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FRAMEWORK FOR THE SUSTAINABLE TRANSITION TO SMART MOBILITY FOR CAR-DEPENDENT CITIES

Summary. Despite efforts being made by various governments towards smart mobility adoption, no studies have been carried out to propose a framework to integrate smart mobility into the current transport system, especially for car-dependent cities in the Gulf region. This study aims to develop a comprehensive framework identifying smart mobility solutions, their challenges, and all the major initiatives and stakeholders by employing a mixed-method approach. The proposed framework is based on the established smart mobility ecosystem and has been shaped using common themes occurring in the regional context of Saudi Arabia after validating it through expert advice and international scholarly evidence. This study found that public transport, autonomous vehicles, and shared mobility are among the preferred smart solutions in the literature as well as in government-funded initiative programs. The analysis cites safety as one of the most important aspects of smart mobility, which aligns with the global sustainability goals. Mobility experts also suggested starting with the pilot projects for the smart mobility solutions before wide-scale implementation. Accordingly, the resulting proposed comprehensive framework was developed to achieve a transition towards

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SM solutions with better understanding and clarity. The framework was further validated by key decision-makers in the transport domain, both the government and the private sectors. The well-established theoretical basis and robust method adopted to develop the proposed make it equally viable for other car-dependent cities.

Keywords: smart mobility transition framework, stakeholder engagement, smart mobility ecosystem, car dependent cities, sustainable mobility

1. INTRODUCTION

The global urban population is growing with limited transport options. Already, 56 percent of the world's population lives in cities; by 2050, nearly seven in ten people will do so [1]. Saudi Arabia's urbanization trend is also growing as people migrate to cities for jobs, education, health care, etc. In response, the Saudi government and decision-makers are investing in smart mobility (SM) solutions, such as the Riyadh metro, public transport, autonomous vehicles, and shared and sustainable mobility options.

SM is crucial for several reasons. First and foremost, it enhances connectivity and accessibility, providing people with better access to services, businesses, and events [2]. Secondly, SM brings efficiency to transport systems by optimizing the use of available resources such as fuel, time, and infrastructure, reducing the overall transport cost [3]. With the integration of digital technologies and data-driven solutions of SM, transport providers can detect potential safety hazards and take corrective measures before accidents occur [4]. Lastly, SM is a key solution for reducing the negative impact of transport systems on the environment [5]. Based on the literature review of SM definitions, there is no consensus on the requirements or attributes that characterize the smartness that cities strive to achieve [6].

Consequently, there is no framework found in the present literature that can facilitate the transition to SM options, considering infrastructure and behavioral changes. Therefore, defining and identifying the possible SM ecosystem requirements is crucial for providing the right direction to achieve the SM transition. This research aims to employ a rich mixed-method approach for developing a comprehensive framework for managing such a sustainable transition to SM for the ultimate transformation to future smart cities. The sustainability of the framework and its associated transition require an all-inclusive approach, which has been taken in this research. The framework addresses the needs of all major initiatives and stakeholders incorporated through several studies made during this research. In addition, a review of the previous research and policy documents has also been conducted and considered for the framework's development. The framework was applied and validated for Saudi Arabia as a prototype. However, it is expected that the proposed framework will also be equally viable for other countries that are pursuing the transition to SM solutions due to the robust approach covering different aspects of the problem.

2. LITERATURE REVIEW

In recent years, with global sustainability challenges and limited resources, the problem of urban mobility has exploded. Consequently, new approaches have been proposed to study and tackle mobility problems. For instance, [7] talked about the "sustainable mobility paradigm" that gives special attention to the user's needs. The European Commission [8] specified the three pillars of a smart city: energy, transport, and Information and Communication Technology (ICT). Scientific literature underlines the role of the transport planning process in attaining sustainable solutions for catering to urban mobility demands [9].

This implies the necessity to gain more insight into the transport systems and their components (demand, supply, and interactions). This is possible with the support of Transport System Models (TSM) integrated with ICT tools that feed decision support systems inside Intelligent Transport Systems (ITS).

According to Caragliu et al. [10], ICT infrastructure, traditional transport, and human capital are the keys to smart cities. Thus, within the context of smart cities, using ICTs in urban transport has played a prominent role in promoting SM. The digital revolution and the transport sector have converged to form the concept of SM [11]. SM is multi-faceted and has recently piqued the interest of local authorities and several other stakeholders involved in city planning and development [12, 13]. In this regard, Alonso-Munhoz et al. [14] suggested that SM can improve sustainability, minimize carbon solutions, improve quality of life, and reduce traffic and parking challenges.

SM includes connected and autonomous vehicles, public transport, mass transit, biking, walking, and shared mobility [15]. The literature indicates that SM is well-recognized as an important component of transforming urban areas into smart cities. SM encompasses a variety of areas of interest; for example, as per USAMI [16], the main areas of SM may include safer driving with vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) systems, efficient street lighting using low-energy solutions, shared mobility for urban areas by encouraging multimodal transport, eco-friendly electric mobility providing, green mobility reducing reliance on hydrocarbons, and new payment procedures using ICT and other modern payment structures.

The entire system of SM is carried on two main elements, the technological backbone of Intelligent Transport Systems (ITS) and the service model of shared mobility. The ITS has transformed the lifestyle of the inhabitants in modern urban cities. Paiva et al. [2] reported that ITS could help achieve efficient mobility systems using variable message signs offering real-time information about congestion, accidents, etc. These ITS solutions help reduce total travel time along with comfort and safety. According to Aldalbahi and Walker [1], integrating ITS with roads and other transport modes makes existing mobility systems ecologically sustainable, efficient, and safer. However, this integration is not an easy task and poses challenges for urban cities, such as gathering and analyzing huge sets of data, which is also called ‘big data” [17].

ITS services provided the critical data and connectivity elements to the shared mobility systems, optimizing their operations and services. A SM ecosystem may comprise three modes of shared mobility solutions: ridesharing [18], on-demand ride services [19, 20] and public transport.

