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Strategic sustainability assessment of rideshare and automated vehicles using the analytical hierarchy process (AHP)

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ABSTRACT

New mobility concepts such as Mobility as a Service (MaaS) are emerging as potential solutions to move people more sustainably in an increasingly urbanized world. Planning for this multi-modal mobility requires a whole system approach (STEEP - social, technical, economic, environmental, and political) to evaluate alternative future scenarios and address varied stakeholder concerns. A strategic planning tool was selected that can model alternative scenarios for how urban mobility systems may evolve over time. A sustainable mobility scorecard was defined, comprised of individual metrics generated from the tool's output. The Analytical Hierarchy Process (AHP) was selected and applied to generate stakeholder weightings from an online survey of U.S. transportation planning professionals. Those weightings were applied to the scorecard to demonstrate their influence on alternative planning outcomes. Results include the scorecard metrics assessed with the greatest relative importance to sustainability; increases in no car ownership, increases in the transit/walk/bike mode share especially in lower income populations, maintaining the average peak traffic speed (actual/posted), and reducing cars per capita. The resulting weighted scorecard, part of a strategic assessment methodology for mobility sustainability (SAMMS), is then used to evaluate four future planning scenarios with contrasting trends (socio-demographics, travel behavior, employment, land use, transport supply) for the greatest overall sustainable mobility outcome.

1. Introduction

Increasingly urgent sustainability challenges, such as continued urbanization around the world, impact the future of mobility. In this context, sustainable mobility is defined according to its aims (accessible, efficient, safe, and green) per the Sustainable Mobility for All (SuM4All) initiative (Gagnet, 2017). These mobility targets align with the United Nation's global sustainable development goals (The UN Sustainable Development Goals [WWW Document], 2024). New mobility concepts such as Mobility as a Service (MaaS) are emerging as potential solutions to move people more sustainably in this increasingly urbanized world. MaaS can be defined as the integration of various transport modes into a single service, accessible on demand, via a seamless digital planning and payment application. MaaS modes of transport may include current modes such as transit and rideshare as well as other projected options, such as automated taxis (Ho et al., 2020; Jang et al., 2021; Roukouni and Correia, 2020; Snelder et al., 2019). Studies have shown a potential reduction in the number of automobiles required to move an urban region's population, with corresponding improvements predicted for environmental impact if automated vehicles (AVs) emerge as part of mobility systems (Becker et al., 2020; Berge, 2019; Boesch et al., 2016; Burns et al., 2012; Crist & Martinez, 2018; Friedrich et al., 2018; Furtado, 2017; Luis & Petrik, 2017; Martínez, 2015; Petrik & Martinez, 2018). However, the limiting assumptions made by these studies highlight the difficulty of predicting how the complex interactions of user demographics and mode choice, vehicle automation, and governance

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models will impact the long-term sustainability of mobility for urban regions.

Previous research concluded that a whole system methodology could address the limiting assumptions and support strategic planning for adoption of emergent mobility concepts, such as rideshare and AVs (Muller et al., 2021). This prior research identified the elements of this methodology as: alternative mobility planning scenarios, an enhanced strategic-level mobility model, and a set of comprehensive whole system metrics using a STEEP (social, technical, economic, environmental, and political) approach (Schmidt et al., 2015; Szigeti et al., 2011). Note that a STEEP approach is consistent with the four aims of sustainable mobility identified above. Informed by this previous research, this paper defines this whole system methodology as a strategic assessment methodology for mobility sustainability (SAMMS).

To further develop the SAMMS whole system methodology, the Impacts 2050 model (Bradley et al., 2014) was selected because it models urban mobility at an aggregated, strategic level and addresses travel behavior driven by demographics, land use, and employment. The travel models in Impacts 2050 are based on statistical modeling of U.S. National Household Travel Survey (NHTS) data. In prior work, Impacts 2050 was enhanced for use in this whole system methodology (Muller et al., 2024). One enhancement included the addition of the rideshare mode to complement the choices of automobile, transit, and walk/bike modes already in the model. Another key enhancement was the integration of a model for the development and adoption of AV technology, based on an underlying S-curve adoption approach from work by (Nieuwenhuijsen et al., 2018). An urban mobility sustainability scorecard was then defined, based on STEEP factors and generated by the enhanced Impacts 2050. Engaging stakeholders is a best practice for strategic planning, especially as deployment scenarios for future mobility concepts are considered. As a result, one of the previous study's recommendations was to investigate how stakeholder weightings impact the sustainability scorecard to ensure that varied stakeholder concerns can be addressed during strategic transportation planning.

The objective of this research, building upon previous work (Muller et al., 2024), is to demonstrate the effect of stakeholder weightings on an urban mobility sustainable scorecard, including its use in the comparison of alternative mobility planning scenarios in a whole system model. Because of the multi-faceted, STEEP criteria for urban transportation systems, this scorecard assessment required the application of a multi-criteria decision analysis (MCDA) / multi-criteria decision-making (MCDM) methodology, such as the Analytical Hierarchy Process (AHP). A method is developed based on AHP to capture and apply the relative weightings of stakeholders to represent differing views on what metrics support the goal of a sustainable urban mobility system. Because of the relevant and unique subject matter expertise of U.S. transportation planning professionals, this was the initial stakeholder group that was selected for study. The result is a sustainable mobility scorecard for evaluating an urban mobility system, generated by a whole system model, that can be influenced by stakeholder weightings with a repeatable and measurable process. By applying these weightings to the analysis of alternative mobility scenarios, a set of conditions that best supports a sustainable mobility objective can be found. This appears to be the first report of a whole system, strategic-level mobility model with an AHP-weighted STEEP scorecard to assess the overall sustainability of an urban mobility system, including rideshare and AV emergence over time, across a set of future scenarios.

The paper is organized as follows: first, the literature is reviewed for urban mobility scorecards comprised of relevant metrics, as well as MCDA/MCDM methods applicable for sustainability assessments. Informed by this review, a methodology is described using AHP for assigning stakeholder weightings to a sustainable urban mobility scorecard. Then, the application of AHP to compute weightings from survey inputs of U.S. transportation planning professionals is presented, followed by the main results of using a weighted sustainable mobility scorecard to compare mobility scenarios. The main conclusions drawn from this work are provided at the end of this paper, along with recommendations for future research.

2. Literature review

A literature review was conducted in two main topics: measuring sustainable urban mobility using a whole system scorecard and then MCDA/MCDM methods, which will be used for the stakeholder weightings for the scorecard.

2.1. Measuring sustainable urban mobility

A whole system assessment methodology for sustainable urban mobility requires a set of comprehensive metrics as a basis of comparison between alternative scenarios. Two approaches to a set of metrics, or scorecard, were reviewed for their focus at the city level. These were the Urban Mobility Index by Arthur D. Little (Lerner, 2011; Van Audenhove et al., 2018, Van Audenhove et al., 2014) and the City Mobility Index by Deloitte (Dixon et al., 2019). A third approach, the Mobility Maturity Global Tracking Framework ("Global Tracking Framework 2.0 | Sum4all,", 2021), measures and compares sustainable mobility at the national level and is included for relevant insights.

All three scorecard approaches employ a two-tiered hierarchy with high-level categories for organizing the individual metrics. For the Urban Mobility Index, the three main categories are "Maturity", "Innovation", and "Performance", with nine metrics in each category (Van Audenhove et al., 2018). The City Mobility Index also has three main categories, which are "Performance and Resilience", "Vision and Leadership", and "Service and Inclusion" (Dixon et al., 2019). For the Mobility Maturity Global Tracking Framework, the metrics are grouped into four categories: safety, universal access, green, and efficiency ("Global Tracking Framework 2.0 | Sum4all,", 2021).

The individual metrics used in each of these mobility metric frameworks are comprised of several different types. One type is a strictly numerical metric; e.g., "annual arithmetic average of the daily concentrations of NO_2 recorded at all monitoring stations within the agglomeration area" (Van Audenhove et al., 2018). Another type is a scaled metric; e.g., "quality of roads, value: 1 = worst to 7 = best" ("Global Tracking Framework 2.0 | Sum4all,", 2021). Finally, some metrics are binary, e.g. "existence of MaaS-based application (yes/no)" (Dixon et al., 2019). Each mobility metric framework uses its own weighting scheme for these metrics to generate a single index value for city-to-city comparison.

To examine these three scorecard approaches relative to the STEEP framework (Schmidt et al., 2015; Szigeti et al., 2011) selected for this research, the metrics were categorized by social, technical, economic, environmental, and political factors (Muller et al., 2021). The result of this assessment is illustrated in Fig. 1 as a heat map. The color gradient of the cells graphically indicates the number of metrics relevant to each STEEP factor. Dark green represents a high count of relevant metrics, while pale yellow represents a low count. For example, 36 of the metrics for the Deloitte City Mobility Index were deemed relevant to technology, such as the efficiency and performance of the mobility system. The STEEP social factor included equitable access-related metrics such as accessibility to public transit, city walkability score, and private car dependency. This review of sustainability scorecards informed the methodology used for this study, including the selection and categorization of metrics that could be generated by the enhanced Impacts 2050 model, described in the Define a STEEP Sustainable Urban Mobility Scorecard section.

