Supporting policy analysis in the Dutch rail sector using System Dynamics approach

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With a sizeable expected growth of demand for rail transport in the Netherlands the coming decades, and limited resources for expansion of the rail network, intensified utilization of the infrastructure is to be expected. To adequately manage this growth appropriate tools for policy analysis are needed. Because of the unstructuredness of many problems in the rail sector and decision-making in a network type environment additional scrutiny is placed on these tools. By performing a modelling study into the interrelations of modal split, mobility and operations using System Dynamics, the possibilities and pitfalls of using this method for policy analysis in Dutch rail system have been explored. Although classical policy analysis has proven to be possible, modelling the operational part of the system has proven challenging. Alternative usages of System Dynamics for enhancing policy analysis, by improving understanding about the complex dynamic behaviour of the system are suggested.

Keywords: Rail System, Netherlands, Policy Analysis, System Dynamics

1. Introduction

The Netherlands has one of the heaviest utilized railway networks in the EU (CBS, 2009). In 2006, trains travelled over 135 million kilometres on the network. This traffic is mainly generated by passenger trains, which account for 80% of all reserved train paths. Combined passenger and freight train paths totals around 2.5 million each year (ProRail, 2011). All this is done on a network which was in 2004, only 2,796 km long, and which consisted of 6,517 km of track. The Dutch railway system is very complex, due to its heavy utilization and network design (ECMT, 2005), organizational and institutional arrangements (Tijdelijke Commissie Onderhoud en Innovatie Spoor, 2012), and number of stakeholders (ProRail, 2011).

In the Netherlands a lot of train movements take place on a relatively small network. In 2006 the Netherlands had the highest number of trains per kilometre of track in the EU (CBS, 2009). Additionally the structure of the rail network in the Netherlands adds to the overall complexity. The network can best be described as having a polynuclear structure, with several cores. This creates a criss-cross of traffic between and inside agglomerations (Nijman, 2012a, 2012b). To complicate matters more, both local and intercity trains operate on the same network. They must share the same infrastructure, complicating operations further. First of all, local problems can spread through the network because of local and intercity trains influencing each other. Secondly local trains have a lower average speed than intercity trains. Speed differences on a railway track severely influence the capacity of the track.

The coming decade a further growth of traffic is expected, and the rail infrastructure manager of the Netherlands, ProRail, has set itself the goal to increase the capacity of the network with 50% in 2020 (ProRail, 2012). With only limited financial resources and an already complex network the goal is to achieve this increase in capacity by more efficient planning and scheduling of railway traffic (MinlenM, 2011). Measures to increase capacity through heavier utilization of the network can harm the robustness of the network. Both may be achieved, but at a very high cost. The real challenge therefore is striking a new balance between capacity, costs and robustness.

Policy Analysis and the resulting decision making process takes place in an environment which can
be described as a network. The rail sector in the Netherlands has a separation of infrastructure manager and train operators. These organizations are independent of the Ministry of Transport, although the ministry has the tools and obligation to steer the sector.

The Dutch railway system is complex in many ways: whether you look at the technical infrastructure, organizational layout, operational planning, (number of) actors involved, goals to be reached or decisions to be made; all of these are complex in itself. Due to the high interdependence of all these parts the overall picture is even more complicated, and in this environment sound decisions have to be made.

Further muddying the waters is the fact that when looking at the policy problems facing the railway system, these problems can only be described as unstructured. Unstructured problems are defined as problems where there is no consensus on values and neither a consensus on knowledge (de Bruijn & ten Heuvelhof, 2002). Although the main actors are all invested in delivering the best train services possible, the definition of this value ‘best’ may vary. Any policy will be a trade-off between these values, and all of these values will be weighted differently by the actors.

