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Heading towards a multimodal city of the future? Multi-stakeholder scenarios for urban mobility

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ABSTRACT

In redesigning city infrastructure to become sustainable and future-oriented, critical city subsystems, such as the urban mobility system, present a serious challenge. In order to avoid regime stalemates and path dependency, substantial changes to the urban mobility systems are required to limit economic, ecological, population and institutional constraints. We argue that the socio-technical system of multimodal mobility has the potential to solve some of today's urban mobility challenges. Multimodal mobility combines both private and public transport modes, thereby capitalizing on the benefits of various systems. Realizing that mobility systems are non-monolithic and transitions require interdisciplinary analyses, we adopt a multi-level perspective with actors across different fields. This paper aims to guide cities in developing a long-term future vision of urban mobility systems in Germany while drawing on considerations of transition theory. Our comprehensive approach, conceptualized through a strategic issue management framework, draws on empirical evidence from three parallel Delphi studies and several focus group workshops to present strategic implications to firms, public authorities, and customers. Among others, the strategy agenda for stakeholders must coordinate efforts to utilize system strengths, advance intelligent transport systems, diversify the portfolio of public and private financing, change business models, and create a renaissance of civil participation.

1. Introduction

Urban areas are populated by over half the world's population and are anticipated to witness most of the population growth in the following forty years. By 2050, the population in urban areas is expected to increase by 2.6 billion to 6.3 billion people [1]. Until recently, the provision and organization of city subsystems was widely perceived to be a simple engineering and administrative issue [2]. However, the contemporary pressures faced by cities cannot be dealt with by the infrastructural systems and legacies often developed over the 20th century in many western contexts [3]. It is of the utmost importance for vital city subsystems, such as the transportation system, to function efficiently to support the future development of sustainable urban infrastructures [4, p. xvii]. Personal mobility is considered to fulfill a societal function [5].

In fact, urban mobility is one of the greatest challenges that cities currently face [6]. Individual mobility in urban areas is increasingly reaching its limits since progressive urbanization has caused continuous rising demand for the urban mobility systems [7,8]. By 2050, urban dwellers will spend an average of 106 h in traffic jams per year, three times more than today [6]. Hence, road networks are suffering from recurrent congestion, the accessibility of city centers is deteriorating, and the environmental impact is already considered to be too high

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[9–11]. In addition to these challenges, the changing urban mobility patterns of people, the related demographic changes, and the dwindling investment capacity of public authorities need to be considered. As a consequence, citizens, businesses, and governments are often dissatisfied with the state of urban mobility.

Therefore, a way to modernize the current urban mobility systems has to be found, so that economic, environmental, and institutional constraints are limited and sustainable, and competitive city mobility subsystems are achieved to further improve personal mobility. Although technological advancements have decreased the impacts of individual journeys, they have often only provided temporary and partial solutions [12–15]. Therefore, it is improbable that such improvements alone can sustainably reduce the impact of transport. In fact, “transitions do not come about easily, because existing regimes are characterized by lock-in and path dependence, and oriented towards incremental innovation along predictable trajectories” [13, p. 495]. Therefore, responses to the current challenges for cities require more fundamental restructuring of the transportation system in the years to come [2,3,16]. Over the past 10 years, researchers have labeled these substantial system changes as ‘socio-technical transition’. Such transition not only requires major changes in technology, but also organizational and structural changes for both supply and demand [e.g. 17].

One measure to deal with urban mobility constraints is to promote public transport. However, efforts to stimulate more frequent use of public transport have seldom been successful. It seems to be impossible to compete with individual motorized transport [18]. The socio-technical system of multimodal mobility, however, seems appropriate for solving some of today's mobility problems. The concept of multimodal mobility changes the view on the traditional strictly dichotomous choice between either private or public transport. Unlike unimodal transport, multimodal transport uses two or more transport services. Combining private and public transport modes offers the benefits of both systems while avoiding their weaknesses [19]. Current multimodal mobility concepts are fragmented since they were developed over different time periods by different actors [2,10]. Therefore, a comprehensive, well-planned multimodal system is required.

A socio-technical transition towards such a new, sustainable urban multimodal mobility system requires long-term orientation to successfully adapt and innovate business models and invest in appropriate resources [20,21]. Approaches deployed in foresight and futures research tend to be suitable for such a long-term transition process [16,22]. Thereby, previous experiences cannot be merely extrapolated into the future [23]. Instead, approaches that promote broad planning perspectives have to be incorporated [24]. Fundamental to such systemic transitions is the notion that mobility systems are non-monolithic and constitutes multiple relationships. Therefore, a large variety of stakeholders, representing diverse social interests, should be involved in planning activities from the onset [25,26], including businesses, political institutions, national governments, and households. Previous research on dynamic market systems has highlighted a variety of different participatory approaches that can be used to assess future activity: Delphi panels [27,28], scenario planning [29], stakeholder analysis [30], and participatory workshops [31,32]. Thus, effective coordination of these forms of analysis would enable successful transitions from current mobility systems to more advanced systems, by predicting numerous challenges for multiple actors.

Strategic issue management (SIM) may support the conceptualization and research of such a socio-technical transition to a multimodal urban mobility system. Strategic issues are generally defined as events that would affect companies in the future [33]. Liebl and Schwarz [34] expanded upon this definition by stating the importance of novelty and adjustment that surround these particular events. Thereby, the integration of SIM and foresight methodology produces a holistic framework to contribute to the quality of long-term decision making quality [35,36].

In this paper, we contend that the limited amount of progress made thus far in enhancing the sustainability of urban mobility indicates the necessity to apply an interdisciplinary approach with multi-level involvement of actors and institutions across different scales [25,37]. We aim to provide insight into the dynamic interactions between stakeholders' actions and the resulting impact on system change. To reflect ongoing discussions and varying perspectives of stakeholders, the purpose of this paper is to develop partially-contradictory multi-stakeholder scenarios on the future of urban mobility in Germany. Inspired by future challenges for urban mobility and considerations of the socio-technical system theory, we develop a vision of urban mobility for the year 2030, based on desired parameters. Additionally, the paper aims to incorporate the various views of future images to study how urban mobility is likely to evolve in the long-term and shed light on the way the preferable future for 2030 can become reality [26], elaborating on managerial and governmental implications. In line with Wells and Nieuwenhuis [38, p. 3] we argue that “transitions need to be managed or orchestrated rather than simply left to market forces.” Thereby, we exemplify a scenario building approach using three parallel real-time Delphi surveys [39] for data generation, along with multiple focus group workshops. A time horizon until 2030 allows the assumption of trend reversals, whether with regards to the environment, technology, or behavior.

The paper commences with a review of previous future-oriented urban mobility research and a discussion of socio-technical transition theory and SIM. A structured research approach demonstrates how a combination of a SIM process and foresight methodologies can guide cities to achieve such transitions to sustainable urban multimodal mobility systems. Next, the results of three parallel Delphi studies are considered, which addressed scenario development from a multi-faceted perspective with more than 200 panelists. Based on normative scenarios, we elaborate on the results of focus group workshops to develop strategies and implement an action plan to make the aspired to urban mobility situation a reality in 2030. Our holistic approach involves all major stakeholder groups in the field of mobility services and supports strategic decision making while offering guidance for firms, public authorities, and customers in creating sustainable urban mobility in Germany. The paper concludes with recommendations for future research.

2. The need for purposive urban mobility system transition

2.1. Review of future-oriented urban mobility research

Foresight activities are useful in identifying diverse future perspectives in order to better understand contrasting ideas and opinions [40]. Acting in dynamic environments requires a well-developed perception of the environment and its inherent societal challenges [41]. Monitoring trends and detecting weak signals in the business environment can better prepare stakeholders for the future while managing everyday business activity [42].

The future of urban mobility has been intensely debated over the past few years and various forms of foresight approaches have emerged in the field. A selection of relevant recent academic research on future-oriented urban mobility publications is presented in Table 1. Since current economic, ecological, population, and institutional circumstances compel companies, agencies, and governments to continuously deal with the future of the urban mobility systems, we did not limit the review to the academic discussion. In fact, we researched 49 reports, from which we derived clusters that included focal topics and overlaps of classification criteria. To visualize the semantic similarity, we applied multidimensional scaling (MDS)[3] [43–45]. The results are presented in Appendices A to C.

Advancements in technology and innovation have been considered to be key success factors in meeting the challenges of urban passenger transport. Especially with regards to decreasing the environmental impact, the focus of previous works was placed on alternative drive technologies, including improved fuel efficiency, alternative fuels, and propulsion systems [e.g. 46–49]. In 2010, the German government launched the National Platform for Electric Mobility (NPE), which was designed to integrate environmental protection into industrial policies and propel Germany at the forefront of the electric mobility market. The initial plan was to have one million electric drive vehicles (EVs) registered in Germany by 2020, supported by approximately €1.5 billion in federal aid [50,51]. However, recent interim reports revealed significant challenges regarding non-monetary incentives for such measures and re-adjusted their initial target for EVs to 600,000 [51,52]. Moreover, such technological perspectives of urban mobility investigate the effectiveness of intelligent transport systems, information technology, and location-based services [e.g. 18,53,54]. Past research has shown that the quality of transport information affects customers' mode of transport choice [18]. In particular, information would be most valuable to the user if traveler data were integrated [82]. Thus, it is important that multimodal travelers are provided with information prior to and during a trip [18]. According to a study by Zografos et al. [83], frequent travelers, as well as older people, perceive the benefits of an integrated journey planning system to be more substantial than non-frequent and younger travelers.

Previous works also modeled customer preferences for urban travelers. Thereby, some authors concluded that costs and personal mobility needs outrank environmental benefits [55–57]. However, Wegener [60] indicates that transport energy will no longer be abundant due to finite fossil fuel reserves, and that in order to accomplish greenhouse gas reduction targets, transport energy must become more expensive. Especially among young adults in Germany, travel trends show decreasing levels of car ownership and use, as well as disappearing gender differences [9].

Another research stream started to assess potential new business models for mobility providers and regarded such reorientation strategies as a key megatrend in the automotive industry [38,63]. Thereby, highly integrated strategies become increasingly important while greater public and private sector synergies need to be encouraged [15,68]. In fact, authors have determined that the types of value resulting from inter-firm relationships have changed over the years from operational performance improvements towards a stronger focus on integration-based values, such as improved collaboration and partnerships [84]. For instance, the growing importance of car-sharing is expected to support changes in mobility patterns [63–65]: Many experts believe that electric mobility will only be successful if suitable car-sharing models are created [e.g. 63,67]. In a study recently conducted by Schäfers [85], more than half of the participating companies perceived it feasible to combine car-sharing with electric mobility in the future. Other research streams focus on modeling the effectiveness of incentives and regulation [e.g. 48,73,74], marketing [e.g. 77], and fare types in public transport [77,79,80].

