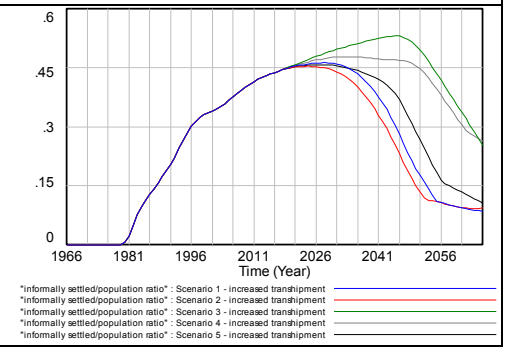
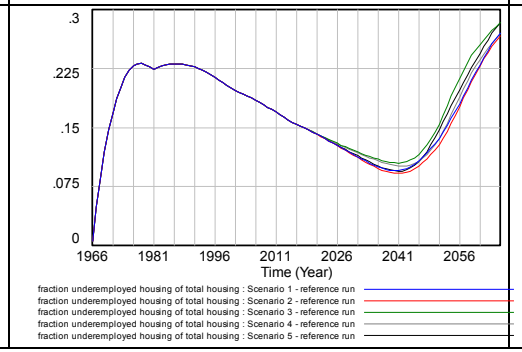
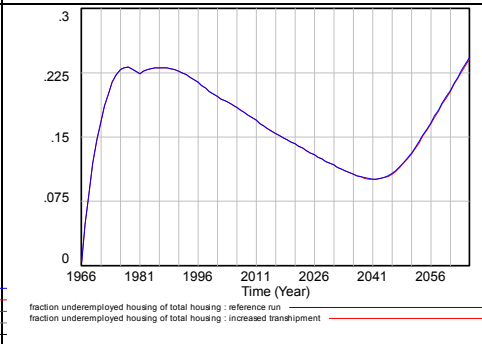
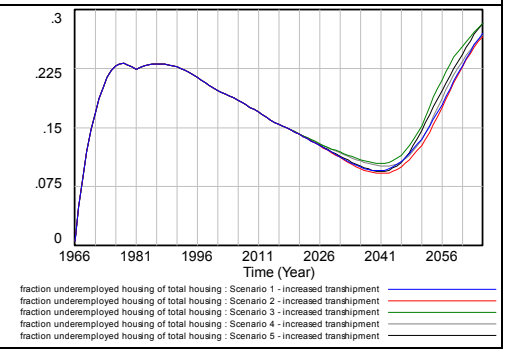
5.2.3 Increasing transhipment to smaller Ghanaian ports (e.g. by the Volta river if possible).

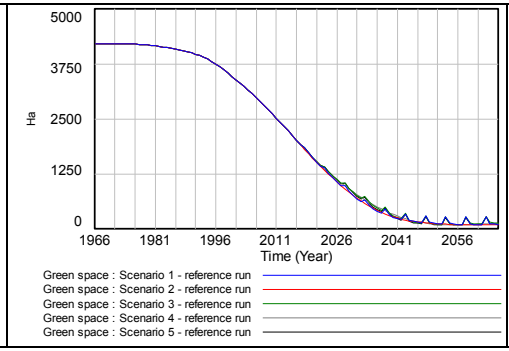
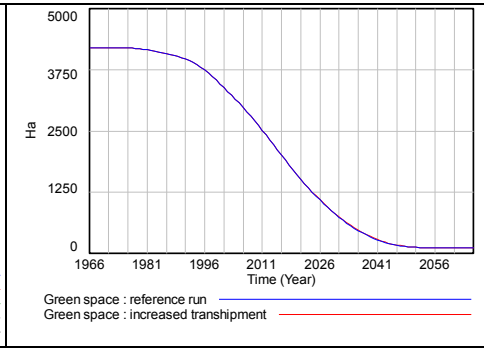
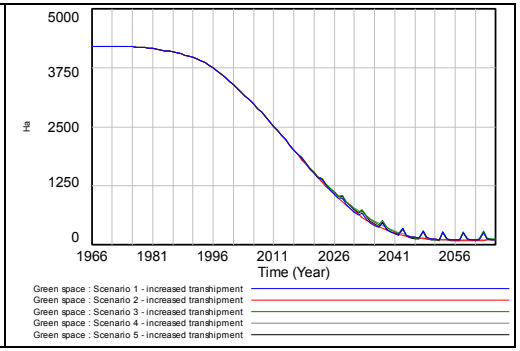
Intervention variable	Specification
Freight transhipment ratio	0.015 + RAMP(0.2/30, 2015 , 2030) +RAMP(0.2/10, 2020 , 2025)

KPI	Reference run	Reference run vs policy run	transhipment ratio +20%
Land fraction occupied			

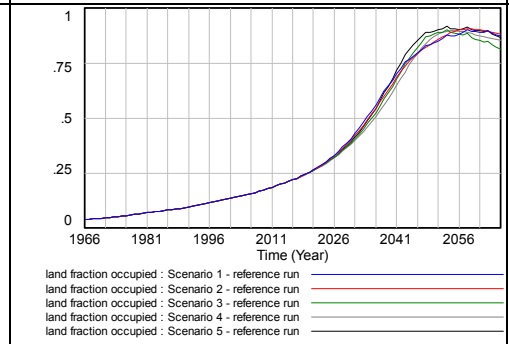
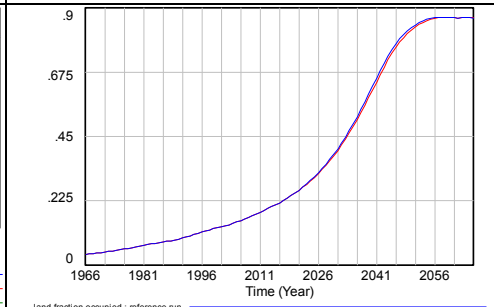
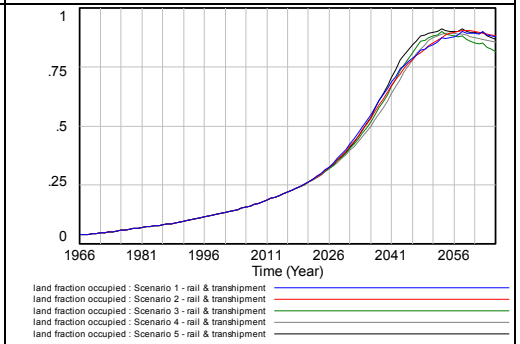
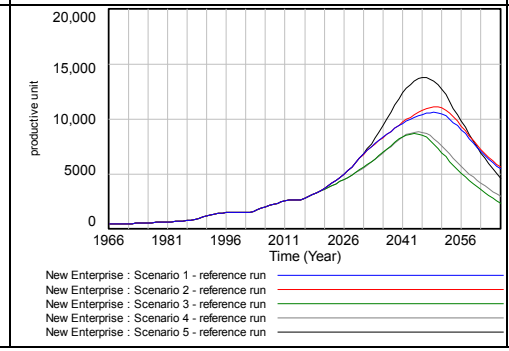
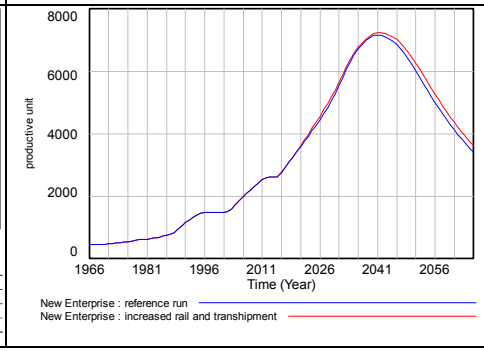
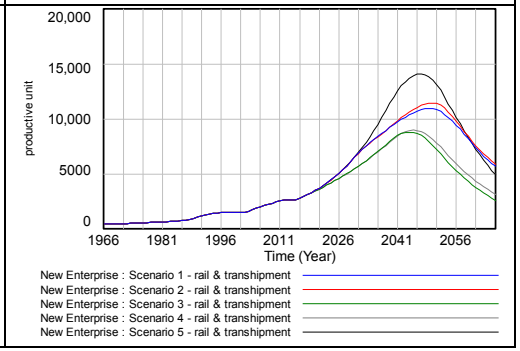
New enterprise			
Road length			
Road congestion			

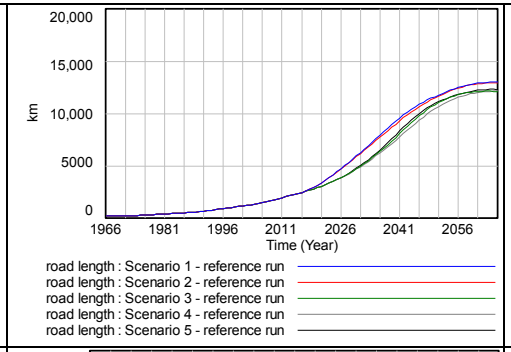
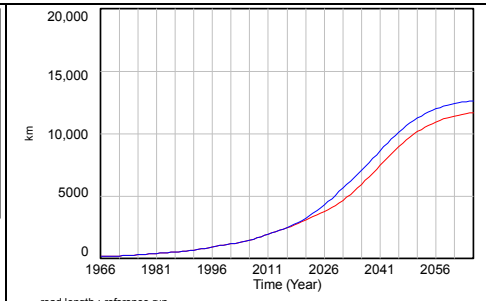
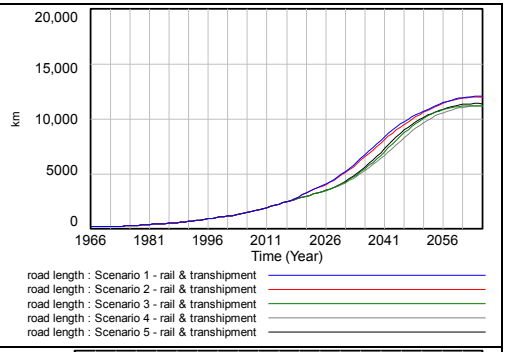
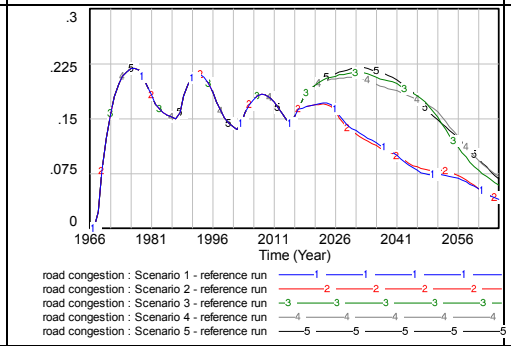
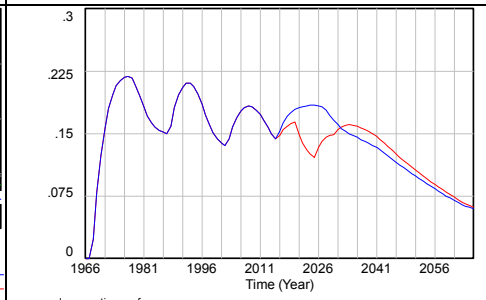
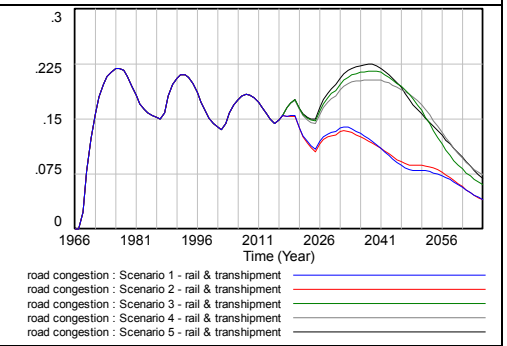
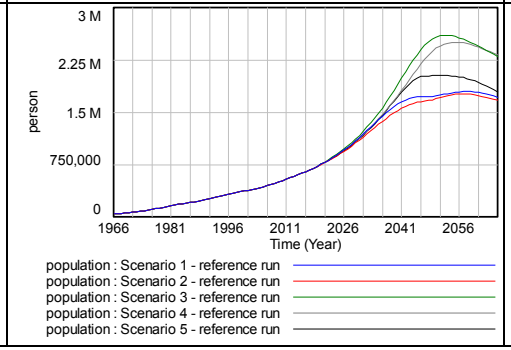
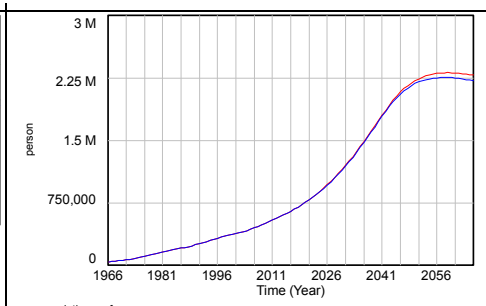
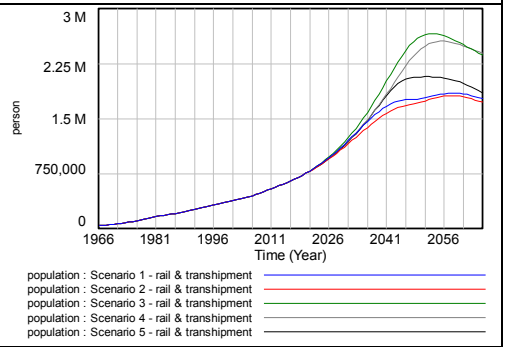
Population			
Fraction underemployed of population			
Housing units total			