2.2. Stakeholder weightings in measuring sustainable urban mobility

In support of the research objective, a literature review was conducted of relevant MCDM/MCDA methods to identify an approach suitable for applying stakeholder weightings to a sustainable urban

Indices for Sustainable Urban Mobility	STEEP Factors				
	Social	Technological	Economic	Environmental	Political
Arthur D Little - Urban Mobility Index	7	11	1	6	2
Innovation	2	7	0	0	0
Maturity	2	3	1	1	2
Performance	3	1	0	5	0
Deloitte - City Mobility Index	12	36	6	5	12
Performance and Resilience	4	13	0	4	0
Service and Inclusion	8	16	5	0	0
Vision and Leadership	0	7	1	1	12
SuM4All - Mobility Maturity Global Tracking Framework	10	19	5	9	2
Efficiency	0	4	5	0	2
Green Mobility	0	0	0	9	0
Safety	8	0	0	0	0
Universal Access	2	15	0	0	0

SuM4All ("Global Tracking Framework 2.0 | Sum4all," 2021), City Mobility Index (Dixon et al., 2019),
Urban Mobility Index (Lerner, 2011; Van Audenhove et al., 2018, 2014)

Fig. 1. STEEP assessment of sustainable urban mobility indices.
SuM4All ("Global Tracking Framework 2.0 | Sum4all,", 2021*), City Mobility Index (*Dixon et al., 2019*), Urban Mobility Index (*Lerner, 2011*;* Van Audenhove et al., 2018*,* Van Audenhove et al., *2014).*

mobility scorecard. A group of transportation-focused studies were identified that employ these methods to determine the relative impact of weighted criteria on outcomes generated by simulations, an approach aligned to the approach of this current research. These studies focused on a range of transportation topics, from driver behavior at traffic lights to flooding risk for an entire urban rail system. A range of MCDA methods were employed, including: AHP (Alemdar & Çodur, 2024), AHP and VIKOR (Alemdar et al., 2020), fuzzy AHP and VIKOR (Alemdar & Yılmaz, 2025), and AHP and TOPSIS (Alemdar et al., 2021). These studies provided examples of a range of MCDM/MCDA methods applied to multi-factor, complex sustainable mobility challenges represented by simulations or models.

Further review identified studies that describe and compare available MCDM methods to each other, including their relevance to sustainable mobility. Two examples are (Cinelli et al., 2014) and (Broniewicz & Ogrodnik, 2021). In particular, (Broniewicz & Ogrodnik, 2021) assert that the most commonly used methods in transport-related problems are AHP, PROMETHEE and TOPSIS. This work identifies the use of pair-wise comparisons for these methods as a critical input. Other work also identified AHP as the most prevalent method used on transportation topics (Kügemann & Polatidis, 2019; Yannis et al., 2020). Several studies focused on the application of an MCDM method to a specific transportation problem, with hybrid adaptations to the main MCDM approach (Hamurcu & Eren, 2020; Kügemann & Polatidis, 2019). One of these, (Hamurcu & Eren, 2020), used a combined AHP–TOPSIS decision model to evaluate candidate alternative solutions for electric bus use in Ankara. Another study (Alkharabsheh et al., 2021) used a grey-AHP method to acquire public opinion related to the current public bus transport system in the city of focus. Note that a grey method was applied to address non-expert respondents.

A relatively recent method was identified for addressing MCDM problems, the Best-Worst Method (BWM) as described in (Rezaei, 2015) and (Liang, 2021). Like AHP, BWM also uses pair-wise comparisons to develop criteria weightings but requires fewer comparisons as input. In one study that made use of BWM, (Ortega et al., 2020), the authors cite a drawback of AHP as its subjectivity because it makes use of an expert's judgement in choosing the appropriate solution. Other work found that consistency of subject matter experts providing the weightings was key to successful employment of both BMW and APH methods (Srdjevic et al., 2022; Yazdi et al., 2020). At least one study that employed both BWM and AHP obtained comparable results (Srdjevic et al., 2022).

Overall, the literature review identified AHP as a widely used and relevant method for applying stakeholder weightings to a metrics scorecard. Several studies show how AHP can be defined in a multi-tiered criteria framework to apply weightings and compute a rank ordering of alternative outcomes (Leal, 2020; Vargas, 2010). Additional papers (Lode et al., 2021; Simons & Wiegel, 2009) investigated AHP as a means of gathering stakeholder inputs to produce ranked weightings of multi-variate criteria for holistic solutions. In modeling-relevant research, (Improta et al., 2018), the AHP multi-criteria analysis is implemented in conjunction with a system dynamics simulation to help decision-makers efficiently perform assessments. Further research, (Anastasiadou et al., 2021; Ignaccolo et al., 2017; Macharis et al., 2012) explores the specific application of AHP as part of a process to support stakeholder decision-making by transportation planners. One study (Anastasiadou et al., 2021) specifically explores AHP application to sustainable mobility and recognizes the need to capture stakeholder inputs, including policy-makers, to support progress towards sustainable mobility at the urban region level of focus. Other work (Gompf et al., 2021) recognizes that AHP is relevant in decision-making in sustainability assessments of mobility services, because of the need for trade-offs between multiple alternatives supported by a participatory stakeholder process.

After consideration of the various MCDM/MCDA methods identified, AHP was selected for this study because of its prevalent use in similar strategic level mobility-related analysis, its suitability for the targeted group of transportation experts that provided the pair-wise comparison inputs for this research, and the ease of implementation for this effort.

3. Methodology

Informed by the literature review, a methodology was developed based on AHP to generate a weighted STEEP sustainability scorecard populated by metrics output from the enhanced Impacts 2050 (Muller et al., 2024). This methodology consisted of collecting and applying stakeholder weights obtained from an online survey of U.S. transportation planning professionals. A weighted sustainability scorecard enables the characterization and comparison of the relative sustainability impacts of alternative mobility adoption scenarios, for a set of selected cities with varying transportation system characteristics. Fig. 2 shows a flowchart for this study, which is described in the following sections.

3.1. Define a STEEP sustainable urban mobility scorecard

The set of metrics selected to compare alternative adoption scenarios for emergent mobility concepts such as rideshare and AVs, generated from the output of the enhanced Impacts 2050 (Muller et al., 2024), is

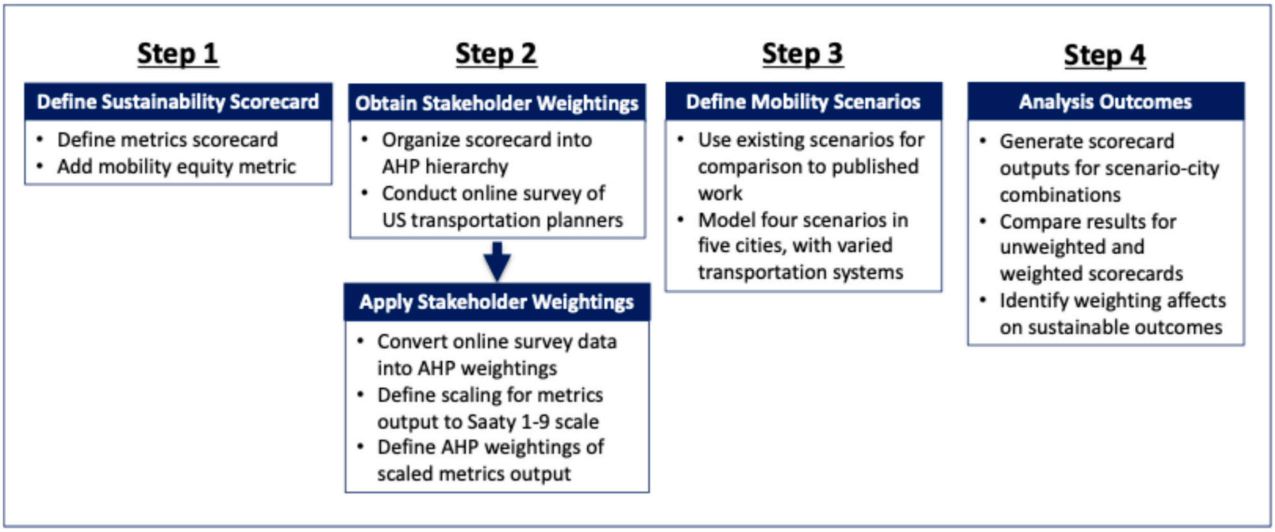

Fig. 2. Flowchart of the study.

shown in Table 1. This scorecard provides two to three metrics, listed in column two, for each of the five STEEP parameters, listed in column one. The rightmost column describes how the metrics were scaled to the Saaty 1–9 scale, which is described in the section Scaling of Output Metrics.

To provide a measure of mobility equity, the computation of a mobility equity metric was implemented to further inform the economic aspect of STEEP for this scorecard. This metric was defined as shown in eq. 1 below, with a further breakdown of the individual parameters used to compute it as shown in eq. 2.

$$Mobility\ Equity\ Metric = \frac{Per\ capita\ trip\ rate_{upper\ income}}{Per\ capita\ trip\ rate_{lower\ income}} \tag{1}$$

$$Mobility\ Equity\ Metric = \frac{\frac{(Wok\ Trips_{upper\ income}) + (NonWork\ Trips_{upper\ income})}{Population_{upper\ income}}}{\frac{(Work\ Trips_{lower\ income}) + (NonWork\ Trips_{lower\ income})}{Population_{lower\ income}}} \tag{2}$$

The desired value for this metric is close to or equal to 1, meaning that mobility is being equally utilized by both upper and lower levels of income. Values greater than 1 indicate that mobility is utilized more by upper-income demographics, while values less than 1 indicate that mobility is used more by lower-income demographics.

Note that the metrics presented in Table 1 are organized in a structured hierarchy, following the general approach found in the literature for AHP (Ignaccolo et al., 2017). This hierarchy is defined to support evaluation of alternative scenarios against an overall goal of a sustainable urban mobility system. Defining this AHP hierarchy informs the collection of pairwise comparison inputs from stakeholders, which in turn are used to compute weightings. To account for how different stakeholders may prioritize these various metrics in support of the overarching goal, weighting categories are defined in Table 1 based on the hierarchy as follows:

- **Tier 1 Weightings:** Stakeholder pairwise comparisons result in weightings for each of the five STEEP categories relative to each other, per column 1 in Table 1.
- **Tier 2 Weightings:** Stakeholder pairwise comparisons result in weightings for the metrics within each STEEP category relative to each other, per column 2 in Table 1.

The Tier 1 and Tier 2 sets of pairwise comparisons are shown in Appendix E. The approach to obtaining and applying stakeholder

Table 1
STEEP sustainable urban mobility scorecard with saaty scaling.