A notable milestone related to ride sharing was achieved in 2016 with an aggressive implementation of car-sharing solutions [19, 20]. The launch of Uber’s product, Uberpool, has since been a great success in New York. The second notable milestone was the introduction of autonomous public transport in 2019. The use of these vehicles designed by Optimus Ride, a self-driving car company, has since taken New York by storm. New York is still on course to achieve full SM transition. The introduction of zero-emission vehicles (ZEVs) in 2021 is a testimony to the efforts implemented in the city [21, 22].

Ride sharing, integrated with infrastructure through the Internet of Things (IoT) and technologies like mobile apps, can do wonders in urban mobility. Currently, there is no system that makes public transport easy and convenient in Saudi Arabia. Moreover, the current research extensively focuses on the technological and ride-sharing service while overlooking the sociocultural aspects in most of the cases. Most importantly, the opinions of different stakeholders and their readiness are rarely considered in the studies concerning SM transition. It is vital that different types of data, collection methods, and analysis techniques are applied to cover all relevant aspects of the multifaceted SM transition problem. Hence, this study tries to fill in on these gaps by employing a rich array of qualitative and quantitative techniques in order to develop its proposed transition framework while incorporating various dimensions.

3. RESEARCH METHODOLOGY

Transportation planning studies rely heavily on the preferences of transport users for the sustainability of proposed solutions [23]. Effective engagement of the users can bring about better policy directions, improved local services, possibly new ways to initiate or plan for a particular situation and a better understanding of the local situation by technical experts and community members [24].

In this research, a framework for managing a sustainable transition to SM is proposed. The methodology followed a four-step process, which is shown in Fig. 1 and described below in more detail.

Firstly, a comprehensive literature review of research using a qualitative research method with an inductive approach to develop key findings from the literature review. In this step, all relevant criteria and processes involved in the SM ecosystem were identified. To support the findings, government's white paper and strategies related to SM in Saudi Arabia was carried out. The review of local documents was due to the ease of access to these documents, but the findings were validated by prior scholarly evidence before being incorporated into the proposed framework.

Once the criteria were identified, the research approach shifted from an inductive to a deductive approach. Survey questionnaires were created to solicit feedback from the experts and common users to evaluate the criteria. After this step, selected smart mobility modes were ranked based on research and questionnaire analysis. These rankings helped in understanding the preferred choices and their respective variables/parameters.

The next step comprised developing the multiple criteria decision analysis (MCDA) model based on inferred criteria for the preferred choices (SM modes) of experts and users from the survey questionnaire developed in Step 2. Analytic Hierarchy Process (AHP) analysis was carried out using a pairwise comparison matrix for the preferred modes and their inferred criteria. The findings from the local experts and users were analyzed to identify unique and common aspects, in comparison to international literature, to ensure the robustness of the framework.

The next step presents a framework developed based on government priorities for SM solutions and customization mechanisms based on the survey results. A panel of experts further validated these values and preferences for a possible transition towards SM. The applicability of the framework became apparent through this activity because of the endorsement of experts at this stage who had vast exposure, experience, and higher qualification than of the experts contacted at this stage. All the surveys for this research were done sequentially, as per Fig. 1, from December 2021 to June 2022.

In this manner, the study implemented different analysis methods for different purposes. In this manner, a mixed-method approach ensured its transferability and the robustness of the proposed framework.

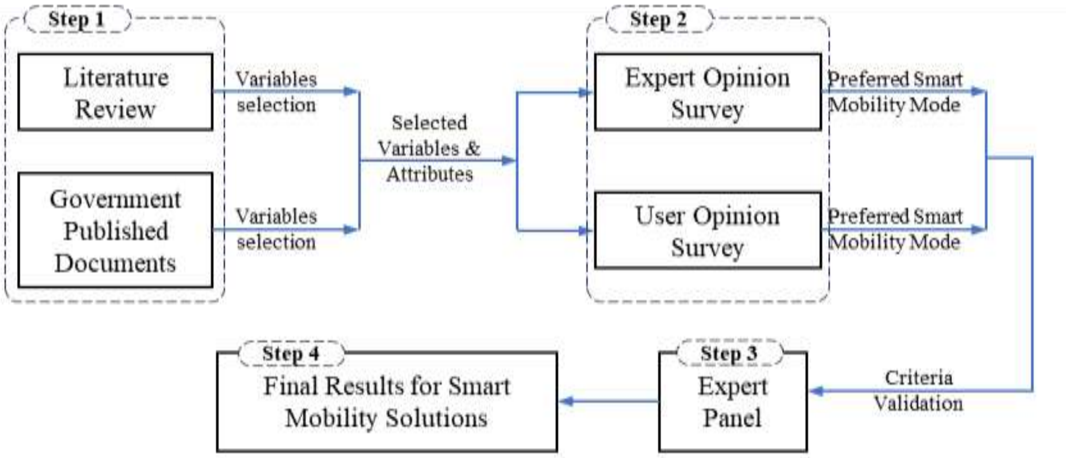

Fig. 1. Research methodology for framework design

4. QUESTIONNAIRE SURVEYS

4.1. User and expert smart mobility mode choice rankings

The surveys were built to answer direct smart mobility questions and were designed to cover two groups of users: mobility suppliers and users. The questions were designed according to the level of expertise of the survey group. Questionnaire surveys comprised an important source of data for this research.

A pilot survey was carried out for both groups to finalize the questionnaires. An online questionnaire was developed using QuestionPro platform and basic structure can be seen in Fig. 2 below. The online survey was available in both "English" and "Arabic" languages for the responder's convenience, and they were given the choice before starting the Basic Questions sections as shown below. The demographic features formed the questionnaire's first section. This section was the common part for both sets of surveys, i.e., the User and Supplier surveys. The second part presents the general beliefs and preferences of common users and experts concerning today's transport conditions in Saudi Arabia.