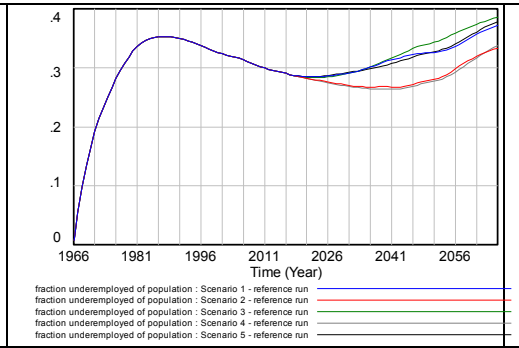
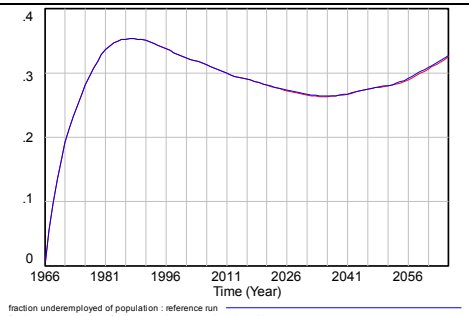
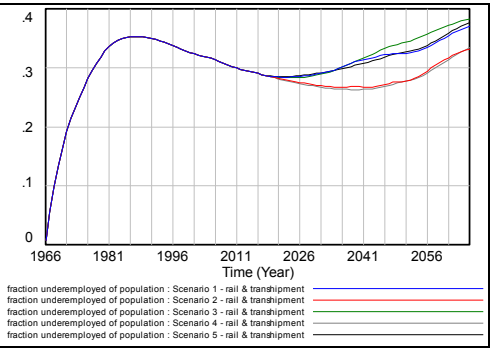
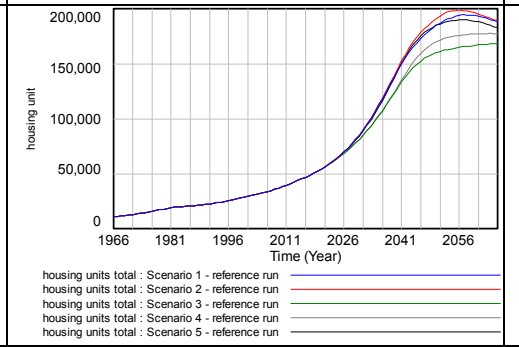
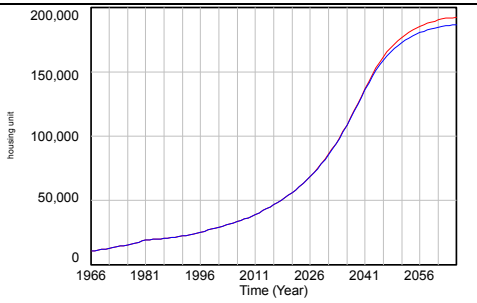
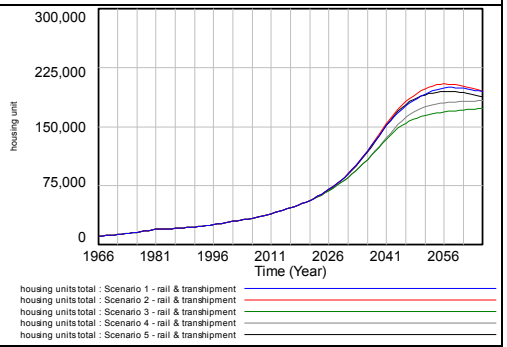
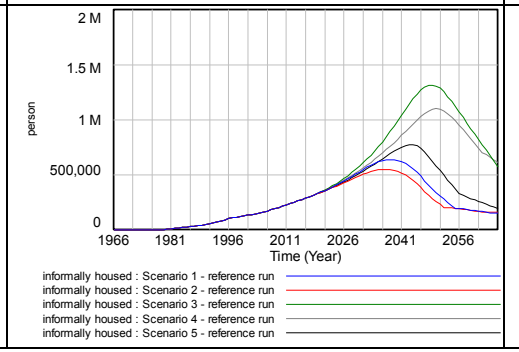
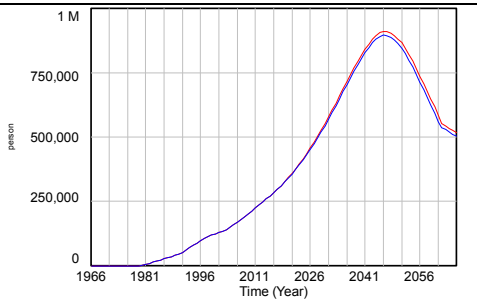
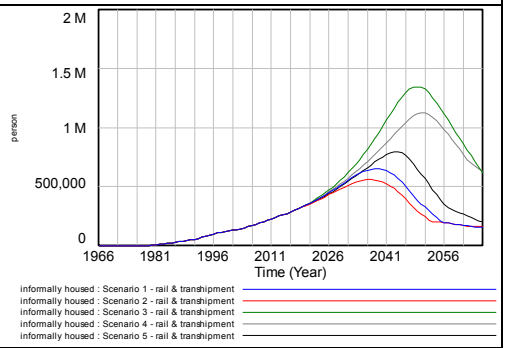
Informally housed			
Informally settled/population ratio			
Fraction underemployed housing of total housing			

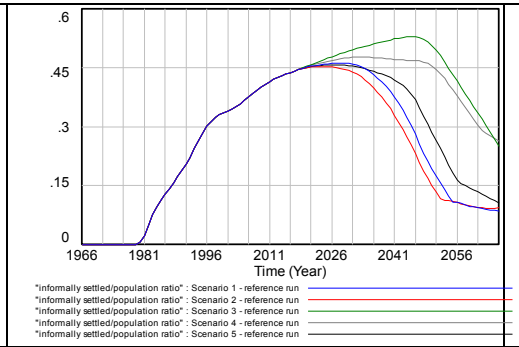
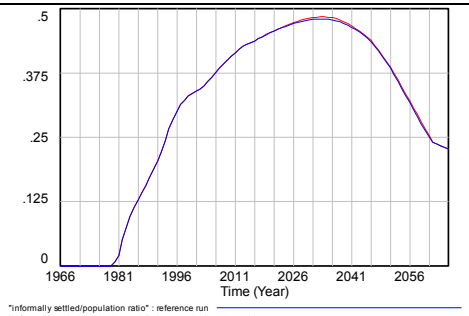
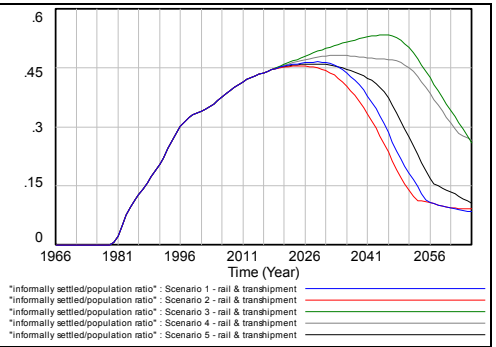
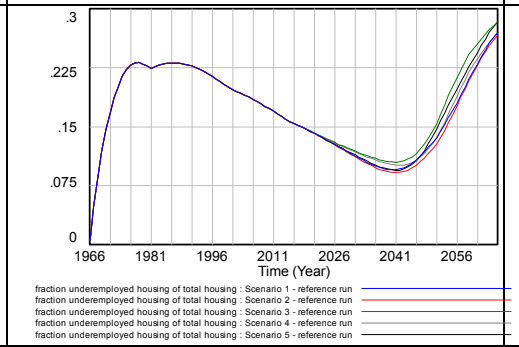
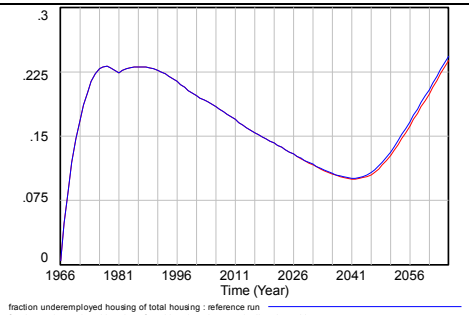
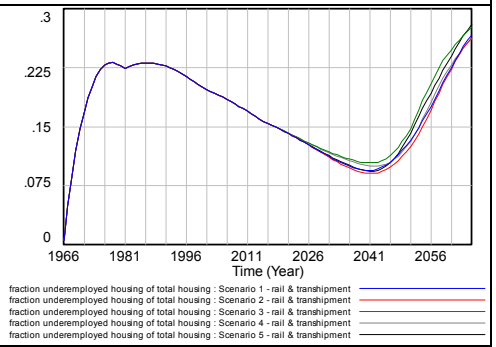
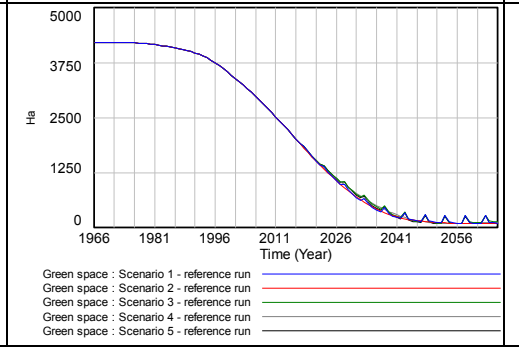
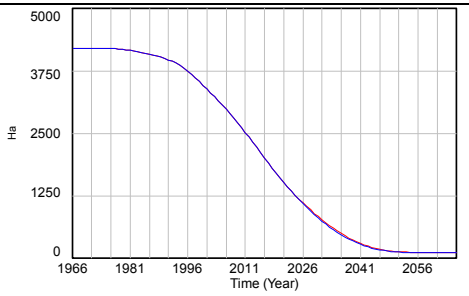
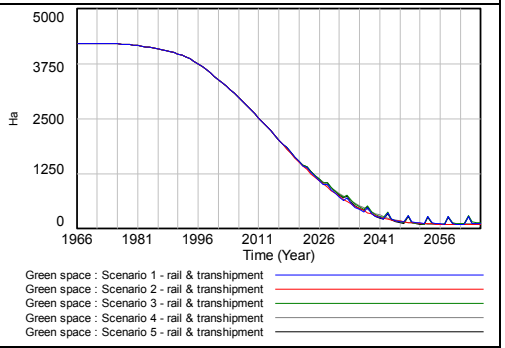
Green space			

5.2.4 Reducing port freight by road & transhipment

KPI	Reference run	Reference run vs. policy run	Rail -0.75 & transhipment ratio +20%
Land fraction occupied			
New enterprise			