For analysing and designing policies in this complex system the System Dynamics (SD) methodology can be used. It supports not only the design of policies themselves (Wolstenholme, 1989), but can also help understand the complexity of a system. Additionally it can also be used in a multi actor environment to communicate about findings and for collaborative analysis and design. Enhancing learning about complex dynamics systems is one of SDs major purposes (Sterman, 2001). This can be done by qualitative analysis of models, but also by using simulation to show users the effects of their decisions. Feedback is not only used in the models themselves, but is the red line that runs through the methodology.

2. Approach

The goal of this research was to explore the possibilities of System Dynamics to better understand the complexity of the Dutch railway system, and the effects of policies on the it. This understanding will have to used and communicated in a complex multi-actor setting.

The use of SD modelling in the rail sector has mostly been limited to the modelling of vehicles and vehicle interactions. In the last three decades three studies have been performed into the dynamic effects of the overall railway system. These focussed on: the effect of maintenance on performance (Gottschalk, 1983); strategic management with a focus on competitiveness with regard to maintenance and investment strategies (Schmidt, 1989); a strategic planning model (Homer, Keane, Lukiantseva, & Bell, 1999); and a study of the performance of the Indonesian railways (Lubis, Pamungkas, & Tasrif, 2005).

In light of the limited literature on SD for policy analysis in the rail sector, an SD simulation study was undertaken to experience first-hand the pros and cons of using SD for policy analysis in the rail sector. This was done by modelling the relation between traveller choice of transport modes and the effect this has on the operations on the network. The SD approach to this problem facilitated a structured approach to system analysis, identification of the feedback structure of the modelled system, evaluation of uncertainty and identification of directions for further policy analysis.

The model itself, the results of qualitative and quantitative analysis, the modelling process and the results of validation and verification have been used to evaluate the usability of SD for policy analysis in this specific case. Recommendations will be given on how to use the SD methodology most effectively for policy analysis in the Dutch rail sector.

The article is structured in sections as follows. Section 3 describes the conceptual model of the railway system and the most important concepts that have been included in it. In section 4 the implementation of the model is discussed as well as validation and verification of it. Section 5 discusses the results of simulation and further quantitative analysis. Section 6 discusses the validity of the of the model in the context of policy analysis in a network environment. In section 7
conclusion will be drawn and recommendations for use of SD in the Dutch rail sector will be given.

3. System Conceptualization
In the model that describes the relations between the choice of travel mode and the operations on the rail network, three distinct subsystems can be found: one that describes the modal split, demand for mobility and operations. These subsystems influence each other as depicted in Figure 1. Each of them will be described shortly. After that a distinction between trip types will be made. Finally the overall feedback structure will be presented.

![Figure 1: General depiction of interrelations between the three subsystems.](image)

**Figure 1: General depiction of interrelations between the three subsystems.**

**Modal split**
Given the distance of trips performed by train in the Netherlands, the car is often the only viable alternative. In the model the modal split is therefore represents the ratio between train and car usage for a certain trip type.

When a traveller ones to undertake a trip, the modes which are available can be seen as products that satisfy this need to a certain degree. The characteristics of a product provides benefits and satisfies needs to varying degrees (Kotler & Armstrong, 2001). Rating of the service of train service in the Netherlands has revealed ten unique dimension on which passengers rate a trip (Brons & Rietveld, 2009). The three most prominent characteristics on which trips are rated have are: travel time reliability, travel comfort and the price-quality ratio.

The characteristics are operationalized by: determining the monetary cost of a trip; the valuation of travel time; and the cost of unreliability. The monetary cost is determined for a whole trip, including if applicable parking costs or cost for access and egress to stations. The valuation of travel time is modelled using the disutility travellers experience during a trip, which relates the time spent traveling and the comfort of different part of the trip (Vaessens, Van Hagen, & Exel, 2008; Wardman, 2004). The costs of unreliability in a trip are modelled by determining the rescheduling costs, which are the costs of early and late arrival due to unreliability, and takes into account the tendency of travellers to leave early in order to prevent arriving late at their destination (Brons, 2005). The higher the unreliability, the higher the rescheduling costs will be.