This study was a non-interventional survey for which ethical approval was not required under the guidelines of University of Bahrain and Bahrain's national regulations. The research presented no more than minimal risk to participants, responses were collected anonymously, and informed consent was obtained from all subjects. A non-probability sampling method has been used in this study, which is convenience sampling (online survey method) [25]. This method has been selected to consider only an educated group of common users and a few selected public and private professionals in the transport industry. A password-controlled Supplier survey was carried out to target researchers and professionals. These professionals belonged to the relevant organizations/ministries in the government sector or to transport service provider companies (such as bus, truck, and taxi companies). A total of 250 participants completed the survey. This included 205 general users and 45 transport experts. As suggested by Risher and Hair [26], the minimum sample size should be between 10 to 15 times the number of observed variables. As the user survey contained 16 questions, the sample size would be 12.81 times the number of observed variables (205 participants/16 observed variables). Noy and Govini [27] used 22 online questionnaires out of a total of 118 survey samples in their study. The study targeted transport experts and entrepreneurs related to SM. Similarly, Xydis et al. [28] carried out an SM study based on the opinion of 61 transport experts through the survey questionnaire. Based on the above studies, smaller sample sizes seem acceptable for surveys focused on experts, as it would be considered similar to the focus group. Hence, the sample size of the supplier survey in this study may also be justified.

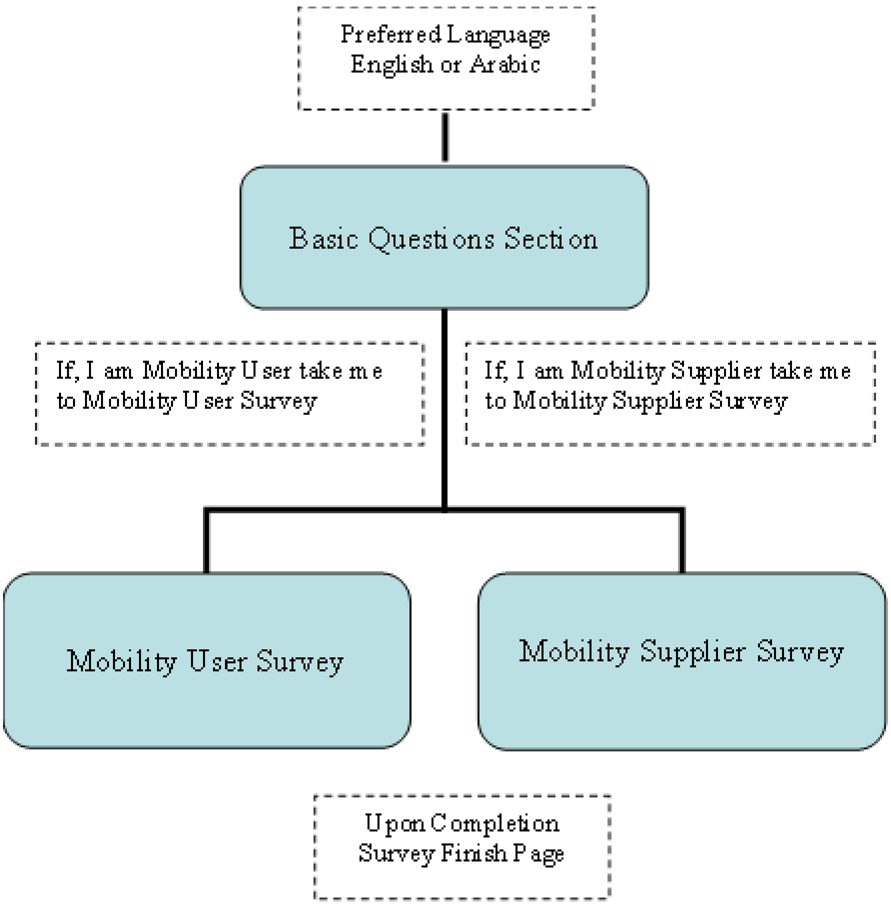

Fig. 2. Structure of user and expert questionnaire surveys

4.2. Multicriteria decision-making survey

AHP was applied to determine the precise interdependencies among selected multiple criteria for the smart mobility solutions. The process was carried out using Microsoft Excel and exhibited in Fig. 3. Five criteria have been selected for the multiple criteria analysis. The criteria were selected based on the previous research and are already identified and discussed as an important challenge for the smart mobility ecosystem in section 2. The selected criteria included cost, flexibility, infrastructure, safety, and speed.

AHP, developed by Saaty [29] is one of the common methods used for pairwise comparison data. In this method, multiple criteria are compared pairwise through the use of the hierarchy process. The questionnaire for mobility experts was developed for the pairwise comparison of the selected five variables. Experts were asked to give their preference for the respective variables. For example, how much is the cost important in comparison to safety in the context of smart mobility. The experts chose on a linguistic scale from equal importance to extreme importance.

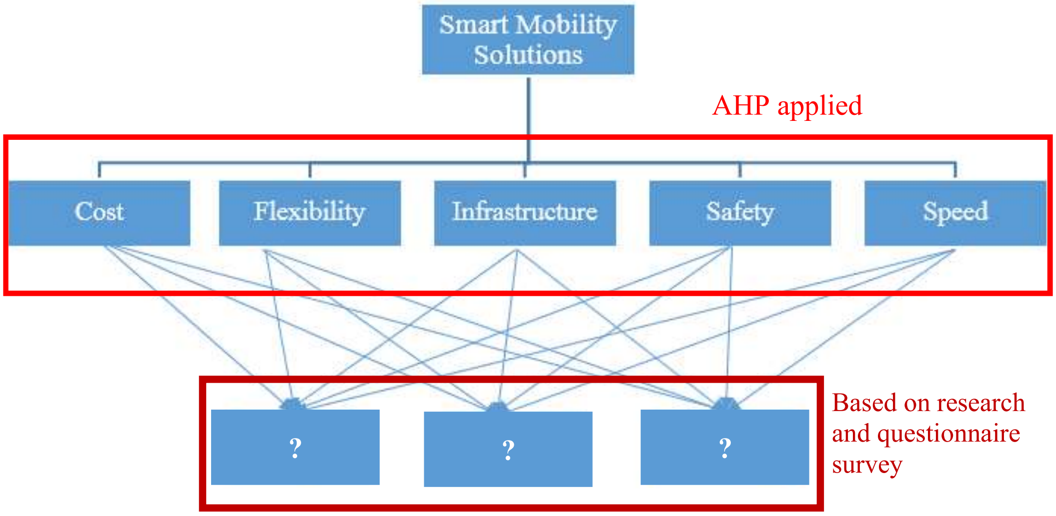

Fig. 3. AHP model for smart mobility multi criteria decision-making

Şahin and Yurdugül [30] stated that the most commonly used sample size, for the AHP method ranges between 2-100 experts. Darko et al. [31] mentioned that there is no such minimum sample size for carrying out AHP analysis and cited studies using a sample size between 4 to 9 experts. Therefore, for weighing the criteria, 20 transport experts were selected for the pairwise comparison questionnaire to rank the selected variables for smart mobility solutions. Based upon the discussion of the above studies, such a sample size can be considered sufficient for this analysis.