Overall, previous publications primarily dealt with rather myopic views and did not adequately consider multi-stakeholder perspectives of corporations, public authorities, and customers. However, future mobility systems require comprehensive services for numerous stakeholders with diverse sets of target systems [e.g. 47,86]. Since a wide range of different stakeholders is seriously concerned with the urban challenges to come, collaborative countermeasures become inevitable [87,88]. To date, only few articles have addressed the topics of future mobility and relationship research. Although the decisive transformative influence of public authorities has been stressed [69–71], cross-sector synergies are rarely explicit, since the link between foresight planning activities and political decision making has often been neglected [89]. Moreover, although undeniably important, technological innovations have often only provided temporary and partial solutions [12–15]. Hence, the broader vision of the urban transport system tends to be neglected, in favor of focusing upon the various technological elements instead. Potter and Skinner [15] stressed the importance of developing holistic strategies that incorporate areas not traditionally associated with the transport planning process. In addition, the majority of identified publications analyzes how already prevalent structures may develop in the future but does not explicitly consider the opportunities for new business model innovations. Although numerous projects show different scenarios, such as car sharing [63–65] or new

[3] Core message of MDS: the closer two points (i.e. reports or publications) are along the graphical illustration, the more similar they are regarding content or structure. Dimensions used in present urban mobility MDS: (1) currentness to see how selected topics have been publicly discussed over time; (2) planning horizon to implicitly illustrate the visionary power of the studies since the further the time horizon is from today, the more weak signals should be taken into consideration; (3) geographical focus; (4) type of study based on differences between more empirically oriented approaches and qualitative driven scenario descriptions; (5) cluster priorities with respect to content characteristics. For further information on multidimensional scaling, please refer to: Borg and Groenen [43] I. Borg, P.J.F. Groenen, Modern multidimensional scaling: Theory and applications, Springer, 2005. and Cox and Cox [44] T.F. Cox, M.A.A. Cox, Multidimensional scaling, Chapman & Hall/CRC, 2000. MDS was created using the program "Permap" [45] R.B. Heady, J.L. Lucas, PERMAP: An interactive program for making perceptual maps, Behavior Research Methods, 29 (1997) 450–455.

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Table 1
Studies concerning the future of urban mobility in scientific research (excerpt).

Research scope	Key findings
Technology	• Analysis of the unfolding technological competition and the most probable technologies for the upcoming decade [46] • Developments in low emission vehicles [47] • Battery-powered and plug-in hybrid electric vehicles are expected to reach sustained market deployment by 2030 [48] • Integration of transport and energy system is crucial; biofuels are not able to solve the problems within the transport sector [49] • National Platform for Electric Mobility (NPE) aim to integrate climate protection with industrial politics by transforming Germany into the leading market for electric mobility [50–52] • Critique on the effectiveness of intelligent transport systems in the public transport sector to improve passenger experience and operator effectiveness [53] • Integrated multimodal travel information is expected to affect customers' modal choice: pre-trip stage vital for collecting information when planning multimodal travel [18] • Implications of location-based services, enabling consumers to (re)discover their proximities to products [54]
Customer preferences	• Costs and personal mobility needs outrank environmental benefits [55–57] • Customer preferences depend on three main aspects: willingness to pay, the importance of owning a car, and the energy source [58] • Travel time expected to be the most important saving [18] • Contribution of cars to total CO_2 emissions will rise to 95% of total CO_2 emissions from road passenger transport [59] • Transport energy will no longer be abundant and cheap [60] • Customers concerned that rapid technological and infrastructural developments will make current models obsolete [55] • The car represents an important overall cornerstone [38] • Continuously increasing vehicular mobility levels are unlikely to occur [61] • Travel trends among young adults in Germany: decreasing levels of car ownership and use, disappearing gender differences, increasing multimodality [9] • Review of land-use transportation scenario planning projects [62]
New business models and cross-sector synergies	• Increasing importance of highly integrated strategies that involve areas not traditionally considered part of the transport planning process (health, urban regeneration, and education) [15] • New business models as key megatrend in automotive industry [38,63] • Growing importance of car-sharing, supporting changes in mobility patterns [63–65] • Visions of car concepts [66] • Discussion of potential business models for electric mobility [67] • Ways to encourage greater public and private sector synergies [68] • Significant challenges for start-ups to claim territory in the mobility system [38]
Regulations and incentives: governance, 7power and institutions	• Discussion about how physical policies, soft policies, and knowledge policies aim to induce changes in consumers' and firms' behaviors [69] • Decisive transformative influence of politics; however, policy decisions highly influenced by the power of carmakers in Germany, leading to only incremental changes [70] • National policy creates pressure for local content, driving production close to end markets; study of the consequences of powerful lead firms that drive the automotive industry [71] • Key role of policy drivers in both supply-side innovation and demand-side change [72] • Financial incentives influencing customers' transport decisions are controversially discussed [58] • Size of direct financial incentives determines purchasing behavior and market share for electric vehicles, preconditioned accurate timing [48,73] • Relevance of increasing subsidies for sustainable mobility modes is questioned, implying impact only under certain circumstances [74] • Review of interventions to change transport behavior, especially to reduce car use [75] • Distance-based road charging restricts traffic growth, while congestion-based road charging, urban transport investments, and new fuel technologies improve energy efficiency [76]
Public transport and modal diversion	• Recommendation to market public transport information simultaneously with public transport use [77] • Well-implemented flexible transport services have the potential to revitalize bus-based public transportation services [78] • Effect of fare type on ridership varies by mode and ticket to travelcard prices; limited effects of fare increases on ridership despite modal competition or cooperation [79] • Higher satisfaction levels of urban transit services in smaller towns than in metropolitan cities [80] • Importance of considering cognitions relating to both car use and alternative transportation in modeling transportation choice [81]

car concepts [66], they do not explicitly assess strategies for different stakeholder preferences, or limit their elaborations to innovative concepts for motorized private mobility with a unimodal transport consideration.

Consequently, by considering a variety of established concepts in foresight, including the Delphi method and a series of multi-stakeholder focus group workshops, this research makes an initial attempt towards an integrated scenario analysis of the future of urban mobility, particularly considering the diversity of stakeholders and their different opinions involved in the transition process.

2.2. Socio-technical transition, the MLP, and the conceptualization towards a multimodal system through SIM

The review of recent literature revealed the shortcomings of addressing the system of urban mobility in a holistic manner to incorporate a diverse set of stakeholders. A multimodal mobility approach has the potential to guide sustainable transition and solve today's transportation problems [9,10]. Consequently, cities need to "…respond strategically to generic pressures by developing managed systemic change in the socio-technical organization of key aspects of their infrastructure" [2, p. 479].

We will discuss how socio-technical transition theory and the conceptualization through a SIM process can support cities in developing sustainable urban multimodal mobility systems.

Socio-technical transitions are characterized by significant technological advancements, market shifts, modified user practices, policy amendments, and alterations to cultural connotations [17]. To understand sustainable transitions, an interconnected three-level framework is offered by the multi-level perspective (MLP) [5,90]: "… (it) provides an overall view of the multi-dimensional complexity of changes in socio-technical systems" [13, p. 495]. (1) The regime level represents the established practices or institutions of a given system. Change occurs incrementally rather than radically. Technological innovations are filtered. (2) At the socio-technical niche level, experimentation and learning are encouraged. Radical innovations and novel technologies are developed and proliferated. Small networks comprise this area, which is largely protected from external influences. (3) The landscape level refers to the overall setting of tangible and intangible aspects. It creates the broader context in which actors and coalitions of actors operate, and applies pressure on existing regimes, leading to tensions and windows of opportunity. As proposed by MLP, transitions need to be managed in order to decrease the inherent uncertainty which goes along with change. Transitions involve regime shifts, where processes interact with each other at the regime level but also with other levels [13]. Socio-technical transitions typically evolve over long time spans and concern diverse stakeholders. Thereby, "in the course of such a transition (radically) new products, services, business models and organizations emerge, partly complementing, partly substituting existing ones" [16, p. 991].

SIM supports the conceptualization of a socio-technical transition to a multimodal system in urban mobility. Traditionally, SIM aims at detecting weak signals and upcoming strategic issues expected to affect organizations and their environments [33]. Dutton et al. [42, p. 308] defined a strategic issue "as an emerging development which, in the judgment of some strategic decision makers, is likely to have a significant impact on the organization's present or future strategies." SIM is highly dynamic and continuous, allowing companies to instinctively react to a particular event, thus making them more tolerant of changing environments [91]. As an actively orchestrated process, SIM requires stakeholders within a system to adapt their strategies in order to ensure or improve the systems' sustainable performance. To analyze the complex multi-dimensional changes in socio-technical systems, we integrate the three analytical levels of MLP into the SIM process.

3. Research approach and methodology

Although various classifications for an SIM framework exist in literature [e.g.92], three generic phases have been identified to guide our conceptual framework (Fig. 1): (1) strategic issue orientation, (2) strategic issues assessment and (3) purposive strategy transition. Since strategic information is usually confidential in nature, it is necessary to consult a variety of sources in order to ensure reliable information [63]. Therefore, we considered a variety of established concepts in foresight, including three parallel Delphi surveys in real-time format [39,93] and a series of multi-stakeholder focus group workshops for data generation.

3.1. Strategic issue orientation for urban mobility system transition

3.1.1. Phase 1.1: Identification of strategic issues

Previous research has emphasized the importance of the systematic identification of strategic issues for consideration in subsequent Delphi studies [94–96]. Therefore, we pursued a rigorous phase-based procedure to unravel a list of strategic issues considered to shape the future state of urban mobility. The process was facilitated by a core team of three senior researchers with several years of experience in urban mobility research, explicitly pertaining to the multi-level transition perspective (please refer to Fig. 2).