Tier 1 Criteria	Tier 2 Sub-criteria	Metric Description	Metric Values (scale all values to Saaty 1–9 range)
Social	Car Ownership	No car ownership share (%)	0–100 bigger is better
	Shared Mobility	Rideshare mode share (%)	0–100 bigger is better
Technological	Efficiency	Average Peak traffic speed (actual/posted - %)	0–100 bigger is better
	Level of Service	SAE Level 5 Automation (% total fleet)	0–100 bigger is better
Environmental	Vehicle Footprint	Cars per capita	Use range of 0–2 cars per capita, smaller is better Normalize to 1-(cars per capita/2)
	Healthy Transport	Transit/Walk/Bike mode share (%)	0–100 bigger is better
	Vehicle Miles Traveled	Auto VMT/capita per day (miles/person/day)	Use range 0–100 VMT/capita/day, smaller is better Normalize to 1-(VMT/capita/day /100)
Economic	Lower Income Healthy Modes	Transit/Walk/Bike mode share for Lower Income (%)	0–100 bigger is better
	Equity Mobility Ratio	Ratio of trips per capita (upper/lower income)	Use 1-abs(1-trips/capita ratio) Closer to 1 is better
Political	Land Use	Ratio Developed Land per Capita (milesˆ2/person)	Use range 0–3 miles^2/person, smaller is better Normalize to (Ratio Developed Land per Capita/Max): where Max = 3
	Infrastructure	Road density (total lane miles/total surface area) (miles/milesˆ2)	Use range 0–50, smaller is better Normalize to 1-(road density/Max): where Max = 50

VMT = Vehicle Miles Traveled

weightings to this hierarchy is described in the next sections.

3.2. Obtain stakeholder weightings for sustainable urban mobility scorecard

To obtain stakeholder weightings for the sustainability urban mobility scorecard, an online survey was conducted. This research focused the survey on a single stakeholder group, transportation planning professionals at U.S. Metropolitan Planning Organizations (MPOs), because of the relevance of their role to potential utilization of a methodology such as SAMMS. Using this single stakeholder group, with potential resulting bias, was intentional to obtain their weightings on the metrics being studied. The MPOs included in the survey were representative of different U.S. census regions with varying sizes and transportation systems. The city regions that provided survey responses were Boston, Chicago, Houston, Los Angeles, New York, Philadelphia, Pittsburgh, and Seattle. Note that this interview research received an exempt determination for research with human participants per Villanova University IRB-FY2023–133.

The web-based survey form was sent to 177 individuals in the designated stakeholder group. Of this total, 41 individuals started the survey form, and of these 34 fully completed it for a response rate of 34 of 177, or 19.2 %. For the 34 individuals who fully participated in the survey (see Table 2), each participant was asked to identify their role (leader, manager, analyst, or other) and the number of years in that role (1–5, 6–10, 11–20, or greater than 20). Most of the participants were managers (42 %) and analysts/planners (42 %), with only 12 % having the role of organizational leader. Note that the survey participants were from urban regions that were representative of the five cities being modeled in this research (see Application to Mobility Scenarios). Three of the modeled cities - Boston, Houston, and Seattle - also had survey participants.

Survey participants were presented with an online form containing a set of 17 pairwise comparison questions, shown in Appendix E. The responses for questions 1–10 were used to generate the Tier 1 weightings, while the responses to questions 11–17 were used to generate the Tier 2 weightings. Per discussion above, participants were asked to provide their comparison responses relative to the overall goal of a sustainable urban mobility system. The following text was provided to survey participants to align their understanding of the STEEP criteria as they made their pair-wise comparisons.

- **Social:** population acceptance and utilization of more sustainable mobility modes (e.g. reduced car ownership, increased rideshare mode share)
- **Technological:** successful development and deployment of technological mobility solutions (e.g. decreased congestion/more efficient travel speeds, percentage of cars that are fully automated - SAE level 5)
- **Environmental:** reduction of negative environmental impact of mobility (e.g. decreased cars per capita, increased mode share for transit/walk/bike, decreased car vehicle miles traveled (VMT)/capita per day)

Table 2
Summary of stakeholder survey participants.

Role	Years in Transportation Planning Role				Role Sub-Total	Role Percentage
	1–5	6–10	11–20	>20		
Leader	1	1		2	4	12 %
Manager	7	5		2	14	41 %
Analyst	7	3	3	1	14	41 %
Other (*)	1			1	2	6 %
TOTAL	**16**	**9**	**3**	**6**	**34**	**100 %**

(*) The "other" role submitted was planner.

- **Economic:** achieving equitable mobility (e.g. transit/walk/bike mode share for lower income, equal utilization of mobility across household income levels)
- **Political:** applying governance and policy methods towards sustainable mobility (e.g. land use via ratio of developed land per capita, road density via total lane miles/total surface area)

Score inputs for each question ranged from 1 to 9 as defined by the criteria described in Table 3 (Macharis et al., 2012). The inputs from all stakeholder participants were equally weighted, not prioritizing any one category of participant. The average score per question from the survey group was used in the weighting calculations described below.

3.3. Apply stakeholder weightings to sustainable urban mobility scorecard

After stakeholder inputs were obtained from the survey, AHP was used to convert these inputs into the weightings needed for application to the metrics scorecard. The following sections describe the methodology that was used to develop the AHP Tier 1 and Tier 2 weightings (Saaty & Sodenkamp, 2010; Vargas, 2010). Also documented is how the metric values output by the enhanced Impacts 2050 were scaled to a common Saaty 1–9 ranking scale to enable application of the stakeholder weights. Finally, the relative ranking approach used to compare weighted metrics across a set of scenario-city combinations is described.

3.3.1. Tier 1 Weightings for STEEP Metric Categories

First, the Tier 1 weightings are determined from the survey results using a comparison matrix, with sample calculations shown in Table 4. The comparison matrix is comprised of the average survey scores for each Tier 1 pair-wise comparison. For example, the average survey score for pairwise comparison 1 per Appendix E, "Social vs. Technological", is entered in the appropriate row and column of the matrix. The matrix is symmetrical, such that the inputs in the upper right of the matrix above the diagonal are the inverse of those in the lower left. The values in the diagonal are all equal to one. The results of the comparison matrix are the weightings of each STEEP category relative to each other. These are shown in the column labeled "Relative Weight". For example, in the column "Relative Weight" in Table 4, "Social" has the highest relative weight of 0.365, while "Political" has the lowest relative weight of 0.083. Note that the Tier 1 relative weightings in this column sum to a total of 1. All Tier 1 weightings were generated using this method.

To obtain the relative weights, first an initial value T_i had to be calculated. T_i (see column "Total" in Table 4) is defined as the sum of the weightings in that row of the matrix divided by the sum of the values in each column, per this equation:

$$T_i = \sum_{j=1}^{n} \frac{M_{ij}}{\sum_{i=1}^{n} M_{ij}} \tag{3}$$

where M is the comparison matrix, i is the row number of M, j is the column number of M, and n is the number of evaluated criteria. An example calculation using this equation for the first row $i = 1$ is: $(1/2.54) + (2.6/4.75) + (2.6/6.97) + (2.6/9.8) + (2.6/11.40) = 1.83$.

The "Relative Weight" values A for each STEEP category are the normalized matrix elements for each row, T_i, divided by the number of

Table 3
AHP ranking scale.

Intensity of Importance	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance

Reference (Macharis et al., 2012).

Table 4
Sample comparison matrix for STEEP Tier 1 stakeholder weightings.

Overall preference matrix								
Alternative	Social	Technological	Environmental	Economic	Political	TOTAL	Relative Weight	Consistency Measure
Social	1.00	2.60	2.60	2.60	2.60	1.83	0.365	5.52
Technological	0.38	1.00	2.60	2.60	2.60	1.25	0.249	5.59
Environmental	0.38	0.99	1.00	2.60	2.60	0.89	0.177	5.39
Economic	0.38	0.38	0.38	1.00	2.60	0.62	0.125	5.17
Political	0.38	0.38	0.38	0.38	1.00	0.42	0.083	5.22
TOTAL	**2.54**	**4.75**	**6.97**	**9.18**	**11.40**		**1.000**	
reflects the consistency of one's judgement							CI	0.095
reference value per method in (Saaty & Sodenkamp, 2010)							RI	1.120
CR of 0.1 or below is considered acceptable							CR	0.085

evaluated criteria, n, as follows:

$$A_i = \frac{T_i}{n} \tag{4}$$

An example calculation using this equation for the first row "Social" is 1.83/5 = 0.365.

Measures of the consistency of the outputs derived from the comparison matrix are then evaluated. First, the "Consistency Measure" *CM* is defined:

$$CM_i = \frac{1}{A_i} * \sum_{j=1}^{n} M_{ij} * A_i \text{ for each } i = 1 \ldots n \tag{5}$$

where M is the comparison matrix, A are the relative weight values, and n is the number of evaluated criteria. An example calculation using this equation for the first row "Social" is ((1*0.365) + (2.6*0.249) + (2.6*0.177) + (2.6*0.125) + (2.6*0.083))/0.365 = 5.52.

The Consistency Index *CI* is a measure of the consistency of the various stakeholder weightings and is defined:

$$CI = \frac{\lambda_{average} - n}{n - 1} \tag{6}$$

where $\lambda_{average}$ is the average value in the column labeled "Consistency Measure" *CM* and n is the number of evaluated criteria. For example, in Table 4, $\lambda_{average} = 5.38$ and $n = 5$.

To determine if the CI is acceptable, the Consistency Ratio *CR* is defined:

$$CR = \frac{CI}{RI} \tag{7}$$

where CI is defined per Eq. 6, and values for the Random Consistency Index (RI) are defined per Table 5 for different values of n. For the *CR*, a value of 0.1 or below is considered acceptable. A sample calculation for *CR* based on the values shown in Table 4 is 0.095/1.120 = 0.085, which is an acceptable *CR*.

3.3.2. Tier 2 weightings for metrics within STEEP categories

Next, the Tier 2 weightings are determined using the same comparison matrix methodology used for the Tier 1 weightings shown above, again using the stakeholder survey results as inputs. In this way, the weighting for the metrics within each STEEP category are determined relative to each other. Sample Tier 2 calculations are shown in Table 6. The comparison matrix is comprised of the average stakeholder survey scores for each Tier 2 pair-wise comparison. For example, the average survey score for pairwise comparison 11 per Appendix E, "no car ownership share (%) vs. rideshare mode share (%)" is entered in the appropriate row and column of the matrix. These inputs are then used to generate the relative weightings for each metric, shown in the column labeled "Relative Weight". For example, in the column "Relative Weight" in Table 6, "no car ownership share (%)" has the highest relative weight of 0.722, while "Rideshare mode share (%)" has the lowest relative weight of 0.278. Note that Tier 2 relative weightings within each STEEP Tier 1 category sum to a total of 1. All Tier 2 weightings were generated using this method.