4.3. Validation survey

In the second stage, a questionnaire was developed to validate the basic parameters of the framework using the focused group method. The focus group members consisted of 5 experts from the field of transport and mobility who were asked to complete a survey that asked questions about SM. The selected experts of the focus group were ministry leaders and chief executive officers from private and government sectors. An online questionnaire was developed using the Question Pro platform. The questionnaire comprised eight questions. The first four questions targeted demographic and general questions, whereas the last four questions targeted validating the designed framework.

5. RESULTS AND DISCUSSION

This section discusses the results of the policy review, online surveys, Multiple-Criteria Decision Analysis (MCDA), and validation surveys.

5.1. Results of the policy review

Several policy documents were reviewed to gain the core insight about the smart mobility solutions prioritized by Saudi government initiatives and the method and level of their incorporation in the policies. A brief description of the reviewed policy documents is provided below for perspective.

The National Spatial Strategy (NSS) is a strategic tool for cross-sectoral operations that provides a link between the programs, initiatives, and projects prepared by all ministries and public agencies, as well as by the private sector and civil society.

National Transport and Logistics Strategy (NTLS) focuses on developing a multimodal, sustainable, and futuristic transport and logistics sector led by national capabilities to transform Saudi Arabia into a global logistics hub.

Learning from the international experience of integrating technology and using smart principles in planning and mobility, key recommendations are proposed under the Integration between Transport Planning and Management and Multi-Dimensions of Urban Planning of Saudi Arabia (ITUP) initiative program.

It was essential to analyze the key findings from these documents to identify the smartest solutions preferred by the important government-funded initiative programs. Therefore, a summary table has been devised to analyze the frequency of different SM elements in each initiative program discussed in the previous section. The analysis results are presented in **Błąd! Nie można odnaleźć źródła odwołania.**1, showing strong and direct alignment with the core SM solutions identified in this study (Section 2): Public Transport, Autonomous Vehicles, Shared Mobility, and ITS, showing the common grounds for the transition mechanism to smart mobility.

The alignment of strategy and implementation is evidenced by mega-projects, such as the Riyadh Metro, and the development of a master transportation plan under NTLS. These efforts correspond to the widely accepted and utilized SM framework.

Tab. 1

Alignment of SM solutions with Saudi government initiatives

Smart Mobility Solution	National Spatial Strategy (NSS)	National Transport & Logistics Strategy (NTLS)	Integration for Urban Planning (ITUP)	Direct Link to Study Framework
Public Transport	○	●	●	●
Autonomous Vehicles		●	○	●
Shared Mobility		●		●
Intelligent Transport Systems (ITS) / Big Data	○	●	●	●
Supporting / Enabling Solutions				
Adaptation of New Tech / Advanced Streets	●			
Adaptive Traffic Signals			●	
Autonomous Public Transport			●	
Integrated Passenger Info / Ticketing			●	

Public Transport Priority	●	●		
Traffic Safety			●	

● (Direct): Explicitly mentioned as a focus or project within the initiative.
○ (Indirect): Supported or enabled by the initiative's goals but not a primary named solution.
Blank: Not addressed by the initiative.

5.2. Results of the questionnaire survey

To begin with, an online pilot questionnaire was sent to several colleagues, regarded as experts in the field of SM, in December 2021. Following that, the first stage questionnaire was finalized and was distributed online, as mentioned before. The questionnaire results were collected separately via two links, i.e., 1) the Mobility Users survey and 2) the Mobility Supplier survey. The data were collected from the 26th of December 2021 until the 28th of February 2022. Participants were introduced to the questionnaire's objectives and purpose before completing it.

The mobility user survey had 326 total responses. After applying filters for irrelevant and incomplete surveys, the study sample of 205 participants (appendix A1) was finalized for analysis.

The mobility supplier survey, which was sent to selected organizations and professionals, was password controlled. After filtering the irrelevant and incomplete responses, the total final responses qualified for the analysis came to be 45 Out of 250 survey questionnaires (appendix A2).

The Statistical Package for the Social Sciences (SPSS) was used for the statistical analysis to check for any dependency between the categorical variables related to each question. Descriptive and cross-table analyses were performed among the variables in the questionnaire.

Both groups (users and suppliers) were predominantly male, aged 25-34, based in Eastern Province or Riyadh. The key divergence was in the prior knowledge of the participants wherein 86.7% of experts were familiar with "Smart Mobility" vs. 45.4% of users. This difference establishes the supplier group's informed perspective.

A deeper look at the supplier respondents and their organizational activities shows two important aspects (Tab. 2 and 3) which confirm the informed perspective assumption. Firstly, majority of them were affiliated with organizations who are actively involved in SM projects. Secondly, a significant proportion (16 out of 45) of the expert respondents hold decision making positions in their organizations. Hence, their opinions and insights are deeply rooted in their practical experience, knowledge and expertise.

Despite this distinction, majorities in both groups reported being "unsatisfied" or "neutral" regarding current transportation options. There was a strong consensus on the need for change, with over 80% of each group (82% users, 86.7% experts) stating it is "Very Important" to develop alternative smart mobility solutions.

Fig. 4 reveals priorities of future transportation choices in both types of surveys. Public transport is the top-ranked priority for both types of respondents, selected by 46% users and 44% suppliers, which directly aligns with government priorities analyzed in Tab. 1. Users' second choice is autonomous vehicles (20%), while experts show a slightly more distributed preference between car-sharing and autonomous vehicles. The difference in opinion could stem from the suppliers' concerns regarding near-term autonomous vehicle implementation challenges. Ride-sharing is ranked lowest by both groups. Similar trends were observed in another study [32] which focused on finding preference of smart mobility options in Singapore.