Road length			
Road congestion			
Population			

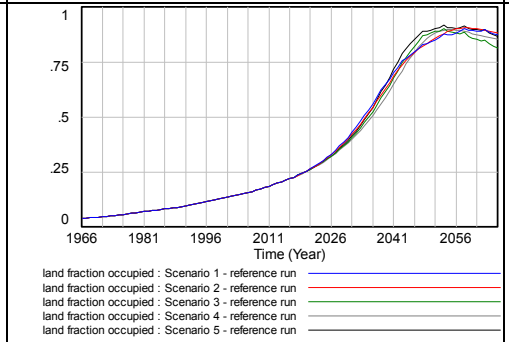
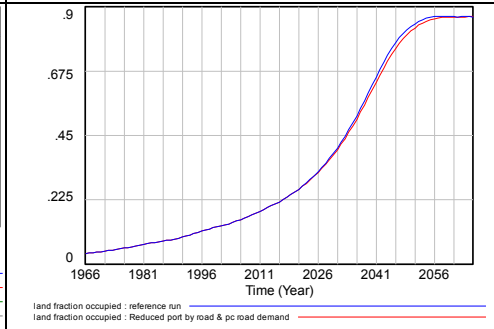
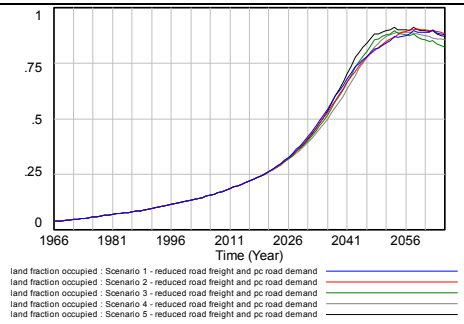
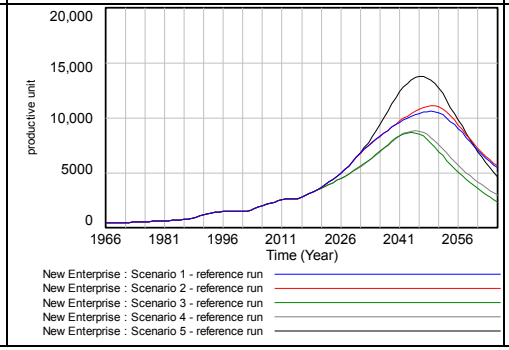
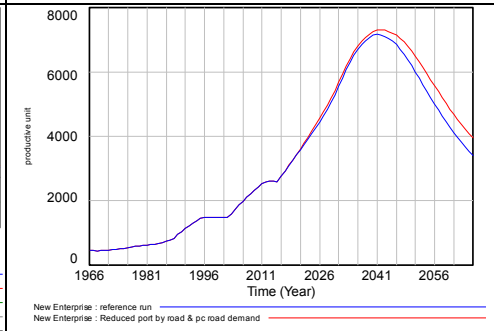
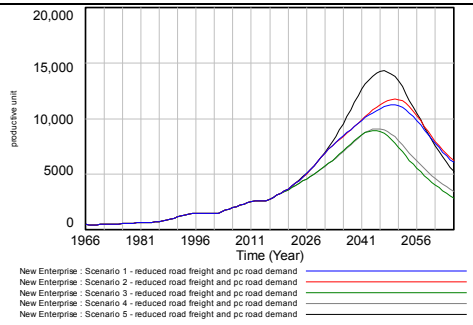
Fraction underemployed of population			
Housing units total			
Informally housed			

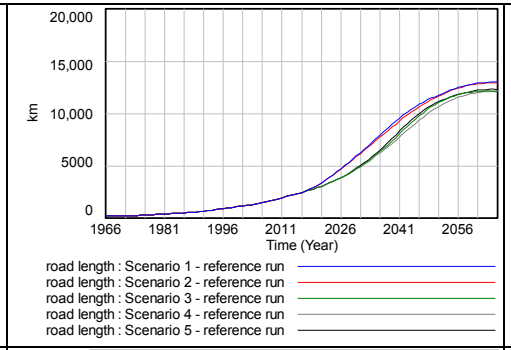
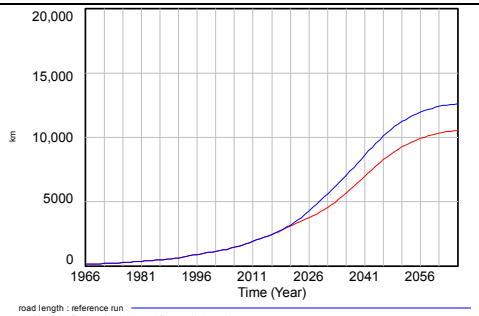
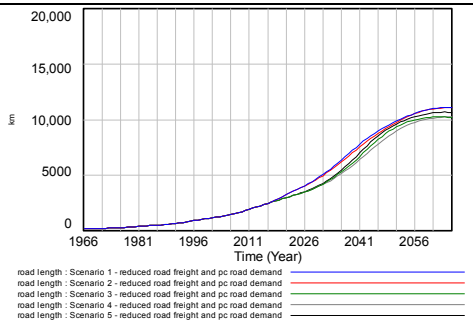
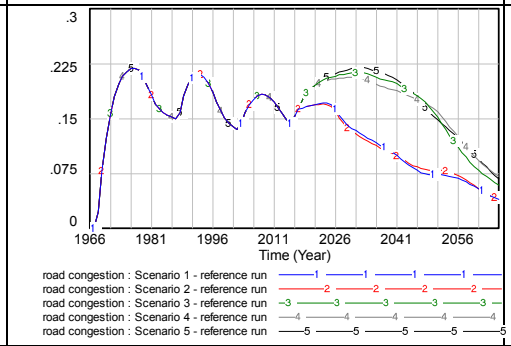
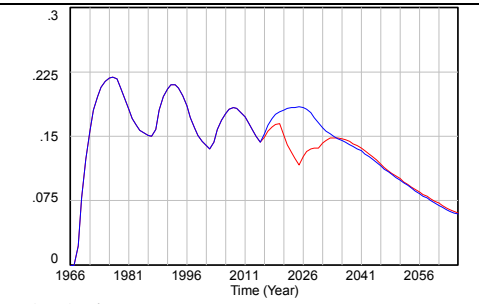
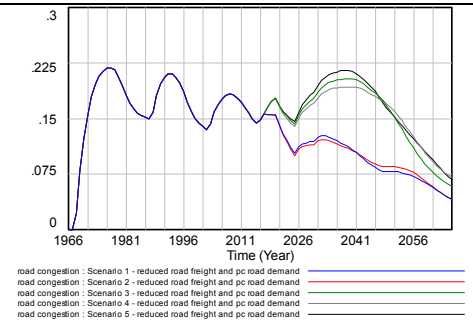
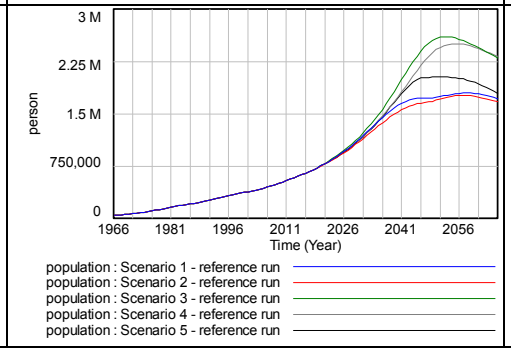
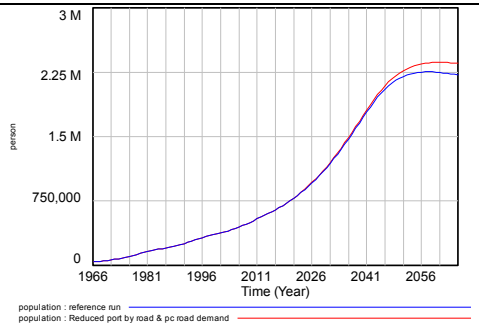
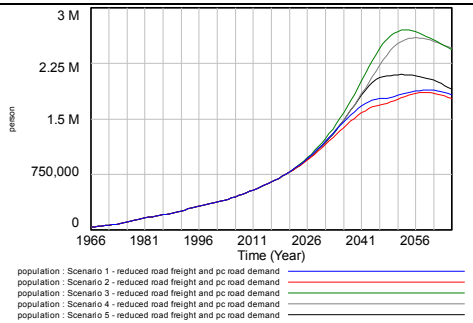
Informally settled/population ratio			
Fraction underemployed housing of total housing			
Green space			

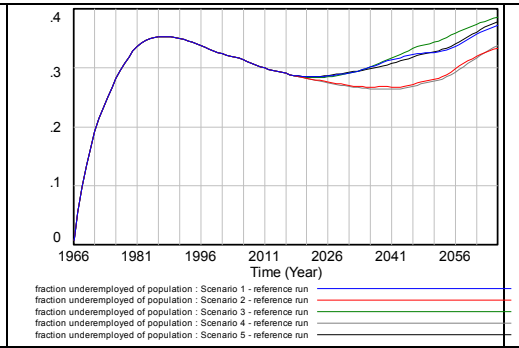
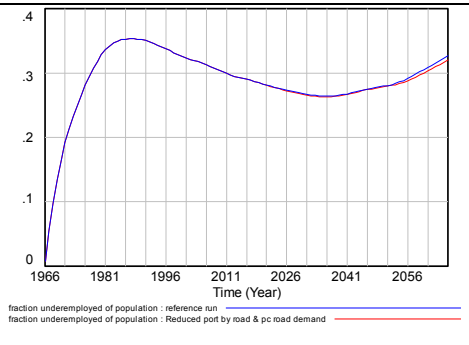
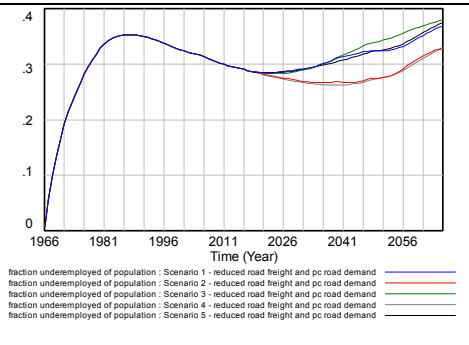
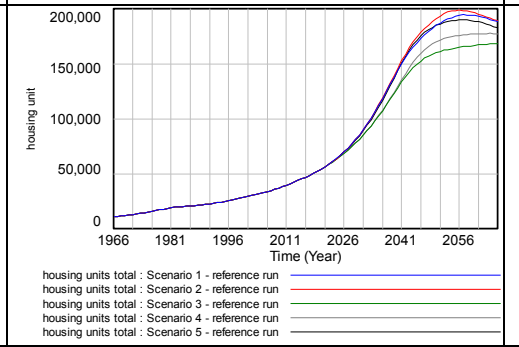
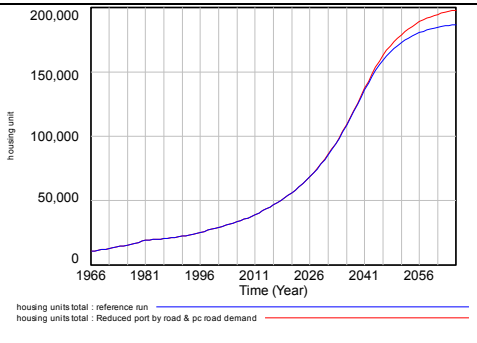
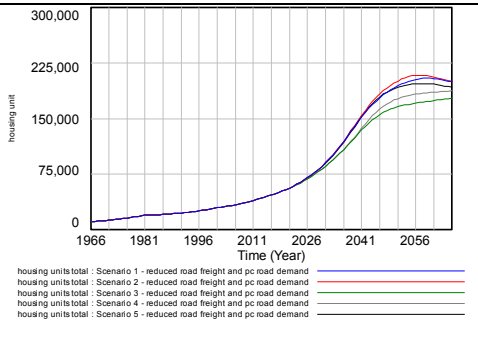
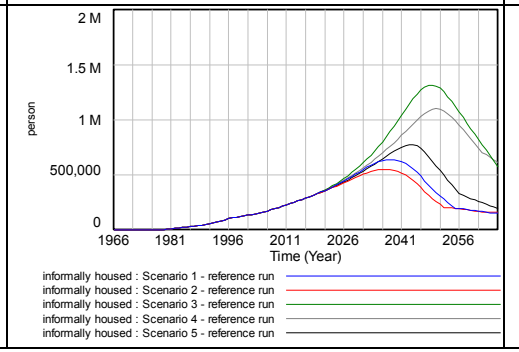
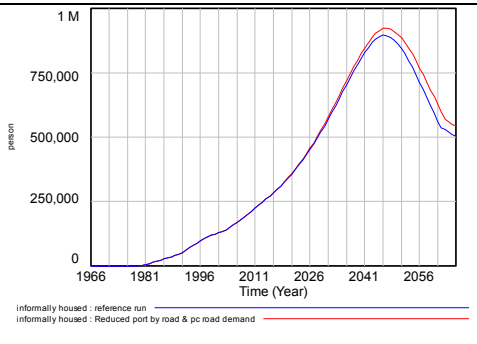
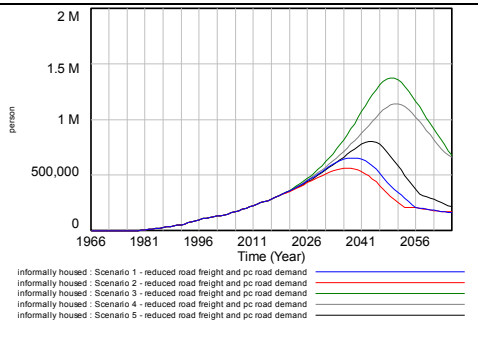
5.2.5 Reducing port freight by road & reducing per capita transport demand