**Mobility**
Of the total amount of kilometres travelled in the Netherlands, only a small amount is done by train. Based on the feasibility of making a trip by train three groups can be distinct: the train is unfeasible (car captives); the train is an option; the train is the only possibility (train captives) (Van Hagen, 2011).

Of the trips in which the train is an option, about 9.5% is actually done by train. The distribution of mobility by feasibility is shown in Figure 2.

![Figure 2: Distribution of mobility in km per year. The trips can either not be done by train (red), possibly be done by train (yellow) or only be done by train (green). Adapted from: Van Hagen (2011)](image)

**Operations**
The demand for transport by rail leads to a capacity requirement which must be fulfilled by train services on the rail network. Additional equipment will lead to an increase of incidents related to equipment. Incidents related to infrastructure are influenced by the quality of the infrastructure. Besides equipment of infrastructure ‘other’ type of incidents are distinguished, that are
often caused by passengers, personnel or third parties. The time needed to recover from an incident and the frequency of the train service determine how many trains are affected by an incident.

Besides these delays that are directly caused by incidents, disruptions will also lead to a spread of delays further through the network, caused by interactions between equipment, personnel or infrastructure. The amount of secondary delays will increase when the utilization (complexity) of the network increases.

**Distinction of Trip Types**
The rail network and road network in the Netherlands both have a dual function. They are used to transport people within agglomerations, as well as between agglomerations. For the rail network this means, different types of services have to be offered: local and intercity.

Different trips will have different characteristics. In a long train trip a transfer is for instance more likely than for a short trip. The effects of access and egress cost and time will relatively be higher for a short trip than for a long trip by train. The same is true for the parking costs of a car. Furthermore a trip can be undertaken with different purposes such as leisure or business.

In the model a distinction is made between trips performed during peak-hours and between short and long distance trips. This results in four trip types as displayed in Figure 3, each with their own set of characteristics, such as value of time.

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<th>Peak Long Distance</th>
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<td><strong>Peak Short Distance</strong></td>
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<td><strong>Off-peak Short Distance</strong></td>
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![Figure 3: The four types of trips in the model.](image)

**Feedback Structure**
Analysis of the feedback structure leads to the identification of seven unique feedback loops, as shown in Figure 4. The main conclusion that can be

![Figure 4: Feedback structure of the conceptual model.](image)
drawn from this causal model is that an increase of capacity through a higher frequency of train services will lead to a decrease of travel time and uncertainty about arrival, but will also complicate operations leading to an increase of delays.

4. Model Specification

Data on the valuation of travel time and reliability was mainly found in scientific articles. Extensive research on this subject has been performed in the United Kingdom (Wardman, 2001, 2004) and the Netherlands (Tseng, Verhoef, & Rietveld, 2012). Values for variables regarding operations were often found and derived from reports by Dutch Rail (NS) and the network manager (ProRail) that contained information on the network and operations.

Most of the data on mobility was derived from ‘Onderzoek Verplaatsingen in Nederland 2011’, performed by Statistics Netherlands (CBS, 2011). This dataset provides information on the daily mobility of the Dutch population and contains responses of 37,754 person. The total dataset contains 127,410 cases which relate to parts of a trip. For these cases 150 variables are defined, which relate to characteristics about household, trip purpose, mode of transportation, departure, arrival, etc. For the purpose of this research this dataset was reduced to trips of interest: namely where car or train were the main mode of transportations. These trips were then based categorized in four groups, reflecting the four trip types.

Modal split

For the modal split the cost component was implemented using a simple summation of costs such as ticket price, parking and fuel costs. The value of time (VOT) was determined by the VOT of the parts of a trip. A car trip consists of a single part (the drive), but a train trip consists of time for access and egress, waiting, transferring and in vehicle time. The costs of unreliability were determined by estimating the average early and late arrival of trips, based on a standardised log-normal distribution which is scaled based on the percentage of trip arriving on time and the time at which 95% of the travellers have arrived.