This provides evidence of common perceptual mechanisms among travelers of different regions with regards to smart mobility options. A chi-square test performed on the user participants showed that gender was the only demographic factor with a p-value < 0.002 affecting satisfaction. This finding also resonates with the available literature as shown by Kendziorra et al. [33] in their review paper which establishes it as a global pattern. They attributed this difference to safety perception of female travelers. Similar tests were performed for other characteristics which returned insignificant results.

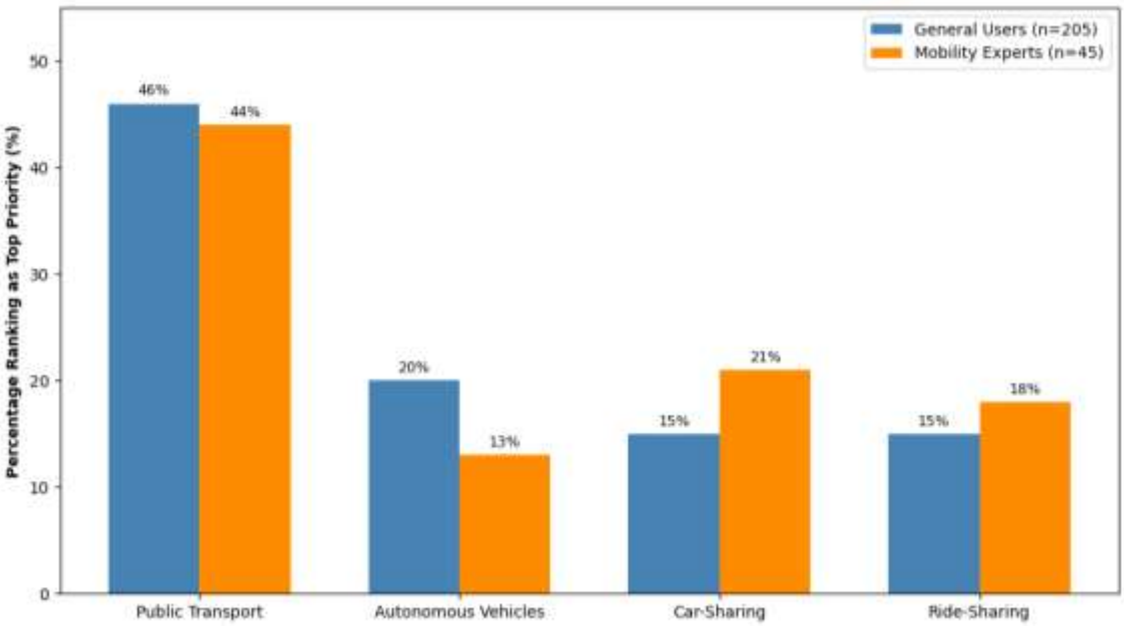

Fig. 4. Top-ranked SM solution by respondent group

Figure 5 reveals a concerning gap in participants' attitude and behavior. Despite the fact that the public transport was selected more than any other mode for recommended systems, a large majority of both groups stated that they would continue using a private car for personal travel (78.5% of users, 71% of experts). This highlights the central challenge for smart mobility shifts in a car-dependent culture. In such context, stated preference for a sustainable alternative mode does not necessarily show willingness to change personal travel behavior. This "Attitude-Behavior Gap" is not exclusive to the gulf region or car-dependent countries. A study done in Norway showed the same differences in perception and practice on the basis of privacy and access issues (Last-Mile barriers) [34]. Therefore, it appears to be a global issue in adoption of smart and sustainable mobility options despite being attributed to different causal factors.

In terms of challenges to transition to SM, suppliers identified cooperation between stakeholders as the most important challenge (27%), followed by development costs and policy/goal alignment (per Fig. 6). Such observations provide insights beyond superficial user perceptions. These aspects have also been empirically proven as barriers and possible reasons for smart mobility failures [35]. Supplier responses also indicate that their organizations' plans align with stated priorities, among which ~ 50% are involved in public transport projects and 20% in autonomous vehicle projects (per Fig. 7). Almost all (98%) of the experts agree on the critical need for pilot projects before wide-scale implementation.