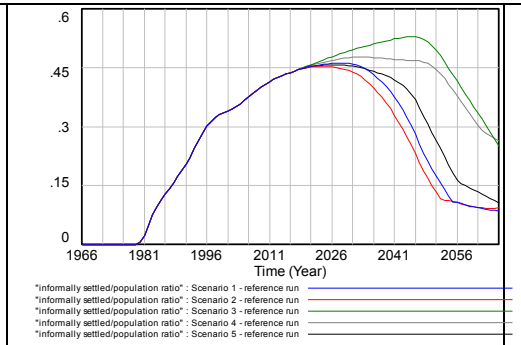
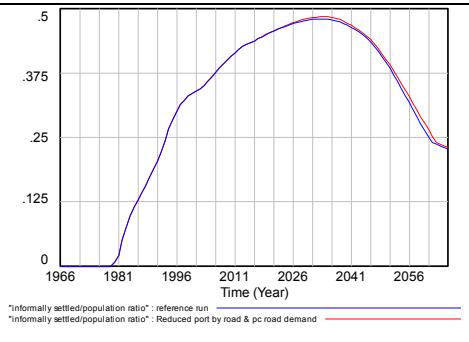
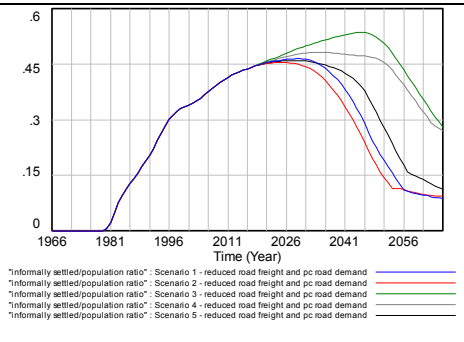
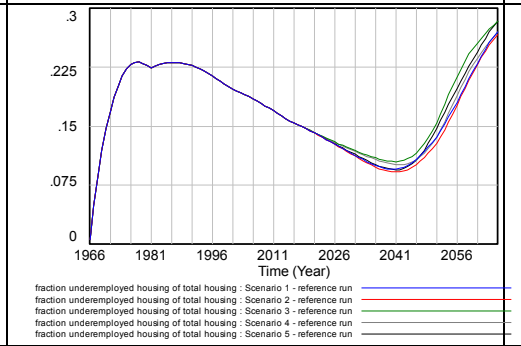
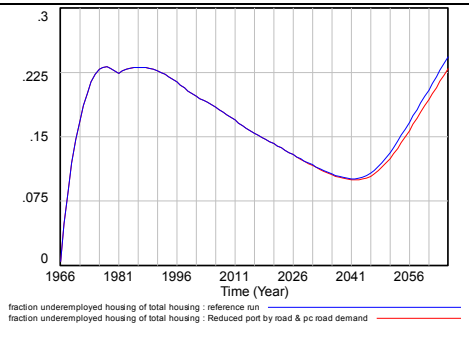
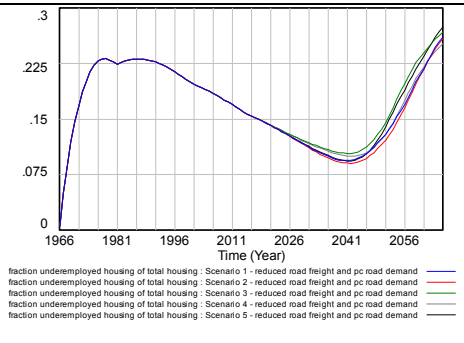
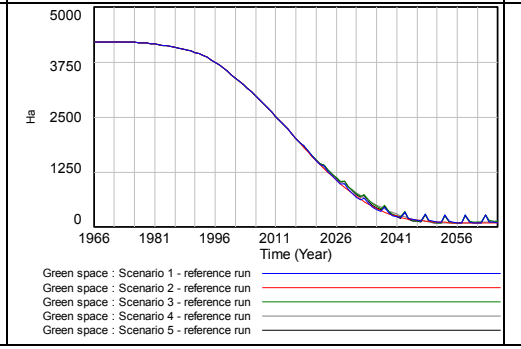
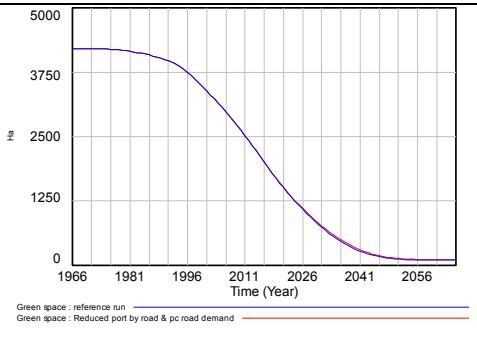
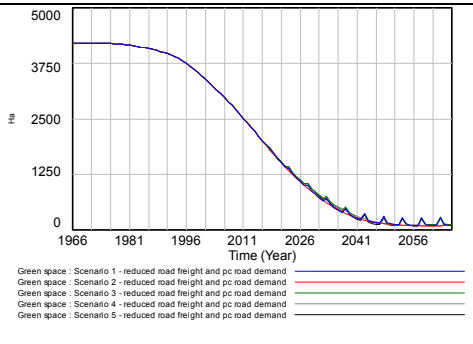
Intervention variable	Specification
road transport change	-0.75
fraction of port freight by road	0.95+RAMP(road transport change/30, 2015 , 2030) +RAMP(road transport change/10, 2020 , 2025)
pc transport demand growth rate	0.05 - RAMP(0.01/10,2017,2027)
max per capita transport demand	2-RAMP(0.4/10,2017,2027)

reduced road freight and pc road demand

KPI	Reference run	Reference run vs. policy run	Policy: Road freight -0.75 & pc transport demand -20%
Land fraction occupied			
New enterprise			

Road length			
Road congestion			
Population			

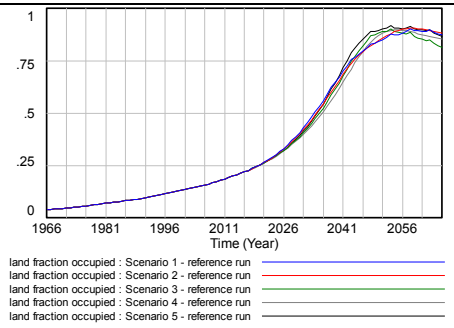
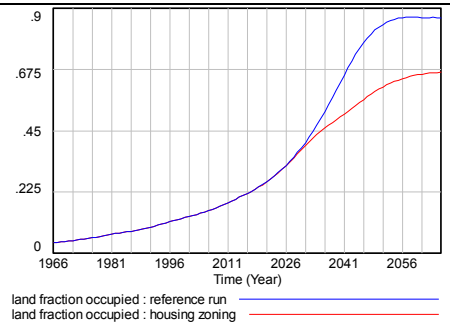
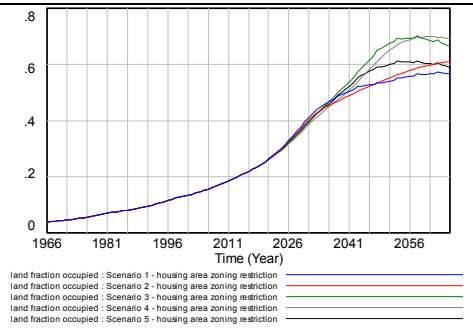
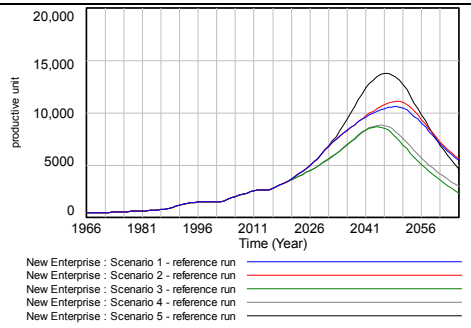
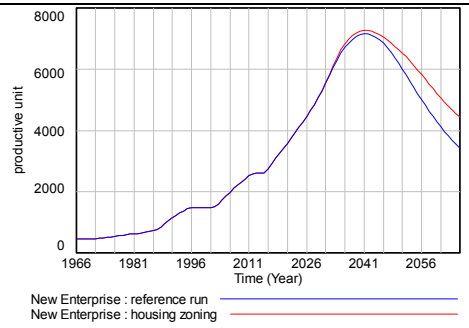
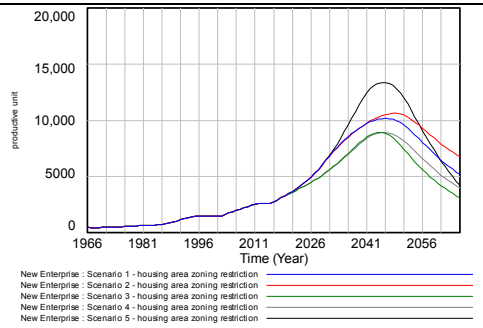
Fraction underemployed of population			
Housing units total			
Informally housed			

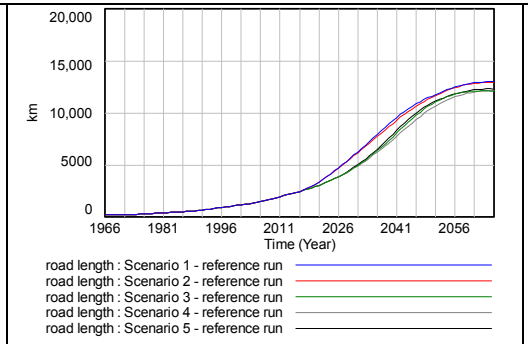
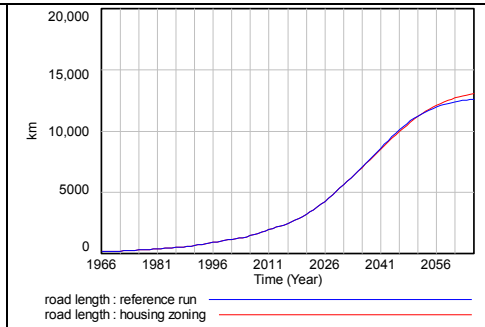
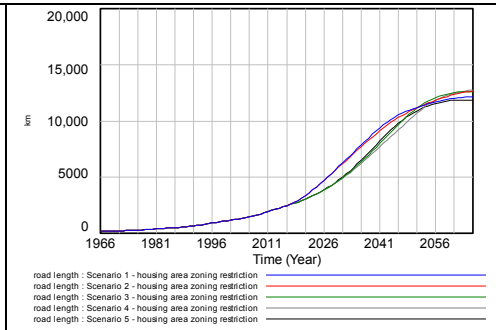
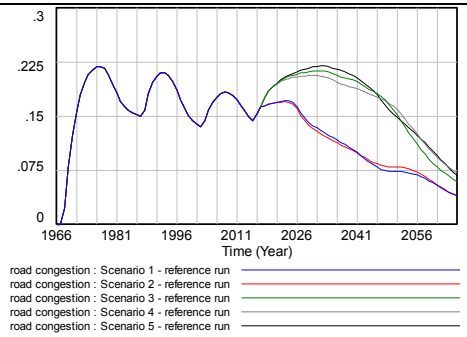
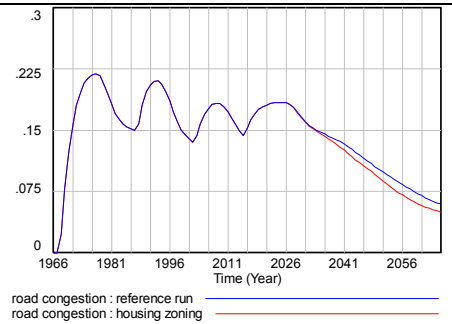
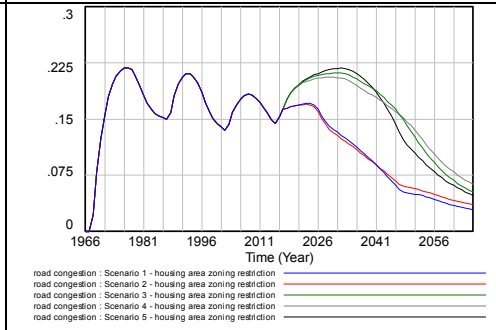
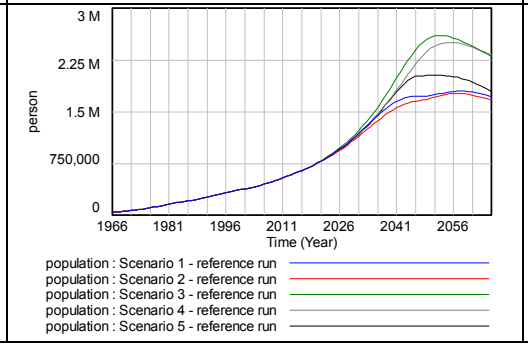
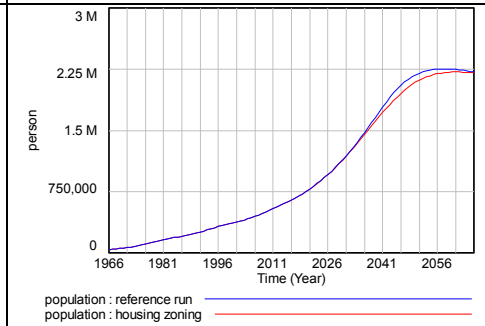
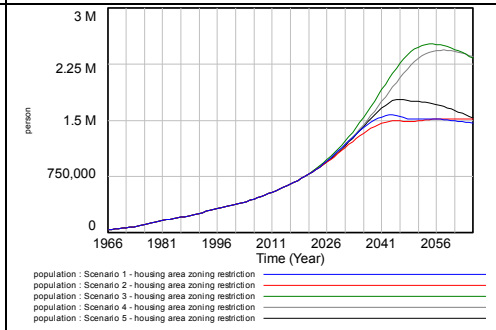
Informally settled/population ratio			
Fraction underemployed housing of total housing			
Green space			