3.3.3. Scaling of output metrics

To enable application of the stakeholder weightings to the metrics scorecard, the metric outputs generated by the enhanced Impacts 2050 (see Table 1) were scaled to the Saaty 1–9 scheme (see Table 3). Many of the metrics that comprise the scorecard are output by the enhanced Impacts 2050 on a 0–100 % scale with bigger representing better, e.g. "No car ownership share (%)". The remaining metrics are non-percentage based, each with their own minimum-maximum expected range of values, e.g. "Ratio Developed Land per Capita (miles^2/person)". For all metrics, the scaling to the Saaty scale was performed using this relationship:

$$f(x) = \frac{(b-a)(x - min\_value)}{(max\_value - min\_value)} + a \tag{8}$$

where:

f(x) = metric output value from Impacts 2050 model linearly converted to 1–9 Saaty scale.

x = metric value output directly from Impacts 2050.

b = 9 (maximum value from Saaty scale, per Table 1).

a = 1 (minimum value from Saaty scale, per Table 1).

max_value = maximum expected value for metric output by Impacts 2050.

min_value = minumum expected value for metric output by Impacts 2050.

A described above, Tier 1 and 2 stakeholder weightings and Impacts 2050 output metrics were placed on a common Saaty 1–9 scale. However, a basis for comparing these results across scenarios was needed, e.g., the relative impact of "No car ownership share (%)" across a set of alternative scenarios (see Table 1). This was done using the same matrix method used above for the Tier 1 and Tier 2 weightings. A sample of these computations for "No Car Ownership Share" is shown in Table 7. However, instead of the matrix inputs coming from stakeholder pairwise comparison results, as was done for the Tier 1 and Tier 2 weightings, the matrix inputs are from the model-generated metrics scaled to the Saaty 1–9 scale. For example, the ratio of the scaled "No Car Ownership Share"

Table 5
Values of random consistency indices (RI).

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49	1.52	1.54	1.56	1.58	1.59

(Saaty & Sodenkamp, 2010).

Table 6
Sample comparison matrix for STEEP Tier 2 stakeholder weightings.

Alternative pairwise comparison for social					
Sub-criteria	No car ownership share (%)	Rideshare mode share (%)	TOTAL	Relative Weight	Consistency Measure
No car ownership share (%)	1.00	2.60	1.44	0.722	2.00
Rideshare mode share (%)	0.38	1.00	0.56	0.278	2.00
TOTAL	**1.38**	**3.60**		**1.000**	
reflects the consistency of one's judgement				CI	0.00
reference value per method in (Saaty & Sodenkamp, 2010)				RI	0.00
CR of 0.1 or below is considered acceptable				CR	0.00

Table 7
Sample Comparison Matrix for "No Car Ownership Share" vs. Scenario-City.

Alternative pairwise comparison of scenarios vs criteria social: Sub-criteria No car ownership share (%)							
Alternative	Momentum	Tech Triumphs	Gentle Footprint	Global Chaos	TOTAL	Relative Weight	Consistency Measure
Momentum	1.00	0.99	1.00	0.99	0.99	0.248	4.00
Tech Triumphs	1.01	1.00	1.01	1.00	1.01	0.251	4.00
Gentle Footprint	1.00	0.99	1.00	0.99	1.00	0.249	4.00
Global Chaos	1.01	1.00	1.01	1.00	1.01	0.252	4.00
TOTAL	**4.03**	**3.98**	**4.02**	**3.97**		**1.000**	
reflects the consistency of one's judgement						CI	0.00
reference value per method in (Saaty & Sodenkamp, 2010)						RI	0.90
CR of 0.1 or below is considered acceptable						CR	0.00

for the "Momentum" scenario divided by the scaled "No Car Ownership Share" for the "Tech Triumphs" scenario, is entered in the "Momentum" row and the "Tech Triumphs" column of the matrix. In this way, the resulting relative contributions of "No Car Ownership Share" across the scenarios is obtained in the column labeled "Relative Weight". These relative scenario-to-scenario weights were determined using this approach for each metric-scenario-city combination. The scenarios referenced in Table 7, as well as the cities that were selected for study, are described in the section Application to Mobility Scenarios.

With the Tier 1 and Tier 2 stakeholder weights obtained as described above, these were then combined into a single set of scorecard metric weights as follows:

$$A1_i * A2_{ij} = A12_k \quad (9)$$

where $A1$ are the Tier 1 weights for the number i STEEP categories, $A2$ are the number j Tier 2 weights for each STEEP category i, and $A12$ are the resulting combined weights for each metric k in the scorecard. These metric weights were then applied to the Saaty 1–9 scaled model outputs for the range of scenario-city combinations as follows:

$$A12_k * RS_{ksc} = RW_{ksc} \quad (10)$$

where $A12_k$ are the weights for the number k of scorecard metrics, RS are the scaled simulation results for each scorecard metric k, scenario s, and city c, with RS obtained per the approach in Table 7. Then, RW are the resulting scaled simulation results RS with the $A12$ weights applied.

In summary, this methodology enables Tier 1 and Tier 2 weightings to be computed from stakeholder inputs. A scorecard of numerical metrics is generated from an urban transportation model, the enhanced Impacts 2050. These metrics are then converted to a common Saaty 1–9 scale (Macharis et al., 2012), and the stakeholder weightings are applied to these metrics. Finally, these weighted metric results are then normalized across a set of scenarios for specific city locations, enabling the relative assessment of sustainability metrics.

4. Application to mobility scenarios

To exercise the weighted stakeholder scorecard defined for this study, the enhanced Impacts 2050 was used to produce metrics using a set of four planning scenarios as inputs. These scenarios had been used in the original development of Impacts 2050 (Zmud et al., 2014), and these same scenarios were selected for use in this study to provide a basis for comparison to published results. These scenarios are described in Table 8. Detailed inputs were used for each of these scenarios to quantify the impact of significant trends for each of the scenario definitions. These inputs are documented in Appendix A to Appendix D. Of special interest are the scenario differences in inputs categorized as "Travel Behavior Subsector" and "Transport Supply Sector" as these impacted the output metrics for the scorecard.

These four scenarios were exercised for a set of five urban regions from the United States, shown in Fig. 3.

These regions (Atlanta, Boston, Detroit, Houston, and Seattle) were used in the initial development of Impacts 2050 and were used here to provide a basis for comparison to published results. These selected regions are representative of five census areas of the United States (Zmud et al., 2014) and reflect differences in:

- Population distribution: age, household type, education, wealth, and housing.
- Spatial distribution: land area and population density.
- Economic base: socioeconomic status, income disparity, unemployment rate.
- Diversity: household structures, age, and racial/ethnic composition.
- Transportation system: highway versus transit supply, congestion levels, commute mode share.

Guided by these considerations, the cities selected for each region represent a range of mobility systems. Boston and Seattle had more public transit supply than the other city regions, while Atlanta and Houston had more road capacity.

5. Results

The results obtained for the development of a STEEP sustainable mobility scorecard, calculation of stakeholder weightings, and application to a set of alternative scenarios are described here.

Table 8
Original planning scenarios for impacts 2050 model.

Scenario Name	Scenario Description
Momentum (M): Extreme Gradualism	Momentum can be considered a baseline scenario for comparing outcomes with the other three scenarios. All model trends are constant from initial time step onward: • Socio-Demographic – no rate change • Travel Behavior – no rate change • Employment – no rate change • Land use – no rate change • Transport Supply– no rate change
Tech Triumphs (TT): Tech Nirvana	Technology Triumphs, notably with socio-demographic benefits, decreased trip rates, and higher capacity growth for road and transit. Some trends are: • Socio-Demographic – death rates decline, people work longer, growth in number of high-income households, slight decrease in foreign immigration • Travel Behavior – reduction in gasoline price, reduction in sharing car/no car • Employment – job creation and job movement increase • Land use – residential space per household increases • Transport Supply – road vehicle capacity/lane and transit capacity/route increase
Gentle Footprint (GF): Clean and Green	Gentle Footprint represents a future state with positive environmental impact, especially mobility. Some trends are: • Socio-Demographic – birth rates decline, people live/work longer, growth in number of low-income households, decline in growth of high-income households, slight increase in foreign immigration • Travel Behavior – gasoline price triples, decrease in car ownership, increased use of shared mobility (passenger, transit, walk/bike), trip rates decrease • Employment – no rate change • Land use – residential space/household and non-residential space/job decreases, land protection increases • Transport Supply – addition to road capacity decreases; transit capacity increases
Global Chaos (GC): Neo-Isolationism	Global Chaos represents a largely negative future state with increasing gasoline prices motivating increases in shared mobility. Some trends are: • Socio-Demographic – birth and death rates decline, growth in number of low-income households, decline in growth of high-income households, slight decrease in foreign immigration • Travel Behavior – gasoline price doubles, increase in sharing car/no car, trip rates decrease, increase in car passenger and walk/bike modes • Employment – job loss rate increases • Land use – land protection decreases • Transport Supply – addition to road and transit capacities decrease (Zmud et al., 2014)

5.1. Stakeholder weightings for a STEEP sustainable urban mobility scorecard

Using the AHP methodology described above, Tier 1 and Tier 2 stakeholder weights were computed from the results obtained from the online survey of U.S. transportation planning professionals. Approximately 80 % of the respondents came from an MPO with a population of greater than 5 million people. The stakeholder Tier 1 and Tier 2 weights are shown for each metric in Table 9 organized by columns into the various stakeholder participant roles (leader, manager, analyst/planner) that were surveyed. The rightmost column titled "All Roles Combined" contains the combined results for all three participant role categories. The column titled "Tier 1 x Tier 2", under "All Roles Combined" contains

Fig. 3. Urban regions modeled with enhanced impacts 2050.

the score of each individual metric relative to each other (i.e., each individual Tier 2 weighting multiplied by its category's Tier 1 STEEP weighting). These values represent $A12_k$ from eq. 9. The groupings by row represent the five STEEP metric categories.