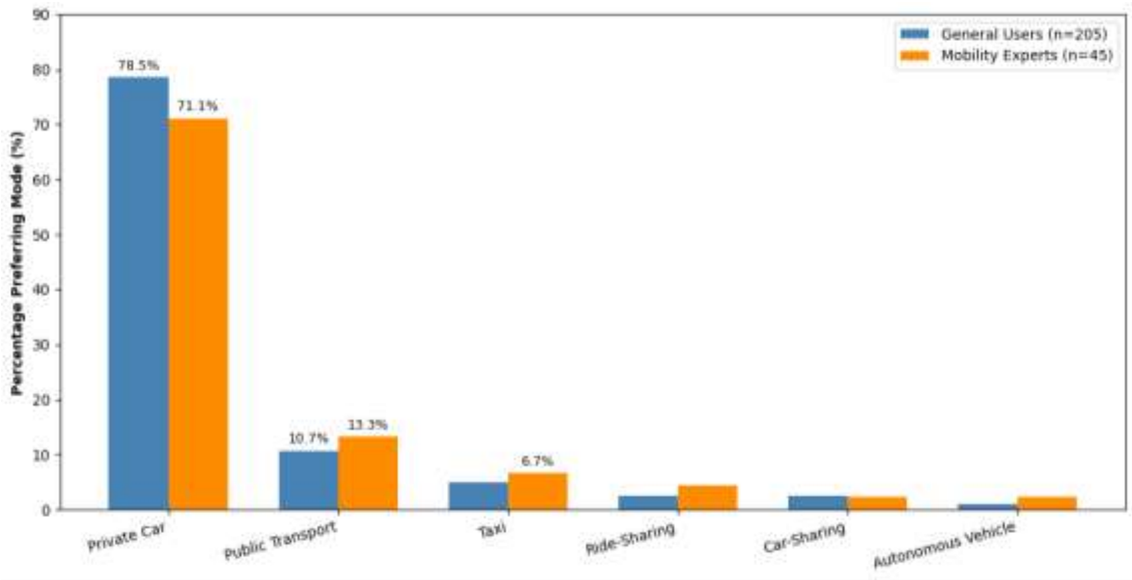

Fig. 5. Personal travel preference within city

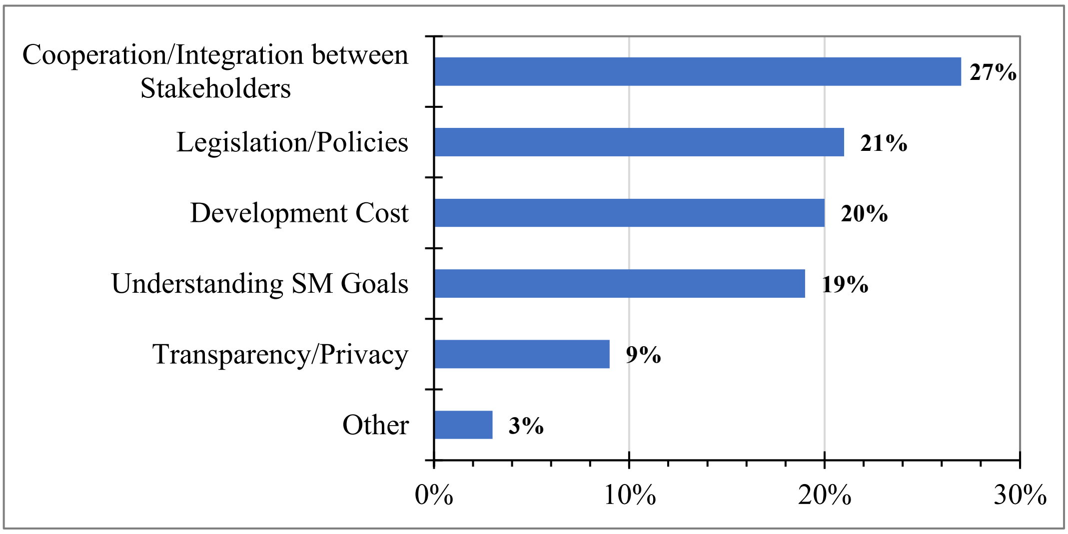

Fig. 6. Challenges associated with SM solutions

The breakdown between public and private sector focus (Fig. 8) provides nuanced insights. On one hand, the public sector shows stronger engagement in public transport and autonomous vehicles, while the private sector has a relatively greater focus on shared mobility solutions. This underscores the complementary roles different stakeholders would play in the SM transition. However, most of the experts emphasized that public sector organizations are the foremost in driving SM transition (Tab. 4). The success of such collaborative mechanisms is validated through practical examples, such as the Helsinki mobility system in Finland, wherein the government provides the public transport and acts as an initiator and facilitator for ride sharing services that are provided by the private sector [36].

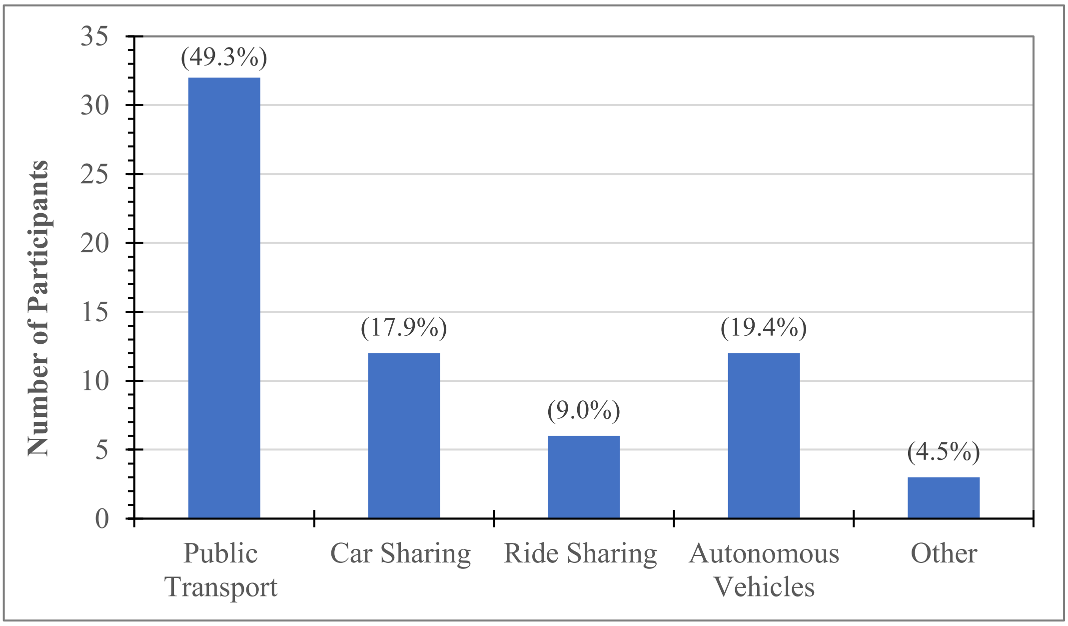

Fig. 7. Mobility solution projects offered or planned by stakeholders' organizations