To determine the various factors that are expected to influence the future of urban mobility, the environmental scanning approach comprised of several creative workshop sessions with the core research team in combination with searches of databases. Consequently, we compiled future-oriented urban mobility knowledge through searches of scientific databases (e.g. EBSCO, Emerald Insight, ScienceDirect,

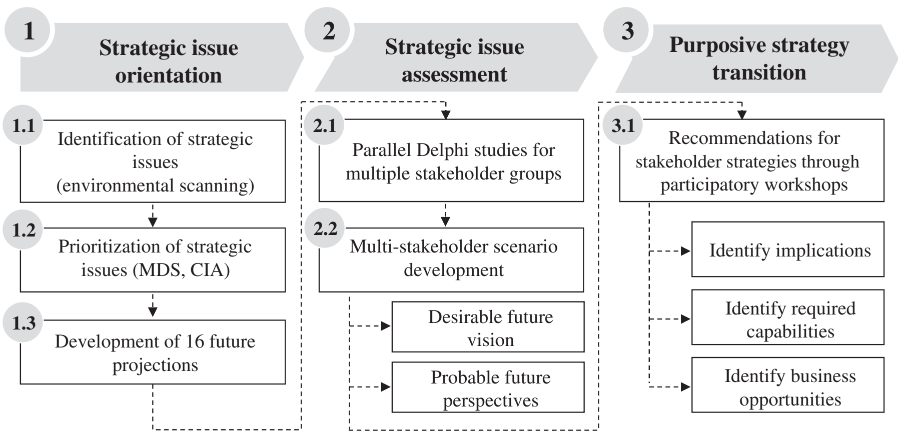

Fig. 1. Research procedure: SIM framework for purposive urban transitions. Notes: MDS: multidimensional scaling; CIA: cross-impact analysis.

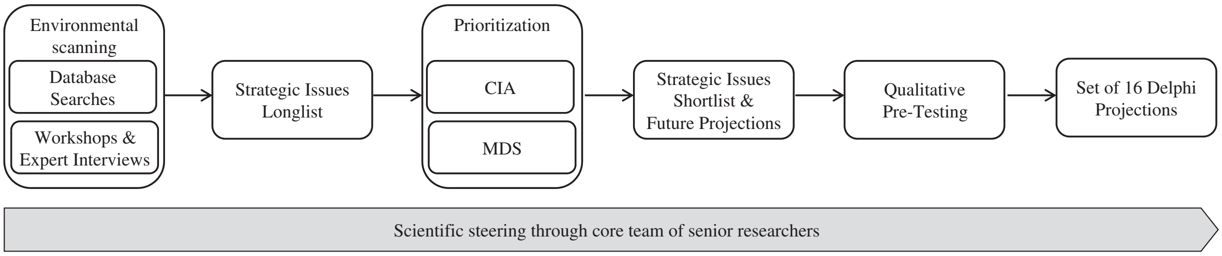

Fig. 2. Process of strategic issue orientation. Notes: MDS: multidimensional scaling; CIA: cross-impact analysis.

Datamonitor) as well as trend databases.[4] Furthermore, in order to cross-validate our initial set of influencing factors (i.e. issues), we consulted the representatives of the senior management of four German automobile manufacturing companies, two politicians, and five frequent urban commuters. This cross-validation of possible issues through the interaction of information-gathering methods ensured face and content validity. Overall, we compiled an initial set of 168 issues based on heterogeneous contributions. In a subsequent assessment of the core research team, the initial set of issues was narrowed to a list of 27 strategic issues with particular relevance to the topic. This scoping was done in an open discussion process, in which consensus for strategic issue selection was perceived as 100% agreement among the core team members. Thereby, particular attention was paid to avoiding similar issues under different labels.

3.1.2. Phase 1.2: Prioritization of strategic issues

Prior research on the design of Delphi surveys has demonstrated that response rates are lower and surveys are more often improperly completed, the more projections are included [97]. Therefore, our goal was to reduce the number of projections to an effective minimum. In order to comprehend the complex topic of the future urban mobility, the long list of 27 strategic issues was transferred into a cross-impact matrix[5] [98–100] to further prioritize them for inclusion in our scenario study. Cross-impact analysis (CIA) is based on the assumption that events are interrelated rather than independent [101]. The core team members individually prioritized the strategic issues based on their highest mutual impact. Subsequent scores of individual intensity of activity and interconnectedness were calculated, leading to a final prioritization of strategic issues. We selected the top 16 strategic issues for Delphi projection formulation, based on methodological practices of CIA research,[6] which was appraised by the researchers to represent a suitable time effort for panelists [102]. The insights from our MDS analysis on current governmental and agency reports (compare Section 2.1) further complemented the prioritization of strategic issues, which were broadly grouped into six dimensions: (1) technology and urban planning, (2) value orientation and consumption, (3) collaboration, (4) financing and capital, (5) market structure and competition, and (6) implementation lead.

3.1.3. Phase 1.3: Development of future projections

In a next step, we transformed the final set of 16 strategic issues into short, controversial Delphi projections for the year 2030. Since the formulation and development of Delphi projections influences the reliability and validity of the obtained data significantly [95,102,103], we deliberately followed methodological rules [e.g. 104]: among others concerning non-ambiguity, exclusion of conditional statements, explanation of scientific or technological terms [103,105], balance of conciseness and length [106,107], and optimal processing time reflected in length of the survey [97,108]. In order to ensure clarity in the formulation and improve ambiguous statements, cognitive interviews were held with respondents from the sample population [104,109]. Based on the results of these qualitative pre-tests, minor modifications were made. The final set of Delphi projections on the future of urban mobility is presented in Table 2.

3.2. Strategic issue assessment through parallel Delphi studies

Delphi surveys were conducted in order to obtain expert-based assessments of the strategic issue-based projections' probability of occurrence and desirability. Thereby, we objectified the process to evaluate strategic issues.

3.2.1. Phase 2.1: Concurrently performed Delphi studies

The underlying principle of the Delphi method is that group-based forecasts are considered to be more accurate, compared against those made by an individual. The method surveys experts and efficiently applies a structured dynamic group communication process to explore and interpret data, thereby avoiding negative effects such as the halo or bandwagon effect [27,110,111]. Gnatzy et al. [39] complemented the work of Gordon and Pease [93] by introducing an online Delphi survey, which provides participants feedback in real time. We applied this method to our research in order to simplify the survey process and improve the validity of the data collected by reducing the effects of panel mortality and research fatigue [112,113]. Our study combines insights from three parallel Delphi studies based on diverse target systems to multi-stakeholder scenarios. By consistently applying the same

[4] We placed explicit attention to trend spotting and searched various trend databases for future-relevant knowledge concerning the focal topic of multimodal urban mobility: e.g. iKnow, Shaping Tomorrow, TechCast, TrendONE, TrendWiki, and Trendwatching.

[5] Cross-impact analysis is an analytical tool for assessing and mapping relationships and interactions between system components. The analysis is performed by means of a cross-correlation matrix. We applied the software CIM 8.1. The program is able to process 8 to 30 components.

[6] The threshold for final inclusion of strategic issues was defined by: (1) the highest level of individual intensity of activity and interconnectedness scores (sum of total active and total passive scores), (2) at least one of the total active or total passive scores was above 26 (accounting for half of the maximum number of individual intensity of activity and interconnectedness scores).

Table 2
Projections for 2030: future of urban mobility.

Technology and urban planning	
TP1	2030: A comprehensive mobility platform for different mobility services providers has been established (e.g. integrated route and tariff planning as well as secure payment processing).
TP2	2030: The willingness of end users to share personal information ("transparent customers") allows optimal matching of mobility services to individual needs.
TP3	2030: Electric drive vehicles are a key success factor for multimodal mobility concepts.
TP4	2030: Multimodal mobility concepts have amplified tensions and conflicts in urban and regional planning.
Value orientation and consumption	
VC1	2030: Consumers primarily use well-organized multimodal mobility services (e.g. local public transportation, car sharing, railways).
VC2	2030: The traditional ownership of transportation means has become less important to end-users.
VC3	2030: Customers appreciate multimodal mobility solutions compared to motorized individual transport due to time savings.
Collaboration	
CO1	2030: Collaborations between different interest groups are the key success factor of multimodal mobility services.
CO2	2030: Public authorities have missed out on promoting collaborations in the field of multimodal mobility.
Financing and capital	
FC1	2030: Multimodal mobility has become a profitable investment.
FC2	2030: Subsidies for multimodal mobility through public authorities have been increased significantly compared to 2011.
Market structure and competition	
MC1	2030: Formerly non-active service providers in the field of mobility (e.g. IT/communication, energy supply) have become serious competitors of traditional mobility services provider and manufacturers.
MC2	2030: Car manufacturers have not been able to establish themselves as mobility services provider.
Implementation lead	
IL1	2030: Industry representatives have assumed the lead in the design of multimodal mobility in relation to customers and public authorities.
IL2	2030: Public authorities have assumed the lead in the design of multimodal mobility in relation to the industry and customer.
IL3	2030: Customers have assumed the lead in the design of multimodal mobility in relation to the industry and public authorities.

Delphi format, we ensured standardization and homogeneity of the studies and a high level of comparability. Each projection in the Delphi studies was assessed according to its expected probability (EP) and desirability (D), and arguments could be given to justify these assessments.

In order to ensure the reliability of research results, it is essential to identify and select the appropriate experts to participate in a Delphi survey [114]. Previous researchers have explicitly emphasized integrating a diverse set of viewpoints in scenario development to prevent misleading consensus of similarly oriented stakeholder opinion [115,116]. We reason that involving groups of individuals with different functional and cognitive backgrounds in evaluating strategic issues could be a way to increase ambivalence in perceptions about strategic issues. Thereby, in addition to representatives from industry and public authorities, we purposely included customers in the panels because they are mostly affected by socio-technical changes to urban mobility. In total, we identified and contacted 721 designated subject matter experts in Germany, distributed among a multitude of 12 stakeholder subgroups. Following suggestions of prior researchers [117], we thereby incorporated both easy-to-observe surface-level panel selection criteria and value characteristics as deep-level diversity dimensions. In particular, criteria in selecting panel members included type of organization, current job position and profile (particularly decision makers with foresight capabilities, such as board members, strategists, analysts, business developers, governors, and ministers), education or academic title, publications, speeches, and recommendations by peers. The final Delphi sample consisted of 201 panelists (76 industry experts, 68 public authorities, and 57 customers), accounting for a diverse set of interests (Table 3). The overall response rate of 27.9% is sufficient for this type of survey and analysis since Delphi surveys do not aim for representativeness, rather a high degree of expertise and heterogeneous viewpoints [117–119]. The satisfactory response rate also reflects the urgency and interest in the topic, as well as the success of personal recruitment of panelists via telephone.

In order to evaluate non-response bias, we separated participants into early respondent and late respondent groups. Late respondents were considered to characterize non-respondents [120,121]. Upon introduction of a Mann-Whitney test to the data, no statistically significant discrepancies were

Table 3
Delphi participants by stakeholder group.