From the results shown in Table 9, the relative differences in perspective for the survey participant groups can be seen across the STEEP categories and their constituent metrics. These results show the relative importance assigned by the stakeholder groups to the eleven metrics in the sustainable urban mobility scorecard. Overall, the combined results of the three planning participant groups (leader, manager, analyst/planner) assessed the relative importance of the STEEP categories as follows: social (32.5 %), environmental (28.8 %), technological (15.7 %), economic (14.8 %), and political (8.2 %). There were some differences by participant group, with leaders and analysts/planners ranking environmental as most important, and managers ranking social as most important.

The relative contribution of the "Social" metrics category was among the highest ranked of the five STEEP categories, with a share that ranged from 25.3 to 38.4 %. The manager participant group ranked this as the most important of the STEEP categories. As for the two metrics in this category, having a higher percentage of people who do not own cars was identified as much more important (69.6 to 84.5 %) than achieving a high percentage of trips using rideshare (15.5 to 30.4 %). This high ranking related to car ownership highlights the importance given by the respondents to decreasing car ownership and increasing the sharing of rides.

The "Technological" category was not among the most highly ranked of the five STEEP categories, with a relative contribution of 5.7 to 17.5 %. For the leader participants, this was the lowest contribution of the five categories. As for the relative importance assigned to the two metrics, maintaining efficient traffic flow (average speed at or near posted limit during peak traffic) has a 70 to 84.6 % share as opposed to achieving a high percentage of the automobile fleet with SAE level 5 automation (15.4 to 30 %). With efficiency as a key contributor to sustainable mobility, non-congested traffic flow was much more highly valued by the respondents than full vehicle automation. The low prioritization for automation may also reflect stakeholder concerns for its unintended effects, e.g. increased congestion from empty trips enroute to passenger pick-up, or from single occupants versus shared rides.

The "Environmental" category contained three metrics and was highly ranked as a category by all three participant groups. The relative contribution ranged from 24.9 to 39.4 % as a total share of the STEEP categories, with the leader and analyst planner groups ranking it as the most important of the STEEP categories. The metric for increasing the percentage of trips made by transit/walk/bike was consistently ranked as most important across the three participant groups, ranging from 51.4 to 61 %. The remaining balance of importance was then split between

Table 9
Summary of weighting results from the stakeholder survey.

Metrics	Relative Weightings (%) by Stakeholder Role								
	Leader		Manager		Analyst/Planner		All Roles Combined		
	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1 x Tier2
SOCIAL	**29.7**		**38.4**		**25.3**		**32.5**		
No car ownership share (%)		69.6		81.8		84.5		82.4	26.8
Rideshare mode share (%)		30.4		18.2		15.5		17.6	5.7
Tier 2 Subtotal		**100.0**		**100.0**		**100.0**		**100.0**	**32.5**
TECHNOLOGICAL	**5.7**		**16.1**		**17.5**		**15.7**		
Average Peak traffic speed (actual/posted) (%)		70.0		84.6		83.6		83.1	13.0
SAE Level 5 Automation (% total fleet)		30.0		15.4		16.4		16.9	2.6
Tier 2 Subtotal		**100.0**		**100.0**		**100.0**		**100.0**	**15.7**
ENVIRONMENTAL	**39.4**		**24.9**		**31.2**		**28.8**		
Cars per capita		19.3		20.6		29.3		25.0	7.2
Transit/Walk/Bike mode share (%)		61.0		51.9		51.4		53.2	15.3
Auto VMT/capita per day		19.7		27.6		19.3		21.8	6.3
Tier 2 Subtotal		**100.0**		**100.0**		**100.0**		**100.0**	**28.8**
ECONOMIC	**16.1**		**13.6**		**16.7**		**14.8**		
Transit/Walk/Bike-Lower Income mode share (%)		60.0		74.5		64.4		69.1	10.2
Ratio of trips per capita (upper/lower income)		40.0		25.5		35.6		30.9	4.6
Tier 2 Subtotal		**100.0**		**100.0**		**100.0**		**100.0**	**14.8**
POLITICAL	**9.0**		**7.0**		**9.4**		**8.2**		
Ratio Developed Land per Capita (mi^2/person)		81.8		78.7		75.1		77.6	6.4
Road density-total lane miles/total surface area (mi/mi^2)		18.2		21.3		24.9		22.4	1.8
Tier 2 Subtotal		**100.0**		**100.0**		**100.0**		**100.0**	**8.2**
Tier 1 Total	**100**		**100**		**100**		**100**		**100**

cars per capita and automobile VMT per capita. Similar to the social metric weightings discussed above, these results reflect the priority given by the survey respondents to increasing the use of shared and/or healthy transport modes and decreasing car ownership and use.

For the "Economic" category, the relative contribution to the STEEP metric categories overall ranged from 13.6 to 16.7 % across the three participant groups. The relative importance assigned to increasing the percentage of trips made via transit/walk/bike by lower-income populations was consistently ranked as more important (60 to 74.5 %) than that assigned to the ratio of trips per capita made by upper-income populations compared to lower-income populations. This category's metrics address issues of mobility equity, and the survey respondents weighted "Transit/Walk/Bike-Lower Income mode share (%)" as one of the top five metrics (see Table 9 "All Role Combined – Tier 1 x Tier2").

The relative contribution expressed for the "Political" category, compared to the other STEEP metric categories, ranged from 7 to 9.4 % across the three groups of participants. There was a consistently greater importance expressed for decreasing the developed land per capita (75 to 82 %) versus decreasing the road density (18 to 25 %).

Finally, in the right-most column of Table 9 titled "All Roles Combined – Tier 1 x Tier 2" the contribution of each metric relative to the overall sustainability weighting score is shown. From these values, "no car ownership share" was ranked by the stakeholder weightings to have the largest contribution to sustainability in urban mobility.

5.2. Scenario application of stakeholder-weighted sustainability scorecard

Metric outputs were generated with the enhanced Impacts 2050 for the four scenarios and five cities for the 50-year period from 2010 to 2060. In considering these metric outputs, the results obtained with the enhanced Impacts 2050 were benchmarked with the work of (Wu & MacKenzie, 2021). That study documents analysis of the 2017 U.S. NHTS to explore the emergence of taxis and ridesharing (T/R) services at the U.S. national level. This same NHTS data set is also used by the enhanced Impacts 2050 to model travel behavior, including rideshare. For the same year circa 2020, the mode choice results output by the enhanced Impacts 2050 compare favorably with those from (Wu & MacKenzie, 2021). For Impacts 2050, mode share results in percent (car: 75–88, transit: 3–11, rideshare: 0.2–0.5, active/walk/bike: 16–35) are comparable to those from (Wu & MacKenzie, 2021), (car: 54.9–86.2, transit 2.9–10.8, rideshare: 0.2–6.1, active/walk/bike 10.0–27.2). Considering there are some underlying differences, e.g. the enhanced Impacts 2050 results are for five specific U.S. cities while those from (Wu & MacKenzie, 2021) are for the total 2017 U.S. NHTS data set, this is a positive benchmark for the enhanced Impacts 2050.

The metric scorecard outputs from the enhanced Impacts 2050 were converted to the Saaty 1–9 scale per Table 1, subjected to the Tier 1 and Tier 2 weights labeled as "All Roles by Metric" in Table 9, and then normalized across the four scenarios for each city. The resulting weighted scorecard, shown in Table 10, contains the relative contribution of the various metrics, listed by row, to the goal of a sustainable urban mobility system for each city region and scenario. The final row, labeled "Total", lists the overall sustainability score for each city and scenario.

In this scorecard, the "Gentle Footprint" (GF) scenario has the largest total score across all the cities and therefore best meets the sustainability goal. This is expected, given this scenario includes sustainability trends such as reduced use of cars compared to the other scenarios (see Table 8). The scenario "Global Chaos" (GC) also has a relatively high total sustainability score. This is caused by the increase in transit/walk/bike mode share resulting from a breakdown in energy systems defined for this scenario. The "Tech Triumphs" scenario, where technology is projected to be solving the sustainability challenges, has the next to lowest scores. The "Momentum" (M) scenario, a "business as usual" future state, has the lowest overall sustainability scores because there are no changes in trends from the present-day that improve sustainability. Note that the influence of stakeholder weights can be seen in Table 10. The relative contribution of each metric to the overall score in Table 10 reflects the relative importance of the stakeholder weights shown in Table 9. For example, "no car mode share (%)", which contributes from 6.5 to 7.0 %, has the largest stakeholder weighting in Table 9 and is the largest single contributor to a sustainable mobility outcome for this scorecard.

When comparing the sustainability metrics in Table 10 across the five STEEP categories, some differences can be seen in both the magnitude and variation of the metrics results. Influenced by the stakeholder weightings, the results for "Social" range from 8.0 to 8.2 across the city-scenario combinations, giving it the overall greatest

Table 10
Stakeholder weighted results: sustainable urban mobility scorecard.