Monetary costs, time value of the trip and the costs of unreliability were traded-off based on a per characteristic basis train vs. car. A non-linear function was used in which large difference between car and train per component have a larger impact than small differences. This equation is presented in Equation 1.

\[
\text{modal split} = \sum_{i \in S} w_i \cdot \frac{1}{q_{\text{train}}} \cdot \left(\frac{1}{q_{\text{train}}} + \frac{1}{q_{\text{car}}}\right) \quad \text{Equation 1}
\]

With \( S = \{\text{costs, time value, reliability}\} \)

Mobility

The total demand for train transport was determined by the effect of the modal split on the number of choice passengers and the mobility of train captives. To reflect the inertia in travel choice (Chorus & Dellaert, 2009) and the assumption that a change in travel choice is caused by changes in the environment (Van Dalen, 2012), a delay in change from choice car to choice train traveller and vice versa was implemented.

Operations

For the operation the effect of incidents on the on the operations was estimated based on the causal model describing the links between incidents, first and secondary delays.

Validation and verification

Validation and verification cannot prove that a model is correct and possible for all possible scenarios, but it can provide evidence (and built trust) that the model is sufficiently accurate for its intended use (Thacker et al., 2004). The model has been evaluated using a wide array of tests as suggested by Sterman (2000) and Wolstenholme (1989). The tests performed verified the adequacy of structure, boundaries, implementation and model results.

The structure of the model and the adequacy of the model have been evaluated during separate discussions about it with two system experts. Dimensional consistency of the model and equations was verified, partial model testing was used to test and correct model parts. The presence of integration errors in the numerical results was disproved. Finally an extensive sensitivity analysis
was performed on variables and model parts, to
evaluate the sensitivity of model results to these
parameters and determine the effect of
uncertainty in the model. Because of the high
uncertainty in the model, variables and structure,
the model is not suitable for prediction or
forecasting. The sensitivity analysis was the main
quantitative result of the model. The outcome of
this analysis is discussed in the next section.

5. Simulation Results
The univariate sensitivity analysis performed
allows for a structured comparison of the model
outcomes. When the model is sensitive to a
variable or component of the system this can lead
to two conclusions, or a combination thereof: (1)
That variable or component of the system can be
used to design a high leverage policy; (2) Because
of the impact of this variable or component,
uncertainty surrounding it must be reduced in
order to improve the validity of the model.
Whether conclusion one or two applies will depend
on whether this component or variable can be
influenced by stakeholders in the system and how
much is known about this component, qualitatively
and quantitatively.

EXTERNAL FACTORS: QUALITY CAR TRIP
IMPORTANT FOR ATTRACTIVENESS TRAIN
The external factors are variables that are
determined outside the railway system an on
which the stakeholders in the system have little to
no direct influence. For most trips the choice is
between taking the train or the car. It is therefore
no surprise that characteristics of the car trip are
important for the usage of the train service.

Raise of speed limit leads to increased competition
for the train outside rush hour for long distance trips
Increase of the average car speed will lead to
increased competition for the train, especially on
long distance trips performed outside rush hour.
Since there will be little to no traffic jams outside
rush hour, the main cause for this would be a raise
of the speed limit.

Improvements of predictability of car arrival times
will lead to reduced train usage
The other major car related factor that affects the
modal split is the reliability of arrival time. If this
reliability increases further this will negatively
affect the portion of train users for all trip types.
Improvements of the road networks, local, regional
or national, that lead to an improvement the
predictability of a car trip will negatively influence
train usage.

Time value of access and egress important for short
distance trips
A change in the value of time of access and egress
costs will lead only lead to a significant
improvement of short distance train trips. This can
be explained by the fact that in a short distance
trip the ratio of access and egress time to in train
time is much higher than for longer trips.