Stakeholder Delphi	Stakeholder subgroup	N	in %
Industry experts (IN)	Original equipment manufacturers (OEM)	23	30
	Automotive suppliers (ASU)	13	17
	Mobility services providers (MSP)	19	25
	Consulting/associations (CON)	21	28
	Subtotal	76	100
Public authorities (PA)	Federal authorities (FAU)	22	32
	District authorities (DAU)	17	25
	Local authorities (LAU)	9	13
	Public transport/organizations (PTO)	20	30
	Subtotal	68	100
Customers (CU)	Young adults (YAD)	15	26
	Employees (EMP)	20	35
	Retired persons (RET)	9	16
	Associations (ASS)	13	23
	Subtotal	57	100
	Total	201	

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observed among early and late respondents. On this basis, we deduce that the study does not exhibit non-response bias.

3.2.2. Phase 2.2: Multi-stakeholder scenario development

The results of the Delphi surveys formed the basis for the multi-stakeholder scenario development process and adjacent stakeholder strategy development. For the identification of relevant scenario content, a consensus analysis of each dimension was conducted. Thereby, a variety of analytical methods guided the development of multi-stakeholder scenario development (Fig. 3).

The results of our inter-Delphi study analysis provided the basis for our scenario levels three and two: the overall basis scenario (level 3) includes those projections where the inter-Delphi analysis results in consensus for each stakeholder group involved; level 2 demonstrates consensus among two of the three stakeholder groups involved. Overall, for inclusion of Delphi projections in the respective scenario levels, we determined that Delphi study results should show an (1) equal and (2) clear tendency in mean values on EP and D. To test for significant differences among the three Delphi panels, we conducted group comparisons among the panels based on the dependent variables of EP and D for our 16 projections. We tested for inter-group consensus in all three Delphi panels which could be achieved through any of the following three criteria: (3a) A satisfactory interquartile range (IQR), whereby we defined consensus by an IQR of not larger than 1.00 for D and 25 for EP [122,123]. (3b) Given that cognitive bias has been said to cloud human reasoning regarding probabilities of occurrence, we considered consensus based on the desirability bias [124]. In comparison to projections with neutral desirability, desirability bias has caused participants in previous Delphi surveys to judge probabilities of occurrence as higher if desirability is high and as lower if desirability is low. Consequently, some projections could have been assessed to be more likely (or unlikely) because experts consider their occurrence to be desirable (or undesirable). (3c) Finally, the Kolmogorov–Smirnov test revealed that our score distribution significantly differed from normal distribution. Therefore, we applied non-parametric tests during our analysis. The Mann–Whitney *U* test was used to control for significant differences of the three major stakeholder groups.

For those projections that did not achieve inter-Delphi survey consensus during the previous analyses, an intra-Delphi analysis provided additional insights in the stakeholder scenarios. The projections with intra-group consensus were assigned to the respective stakeholder scenario in level 1. As a final scenario level, a subgroup comparison was conducted for those projections that could not be allocated up to this point (level 0). Furthermore, the participants' arguments (3492 in total) guided the allocation of projections in the respective multi-stakeholder scenario levels.

3.3. Phase 3.1: Purposive transition strategies: a participatory multi-stakeholder workshop approach

Based on earlier strategic issue assessments, we conducted a series of three focus group workshops to elaborate on appropriate strategies for the three stakeholder groups (industry, public authorities, and customers). The workshops with a total of 39 participants, who also participated in the Delphi surveys, were conducted in order to discuss recommendations for stakeholder strategies on the transition paths. Thereby, the discussions aimed at gaining insights in the different stakeholder objectives. The focus group method was chosen because it facilitates a small group of individuals to intensely investigate topics [125]. We restricted our focus groups to a maximum of 15 people to keep the group manageable [126]. Participants were selected based upon their positions in the organization and their high degree of commitment to the Delphi survey (according to number and length of written arguments).

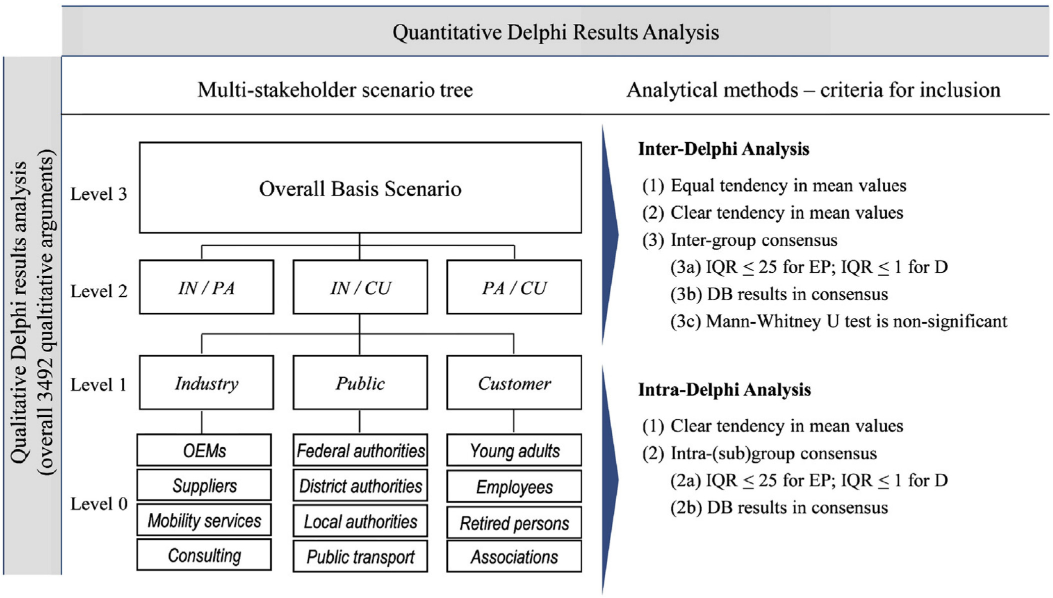

Fig. 3. Framework of multi-stakeholder scenario development. Notes: IN = industry experts; PA = public authorities; CU = customers; EP = expected probability (0–100%); D = desirability (5 pt. Likert scale; 5 = very high); IQR = interquartile range; DB = desirability bias.

The core research team of three senior researchers guided the conversation. The workshop discussions were based on previously identified dissent topics from approximately 3500 Delphi arguments (1322 arguments stemming from industry; 1246 arguments provided by public authorities; and 924 arguments stated by customers). In order to induce honest and detailed responses, specific questioning techniques were used by the moderators. In addition, various respondent reactions were prompted by considering different aspects of an issue and clarifying or amplifying where necessary. However, the moderators also ensured that the discussion was spontaneous and natural in order to promote comments and ideas unexpected or unimagined by the researchers. As a result, we were able to determine a path towards sustainable urban mobility scenarios in Germany for the year 2030 while identifying implications, capabilities required, and business opportunities for involved stakeholders.

4. Multi-stakeholder perspectives on the future of city mobility

Invited experts were asked to assess the desirability (D) and probability of occurrence (EP) of the projections on the future of urban mobility, and to provide reasons for all answers. The qualitative arguments were generated from the expert panel discussions and were used to enrich the scenario formulation and to identify influencing factors. The outlined methodological approach enables stakeholders to address multifaceted challenges of multimodal transport systems, analyze opportunities, and provide a more precise understanding of conditions required to implement such a system. Formulating scenarios presents an alternative to linear extrapolations. Due to the considerable amount of changes expected for a wide range of different stakeholders, we conducted a multi-stakeholder analysis on the future of urban mobility.

4.1. Aggregated results for scenario development

Table 4 provides an overview of the quantitative results of our three Delphi studies, whereas Table 5 shows the summary of projection allocation based on stakeholder consensus. Based on the criteria framework for our multi-stakeholder scenario development outlined in Section 3.2.2, consensus was achieved for certain projections of the desirability dimension. Eight projections, in which consensus was achieved for all three panels, account for the basis level of the desirable scenario development [TP1, TP3, TP4, VC1, VC3, CO1-2, MC2) since dissent discussion did hardly occur between the stakeholder groups. With regards to level 2, we allocated projection FC2 to consensus among industry representatives and public authorities, while projections TP2 and IL account for consensus among public authorities and customers. Since these evaluations indicate significant differences in some cases among the three stakeholder groups, we tested for intra-group consensus (levels 1 and 0). Since projections FC1 and IL3 account for intra-group consensus, some projections only result in subgroup consensus. In three cases, dissent remained and could not even be resolved by a subgroup analysis.

Drawing on the results of the probability dimension, the average results are marked by considerable dissent among the panelists. Consensus for all three panels was achieved for only three projections [TP1, VC1, CO1] while seven projections were allocated to scenario level 2 [MC1, MC2, TP4, CO2, IL1-3]. Resulting projections were checked for intra-group consensus

Table 4
Quantitative results for the future projections.

Projections for 2030	Industry						Public authorities						Customer					
	EP statistics				D statistics		EP statistics				D statistics		EP statistics				D statistics	
	EP [%]	IQR	EP adj	IQR adj	D	IQR	EP [%]	IQR	EP adj	IQR adj	D	IQR	EP [%]	IQR	EP adj	IQR adj	D	IQR
Technology and urban planning																		
TP1 Mobillity platform	69	40	54	28	4.1	1.0	77	20			4.5	1.0	70	30			4.5	1.0
TP2 Personalized information	57	24	56	23	3.0	2.0	50	30			2.4	1.0	52	35	54	34	2.5	1.0
TP3 Electric drive vehicles	59	41	47	30	3.8	1.0	51	40	50	29	3.5	1.0	54	20	49	20	3.3	1.0
TP4 Urban and regional planning	44	40			1.6	1.0	29	33	48	20	1.5	1.0	50	30			1.5	1.0
Value orientation and consumption																		
VC1 Multimodal transport	64	30			4.0	1.0	55	38			4.2	1.0	58	41			4.0	1.0
VC2 Ownership	58	50	54	39	3.2	2.0	57	36	52	33	3.9	2.0	56	40	52	27	3.2	2.0
VC3 Time savings	55	30	46	21	3.6	1.0	52	30			4.3	1.0	56	40			3.8	2.0
Collaboration																		
CO1 Collaborations	66	30			4.0	1.0	61	30	54	20	4.2	1.0	59	25			4.0	1.0
CO2 Policy promotion	53	30			2.0	1.0	44	24	63	30	1.4	0.3	55	40			1.8	1.0
Financing and capital																		
FC1 Investment opportunity	52	35	40	30	3.8	1.0	49	31	50	28	3.1	1.0	50	40			3.1	2.0
FC2 Subsidies	52	43	43	37	3.5	1.0	40	40	37	30	3.8	2.0	52	30	47	22	3.2	2.0
Market structure and competition																		
MC1 Formerly non-active players	58	40	55	25	3.1	1.0	58	35	59	23	3.3	1.0	48	40	45	27	3.2	1.0
MC2 OEMs as services provider	31	23			2.1	0.8	41	40			2.5	1.0	44	30	45	32	2.7	1.0
Implementation lead																		
IL1 Industry lead							59	39			2.8	1.0	56	20	55	27	2.9	2.0
IL2 Public authorities lead	35	30	40	20	2.4	1.0							36	30	38	23	2.7	1.0
IL3 Customer lead	33	23	33	22	3.0	2.0	41	31			3.4	1.0						

Notes: EP = Probability of occurrence (0–100%); D = Desirability (5 pt. Likert scale; 5 = very high); IQR = interquartile range; EP/IQR adj = calculated potential desirability bias; missing values for IL1, IL2, IL3 result from stakeholder-specific Delphi study design: for instance, industry experts were not requested to rate their own leading skills since we expected these ratings to be highly subjective.