Metrics	Atlanta				Boston				Detroit				Houston				Seattle			
	M	TT	GF	GC	M	TT	GF	GC	M	TT	GF	GC	M	TT	GF	GC	M	TT	GF	GC
SOCIAL	**8.1**	**8.2**	**8.2**	**8.0**	**8.0**	**8.0**	**8.2**	**8.4**	**8.1**	**8.1**	**8.2**	**8.2**	**8.1**	**8.2**	**8.1**	**8.1**	**8.1**	**8.2**	**8.1**	**8.1**
No car mode share (%)	6.7	6.8	6.7	6.7	6.5	6.6	6.7	7.0	6.7	6.7	6.7	6.7	6.7	6.8	6.7	6.7	6.6	6.7	6.7	6.7
Rideshare mode share (%)	1.4	1.4	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.5	1.4	1.4	1.4	1.5	1.4	1.4	1.4	1.5	1.4
TECHNOLOGICAL	**3.6**	**3.9**	**4.4**	**3.8**	**3.3**	**4.0**	**4.5**	**3.9**	**2.9**	**4.1**	**5.2**	**3.4**	**3.3**	**4.1**	**4.6**	**3.7**	**3.6**	**4.0**	**4.2**	**3.9**
Average peak traffic speed (actual/posted) (%)	3.0	3.2	3.7	3.1	2.7	3.3	3.8	3.3	2.3	3.4	4.6	2.7	2.6	3.4	3.9	3.1	2.9	3.3	3.5	3.2
SAE Level 5 Automation (% total fleet fraction)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
ENVIRONMENTAL	**6.7**	**6.5**	**8.0**	**7.5**	**6.6**	**6.5**	**8.1**	**7.6**	**6.7**	**6.5**	**8.1**	**7.5**	**6.8**	**6.6**	**7.9**	**7.4**	**6.6**	**6.5**	**8.0**	**7.5**
Cars per capita (%)	1.8	1.8	1.8	1.8	1.8	1.7	1.8	1.9	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.9
Transit/Walk/Bike mode share (%)	3.4	3.3	4.6	4.1	3.3	3.2	4.6	4.1	3.4	3.3	4.6	4.1	3.5	3.4	4.4	3.9	3.3	3.3	4.6	4.1
Auto VMT/capita per day	1.5	1.5	1.7	1.6	1.5	1.5	1.6	1.6	1.5	1.5	1.7	1.6	1.5	1.5	1.7	1.6	1.5	1.5	1.6	1.6
ECONOMIC	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**
Transit/Walk/Bike mode share for Lower Income (%)	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Ratio of trips per capita (upper/lower income)	1.2	1.2	1.2	1.1	1.2	1.2	1.2	1.1	1.2	1.2	1.2	1.1	1.2	1.2	1.2	1.1	1.2	1.2	1.2	1.1
POLITICAL	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**
Ratio Developed Land per Capita (mi^2/person) X 100,000	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Road density-total lane miles/total surface area (mi/mi^2)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
TOTAL	**24.1**	**24.4**	**26.4**	**25.1**	**23.7**	**24.2**	**26.4**	**25.7**	**23.4**	**24.5**	**27.2**	**24.8**	**23.9**	**24.7**	**26.4**	**25.0**	**24.0**	**24.5**	**26.1**	**25.3**

Scenarios: M = Momentum, TT = Tech Triumphs, GF = Gentle Footprint, GC = Global Chaos

relative contribution. "Environmental" is the next largest contributing STEEP category with scores that range from 6.5 to 8.1. The third largest contribution is from the "Technological" category with scores that range from 2.9 to 4.6. In contrast, "Economic" and "Social" are the fourth and fifth largest contributors to the scorecard, and both show no variation across the city-scenario combinations that were analyzed. There are several factors that likely contribute to this outcome. Both received low relative weightings from the survey results compared to the other three categories, which corresponds to their relatively small contribution to the scorecard. In addition, the lack of variation in these metrics may also be a result of the Saaty 1–9 scaling. The minimum-maximum range of expected values selected to scale these metrics may have been too large, obscuring variation.

To further examine the impact of stakeholder weights on the scorecard results, the overall scorecard results with and without stakeholder weightings are shown in Fig. 4 across the five cities and four scenarios. The underlying data for this chart are provided in Appendix F. As was shown above, the "Gentle Footprint" and "Global Chaos" scenarios can be seen to have the highest sustainability scores across the five cities studied. While this sustainability result is not surprising for "Gentle Footprint", it may seem counter-intuitive for the "Global Chaos" scenario. This result was driven by the impact of extreme weather and climate events on reducing the number of trips and increasing walk/bike mode share. For these two scenario results, the weighted scores were greater than the unweighted scores, showing how the weighting of influential sustainability metrics amplified the overall score. In contrast, the "Momentum" and "Tech Triumphs" scenarios had the lowest sustainability scores overall, and the weighted scores were lower than the unweighted scores, suggesting the negative impact of poor sustainability performance and weightings on influential metrics.

Similar trends in the amplification effect of the stakeholder weightings can be seen in the results when viewed relative to the cities that were studied. Specifically, Detroit had the lowest overall unweighted score for the "Momentum, business as usual" scenario. However, Detroit then had the largest overall weighted score across all five cities for the scenario with the most sustainable trends, "Gentle Footprint". Based on the results in Table 10, this score seems to have been driven by greater performance in "Average peak traffic speed (actual/posted)" compared to the other cities. In this way, the weightings can highlight areas of improvement that can yield the most gain as driven by stakeholder prioritization.

Review of the contributions of the five individual STEEP components to the unweighted and weighted scores, shown in Appendix F, provides further insight into how the weightings influence the score results. If the metrics scores and weightings were all equal for each city-scenario combination, the scores for a given city would be equally distributed across the four scenarios for a 25 % score for each scenario. However, the weighted scores range from 23.4 to 27.2 % across the five cites and four scenarios, while the unweighted scores range from 23.9 to 26.6 %. In Appendix F, the weightings are shown to modify the relative contribution of metrics and their STEEP categories towards the total score for each city-scenario result. The weightings increase the relative contribution of the social and environmental metrics and decrease the relative contribution of the technological, economic, and political metrics. However, because the total of the four scenario scores for each city is constrained to sum to 100 %, this compresses the overall differences between the weighted and unweighted total scores for this analysis to a range of −0.5 to 0.6 percentage points. More dramatic differences between the scenarios for the more heavily weighted metrics would be expected to increase the spread between the weighted and unweighted scores.

These results show how stakeholder weightings, obtained from survey participants, can impact a metrics scorecard generated by the enhanced Impacts 2050 model. The weightings emphasized which scenarios are more sustainable. Scenarios provide proposed courses of action or anticipated trends. These inputs can be used to explore which

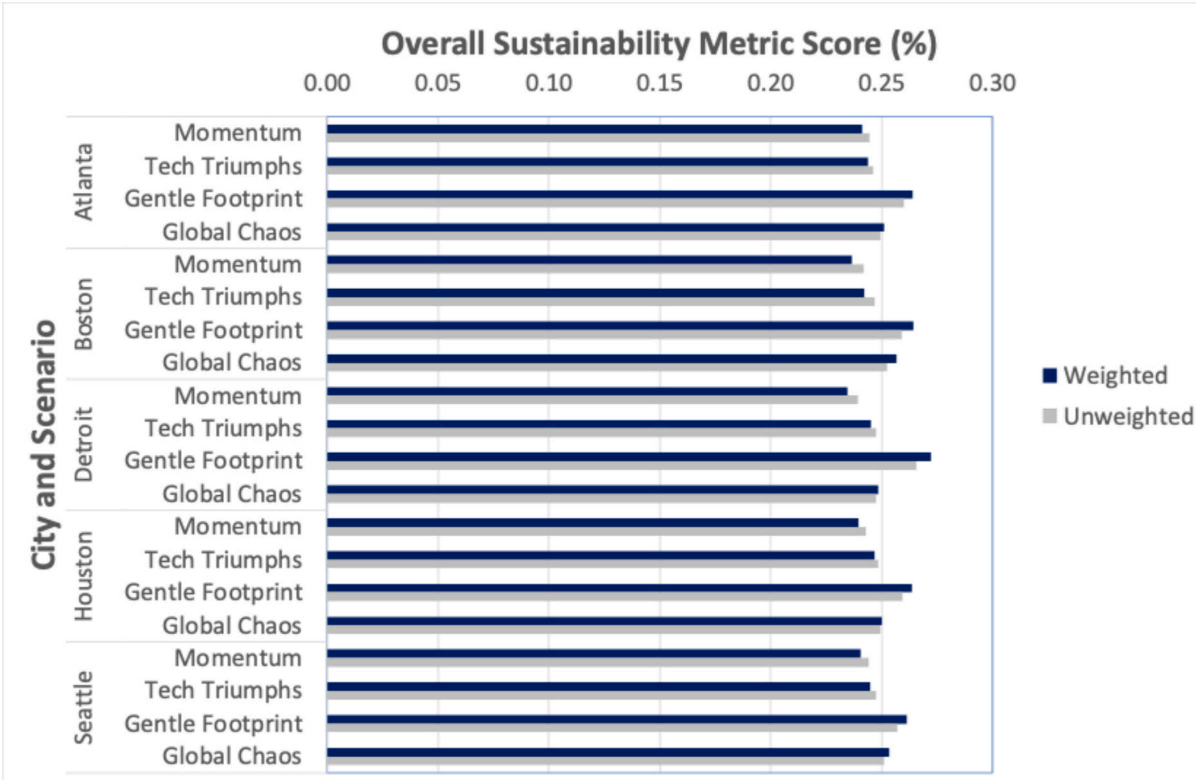

Fig. 4. Sustainable urban mobility scorecard: unweighted vs weighted results.

have the greatest effect on the sustainability objective, as measured by the metrics scorecard. The AHP hierarchy of the scorecard provides visibility to the relative importance of different STEEP categories and the underlying metrics in achieving sustainable results. This weighted scorecard can then be used to conduct sustainability evaluations across a range of scenarios for differing urban regions, as part of the exploration required to support the long-term planning process.

6. Conclusions and future work

A summary of the key findings of this research and recommended future work are provided below. Presented first are the key results obtained from a whole system assessment methodology. Specifically, these are results obtained from defining and applying a sustainable urban mobility scorecard with output generated by the enhanced Impacts 2050 (Muller et al., 2024), along with AHP weightings obtained from an online survey of U.S. transportation planning professionals. Recommendations for future work are then presented.

6.1. Conclusions

The results show the ability of the enhanced Impacts 2050 (Muller et al., 2024), which was modified to account for rideshare and AV technology adoption/diffusion, to support scenario-driven analysis of alternative mobility adoption scenarios. This enhanced Impacts 2050 generates outputs that populate a sustainable urban mobility scorecard. This model and scorecard were integrated with a stakeholder weighting scheme. Taken together, the enhanced Impacts 2050 model, the scorecard, and the stakeholder weighting scheme support the goal of providing a whole system methodology for evaluating the long-term sustainability impact of emergent mobility concepts.

For this research, an initial set of stakeholder weightings was obtained from an online survey of U.S. transportation planning professionals. This specific stakeholder group was selected intentionally because of the relevance of a whole system methodology to their role. Overall, the combined inputs of the three planning participant groups (leader, manager, analyst/planner) assessed the relative importance of the STEEP categories as follows: social (32.5 %), environmental (28.8 %), technological (15.7 %), economic (14.8 %), and political (8.2 %). There were some differences by participant group, with leaders and analyst/planner ranking environmental as most important, and managers ranking social as most important. Approximately 80 % of the respondents came from an MPO with a population of greater than 5 million people.