RELIABILITY IMPORTANT FACTOR IN MODAL
CHOICE COMMUTE
Reschuling costs during peak hours have the
most impact on the total kilometres travelled by
train in the sensitivity analysis. Additionally the
modal split and passenger kilometres travelled by
train is also sensitive to the predictability of train
arrival times. The reliability ratio of the car
compared to the train is too high outside peak
hours to have effect, but during peak hours the
train is a better match. Improvements of reliability
will therefor mostly lead to increased usage of the
train service during peak hours.

EFFECTS OF INCREASED DEMAND: MORE TRAINS
LEAD TO HIGHER AVERAGE DELAY
Analysis of the feedback structure of the
contceptual model in Section 3 already suggested
that an increase in demand will have an impact on
the performance of the rail network due to
increased complexity of operations of the
frequency of train services was increased. This was
confirmed by the sensitivity analysis.

Growth of mobility leads to more train usage at the
cost of more delays
The growth of mobility leads to an increased usage
of train for transport, but this is reflected in and
intensified utilization of the rail infrastructure. The
increase of the number of trains will lead to more
incidents, and increased spread of delays. This will lead to an increase of the average delay of trains.

**Infra reliability and repair time major influence on average delay**

The reliability of the infrastructure and the time needed to restore it in case of incidents is a major factor in determining the average delay. This is becoming more and more important when the frequency of trains is increased because it affects more trains and spreads more through the system.

TRADE-OFF FUNCTION VERY SENSITIVE TO VALUATION OF DIFFERENCE BETWEEN QUALITY ASPECTS

The overall model performance is very sensitive to the parameters of the trade-off function. This function is also one of the softest parts in the system. It represents an accumulation of human behaviour in a very generalized way. The way the trade-off of quality aspects is modelled can be seen as the most important part of the system in terms of influence in has on model outcomes and because uncertainty about how the real-world decisions allow for different trade-off functions.

6. Value and Validity of the Model Analysis in a Complex Dynamic Network

Because of the separation of operations, management and oversight in the Dutch railway system, decision making will require the cooperation of stakeholders. The policy analysis and decision making process become even more complex when taking the institutional arrangements into account. None of the stakeholders is able to impose their own will upon the others. Any collective decision will therefore be the result of a process of consultation and negotiation, which allow actors to use all sort of strategies to maximize their influence on the final decision (de Bruijn & ten Heuvelhof, 2002).

The decision-making also takes place in an environment that corresponds to the definition of a network by de Bruijn and ten Heuvelhof (2002): the stakeholders are interdependent, unable to impose their own problem definition, aims and information on others and not able to make an unilateral decision. They also list four main reasons why a policy analysis is not authoritative in a network environment:

1. The quality of the analysis;
2. Stakeholders do not understand the analysis;
3. Stakeholders do not commit themselves to the way the analysis is carried out and therefore do not commit to the results;
4. The analysis does not match the dynamic of the game playing during the decision-making process.

The main remedy for the first reasons is improvement of the analysis. For the other reasons the main remedy involves improving communication about the analysis and improving interaction between the analysts and the stakeholders. In fact, inadequate communication between policy analysts and policy actors is one of the reasons for the limited impact that policy analysis on policy making has (Geurts & Joldersma, 2001).

In the following paragraphs methods will be discussed that can improve the validity of the analysis and the value of it to the decision making process. This will be done by discussing the ways the model can be improved, what knowledge gaps should be addressed, and how policy actors can be involved.

**IMPROVE THE MODEL**

Improving the model can be achieved by expanding the model boundaries and adding additional components to the model structure. Adding of these components can help by improving the quality of the analysis because of the inclusion of additional feedback loops. Inclusion of concepts and models that are not yet in the model, that are deemed important by stakeholders, can also help convince them of the validity of the model.

Also during development of the model some concepts were implemented using the SD methodology that would be easier to represent in a different type of model. This resulted in a very complex structure of that part of the model. A hybrid combination of multiple model types could help improve the validity of the model by providing
more accurate results, but also reducing the complexity of the SD model.