Table 5
Multi-stakeholder scenario matrix: projection allocation based on stakeholder consensus.

Scenario level	Variable-based projection allocation			
	Desirability dimension		Probability dimension	
	Low	High	Low	High
Level 3				
Basis scenario	TP4 CO2 MC2	TP1, TP3 VC1, VC3 CO1		TP1 VC1 CO1
Level 2				
IN/PA		FC2	TP4 MC2 IL3	MC1
IN/CU			IL2	CO2
PA/CU	TP2 IL2			IL1
Level 1				
IN		FC1		TP2, TP3 VC2
PA		IL3	CO2	
CU				
Level 0				
IN (subgroups)		VC2 (CON) MC1 (CON) IL3(CON)		VC3(OEM, ASU, CON) FC1(MSP)
PA (subgroups)	IL1(DAU)	VC2(LAU, PTO) FC1(LAU, PTO) MC1(LAU, PTO)	VC2(DAU) VC3(DAU) FC1(FAU, DAU, LAU) FC2(DAU, PTO)	VC2(FAU, LAU, PTO) VC3 (FAU, LAU)
CU (subgroups)	FC1(ASS)	FC1(YAD, EMP) FC2(YAD) MC1(ASS)	TP2(YAD, RET) VC2(RET) FC1(ASS) MC2(YAD,EMP)	TP3(YAD, RET) VC2(YAD, ASS) VC3(YAD, EMP, RET) FC1(YAD) FC2(YAD, EMP)
Dissent remains	TP2(IN) VC2(CU) IL1(CU)		TP2(PA), TP3(PA), TP4(CU) FC2(IN) MC1(CU)	

Notes: IN: industry (subgroups OEM: original equipment manufacturers; ASU: automotive suppliers; MSP: mobility services provider; CON: consulting/associations); PA: public authorities (subgroups FAU: federal authorities; DAU: district authorities; LAU: local authorities; PTO: public transport/organizations); CU: customer (subgroups YAD: young adults; EMP: employees; RET: retired persons; ASS: associations).

and in five cases, dissent could not be resolved by a subgroup analysis.

In addition to the quantitative assessments, qualitative information was evaluated; this was derived from the written arguments that were given by panelists, concerning their opinions towards projection characteristics. In previous conventional Delphi studies, conclusions were primarily drawn from the quantitative assessments. However, in recent years the qualitative results have gained more credibility [127]. We aimed at identifying underlying assumptions of experts' ratings to explore not only what experts believe, but also why they do so. As we sought to formulate scenarios that necessitated ample contextual and argumentative information, qualitative analysis was essential. Thereby, we gained insights as to which factors will advance and influence the future of urban mobility. The panel discussions were comprehensive and intense, which corresponds to the complexity of the topic. Therefore, quantitative assessment alone would not have been sufficient to understand all ambiguities.

4.2. A desirable vision of urban mobility

The vision of urban mobility describes a desired state for the year 2030, shared by a diverse set of stakeholders, to provide guidance and orientation to relevant actors [128]. In reference to Fig. 3, the overall basis scenario (level 3) constitutes the foundation of the desirable multi-stakeholder vision, indicating consensus on projections among the entire panel.

4.2.1. City mobility 2030 is multimodal, driven by collaborations, and thereby efficient

The basis scenario is derived from consensus among the 201 panelists, where a multimodal mobility system is most desirable [VC1]. In 2030, customers will use a variety of complementary mobility options, whereby the use of private motorized vehicles will be substituted by mobility services to a significant degree. Customers will appreciate multi-modal mobility solutions compared to motorized individual transport due to time savings [VC3]. Traditional business models will expand, providing integrated mobility services to customers. A comprehensive mobility platform will facilitate integrated route and tariff planning, efficient choices of service offerings, as well as secure payment processing from a single source [TP1]. Thereby, smartphones and other mobile devices will become the omniscient companion and enabler of multimodal city travel. In the ideal case, after registering, users will be able to personalize a multimodal mobility application according to their requirements. Thereafter, location-based information about next travel options will be received based on individual travel preferences, including integrated options for motorized

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individual transport, public transport, or sharing options (e.g. car sharing, rent a bicycle, or shared-ride). This information will be filtered according to price, comfort level, as well as travel time since latest real-time information on traffic conditions will be integrated. Simultaneously, the choice of the respective transport mode(s) can be reserved while receiving the electronic booking code. When entering the respective transport mode, the user will be automatically recognized via chip or code. At the end of his or her journey—with or without a combination of different modes—the payment processes will be handled automatically. At the end of the month, the customer will receive an overview of his or her mobility account, in which all trips are listed in detail. Thereby, individuality, transparency, and data security will remain in focus: For instance, different payment systems will be offered to customers (e.g. flat rate, prepaid) and applications will be expandable to provide information on charging conditions of electric vehicles or the location of the nearest charging station.

The main prerequisite for successful future urban mobility will entail customer-oriented collaborations, comprising traditionally independent infrastructure subsystems and the public sector [CO1, CO2]. The multimodal mobility market will be controlled by corporations that provide and understand mobility as a service [MC2]. The mere production of infrastructure and transportation means will cumulatively play a minor role.

Thereby, multi-modality will allow users a convenient, ecologically-friendly and resource-optimal locomotion, making it the most appealing and sustainable form of mobility [TP3]. Traffic problems will become a thing of the past—existing resources and infrastructure will be deployed optimally in all respects [TP4].

4.3. Perspectives on the probable future of urban mobility

The outlined vision can only become a reality if it suits the determining factors and is attractive to the various stakeholder (levels) involved. The results of the main influencing factors for the probable futures showed a limited amount of overall consensus. However, since the analysis of qualitative arguments revealed that there are comprehensible explanations for both directions of future development in many of the presented topics, we derived clear indications of likely developments in the major fields. In fact, the main purpose of the exchange of arguments in a Delphi survey is to reduce the information asymmetry and to generate convergence or divergence in experts' assessments. Despite widespread dissent among experts, we clustered clear indications of likely developments of the socio-technical transition for urban mobility based on major strategic issue dimensions identified.

4.3.1. Individualization of lifestyles and flexible access to multimodal services

Lifestyles in the post-industrial society will be subject to more dynamic changes than ever before. The diversity of options in all areas of life will contribute to everyday life becoming increasingly complex. The focus will be on the need for individuality. Substantial evidence indicates that there will be the need for more flexible, individual mobility.

According to our panelists, the emotional attachment to cars will dissolve in a large portion of the population. The analysis of projection VC2, reflecting mobility users' value orientation regarding the traditional ownership of transportation means, points to the importance of considering differing age groups during the establishment of urban mobility solutions. In particular, younger adults will no longer place mobility on the same level with car-mobility [VC2(YAD)]. More and more (young) people will consider their choice of transport more consciously and situational for many reasons. Among others, mobile, multifunctional and prestigious devices, such as smartphones, will play a major role for the generation of "digital natives". Thus, with the use of new technologies, time, attention, and budget are finite. With limited budgets, different desires have to be fulfilled and expensive items, such as cars, might lose their appeal. The car orientation, which developed for every age cohort over recent decades, will stagnate and is expected to decline in the future. However, since the majority of the panelists argue in favor of rationalizing mobility (i.e. paradigm shift) and expect modal choices to be made according to the situation, a number of retired persons regard private transportation as a status symbol even in the future that includes pride of ownership and fascinates [VC2(RET)]. Therefore, in view of continuing demographic changes, the expectations of retired persons have to be considered with particular attention.

Against this background and in the light of rising costs of mobility and a more subdued economic outlook, urban mobility requirements will be increasingly pragmatic and often resolved via multimodal transportation [VC1]. Current borders between individual and collective mobility markets—partly supported technologically—will be overcome by 2030. The social movement will turn away from universally usable transportation means towards a flexibly applicable "virtual fleet" that combines various means of transportation. Thereby, features, such as convenience (e.g. ticketing, pricing, and mobility cards), ease of use, and constant transport availability, will be key enablers. The more intuitively people can use mobility services, the more likely that multimodal mobility behavior will become a routine (and used without "thinking").

Innovative sharing options, such as car-sharing or bike-sharing, demonstrate exceptional future potential according to the Delphi panels. Thereby, the flexibility during the choice of individualized modes is expected to be more important than single technology solutions, such as the electric car. Moreover, experts expect demand responsive transport (DRT) to become increasingly prevalent in urban areas. DRT will provide shared-ride transportation according to passenger requirements in pick-up and drop-off locations. Hereby, advanced technology will be used to flexibly adapt routing and scheduling of small and medium-sized vehicles [78].

Overall, according to the survey panelists, users' modal choices will differ, depending on individual needs, personal budgets, available alternatives, and regulatory restrictions, such as low emission zones or access restrictions. In fact, there will also be future customer segments with distinct differentiation and individualization desires: customers who are willing to pay extra for safety, comfort, reliability, and swiftness.

4.3.2. System strengths—multimodality as a collaborative measure

The future of the urban mobility systems is expected to involve mobility clusters that can provide mobility services as a one-stop service. In line with previous research, our panelists valued customer-oriented collaboration as the basic condition for success [CO1]. It is apparent that a single company will not be able to satisfy the needs of all customers, given the complexity of the urban mobility systems. Demand for additional expertise, which in turn is present outside the traditional mobility domain will increase. Therefore, service companies and business clusters will dominate the market for multimodal mobility. Transversal "mega-operations" are expected to become mandatory and necessary for survival in the industry.