Within a STEEP category, the relative importance of the individual supporting metrics to sustainable mobility was assessed by survey participants and was generally consistent across the three participant groups. The top five metrics with the greatest relative importance from the combined inputs were: increases in no car ownership, increases in the transit/walk/bike mode share, increases in the transit/walk/bike mode share in lower income populations, maintaining the average peak traffic speed (actual/posted), and reducing cars per capita. Notably, increasing rideshare mode share or the percentage of the automobile fleet with SAE level 5 automation were ranked among the metrics with the least overall contribution to sustainability. This may reflect the fact that AVs are not considered to be the only method of achieving the most highly ranked metric, no car ownership. It may also reflect concerns for automation's unintended effects, e.g. increased congestion from empty trips enroute to pick-up, or single occupants versus shared rides. These results highlight how the relative importance and interaction of these metrics are relevant to strategic consideration of new mobility concepts.

There are several limitations of this research that should be noted. The scorecard weightings reflected only one stakeholder group, U.S. transportation planning professionals. While this was intentional as a focused pilot the SAMMS methodology (scenario-model-scorecard), a broader set of stakeholders would provide an interesting contrast in how different perspectives weight the metrics and impact the overall scorecard results. The scenarios that were used were general future state scenarios, which included multiple parallel trends that drove the model outcomes. These scenarios were selected because they were published with the original Impacts 2050 model. However, as a result they do not highlight more specific issues, e.g. urban sprawl or rideshare adoption, with the resulting focus. Recommendations for addressing these limitations are provided below in Future Work.

The results showed the impact that stakeholder weightings can have when combined with a model metrics scorecard to support long range planning by an MPO. For a range of cities and scenarios, stakeholder weightings amplified sustainability metrics scores compared to unweighted scores; scores for more sustainable scenarios increased while those for less sustainable scenarios decreased. This shows how the stakeholder weights can highlight which sets of inputs, i.e. scenarios, will result in the desired sustainability outcome. Using a STEEP whole system approach, stakeholder inputs can be captured and applied by role. The SAMMS methodology used here provides a quantitative approach that is traceable and repeatable. Enabling specific stakeholder perspectives to quantitively effect model metrics outcomes across a range of alternative scenarios can support stakeholder discussion and decision-making on how to achieve a sustainable mobility objective.

6.2. Future work

Recommendations for future work include development of new scenarios that have a more specific focus, such as rideshare adoption and the potential impacts of AV development and deployment. These scenarios would vary fewer input parameters for the enhanced Impacts 2050 than the scenarios used for this work. This would enable great focus on the impact of the specific input parameters that were varied. These new scenarios could then be evaluated with the stakeholder weights obtained in this research, to determine their impact on more focused transportation questions.

Surveys of additional stakeholder populations could be conducted to see how the resultant weightings might differ. By design, the stakeholder weightings for this research were from U.S. professional transportation planners. Surveys of stakeholder populations beyond this group could reveal how the resultant STEEP weightings might differ. Candidate stakeholder groups for future surveys include technologists, MaaS providers, and citizen groups that represent issues of equity in mobility. Stakeholder inputs from less-populated urban areas and rural areas could also be sought. The relative weightings would be expected to indicate a different emphasis on the STEEP categories and metrics aligned with each group's perspective on sustainable mobility outcomes. For example, developers of car automation might rank the Technological STEEP category to have the greatest influence. Obtaining inputs from a greater range of MPO population sizes would also provide greater diversity. The effect of different stakeholder group weightings on the scorecard results could then be evaluated.

For this work, AHP was employed as to obtain stakeholder weightings. A future survey of sustainable urban mobility stakeholders could employ a different MCDA/MCDM method, such as the Best-Worst Method, to determine the method's effect on survey response rates and the specific weightings obtained. To conform to the AHP methodology for this study, quantitative outputs from a transportation model were converted to the Saaty 1–9 scale using values selected to represent a minimum-maximum expected range. For some metrics, such as "Ratio Developed Land per Capita" and "Road density-total lane miles/total surface area", reducing the minimum-maximum range of expected values would be anticipated to result in greater sensitivity to the weighted values. Future work could explore the sensitivity of scaling to the minimum-maximum values selected, and any resulting effect on scorecard results.

While this research focused on metrics and scorecards to provide a whole system view of a city's sustainable mobility, including rideshare and AVs, there is a need to measure the adoption of MaaS. MaaS is an emerging mobility concept which could benefit from a whole system approach. Related research (Shaheen et al., 2016) indicates the challenge of defining and tracking metrics for shared, multi-mode mobility needed by transportation planners and policy makers. Car ownership rates may be one candidate indicator. Future work could focus on development of MaaS adoption metrics as part of the overall whole system approach. To support this future metrics work, additional enhancements to Impacts 2050 would be required to better represent the multi-modal nature of the MaaS concept; e.g., modeling trips that involved multiple modes of transport, and the resultant adoption metrics.

Impacts 2050 was developed as a decision support tool to assist transportation planners and other stakeholders in exploring a broad set of alternative future scenarios. After preparing the necessary input data, the model's runtime allows rapid exploration of potential outcomes. Combined with a scorecard and a methodology for applying stakeholder weightings, urban agencies can use the enhanced Impacts 2050 to explore the relative impact of parameters on a sustainable mobility outcome. For example, planning agencies examining per capita car ownership could set the exogenous variable "No Car Fraction" below the value of 1 to model an increased percentage of the population that does not own a car. This resulting impact on the sustainability scorecard metrics could then be reviewed. This example highlights the potential application of this whole systems approach towards seeking sustainable mobility outcomes for city regions.

Authors contributions

The authors confirm contribution to the paper as follows: study conception and design: M.M., G.H.d.A.C., S.P., Y.Z., B.F., R.L.; data collection: M.M.; analysis and interpretation of results: M.M. G.H.d.A.C., S.P., Y.Z., B.F.; draft manuscript preparation: M.M., G.H.d.A.C., S.P., Y. Z., B.F., R.L. All authors have read and agreed to the published version of the manuscript.

CRediT authorship contribution statement

Mark Muller: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Gonçalo Homem de Almeida Correia:** Writing – review & editing, Methodology. **Seri Park:** Writing – review & editing, Methodology, Formal analysis. **Yimin Zhang:** Writing – review & editing, Methodology, Formal analysis. **Brett Fusco:** Writing – review & editing, Methodology. **Ross Lee:** Writing – review & editing, Supervision, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Scenario “Momentum” Inputs for Enhanced Impacts 2050

Scenario multipliers on base rates	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
SOCIO-DEMOGRAPHIC SECTOR											
Death Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Birth Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Marriage Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Divorce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Empty Nest Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Leave Workforce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Enter Workforce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Leave Lowest Income Group Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Enter Lowest Income Group Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Leave Highest Income Group Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Enter Highest Income Group Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Foreign Inmigration Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Foreign Outmigration Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Domestic Migration Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Intra-Regional Migration Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Death Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Death Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Birth Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Birth Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Marriage Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Marriage Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Divorce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Divorce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Empty Nest Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Empty Nest Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Space Per Household	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Space Per Household	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TRAVEL BEHAVIOR SUBSECTOR	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Gasoline Price	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Shared Car Fraction	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
No Car Fraction	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Trip Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nonwork Trip Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Car Passenger Mode Share	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Transit Mode Share	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Walk/Bike Mode Share	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Rideshare Mode Share	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Car Trip Distance	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Age Cohort Effects in Travel Models	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EMPLOYMENT SECTOR	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Job Creation Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Job Loss Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Job Move Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LAND USE SECTOR	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Residential Space Per Household	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Non-Residential Space Per Job	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Land Protection	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TRANSPORT SUPPLY SECTOR	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Road Capacity Addition	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Transit Capacity Addition	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Road Vehicle Capacity Per Lane	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Transit Passenger Capacity Per Route	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EXTERNAL INDICES FOR OTHER REGIONS OF THE US	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
External Job Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
External Non-Residential Space Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
External Residential Space Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
External Road Capacity Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Appendix B. Scenario "Tech Triumphs" Inputs for Enhanced Impacts 2050

Scenario multipliers on base rates	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
SOCIO-DEMOGRAPHIC SECTOR											
Death Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Birth Rate	1.00	1.00	1.00	0.80	0.80	0.90	0.90	0.90	0.90	0.90	0.90
Marriage Rate	1.00	1.00	1.00	0.95	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Divorce Rate	1.00	1.00	1.00	1.05	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Empty Nest Rate	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.20	1.20	1.20	1.20
Leave Workforce Rate	1.00	1.00	1.00	0.70	0.70	0.65	0.60	0.60	0.55	0.55	0.50
Enter Workforce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Leave Lowest Income Group Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Enter Lowest Income Group Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.80	0.80	0.80	0.80
Leave Highest Income Group Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Enter Highest Income Group Rate	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
Foreign Inmigration Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.80	0.80	0.80	0.80
Foreign Outmigration Rate	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.20	1.20	1.20	1.20
Domestic Migration Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.80	0.80	0.80	0.80
Intra-Regional Migration Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.80	0.80	0.80	0.80
Low Income- Effect On Death Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Death Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Birth Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Birth Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Marriage Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Marriage Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Divorce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Divorce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Empty Nest Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Empty Nest Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Space Per Household	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Space Per Household	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TRAVEL BEHAVIOR SUBSECTOR	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Gasoline Price	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.80	0.80	0.80	0.80
Shared Car Fraction	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.80	0.80	0.80	0.80
No Car Fraction	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.80	0.80	0.80	0.80
Work Trip Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nonwork Trip Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Car Passenger Mode Share	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Transit Mode Share	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Walk/Bike Mode Share	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Rideshare Mode Share	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Car Trip Distance	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Age Cohort Effects in Travel Models	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EMPLOYMENT SECTOR	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Job Creation Rate	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
Job Loss Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Job Move Rate	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
LAND USE SECTOR	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Residential Space Per Household	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
Non-Residential Space Per Job	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Land Protection	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TRANSPORT SUPPLY SECTOR	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Road Capacity Addition	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Transit Capacity Addition	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Road Vehicle Capacity Per Lane	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
Transit Passenger Capacity Per Route	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
EXTERNAL INDICES FOR OTHER REGIONS OF THE US	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
External Job Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
External Non-Residential Space Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
External Residential Space Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
External Road Capacity Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Appendix C. Scenario "Gentle Footprint" Inputs for Enhanced Impacts 2050