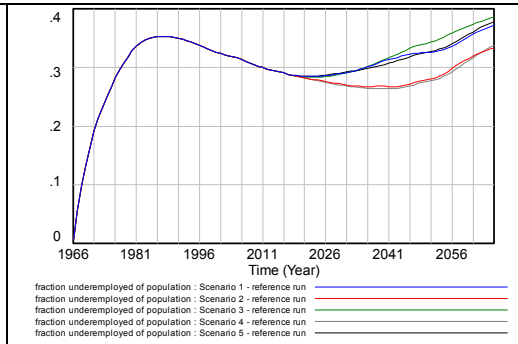
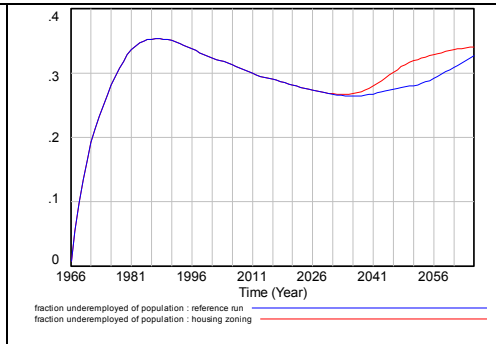
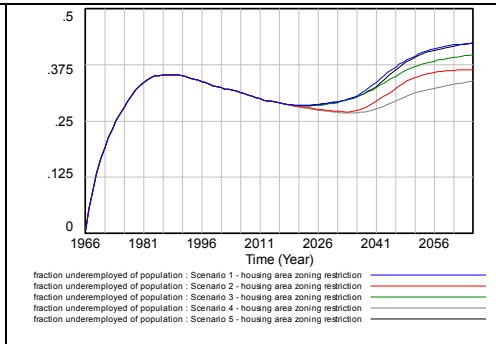
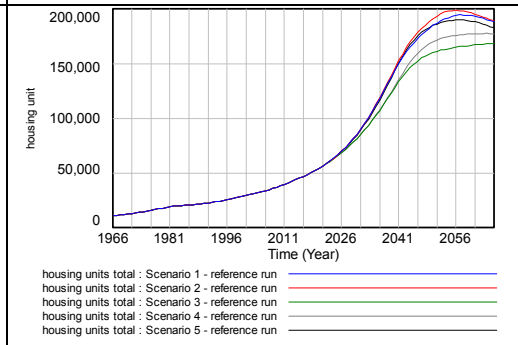
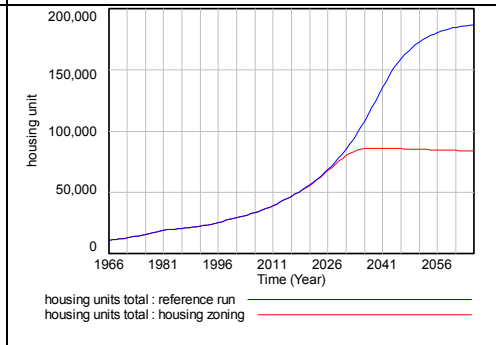
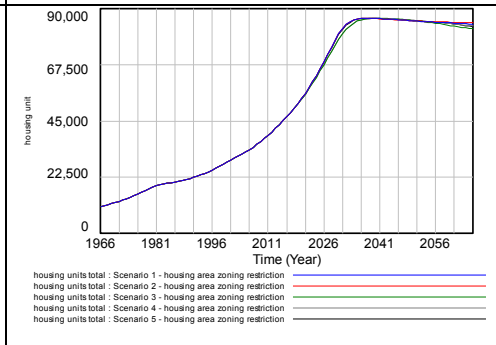
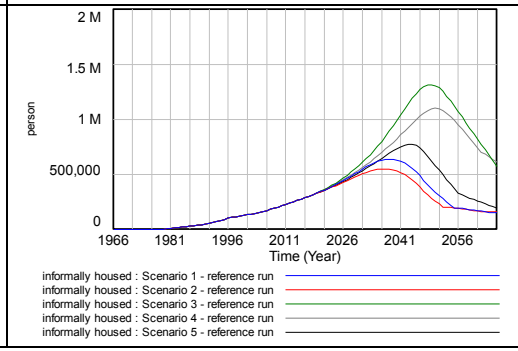
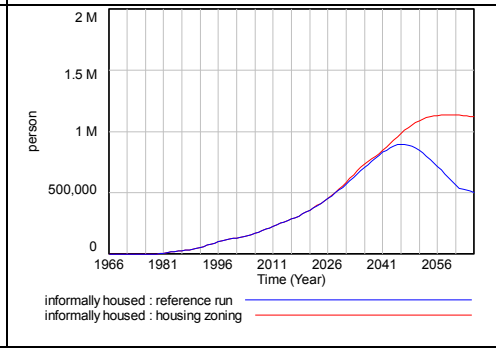
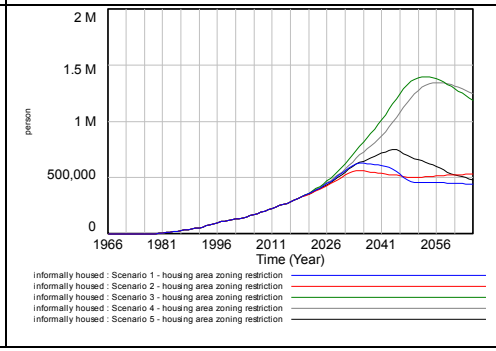
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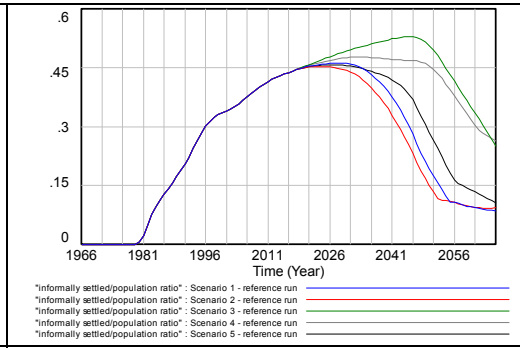
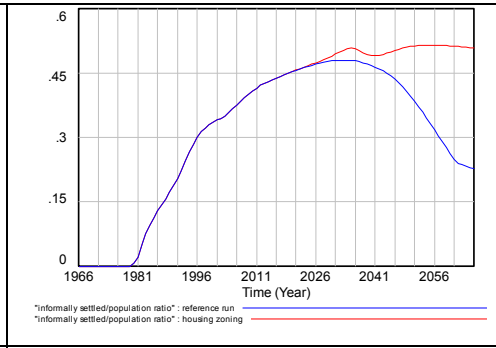
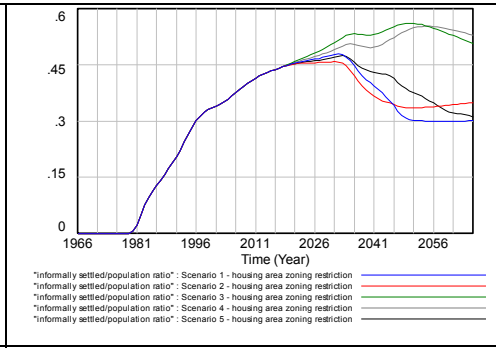
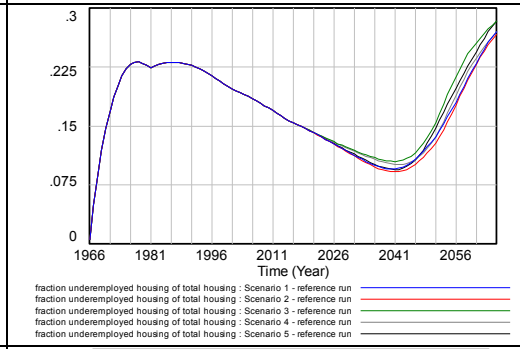
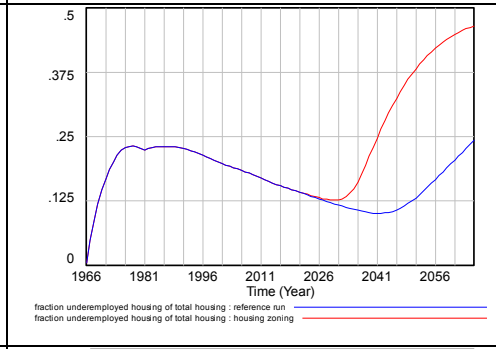
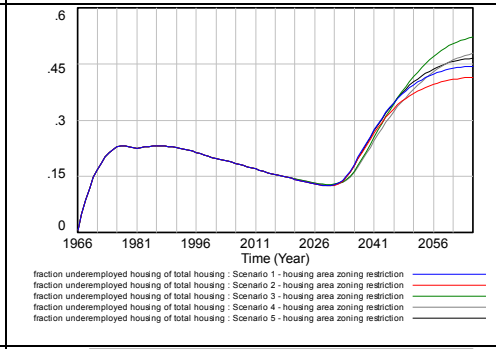
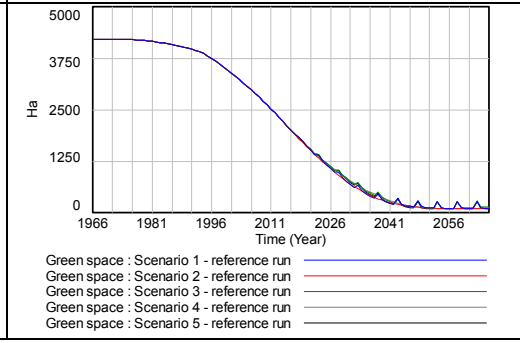
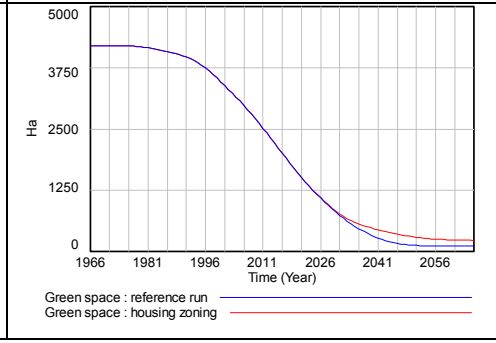
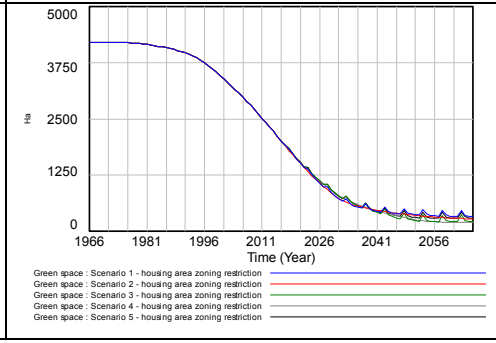
5.3.1 Housing zoning policy