In fact, collaborative urban measures need to be seen from an even broader perspective than ever before. Due to technological, political, and social dynamics, relevant and growing system interfaces will emerge. The surveyed experts expect a shift away from individual companies offering short-term, fragmented services to strategic partnerships offering long-term mobility. City subsystems, which were formerly largely unrelated, will converge and mobility, energy and telecommunications will interlink noticeably. Corporations will be able to offer triple-networked mobility with transport, energy, and communication services. In the long-run, these convergences will lead to the development of new market segments and an extension of the traditional mobility concept. Thereby, industry representatives and policy makers from the survey expect new players, especially in the area of information and communication technology (ICT), who were formerly inactive in the mobility domain, to increasingly access the mass market of mobility [MC1]. Some have already entered the market with innovative solutions (e.g. Google, Microsoft, and Apple). Given a comparable offer, long-term competition will depend on the quality of customer data and the depth of services.

The surveyed industry representatives and public authorities expect car manufacturers to transform their business models to provide mobility services [MC2]. In addition to technical challenges, multimodal mobility will mainly be a question of marketing attractive offers. Thereby, marketing and technology are expected to be the core competencies of OEMs.

4.3.3. Integrated multimodal travel information

Modern data communication will provide unprecedented opportunities for networking in the area of mobility and will demonstrate the potential of collaborating measures between the transportation system and the ICT system. Since future urban mobility is expected to be the intelligent combination of all modes and offerings, it is conjectured that the quality of urban mobility systems that adopt a multimodal approach [TP1] will be increased through the supply of travel information. Nevertheless, there are considerable challenges involved in the integration of data derived from multiple stakeholders in the multimodal mobility domain for information and direction guidance.

An interconnected trip planning system would be the most effective way to provide individualized information to multimodal travelers [TP1]. The advantage of such an integrated and comprehensive mobility platform is indisputable: consensus was achieved among all panelists and this projection had the highest mean EP estimate of the study. Customers of urban mobility systems are primarily concerned with how to travel from one location to the next: they will require a one-stop shop solution, a synergetic overall system covering all phases of the trip through a single source. A satisfactory solution has to consider all alternatives and adapt to personal user preferences concerning time, costs, and number of hops on a trip [VC3]. Moreover, transport uncertainties, for example due to unexpected transport disruptions, could be mitigated by sending personalized real-time information to the traveler via various means of communication (e.g. text messages, email, or other smartphone applications). From a customer perspective, this kind of comprehensive platform would offer one single Graphical User Interface (GUI), which is fed by different individual solutions based on the one-face-to-the-customer principle.

A promising interconnected multimodal mobility platform has already been set up by a European Commission-funded project called WISETRIP.[7] Thereby, multimodal trip information is sourced from a diverse set of journey planners to provide a user-friendly communication interface. It combines multi-level information and delivers dynamic personalized data by linking and cooperating with various sources of journey planning engines. Travelers will be able to easily request information, regardless of place and time, and receive various solutions for their trip. Further developments need to consider real-time events affecting trip performance (e.g. traffic, accidents, and weather conditions) as well as mobile and social media extensions [129].

To individualize information even further, experts expect a personal mobility assistant to be available on customers' smartphones. This application would update the traffic situation and gradually learn customers' personal mobility habits, such as their usual travel times, frequent trip destinations, preferred means of transport. An increased willingness of customers to disclose personal information is therefore required to offer cumulative individualized service offerings. The transition towards future urban mobility will be driven by those who accept such personal information being used for mobility purposes—the so-called digital natives. Our Delphi foresight project participants regard themselves as being spearheads for the mobility transformation to multimodal systems. These individuals will trigger a paradigm shift in information: Rather than information being "pulled" by the customer to actively obtain travel guidance, information will be "pushed" or sent to the customer based on the stored mobility profile. By 2030, the integration of travel information will be advanced significantly through intelligent transport systems and smart vehicles. However, complete connectivity and intelligent traffic solutions will remain a vision well beyond 2030. Panel experts indicated that there will be an expected trade-off between customer convenience and company access to personal information [TP2].

4.3.4. Multimodal transport initiation through private sector leadership

The current economic situation in Germany is considerably better than in other parts of Europe. For 2012, a record amount of tax revenue is expected. Nevertheless, aspirations to reduce long-term national debt remain. The combined debt of federal, state, and local budgets in 2010 amounted to a record €2 trillion, the per capita debt to almost €25,000 and the debt ratio (i.e. the amount of public debt to GDP) amounted to just over 80% [130,131]. Accordingly, by 2030, measures for fiscal debt

[7] WISETRIP refers to a large network of multiple E-systems that are concerned with multimodal journey planning, as well as the provision of personalized trip-related data. A further description of the system's capabilities is outlined at www.wisetrip-eu.org.

reduction are expected to still be in place. In addition to these known and quantifiable risks, there are uncertainties about the impacts of the financial commitment to the European Union. Over the next years, EU payments for transport infrastructure and public transport services will be due. For instance, by 2014, the revision of the regionalization of federal funds for urban rail transport will have to be paid. Moreover, legislation has decided that federal government financial support of transport infrastructure in federal states shall terminate after 2019 [132].

As a consequence, the complexity of a future multimodal transport chain can (and will) not be handled by general governments independently. Increasingly, the focus will be placed on private sector leadership to design efficient multimodal mobility concepts that promise optimal operational success [IL1]. The public sector will control regulatory actions and will primarily moderate tasks and provide resources [IL2]. An adequate supply of public transport will have to be financed with less public and more private funding in the future. Government subsidies for urban transport are expected to be reduced further [FC2], leading to privatized public transport that will become partially more expensive. Moreover, despite denials from public authorities, road use charges in cities will be very likely by 2030 [TP4]. Overall, mobility users will be forced to dig deeper into their own pockets.

The participants agreed that governments will ensure multimodal mobility. Thereby, the government will safeguard the provision of basic services in terms of organization and control mechanisms (through laws), but will leave the operation to private firms. Transportation and infrastructure must be guaranteed by the government (at least roads and possible modes of transport) but implementation and execution will be the responsibility of private corporations. Thereby, mobility operators will have to cover their own costs as well as the costs for maintaining their products and services. Bidding and commissioning will be based on the principles of free market economy: the best companies will be selected. Through tariff restrictions, the government may influence the use of certain modes of transportation. The administration will be handled by infrastructure companies, with the state determining the quality management.

4.4. Stakeholders' disputes over the future of urban mobility

In order to sustain the constructive debate among the stakeholders involved in the transition process, we elaborate on conflicting stakeholder viewpoints. Since complete presentation of all controversial topics is beyond the scope of this paper, we restricted the content to three key unexpected aspects and unique findings of the multi-stakeholder scenario matrix and qualitative arguments provided by Delphi panelists.

First, while public authority experts are indecisive regarding the willingness to share personalized information for optimal mobility service offerings [TP2(PA)], industry experts endorse its prevalence. Personal needs can be better targeted with greater access to data. These panelists also expect convenience to prevail over data sensitivity since “transparent customers” already exist (e.g. social media profiling). On the contrary, panelists belonging to the users of mobility, namely young adults and retired people, would prefer to restrict the provision of personal data [TP2(YAD, RET)]. These groups fear data breaches will continue to increase and a low level of standardization will impede implementation: depending on the mobility provider, specific requirements should have to be met as part of the system integration. Consequently, the expected spearheads for the urban mobility transformation (i.e. the so-called digital natives) cannot simply be ascertained by the inclusion of surface-level criteria, such as age differences.

Second, industry representatives picture electric drive vehicles as a key success factor for multimodal mobility concepts (TP3), since they not only account for a modified drive system, but also a system change for developing new business models that foster multimodal mobility. The alleged weaknesses of alternative drives make them an ideal complement to traditional public transport for short distances in urban settings. The electric vehicle can be integrated into multimodal concepts and help promote the meaningful integration of transport modes, particularly in conurbations. Furthermore, it is argued that electric mobility will serve as a networking function in different industries. Surprisingly, some public authority representatives are undecided concerning this issue and voice the opinion that the technology of the drive system is irrelevant to multimodal mobility concepts or that electric mobility solely accounts for a transition technology in motorized private transport [TP3(PA)]. In reality, federal, district, and local authorities as well as public transport organizations do not agree on the issue. Nonetheless, Germany is currently pursuing novel energy policies and has the most ambitious and longest-term expansion targets for renewable energy internationally. In fact, the federal government initiated the Energy Concept 2050 and the National Platform for Electric Mobility (NPE) that aims to connect climate protection with industrial policies, thus placing Germany as the leader within the market of electric mobility. Another stakeholder controversy between industry and public authorities regards the financing and capital dimension of our study. Mobility services and infrastructure providers expect multi-modal mobility to become a profitable investment by 2030 [FC1(MSP)]: as an emerging megatrend, multimodal mobility presents attractive opportunities and provides a sound return on investment. Thereby, access to (private) investors will fuel the necessary innovations. In addition, due to the diverse set of stakeholders involved, complex structures will require a variety of investors and specialists. In contrast, federal, district, and local authorities mutually agree that return on investment should not be the focus of financial investments since lucrative offers for investors mean high costs for the end user [FC1(FAU, DAU, LAU)].

5. Purposive transition strategies: towards a multimodal city design

Hasson and Keeney [133] recommended validation and continuation of Delphi findings via other methods and external knowledge. Hence, subsequent to the Delphi study, focus group workshops were held to identify the most important factors for potential users and stakeholders of multimodal mobility in order to realize sustainable mobility.

5.1. General stakeholders—strategic agenda

According to the focus groups, attractiveness will be the leading criterion to establish customer-focused integrated multimodal transport. Mobility systems are often designed for the comfort of operators, rather than for the needs of consumers. The focus groups derived four essential attractiveness features from a customer perspective: (1) ease of use, (2) availability, (3) the total cost of ownership, (4) and comfort.

In addition, a diversified portfolio of public and private sources of financing will be needed, including new financial instruments and a move towards the "user pays" and "polluter pays" principles. Thereby, public and private transport "pay-as-you-go" charges should be integrated while reflecting marginal costs. Integrating these costs may be achieved with global position systems (GPS), direct short-range communication, smartcards, mobile telephones, and other technological advancements.

The tenor of the focus groups was that efforts of individual sectors and actors should be better aligned. Although multiple research efforts enhance the probability of innovations and the range of solutions, joint or coordinated efforts across sectors and actors may be more effective in certain fields. Transport service providers often complain of a lack of innovative solutions. However, manufacturers of transport solutions often wait for clear market signals before developing new solutions and do not always comprehend users' needs. It is important to overcome technology lock-in and institutional 'silo' thinking. Existing structures and stakeholder alliances hamper full realization of the potentials of alternative modes of transportation or benchmarking examples from other industries. Innovations in adjacent city subsystems could benefit the mobility industry. Such innovations would be advantageous to transport operators, but, since they normally function at low profit margins, they do not have sufficient incentives to make investments in fresh strategies. Therefore, stimulating innovation in mobility and transport will require mobilizing not only mature segments of the transport market but also integrating them with existing or emerging players from the telecommunications, health, financial services, and energy supply sectors. As a result, a clash of interests and entrepreneurial cultures may be conducive to non-conventional and visionary thinking.