An example of this is the calculation of unreliability of arrival times in a chain of transport modes: the effect of the unreliability of the arrival time of a train was used to determine the unreliability of a trip. Due to limitations of the SD approach and the simulation package, this was modelled using a single arrival distribution which values would be determined based on the chance of making a connection. This resulted in a distribution that would have the same properties of the distribution of arrival times for a trip, but not exactly represent it. During development of the SD model, a very simple model of arrival distribution was developed in an Excel spreadsheet. This model was used to calibrate a generalized version of the arrival distribution in the SD model. The spreadsheet model however did represent the actual distribution for a trip under specific conditions more naturally than the one in the SD model. It could however not be directly used in the SD simulation because the conditions would change over time. Implementing the simulation model is a package that would allow the import and export of values during simulation and the execution of other programs would allow the coupling of the model for policy analysis to specific and detailed models that could better represent the operational effects of policies.

RESEARCH KNOWLEDGE GAPS

During the modelling process knowledge gaps where encountered that limited the validity of parts of the model. Additional research into the these specific areas is required before the model can be improved to better reflect the real world system and thus improve the validity and authority of the model.

Trade-off Function

During sensitivity testing of the model it was found that the model results were very sensitive to the trade-off function itself, as well as the aspect of how heavily large difference are weighted. To improve the validity of the model it is suggested that more research is performed in determining which kind of trade-off function is most appropriate for the model. This trade-off function would have to take into account the modularity of the model, which supports adding any finite number of trade-off aspects by trading off the train to car values per quality aspect, to allow a weighted averaging regardless of the unit the quality aspect is measured in.

Effect of Utilization on Reliability

In the model increased utilization of the infrastructure results in an increase of delays because incidents affect more trains and because of smaller buffer times they spread more easily through the system. The effect of increased utilization of the network was not linked to an increase in unreliability of the arrival times of trains. The sensitivity analysis of the simulation model revealed that the model results were significantly influenced by the reliability of arrival times. Although the effects of unreliability trains services on customer satisfaction has been focus of many studies, quantification of the effect of operational aspects on the reliability of arrival times has not. A statistical study of the operational results of rail networks or a simulation study of such a system could improve the quantitative insight in this relation.

Trip Data

The parameters that were used for description of different trip types were extracted from the OVIN database (CBS, 2011). Most of the trips of the database concerned car travel, and although the results were weighted for the frequency of trip types this posed some problems during implementation. For example the number of long distance trips was very limited, which may result in unreliable averages for the trip types. Furthermore some data such as the average speed had to be calculated from the data based on departure and arrival times and the distance travelled. The results of the model could be improved if more specific and reliable data was gathered tailored to the data needs of the current model.

INVOLVE POLICY ACTORS

To improve the authority of a policy analysis, resulting in trust in and acceptance of the results, interaction and communication between the analyst and the stakeholders is very important. Furthermore, most of the insight in a complex
system is generated in the modelling process itself. Involving stakeholders can thus not only result in increased acceptance of the system, but also in enhancing the understanding of the actual decision-makers in the system.

In participatory policy analysis the focus is on the network perspective in policy making. It focuses on improving the process of communication between the policy analyst and the stakeholders on the network. The main goals of this process is not on providing an analysis of policies options, but on increasing the problem solving capacities of the stakeholders. It is directed at improving as well as integrating the mental models of different actors in a policy network (Geurts & Joldersma, 2001).

Two common methods for participatory policy analysis in System Dynamics literature are collaborative modelling and gaming. Collaborative modelling focuses on integrating divided or subjective knowledge, different views and values, mediation and the generation of a shared system view. Gaming focuses on improving the understanding of participants of the relation between the structure and the dynamics of the system by means of role-playing and interaction of stakeholders in a simulated environment (Geurts & Joldersma, 2001). It is often supported by or based on a simulation model.