Variable	**Specification**
housing area zoned *(reduction to 3500 Ha)*	20040-STEP(16540,2017)

KPI	Reference run	Reference vs. policy run	Housing area zoning restriction (3500 Ha)
Land fraction occupied			
New enterprise			

Road length			
Road congestion			
Population			

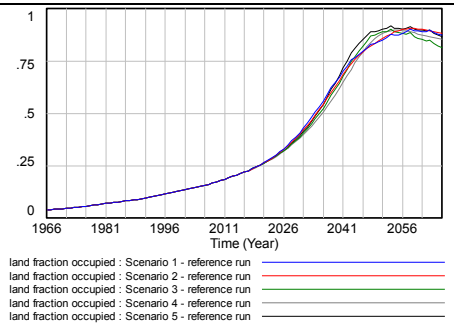
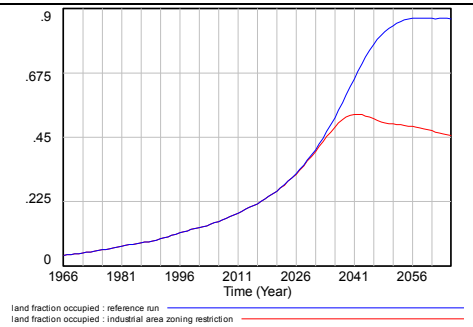
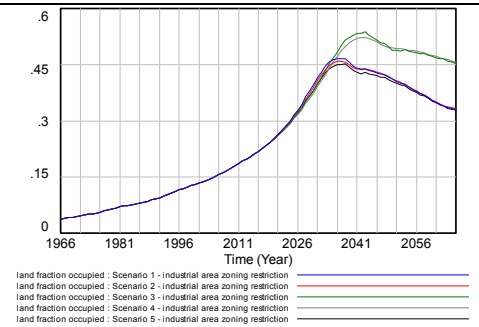
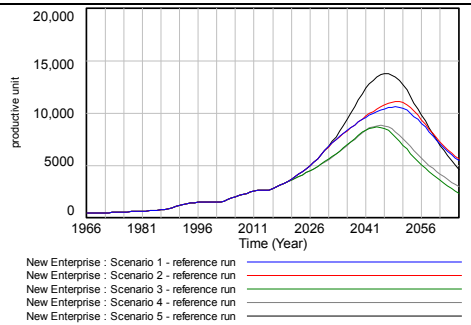
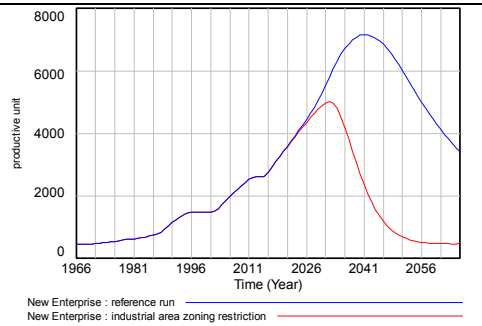
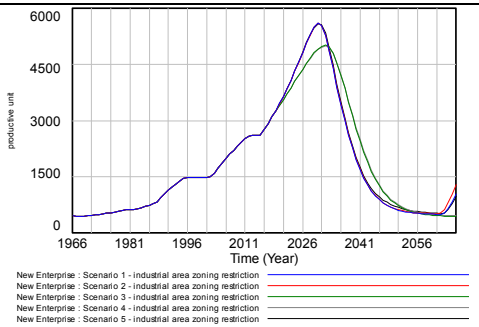
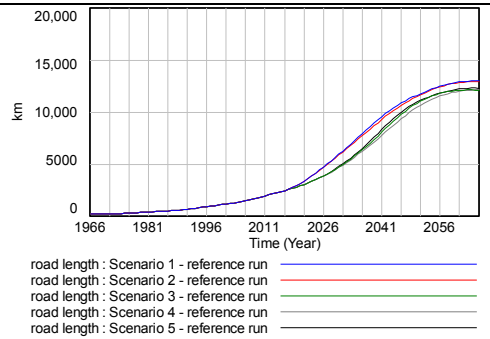
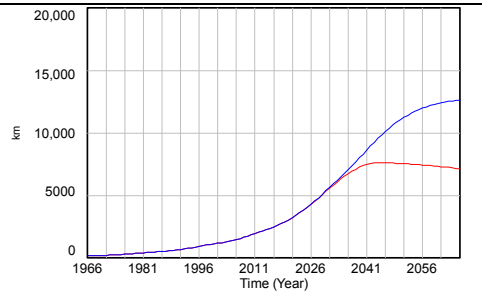
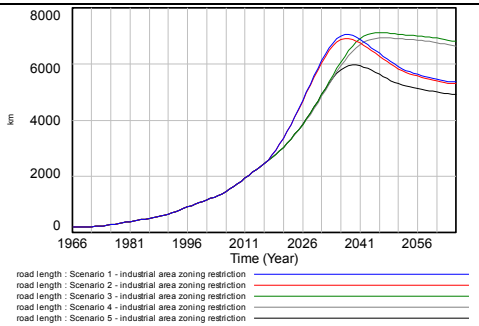
Fraction underemployed of population			
Housing units total			
Informally housed			

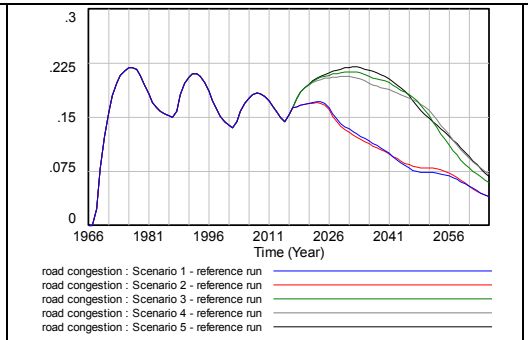
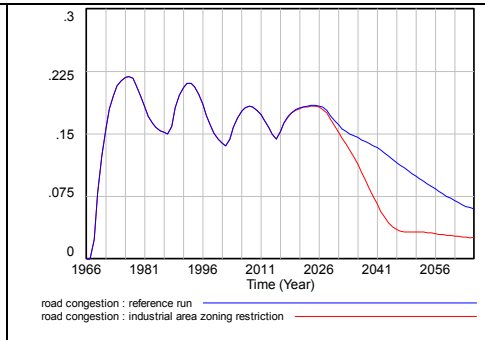
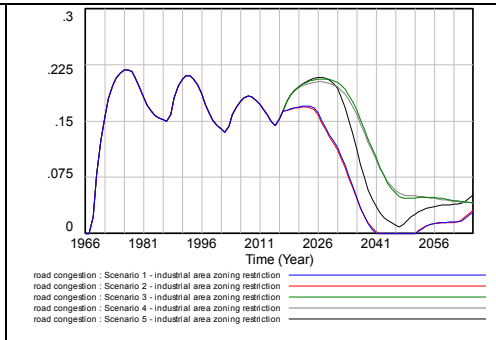
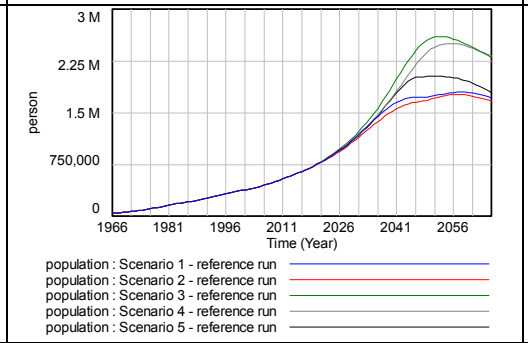
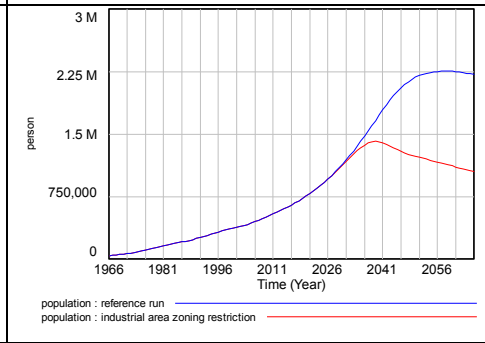
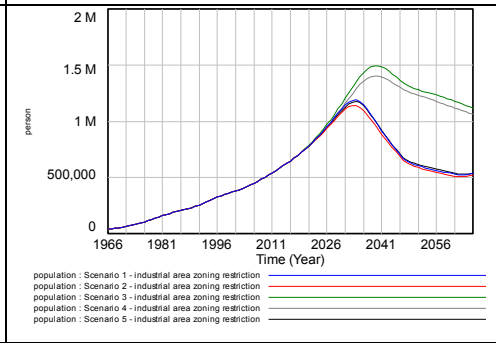
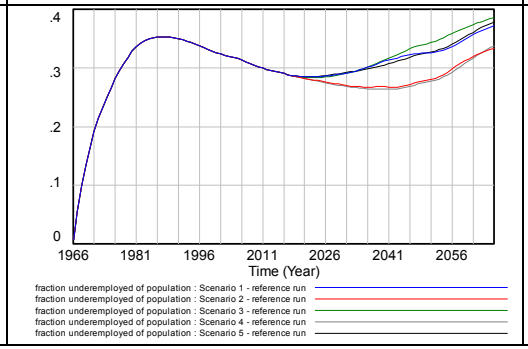
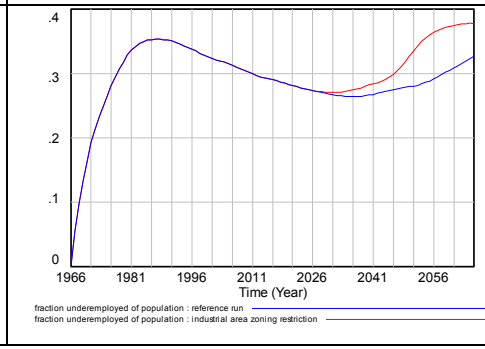
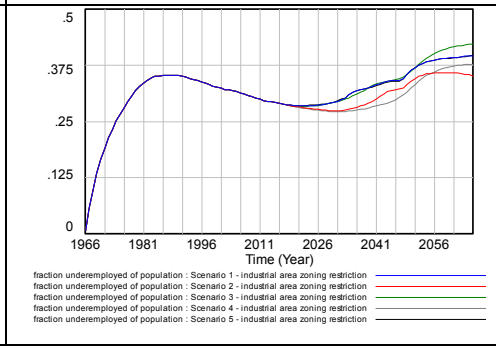
Informally settled/population ratio			
Fraction underemployed housing of total housing			
Green space			