These measures will support in focusing efforts and creating new dynamics. However, to ensure quick, large-scale implementation and deployment of new transport technologies and services, public intervention may also regulate and create standards to ensure interoperability or continuity of service, ensure intellectual property rights, and provide procurement and financial incentives if the market does not respond sufficiently.

In addition to identifying general stakeholder issues, the focus groups proposed solutions for current and future challenges, targeting the three main stakeholder groups involved in the multimodal mobility system.

5.2. Industry—strategy agenda

Establishing connectivity among urban mobility subsystems appears fundamental for multimodal mobility transition. Essential conditions for the success of connected mobility are already in place and technological progress in terms of front-end and back-end technologies will advance passenger transport further: front-end technologies include cellular network technologies (i.e. long-term evolution (LTE) and 5G in the near future), Internet Protocol version 6 to allow encryption and verification of authenticity of data packages, and near field communication (NFC) to allow unique user identification and thus secure authorization of payment transactions; back-end technologies include cloud computing, digital identity, and new methods of analysis to handle "Big Data". The focus groups consider the ability of cars to communicate with their environments (C2E), or cars with other cars (C2C), or both (C2X) a difficult challenge in the future. However, it can be argued that technological progress makes deployment of, for instance, road-side units not a mandatory aspect, since upcoming cellular network technologies will probably allow to accommodate the car-generated traffic. Google believes that in the future, internet-based applications for C2X communication will be possible in cars via smart devices, therefore, built-in solutions will not be required [134].

Overall, to set up intelligent transport systems, networks are required. Despite technical progress, smart solutions for better traffic flow require overcoming old barriers. So far, competitors have largely limited efforts to their domains. Although technically possible, networking with other modes of transport or mobility services is hardly seen. This fragmented value chain is not only economically unsatisfactory but countervails the logic of connected mobility in which value is created in networks, intermodal and transsectorally. Nevertheless, the first intelligent transport system programs are ongoing[8]: for instance, a first field trial to test C2X opportunities and challenges is currently being held in the Frankfurt am Main region of Germany, where OEMs, suppliers, and ICT companies have bundled efforts.[9]

Nevertheless, the real quantum leap into the modern age is likely to be "Mobility 2.0". Today, we refer to "City 2.0" as the city of the future with many intelligent components: real-time traffic management, interactive and communicative intelligent charging systems, lighting that is adapted to the requirements and the number of members present at a particular place, etc. Thereby, "Mobility 2.0" is based entirely on the city of tomorrow. Intelligent interaction among mobility modes would be a main element of such a city and available to all residents.

As previously demonstrated, some innovative solutions already exist that have not yet been broadly used by companies. For connected mobility to become a reality, they will have to rethink their business models. At present, corporations almost entirely lack comprehensive strategies for integrated mobility. Integrating changing mobility business with current business activities and processes will become critical for future sustainable success. Corporations must anticipate modified mobility behaviors by 2030 in planning endeavors. The adaptation needs to go far beyond a gradual change in the product portfolio. Firms need to deduct future business areas based on a mobility vision. Structured analysis of make-or-buy decisions is required. An appropriate strategy must be aligned to the company's individual market

[8] Additional programs are ongoing in the U.S. (Intellidrive), in Japan Developed (Advanced Security Vehicle), France (PREDIT), United Kingdom (CHVS), Sweden (IVSS) or at the European level (CVIS, 7 SAFESPOT, Coopers).

[9] The simTD research project, funded by German Federal Ministries, aims at shaping the future of road safety and mobility via car-to-x communication. A more detailed description of the project initiative can be found at www.simtd.org.

positioning (e.g. premium vs. low-cost vs. entry segment) and must not dilute it. In establishing an integrated business model, close integration with the traditional core business is crucial. Given the wide range of possible activities, companies need to define strategic areas in order to not miss opportunities for growth. Companies that expand into new mobility services have to base future business models on existing skills, and source expertise from other sectors via collaborative activities. Early positioning of mobility services with specific test cases (trial & error) may provide crucial information to develop comprehensive future mobility solutions. It is necessary to anticipate new competitors at critical points in the value chain—especially where customer interfaces are compromised. Especially in the initial phase, it is important to create high degrees of media coverage in order to convince potential users of certain mobility concepts.

Some mobility concepts have already been successful: especially the concept of car sharing is a showcase innovation model of the mobility services industry with tremendous potential. In 2005, there were 77,000 car sharers in Germany, using 2,600 cars; the numbers increased to 220,000 sharers and 5600 cars by 2012 [135]. Schaefers [85] determined that over 30% of the population would at least test car sharing; while approximately two-thirds have a positive attitude and would consider car sharing for private purposes. Currently, a new concept is emerging concerning private car sharing among individuals. The provider autonetzer.de provides a platform to find the appropriate and nearest shared car with various insurance solutions.

5.3. Public authorities—strategy agenda

Past protests against large infrastructural projects have demonstrated that it has become more difficult for public authorities to execute plans. Public opinion frequently suggests that people do not feel adequately informed about planning projects. A frequently voiced suspicion is that many citizens have become less interested in societal needs and more in preventing projects being implemented "in their own backyard". Furthermore, a whole new dimension of citizen participation has evolved: people have started taking over parts of infrastructural planning. In the last three years, more than 400 new cooperative associations have been established to jointly develop local climate-friendly energy supply in Germany [136]. Therefore, the focus groups questioned how timely government planning actually is. With current planning procedures, affected citizens can only make objections within a limited period of time and address very specific conflicts of interest. By the time the project is made public, the primary planning of the project has already been completed and the social benefits of a project are not subject to discussion with the citizens.

Early and extensive public participation in multimodal mobility planning processes would require qualitative information, a results-oriented methodology, a culture of dialogue and an increased amount of communication in order to meet the growing need for information and citizen participation. Mobility policies will have to accommodate public participation with new designing and planning methods, in addition to the formal and prescribed procedures by law. Public contribution to mobility projects could lead to sustainable multimodal mobility systems.

In addition, the focus groups highlighted the need to develop new business models for public and private transport services, such as shared ownership. There is general agreement that public passenger urban transport accounts for a service which cannot be provided by private organizations without governmental intervention. However, public transport requires financial support. Since governmental budgets are restricted, public transport funding by users and additional private capital is required to finance infrastructure investments. Other approaches, such as public–private-partnerships (PPP) in road construction will also be adopted for public transport and their effectiveness and efficiency can be measured empirically. In this context, public authorities should promote competition and market liberalization in the field of public transport. Although it is expected that a large portion of public transport companies would not be competitive in an open market, it is the only way to improve efficiency and make mobility more cost-effective in the future.

Furthermore, local, state, and federal governments should cooperate in allocating investments to multimodal mobility. Funding should be fairly distributed in creating transport systems. Control instruments, such as regular process reports and key performance indicators, also have to be implemented to measure if public authorities are working efficiently and if funding is being used wisely. Such measures would cause the different levels of government to compete against each other in a healthy manner. Furthermore, competition would be encouraged among regions. If one city works efficiently, it is considered to be good for its image. Other cities will strive to follow. Moreover, the focus groups discussed restructuring internal processes to reduce operational and administrative overhead, data privacy regulations, and incentive schemes for multimodal mobility including mobility counseling.

5.4. Customers—strategy agenda

During panel discussions it became apparent that the transformation towards more efficient, clean, and safe urban transport requires proactive customer support. Since more detailed and reliable information is required by consumers to improve their individual mobility situation and to attain the best offers (in terms of price, time, comfort, etc.), a comprehensive mobility platform to support such optimal information access in travel planning (i.e. information to be "pushed" to the customer) requires continuous maintenance of end-user profiles. By joint efforts, industry, public authorities, and customers continuously need to promote the substantial added value that such systems offer in multimodal mobility while simultaneously considering the voiced fear of data misuse. Furthermore, the perspectives of end-users should be considered already in the design of future mobility services. As such, end users need to communicate their ideas and become involved as "active citizens" (e.g. during citizens' initiatives) to ensure sustainable and environmentally-friendly multimodal mobility. Overall, the greater the interest and involvement of citizens is, the more current and on large-scale multimodal mobility arises.

Finally, customers have to be willing to pay for improved mobility performance. In fact, mobility users must critically examine and balance their demands: while some customers require a continuous increase in individuality and exclusiveness, their payment behavior will need to be aligned accordingly. Therefore, advancements in mobility, which cater to diverse customers' demands and needs, can be costly in terms of time, money, and effort.

6. Conclusion

This research has found that large scale changes will be necessary to deal with the challenges facing the German urban mobility systems. In fact, the mobility sector, public authorities, and customers must break away from conventional thinking. Consequently, the socio-technical transition theory guided our research and the conceptualization through a SIM process helped to analyze the complex multi-dimensional changes required in developing sustainable urban multimodal mobility systems. By applying a participatory research approach, we provided an initial attempt towards integrated multi-stakeholder scenario planning for future urban mobility. Such prospects for the future generate stimulating perspectives not only for strategic planners, but also for governmental authorities and other stakeholders in making city mobility more effective and efficient. With regards to methodological advancements, integrating multi-stakeholder viewpoints in scenario development meaningfully complements the methodology by enhancing information substance and eventually increasing the usability of scenarios. The Delphi-based SIM process provides a new functional approach concerning the various issues that surround multimodal mobility, thus allowing researchers to develop strategies and frameworks that consider the dynamic nature of the environment. Urban mobility is a highly dynamic and complex concept to consider with the goal of redesign. Therefore, we argue that a preferred vision of the future has to first be articulated before a new urban mobility system can be designed and implemented: one which is sustainable and matches user requirements.

The Delphi study results highlight that the integration of individual and public passenger transport is highly desirable and expected to be essential for future urban mobility. Thereby, multimodal mobility—a concept that uses a variety of different transport modes for travel—will increase. Overall, multimodal mobility presupposes three conditions: the presence of multiple transport means customized to the specific situation; sufficient information for the correct decision between several options in real time (especially with the support of mobile technology); and a change in social habits and behaviors.

Although there is a mixed picture for the development towards such a multimodal mobility system, we extracted major elements that will influence multimodal city design. Thereby, customers expect increasing freedom of choice in the design of their mobility chains and a variety of transport means with different goals. Nevertheless, the demand for individual locomotion and high autonomy remains. To account for multimodal options, the utilization of system strengths is indispensable. Alternative vehicle drives are expected to gain in importance, not only in terms of emission reduction but also as a meaningful supplement to traditional public transport. Intelligent transport systems with modern data communication are advancing; complete connectivity however will remain a vision beyond 2030. The private sector leads in designing multimodal mobility systems due to more efficient approaches for commercial success.