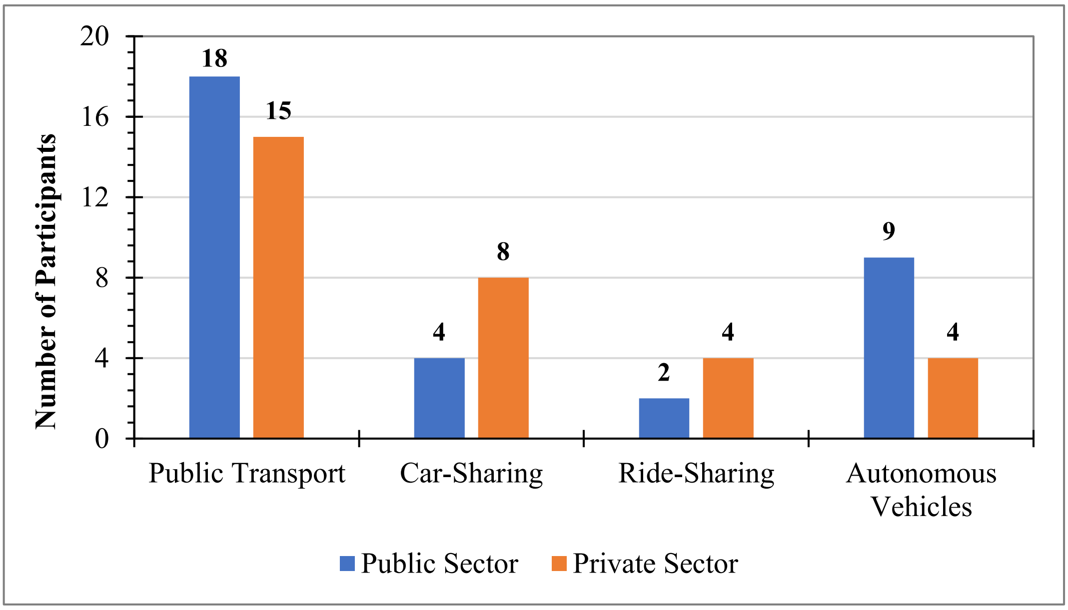

Fig. 8. Comparison between public and private sector – future projects

Tab. 2

Alignment of SM solutions with Saudi government initiatives

Question	Option	Q2 - Is your organization directly involved in SM Initiatives?				Total
		Yes	Partially yes	No	Not Sure	
	Yes	10	16	2	0	16

Q3 - Are you a decision-maker in your company?	No	6	29	6	4	29
Total		16	17	8	4	45

Tab. 3

Decision makers and their organizations

Question	Option	Q4 - My responsibility in my company is?		Total
		Local	Regional	
Q3 - Are you a decision-maker in your company?	Yes	8	8	16
	No	27	2	29
Total		35	10	40

Tab. 4

Best placed organizations selected by experts

Industry/Sectors	Selection by Participants	Selection percentage	Industry/Sectors
Automotive	12	8.89%	Automotive
Consultant/Engineers	16	11.85%	Consultant/Engineers
Government/Public	30	22.22%	Government/Public
Ministries	19	14.07%	Ministries
Transport/logistics	29	21.48%	Transport/logistics
Media, Entertainment	8	5.93%	Media, Entertainment
Energy/Oil/Gas	8	5.93%	Energy/Oil/Gas
Telecommunication services	7	5.19%	Telecommunication services
Software services	6	4.44%	Software services

5.3. Multiple Criteria AHP analysis

The pairwise comparison questionnaire results were evaluated to find the importance of each criterion in comparison to the other in pairs. This was on the Saaty's scale of 1 to 9, considering the 5 criteria. The calculations were done using a Microsoft Excel sheet created by Goepel [37].

Answers from the 20 responses of the experts were filled in a pairwise comparison matrix. After that, each value in each column of the filled matrix was divided by the sum of the respective column to calculate its normalized score. Consistency ratios were calculated, which came out to be less than 0.1 for the analyzed matrix; therefore, the answers from the 20 experts are consistent for ensuring the research answers and results.

As shown in Tab. 5 safety is ranked with the highest importance by experts. Because of the multifaceted nature of road accidents, experts around the world have been actively trying to solve this problem for many years [38]. As a result of policies and concepts like "Vision Zero", road traffic safety policies have been seen as potentially promising on a global scale [39]. Safety has also become an important parameter when it comes to smart mobility initiatives in Saudi Arabia. According to NSS [40], Saudi Arabia tends to move forward with the objective of improving life quality, better safety and security of their citizens. Furthermore, Goal eleven of Vision 2030 also makes it a priority to make urban cities more resilient, secure, and sustainable with a strong focus on making them safer. Thus, the literature and administrative focus dictate that safety should be given priority over other parameters during planning and design phases for ensuring trust from the stakeholders. The rest of the parameters are closely packed from the weightage perspective, and experts think infrastructure should have the least importance when comparing against selected parameters shown in Tab. 5.

Tab. 5

Rankings of variables based on weightage

Variable	Weightage	Ranking
Safety	41.0%	1
Flexibility	16.9%	2
Cost	14.4%	3
Speed	14.3%	4
Infrastructure	13.4%	5

6. ROADMAP AND FRAMEWORK TO TRANSITION TO SMART MOBILITY

Based on the qualitative review, survey results, and analysis done by the researchers, a roadmap for transition to SM was developed, which is shown in

Fig. 9. This roadmap could play an important role as a strategic tool for the desired outcome and includes the major milestones needed to reach it. The roadmap covers the well-known challenges to the adoption of smart mobility which have been highlighted in this study and confirmed in previous literature, such as alignment of stakeholders and policies. This road map is an extension of the current research; hence, the initial steps have already been carried out during this research at a smaller scale. The researchers envision that it could serve as a guideline for the relevant stakeholders to initiate and carry out the transition toward SM in car dependent cities. In line with government initiatives, these milestones should be finished within 5 years so that the actual execution of the SM project may start in time to achieve the desired objectives.

A comprehensive framework for transition to SM, developed in the course of this research, can be seen in Fig. 10. This framework identifies key areas and elements for shifting towards new SM options and provides dimensions to work along for achieving a successful shift. The foundations of this framework are based on the alignment of findings from this study with previous literature and benchmarked practices. Some of the important aspects are the identification of stakeholders and an inclusive approach toward them in the transition process, the prioritized list of SM options, and the highlighting of the most important challenges for the transition. These linkages between the framework and current research are provided on the right-hand side of

Fig. .

A validation survey was conducted in a focus group to validate the framework. In this focus group, all five participants were men with at least a graduate education in transport-related fields. All five participants were men having at least graduate education in the fields related to transportation. 3 participants (out of 5) had the post-graduate degree (master's or PhD). Three of them work in government/public sectors, and the other two work in the private mobility sector. All the expert participants said that their respective organizations are directly involved in SM initiatives. All these experts are well-versed in the knowledge of SM in local and global contexts; hence, their endorsement of the findings of this research serves as the validation of the international application of the proposed framework.