Both participatory modelling an gaming allows the transfer of knowledge acquired during the analysis to be transferred to stakeholders while avoiding some of the validation problems encountered in a ‘classical’ policy analysis setting. With participatory modelling validity is less important, as long as there is agreement between participants regarding the relations in the model it satisfies its purpose. With gaming key learning concepts identified during the modelling process can still be transferred, in an environment where the results of a formal modelling process will and can be endlessly scrutinized. Participating in a game can also be considered less of an obstacle by participants than committing themselves to the results of a policy analysis. This does not prevent the game from being able to influence the perception of the system, problems and solutions.

7. Conclusions and Recommendations
Analysis of the feedback structure of the system has shown that a further growth of passenger transport can both lead to lower travel times and higher reliability of the rail network, but also to an increase of delays due to the added complexity of the operations.

This was confirmed by the quantitative analysis which has shown further that the reliability of infrastructure and the recovery time is major component in the size of this delay. Furthermore the effect of unreliability in a trip was quantified and was found to be of significant importance in determining the choice of travellers between the car or train. Finally it was found that characteristics of a car trip such as average speed and improvement of reliability of car travel was of significant effect on this choice. Improvements to the road network could therefore be a threat to the competitiveness of the train.

Because of network type of decision making surrounding policy design for the Dutch rail network, the validity, trust and authority of a policy analysis is very important. Because of the complexity of the system, unstructuredness of the problems and different stakeholders, performing an authoritative and acceptable policy analysis is difficult. The modelling process undertaken for this research has shown that in general System Dynamics can be valuable and is up to this task, but that for modelling part of the operational aspect of the system it is not the most suitable method.

This problem can be handled in three different ways: first as was down in this research, relations can be simplified and represented on a higher level of aggregation. Second the relations can be represented and estimated by using additional methods such intensive modelling and validation supported by experts, performing additional research to uncover empirical evidence to support these relations or perform additional simulation studies to support them. Thirdly more appropriate models or simulation could be coupled to the SD model to better represent these relations.

The high requirements for validity and acceptance of the model, due to the unstructuredness of the problems and the network type decision making,
means that the first option is not viable. Simplification of the model would reduce the authority of the analysis and would give ample opportunity to criticize it. Performing additional research or developing additional models to support the SD model would be both costly and labour-intensive. The relative newness of System Dynamics for policy analysis in the rail sector in general, and in the Netherlands in specific might pose a problem to the willingness of making this investment.

Besides the classical usage of System Dynamics for policy analysis it can also be used in different ways, that would better fit with the problem, the environment wherein the policy analysis takes place, and be less costly while still staying true to the main purpose of System Dynamics: enhancing learning about complex dynamic systems. This leads to the following three recommendations for use of System Dynamics for policy analysis in the Dutch Rail Sector:

In the context of a single organization or department System Dynamics can be used as problem structuring tool. Modelling of the system has supported a guided search into concepts and interactions, leading to a formalization of the interactions and assumptions about the system. Qualitative analysis revealed important trade-offs and feedback in the system. Implementation of the model revealed knowledge gaps and the need for data essential for any analysis of the system. System Dynamics can be used to research other problems as well and lead to a comprehensive overview and better understanding of the workings of the system.

System Dynamics can be used as a simple and easy to use tool in a participatory modelling process. Participatory modelling can be used for the creation of a shared problem perception. The concept causal diagrams are easy to understand and use, but also allow for representation of complex system structure. They can be used to structure debate and better understand the effects of feedback. If such process would result in a shared system view, the conceptual model can than even be converted and simulated to allow quantitative analysis.

Because the needs for an authoritative analysis requires substantial research, development and validation of a model for classical policy analysis, this does not mean simpler, less substantiated models developed within one organization cannot be used in a multi actor environment. Many of the findings about the effects of feedback and the need for effective policies can also be represented in a game. This game can be developed based on a causal model, or be supported by a quantified simulation. Due to the nature of gaming the requirements for validity of the model will be less high. Important insights gained from an analysis, such as the importance of reliability in a train trip, can this way still be conveyed to policy makers.

References