Scenario multipliers on base rates	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
SOCIO-DEMOGRAPHIC SECTOR											
Death Rate	1.00	1.00	1.00	0.95	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Birth Rate	1.00	1.00	1.00	0.80	0.80	0.70	0.70	0.70	0.60	0.60	0.60
Marriage Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Divorce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Empty Nest Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Leave Workforce Rate	1.00	1.00	1.00	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Enter Workforce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Leave Lowest Income Group Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Enter Lowest Income Group Rate	1.00	1.00	1.00	1.05	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Leave Highest Income Group Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Enter Highest Income Group Rate	1.00	1.00	1.00	0.95	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Foreign Inmigration Rate	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.20	1.20	1.20	1.20
Foreign Outmigration Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Domestic Migration Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Intra-Regional Migration Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Death Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Death Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Birth Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Birth Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Marriage Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Marriage Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Divorce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Divorce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Empty Nest Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Empty Nest Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Space Per Household	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Space Per Household	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TRAVEL BEHAVIOR SUBSECTOR	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Gasoline Price	1.00	1.00	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
Shared Car Fraction	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.50	1.50	1.50
No Car Fraction	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.50	1.50	1.50
Work Trip Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Nonwork Trip Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Car Passenger Mode Share	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.50	1.50	1.50
Transit Mode Share	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.50	1.50	1.50
Walk/Bike Mode Share	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.50	1.50	1.50
Rideshare Mode Share	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Car Trip Distance	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.80	0.80	0.80	0.80
Age Cohort Effects in Travel Models	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EMPLOYMENT SECTOR	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Job Creation Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Job Loss Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Job Move Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LAND USE SECTOR	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Residential Space Per Household	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Non-Residential Space Per Job	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Land Protection	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
TRANSPORT SUPPLY SECTOR	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Road Capacity Addition	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Transit Capacity Addition	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
Road Vehicle Capacity Per Lane	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Transit Passenger Capacity Per Route	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EXTERNAL INDICES FOR OTHER REGIONS OF THE US	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
External Job Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
External Non-Residential Space Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
External Residential Space Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
External Road Capacity Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Appendix D. Scenario “Global Chaos” Inputs for Enhanced Impacts 2050

Scenario multipliers on base rates	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
SOCIO-DEMOGRAPHIC SECTOR											
Death Rate	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80
Birth Rate	1.00	1.00	1.00	0.80	0.70	0.70	0.70	0.60	0.60	0.50	0.50
Marriage Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.80	0.80	0.80	0.80
Divorce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Empty Nest Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.80	0.80	0.80	0.80
Leave Workforce Rate	1.00	1.00	1.00	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Enter Workforce Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Leave Lowest Income Group Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Enter Lowest Income Group Rate	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80
Leave Highest Income Group Rate	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80
Enter Highest Income Group Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Foreign Inmigration Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Foreign Outmigration Rate	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
Domestic Migration Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.80	0.80	0.80	0.80
Intra-Regional Migration Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Death Rate	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
High Income- Effect On Death Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Low Income- Effect On Birth Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Birth Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Marriage Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Marriage Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Divorce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Divorce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Empty Nest Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Empty Nest Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Space Per Household	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
High Income- Effect On Space Per Household	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60

TRAVEL BEHAVIOR SUBSECTOR	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
Gasoline Price	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80
Shared Car Fraction	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80
No Car Fraction	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80
Work Trip Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.80	0.80	0.80	0.80
Nonwork Trip Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Car Passenger Mode Share	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80
Transit Mode Share	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Walk/Bike Mode Share	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80
Rideshare Mode Share	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Car Trip Distance	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Age Cohort Effects in Travel Models	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

EMPLOYMENT SECTOR	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
Job Creation Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Job Loss Rate	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
Job Move Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60

LAND USE SECTOR	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
Residential Space Per Household	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Non-Residential Space Per Job	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Land Protection	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60

TRANSPORT SUPPLY SECTOR	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
Road Capacity Addition	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Transit Capacity Addition	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Road Vehicle Capacity Per Lane	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Transit Passenger Capacity Per Route	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60

EXTERNAL INDICES FOR OTHER REGIONS OF THE US	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
External Job Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
External Non-Residential Space Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
External Residential Space Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
External Road Capacity Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Appendix E. AHP stakeholder weighting survey form

	Extremely Preferred 9	Very Strongly Preferred 7	Strongly Preferred 5	Moderately Preferred 3	Equally Preferred 1	Moderately Preferred 3	Strongly Preferred 5	Very Strongly Preferred 7	Extremely Preferred 9	
Social	○	○	○	○	○	○	○	○	○	Technological
Social	○	○	○	○	○	○	○	○	○	Environmental
Social	○	○	○	○	○	○	○	○	○	Economic
Social	○	○	○	○	○	○	○	○	○	Political
Technological	○	○	○	○	○	○	○	○	○	Environmental
Technological	○	○	○	○	○	○	○	○	○	Economic
Technological	○	○	○	○	○	○	○	○	○	Political
Environmental	○	○	○	○	○	○	○	○	○	Economic
Environmental	○	○	○	○	○	○	○	○	○	Political
Economic	○	○	○	○	○	○	○	○	○	Political
High percentage of people do not own cars	○	○	○	○	○	○	○	○	○	High percentage of trips use rideshare services
Average speed during peak traffic at or near posted limit	○	○	○	○	○	○	○	○	○	High percentage of cars are fully self-driving (SAE Level 5)
Decreasing number of cars per capita	○	○	○	○	○	○	○	○	○	High percentage of trips made via transit/walk/bike
Decreasing number of cars per capita	○	○	○	○	○	○	○	○	○	Decreasing Vehicle Miles Traveled (VMT) per capita per day
Increasing percentage of trips made via transit/walk/bike	○	○	○	○	○	○	○	○	○	Decreasing Vehicle Miles Traveled (VMT) per capita per day
Increasing percentage of trips made via transit/walk/bike by lower income population	○	○	○	○	○	○	○	○	○	Equal number of trips per capita for upper income and lower income population
Decreasing ratio developed land per capita (acres/person)	○	○	○	○	○	○	○	○	○	Decreasing road density-total lane miles/total surface area

Appendix F. Sustainable Urban Mobility Scorecard: Unweighted vs Weighted Results

City	Scenario	Unweighted Scores						Weighted Scores					
		Soc.	Tech.	Env.	Econ.	Pol.	TOTAL	Soc.	Tech.	Env.	Econ.	Pol.	TOTAL
Atlanta	Momentum	4.9	4.8	4.7	5.0	5.0	**24.4**	8.1	3.6	6.7	3.7	2.1	**24.1**
	Tech Triumphs	5.0	5.0	4.6	5.0	5.0	**24.6**	8.2	3.9	6.5	3.7	2.1	**24.4**
	Gentle Footprint	5.2	5.4	5.4	5.0	5.0	**26.0**	8.2	4.4	8.0	3.7	2.1	**26.4**
	Global Chaos	4.9	4.9	5.2	4.9	5.0	**25.0**	8.0	3.8	7.5	3.7	2.1	**25.1**
Boston	Momentum	4.9	4.6	4.7	5.0	5.0	**24.2**	8.0	3.3	6.6	3.7	2.1	**23.7**
	Tech Triumphs	5.0	5.0	4.6	5.0	5.0	**24.7**	8.0	4.0	6.5	3.7	2.1	**24.2**
	Gentle Footprint	5.0	5.4	5.4	5.0	5.0	**25.9**	8.2	4.5	8.1	3.7	2.1	**26.4**
	Global Chaos	5.1	5.0	5.2	4.9	5.0	**25.2**	8.4	3.9	7.6	3.7	2.1	**25.7**
Detroit	Momentum	4.9	4.3	4.7	5.0	5.0	**23.9**	8.1	2.9	6.7	3.7	2.1	**23.4**
	Tech Triumphs	5.0	5.1	4.6	5.0	5.0	**24.8**	8.1	4.1	6.5	3.7	2.1	**24.5**
	Gentle Footprint	5.1	6.0	5.4	5.0	5.0	**26.6**	8.2	5.2	8.1	3.7	2.1	**27.2**
	Global Chaos	5.0	4.6	5.2	4.9	5.0	**24.7**	8.2	3.4	7.5	3.7	2.1	**24.8**
Houston	Momentum	5.0	4.5	4.8	5.0	5.0	**24.3**	8.1	3.3	6.8	3.7	2.1	**23.9**
	Tech Triumphs	5.0	5.1	4.7	5.0	5.0	**24.8**	8.2	4.1	6.6	3.7	2.1	**24.7**
	Gentle Footprint	5.1	5.5	5.4	5.0	5.0	**25.9**	8.1	4.6	7.9	3.7	2.1	**26.4**
	Global Chaos	5.0	4.9	5.2	5.0	5.0	**25.0**	8.1	3.7	7.4	3.7	2.1	**25.0**
Seattle	Momentum	5.0	4.7	4.7	5.0	5.0	**24.4**	8.1	3.6	6.6	3.7	2.1	**24.0**
	Tech Triumphs	5.0	5.1	4.6	5.0	5.0	**24.8**	8.2	4.0	6.5	3.7	2.1	**24.5**
	Gentle Footprint	5.1	5.2	5.4	5.0	5.0	**25.7**	8.1	4.2	8.0	3.7	2.1	**26.1**
	Global Chaos	5.0	5.0	5.2	4.9	5.0	**25.1**	8.1	3.9	7.5	3.7	2.1	**25.3**
maximum		5.2	6.0	5.4	5.0	5.0	**26.6**	8.4	5.2	8.1	3.7	2.1	**27.2**
minimum		4.9	4.3	4.6	4.9	5.0	**23.9**	8.0	2.9	6.5	3.7	2.1	**23.4**
maximum-minimum		0.2	1.7	0.8	0.1	0.0	**2.6**	0.5	2.3	1.6	0.0	0.0	**3.8**

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