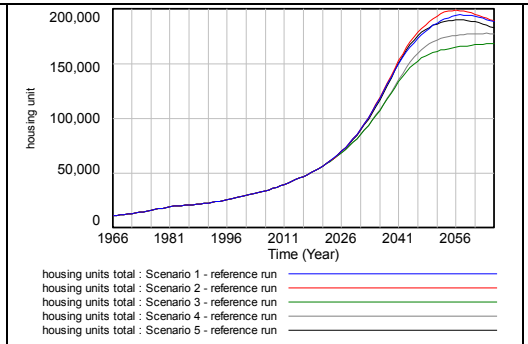
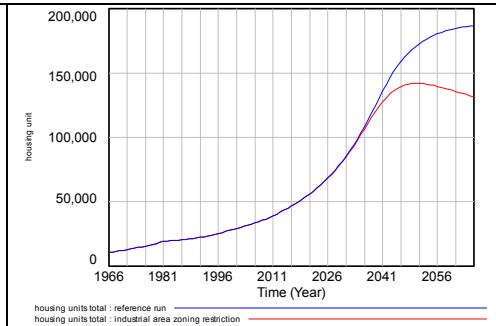
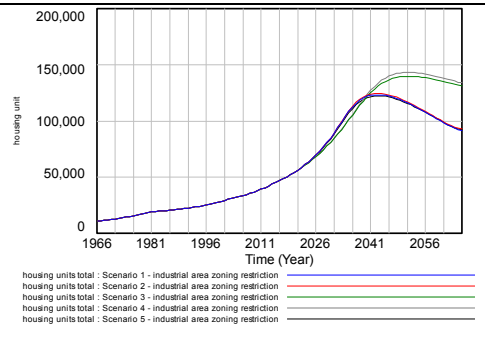
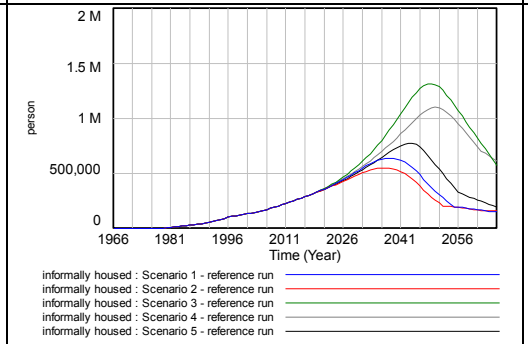
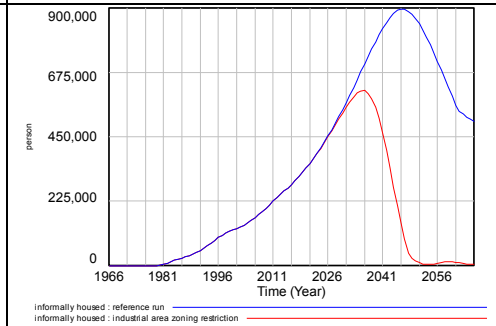
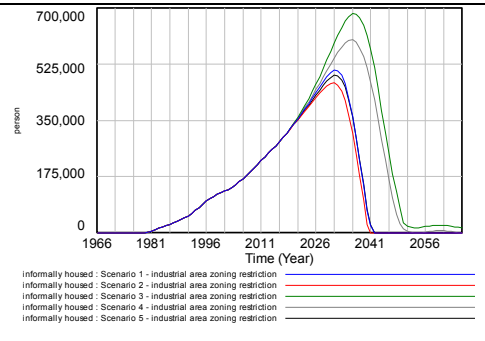
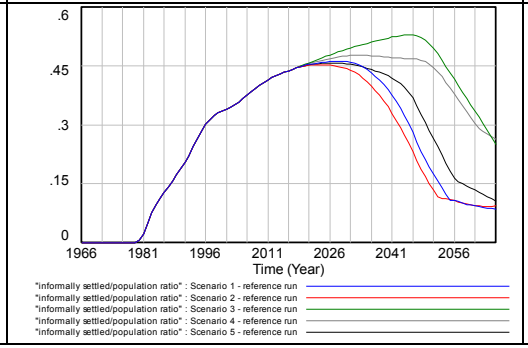
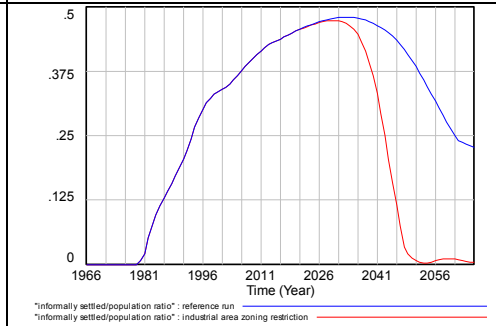
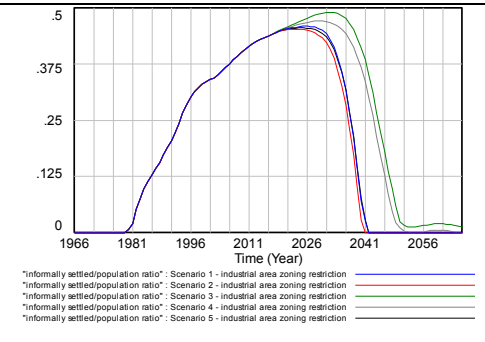
5.3.2 Industrial zoning policy

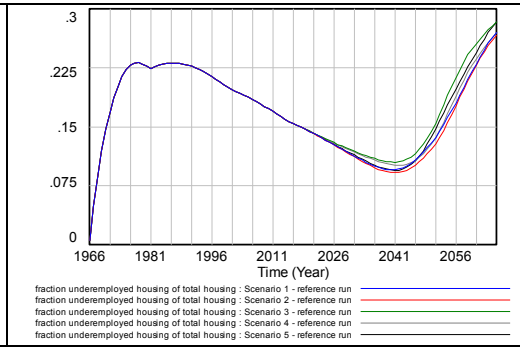
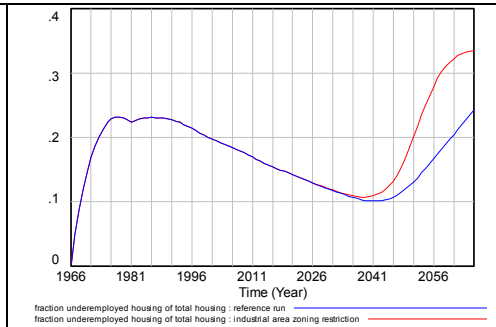
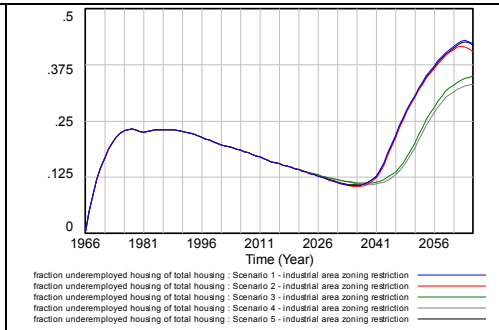
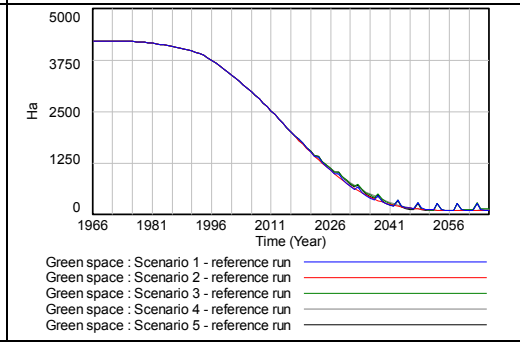
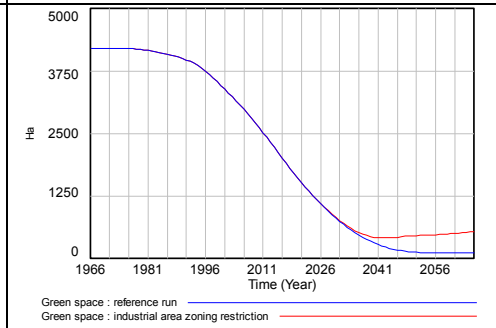
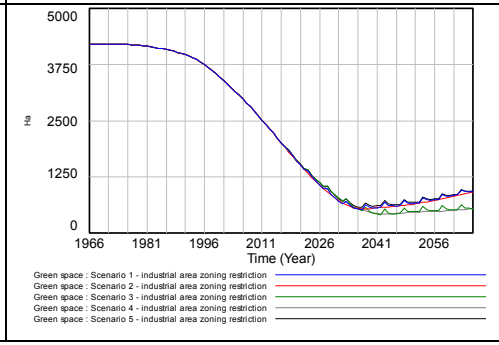
Variable	**Specification**
industrial area zoned *(reduction to 350 Ha)*	20040-STEP(19040,2017)

industrial area zoning restriction

KPI	Reference run	Reference vs. policy run	Industrial area zoning restriction (1000 Ha)
Land fraction occupied			
New enterprise			
Road length			

Road congestion			
Population			
Fraction underemployed of population			

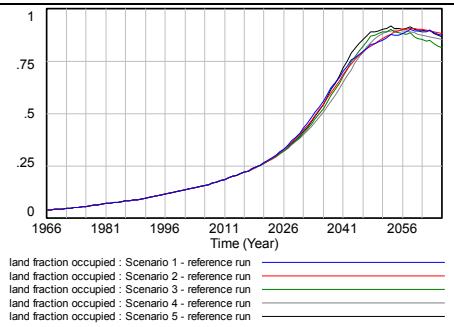
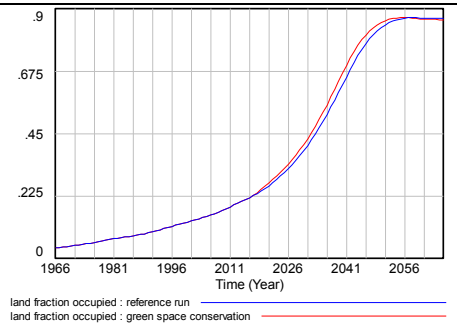
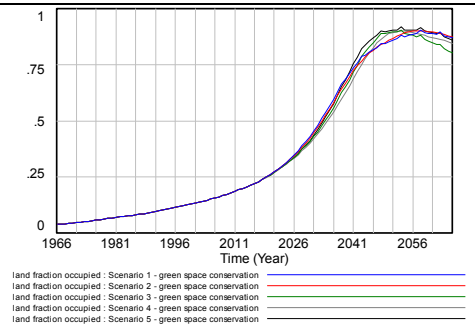
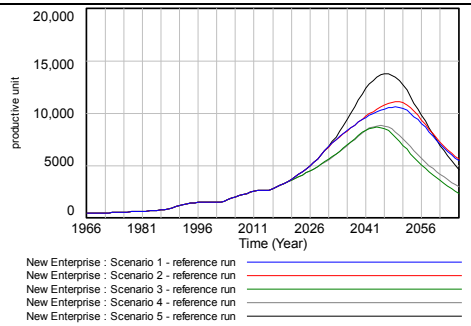
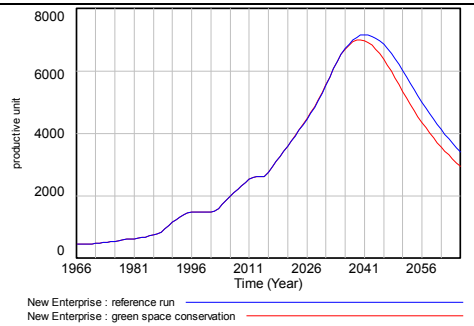
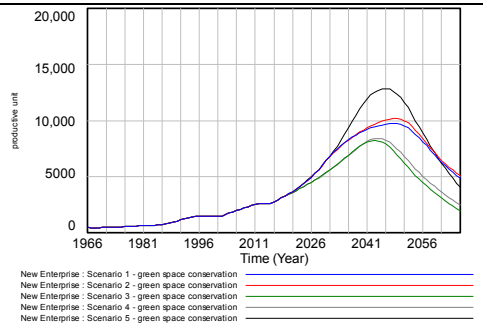
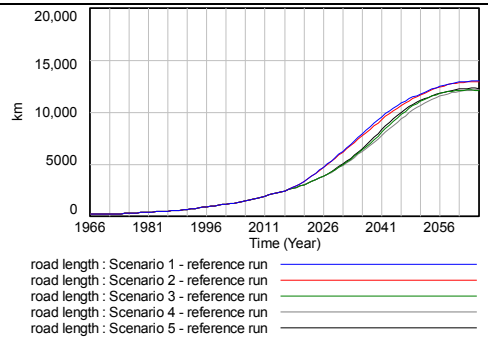
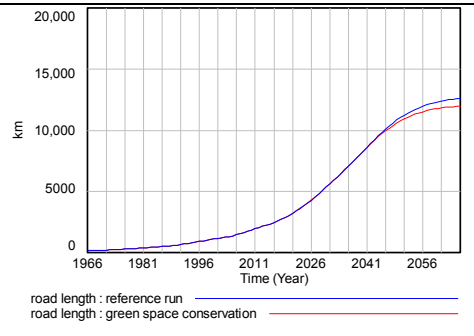
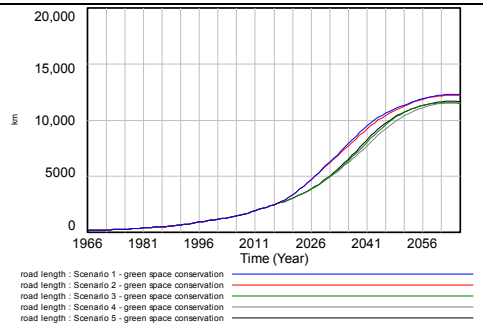
Housing units total			
Informally housed			
Informally settled/population ratio			