In the course of our research, focus groups proposed solutions for current and future challenges in urban mobility systems. Technological advancements in intelligent transport system communication, including connected mobility for private and public transport, will be provided by the private sector. However, technical solutions alone are unlikely to reduce the impacts of transport to a level which is deemed sustainable. In fact, integrated strategies are necessary that also involve areas not typically associated with the transport planning process. Among others, the strategy agenda must coordinate efforts, diversify the portfolio of public and private financing, change business models, and create a renaissance of civil participation.

As with every research endeavor, this paper faced some challenges throughout the course of research and has its limitations. Although we identified the strategic issues through structured environmental scanning techniques and expert interviews, we focused on an overall and broad discussion of major aspects to keep the level of complexity manageable and the time effort required of participants reasonable. However, while accounting for such a variety of dimensions, it is important to capture the complexity of the multimodal mobility system. The authors acknowledge that the work could benefit from additional content assessment. Therefore, further research could address: (1) individual aspects identified in the present paper at a much higher level of detail; (2) discontinuities, wildcards, and weak signals since their selective inclusion may highlight new strategies and scenarios, possibly evoking a greater degree of tolerance to withstand changes within the environment and industry; (3) more in-depth dissent analysis by age, gender, functional area, and position in the organization and also by responses on probability and impact. Furthermore, we acknowledge that developments in different regions or so-called mega-cities differ from the German urban mobility context and therefore, to some extent, require adaptations to the recommendations presented in this paper. However, we feel that innovative socio-technical transition approaches for the German urban mobility systems can be transferred and guide as an initial field trial for developing innovative ideas: in particular, future research avenues could focus on developing countries and their enormous market potential for developing and expanding mobility infrastructure over the upcoming decades. Finally, this paper focused on passenger transport; future research could consider freight transport and even expand the scope to considering related city subsystems, such as the utilities or health system [137]. Conclusively, future research could investigate the interconnectedness of city subsystems in more depth.

Overall, we feel that multimodal mobility will become essential for city center accessibility, and its attractiveness will depend on the quality of mobility services offered. Therefore, we return to where this paper commenced: in the future, it is not about reducing mobility as such since individual mobility is the prerequisite for social participation, progress, growth, and self-realization. Rather, a socio-technical transition towards a sustainable urban mobility system should organize transportation smartly while fulfilling the multi-dimensional complexity of the changes outlined. So far, many researchers and practitioners have had a unidimensional mindset and have concentrated on vehicle transportation, primarily cars. However, this does not suit the complexity of requirements for urban mobility. We need to understand mobility systematically. Future research efforts will certainly support in broadening multimodal mobility perspectives.

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Appendix A

Table 6
Studies on the future in urban mobility—agency and governmental reports.

Nr	Author(s)	Title of report	Year
1	Acatech	Mobilität 2020—Perspektiven für den Verkehr von morgen	2006
2	Alpiq	Elektrofahrzeuge: Marktpenetration in der Schweiz bis 2020	2010
3	Arthur D Little	Future of Mobility 2020	2009
4	BMVBS	Prognose der deutschlandweiten Verkehrsverflechtungen 2025	2007
5	BMWi	Mobilität und Verkehr—Nachhaltigkeit, Sicherheit und Wettbewerbsfähigkeitdurch intelligenten Verkehr	2007
6	Continental	Mobilitätsstudie 2011	2011
7	DLR	Mobilität in Ballungsräumen (Literaturstudie)	2009
8	DIW Berlink	Ageing and Mobility in Germany: Are Women Taking the Fast Lane?	2009
9	EIFER	Spatial diffusion of electric vehicles in the German metropolitan region of Stuttgart	2011
10	Europcar	European Transportation & Mobility Observatory 2010	2010
11	Fraunhofer IAO u. PwC	Elektromobilität—Herausforderungen für Industrie und öffentliche Hand	2010
12	Fraunhofer ISI	Vision für nachhaltigen—Verkehr in Deutschland	2011
13	Fraunhofer IAO	Projektbeschreibung Innovationsnetzwerk FutureCar	2011
14	Hamburgisches WeltWirtschafts Institut	Mobilität—Strategie 2030	2009
15	ifmo	Zukunft der Mobilität - Szenarien für das Jahr 2020	2002
16	ifmo	Zukunft der Mobilität – Szenarien für das Jahr 2025	2005
17	ifmo	Zukunft der Mobilität - Szenarien für das Jahr 2030	2010
18	ifmo	Mobilität 2025: Der Einfluss von Einkommen, Mobilitätskosten und Demografie	2008
19	InnoZ	Megatrends und Verkehrsmarkt Langfristige Auswirkungen auf den Personenverkehr	2008
20	KISD	Frauen und Mobilität 2025	2009
21	Infas, DLR	Mobilität in Deutschland 2008	2010
22	Oliver Wyman	Urbane Mobilitätskonzepten der Zukunft	2011
23	Shell	PKW-Szenarien bis 2030	2009
24	Stadt Hannover	Masterplan Mobilität 2025	2011
25	Stadt Tübingen	Mobilität 2030	2010
26	TU Braunschweig	Mobilitäts-Stadt-Region 2030	2004
27	TU Dresden	Zukunft von Mobilität und Verkehr	2011
28	VDI Technologiezentrum	Elektromobilität ITA-Kurzstudie	2011
29	WBCSD	Mobility For Development	2009
30	WBCSD	Mobility 2030	2004
31	Z_Punkt	E-Mobility 2030 – Szenarien für die Region Berlin	2011
32	Z_Punkt	Nutzerverhalten und Raumplanung Regionale Infrastruktur	2011
33	Universität Siegen	Zukunftsstudie zur Wettbewerbsfähigkeit der Automobilzulieferindustrie in Südwestfalen 2015	2009
34	Arthur D Little	Powwertrain at the Crossroads	2009
35	Arthur D Little	Shifting Centers of Gravity	2009
36	BCG	Car Batteries: Plugging into a $25 Billion Market	2010
37	BCG	Powering Autos to 2020	2011
38	Deloitte	A new Era—Accelerating toward 2020	2009
39	Ernst&Young	Automobilbarometer 2009	2009
40	Ernst&Young	European Automotive Survey 2009	2009
41	Ernst&Young	European Automotive Survey 2011	2011
42	IBM	Automotive 2020	2008
43	IBM	Truck 2020	2009
44	KPMG	KPMG's Global Auto Executive Survey 2010	2010
45	Market Research	Managing the Future—World vehicle forecasts and Strategies to 2020	2003
46	Market Research	Managing the Future—global Automotive Megatrends to 2030	2005
47	Oliver Wyman	Car Innovation 2015	2007
48	VDA	Antriebe und Kraftstoffe der Zukunft	2010
49	VDA	Agenda Mobilität 2020	2008

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Appendix B

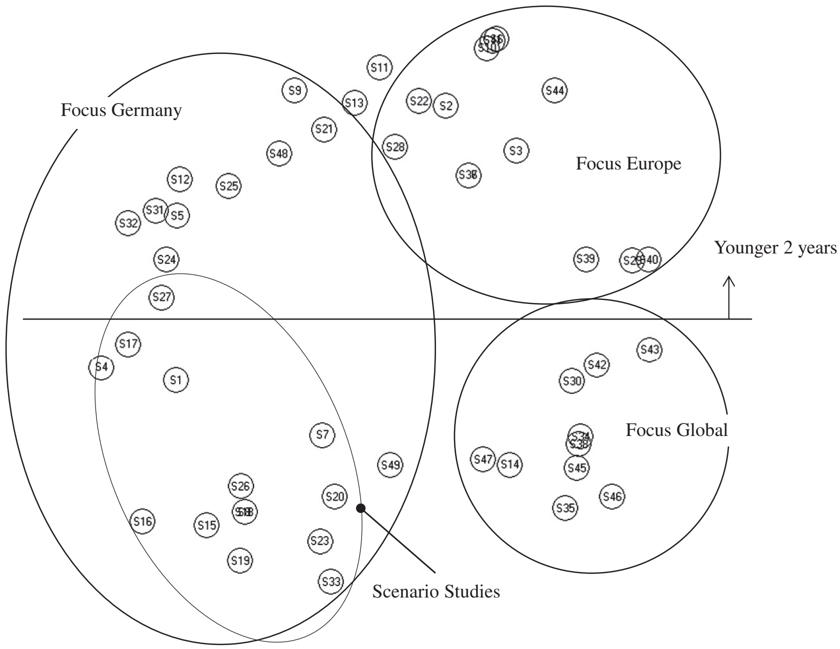

Fig. 4. MDS: Cluster priorities with respect to the structural characteristics.

Appendix C

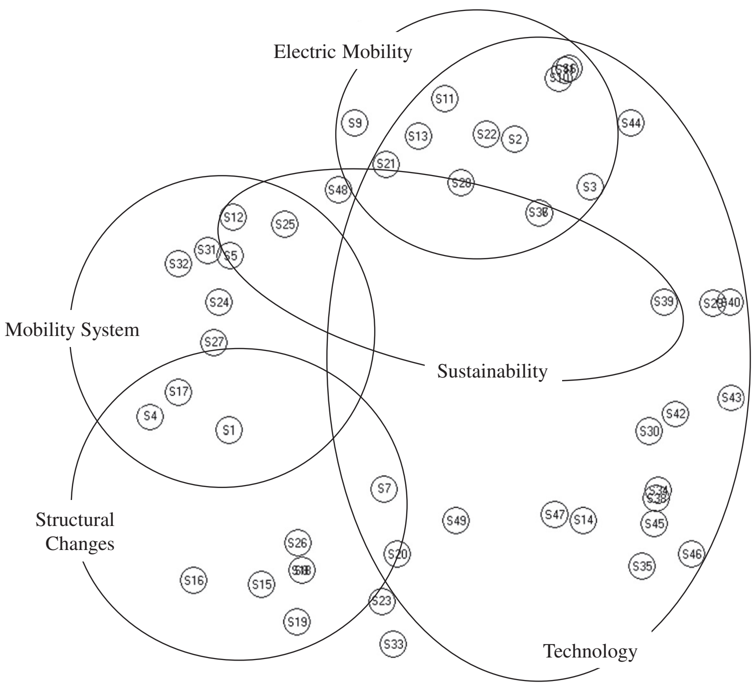

Fig. 5. MDS: Cluster priorities with respect to content characteristics.

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