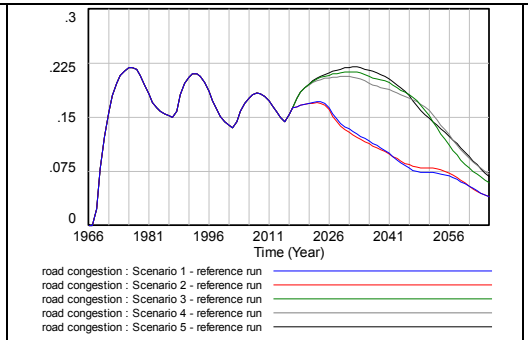
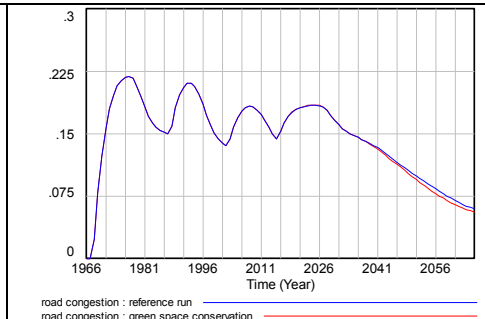
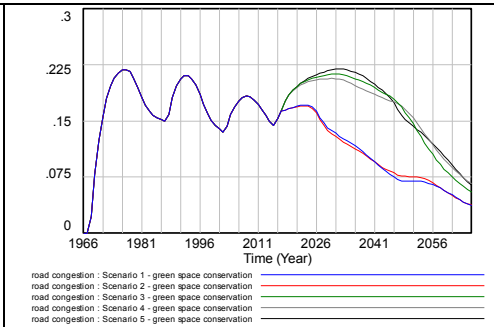
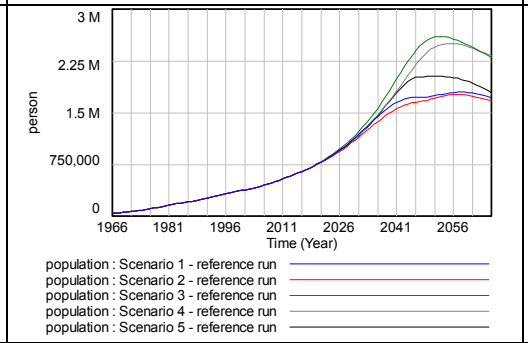
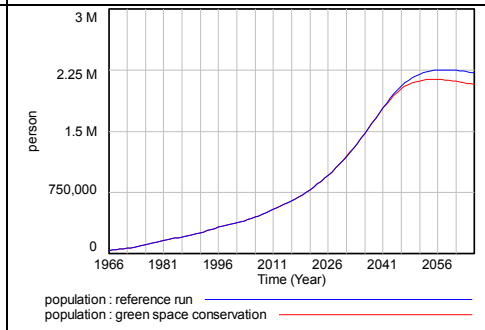
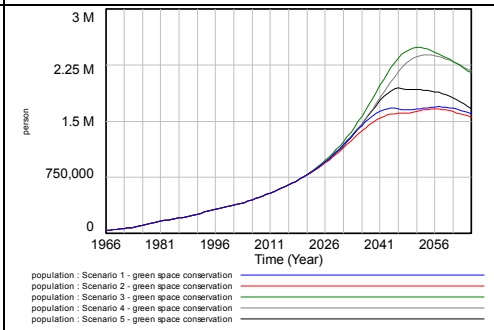
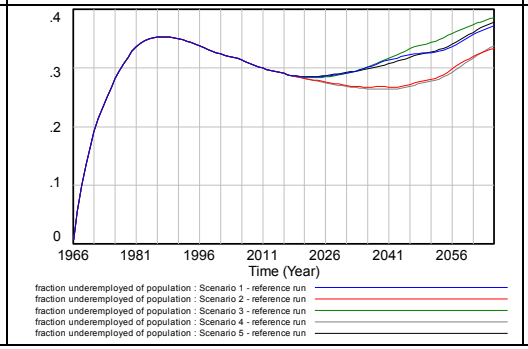
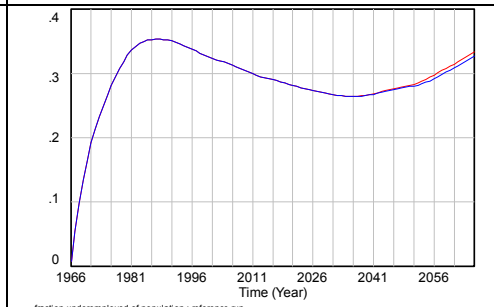
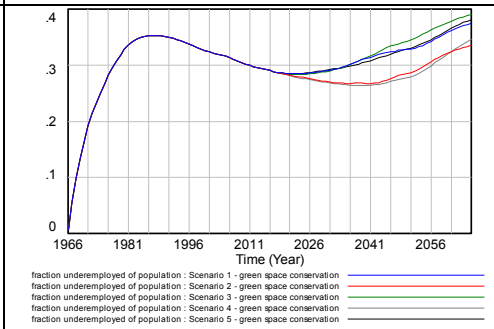
Fraction underemployed housing of total housing			
Green space			

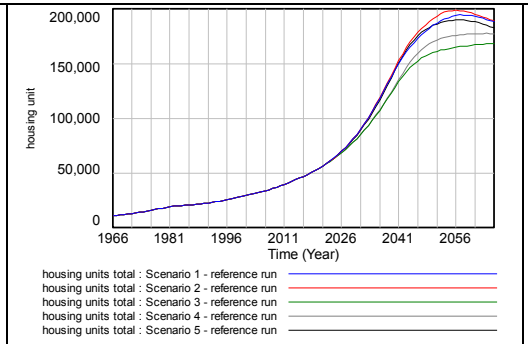
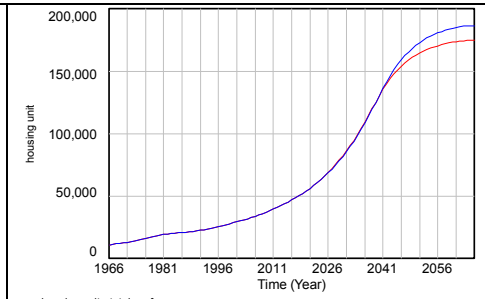
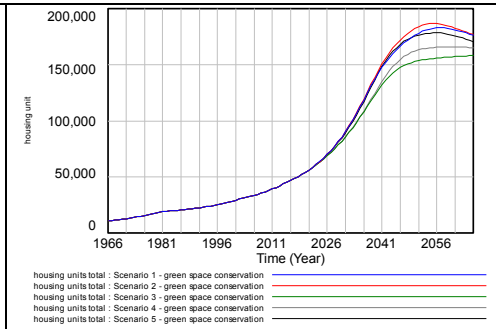
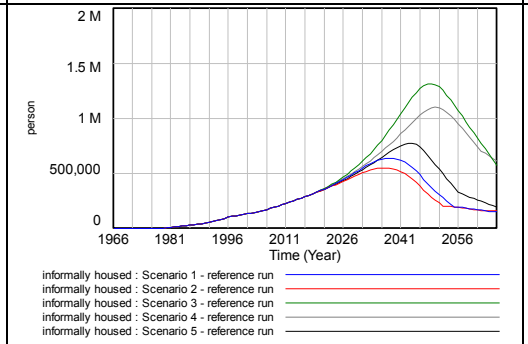
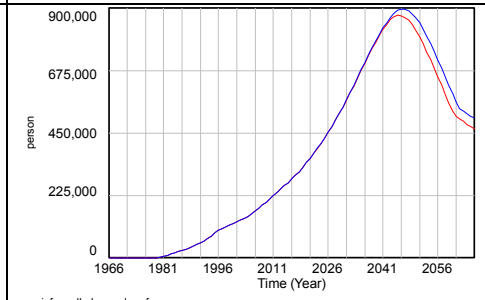
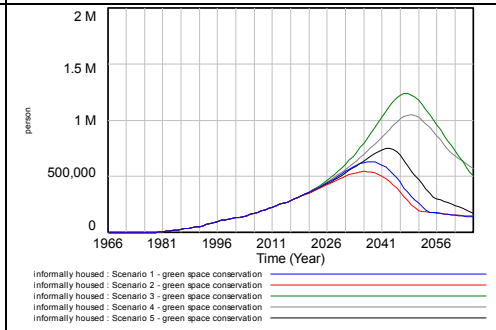
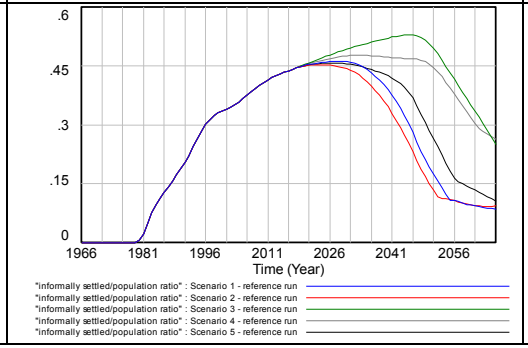
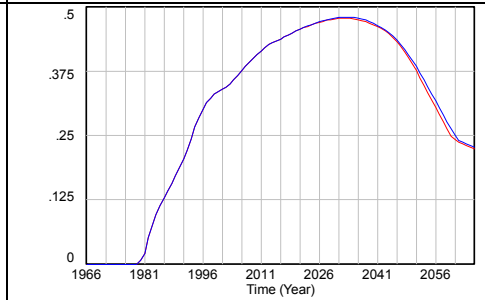
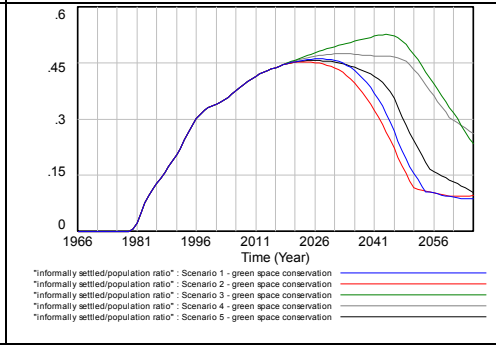
5.3.3 Green space protection/conservation

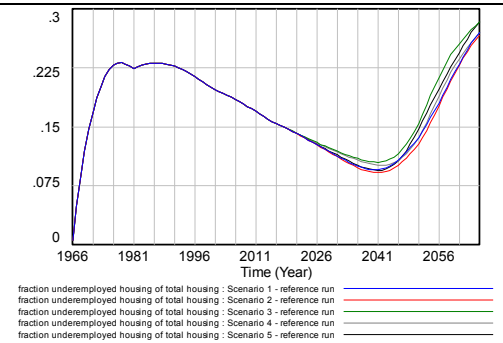
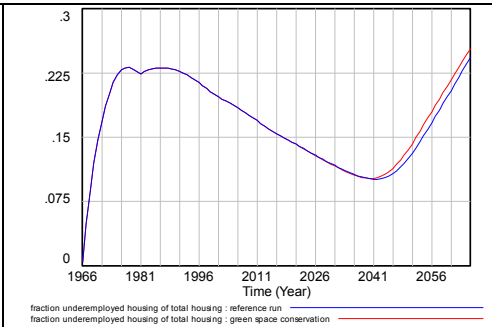
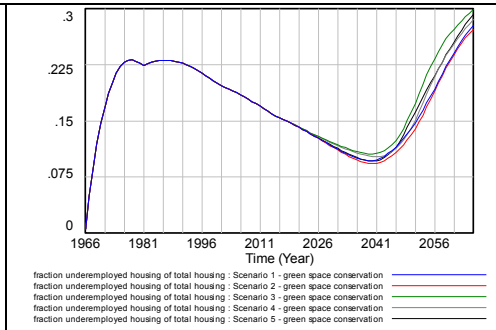
Variable	**Specification**
Min green space (Ha)	50 + 950

KPI	Reference run	Reference vs. policy run	Green space conservation (1000 Ha)

Land fraction occupied			
New enterprise			
Road length			

Road congestion			
Population			
Fraction underemployed of population			

Housing units total			
Informally housed			
Informally settled/population ratio			

Fraction underemployed housing of total housing			
Green space	