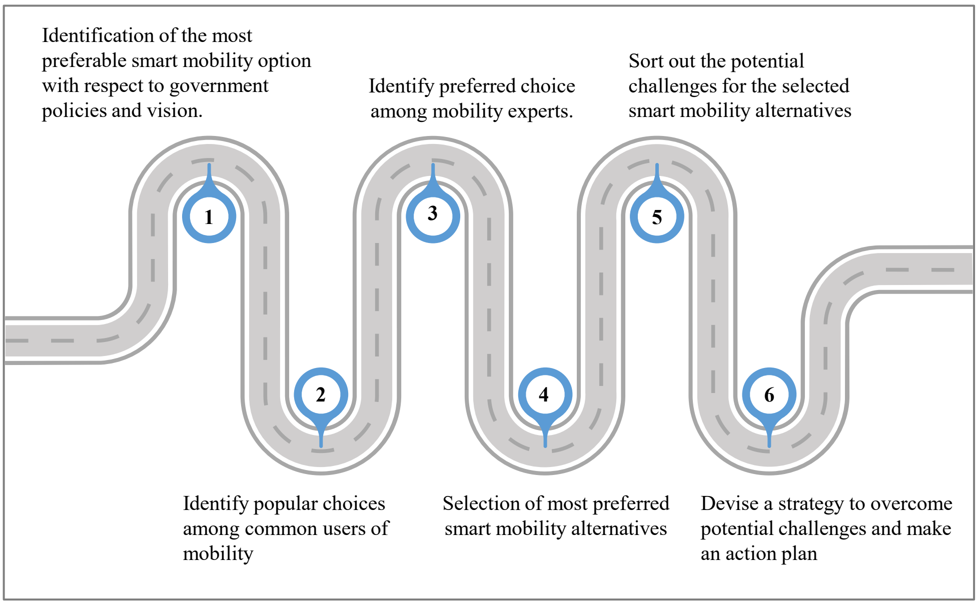

Fig. 9. SM transition roadmap

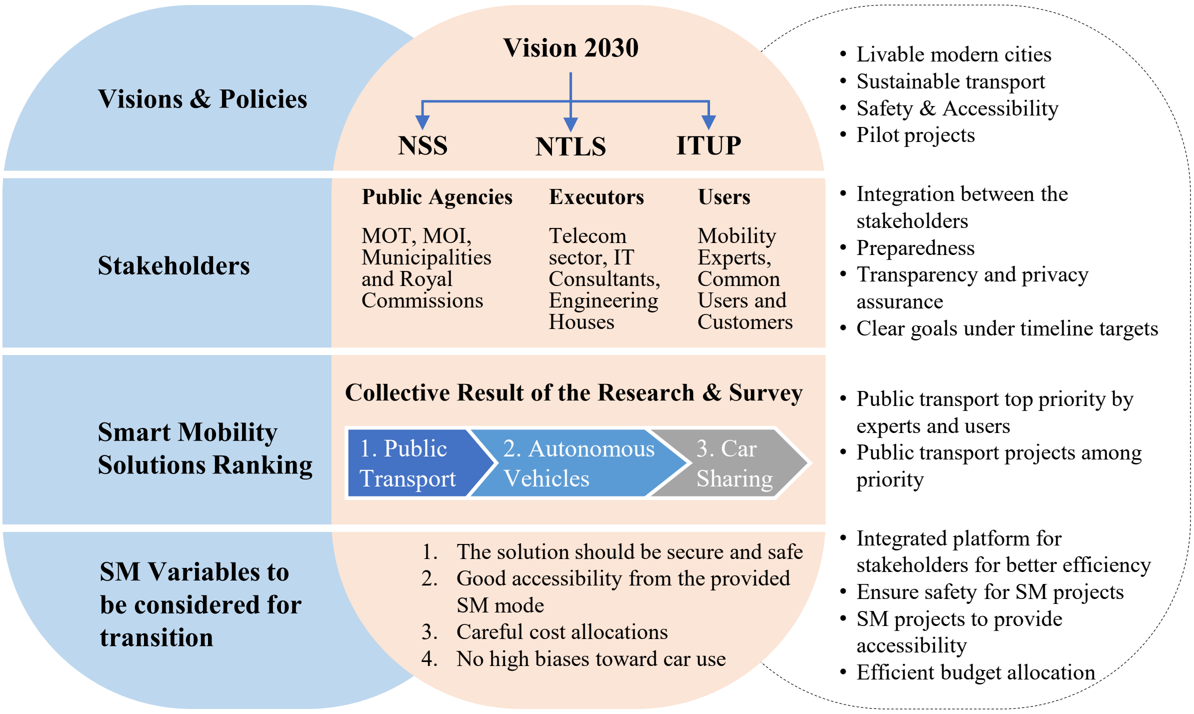

Fig. 10. SM executed framework

The responses to the initial four questions (related to the professional background and educational level) served as a justification for selecting these participants for the validation survey. Afterward, three specific questions were asked to validate the framework. Question 5 was directed toward the observed ranking of preferred SM options in the research study. Four out of five participants agreed on the ranking order of the study (Public Transport, Autonomous Vehicles and Car Sharing, respectively). This question was directed towards the observed ranking of preferred smart mobility options in the research study. 4 out of 5 participants agreed on the ranking order of the study, whereas 1 participant appeared to be in disagreement. Since 80% of the participants agreed with the ranking, it can be said that "experts agree with the ranking results of this research study”.

Question 6 asked if the experts agree or disagree with the following ranking of the smart mobility elements for implementing smart mobility modes in Saudi Arabia (Safety, Flexibility, and Cost, respectively). Similar to the results of question five, 80% of the experts agreed with the ranking suggested by this research study. One participant did not agree with the ranking order. As 80% (4 out of 5) of the respondents agreed with the ranking, it can be said that “experts are in agreement with the results of this study”.

Question 7 asked if the experts agree or disagree with the following statement: “Governance failures cause complications and inefficiency of the smart mobility paradigm, especially at the implementation level". Among the major findings of this study is the fact that lack of integration leads to governance issues, which impedes the implementation of smart mobility initiatives. All five participants agreed to this statement. Thus, it can be concluded that “this study's results have been endorsed by experts”

Lastly, experts were asked for any suggestions regarding the study; one of the participants advised the usage of smart apps on mobile phones, such as parking apps, car-sharing apps, etc. From the results of this validation survey, it is evident that “the results of this study are largely agreed upon by the experts”. Thus, the proposed framework could be considered applicable for the transition to SM. The confirmation of this validation survey further reinforces the validity of this transferable framework, which complies with the reported trends in the literature and successfully incorporates proven mechanisms.

7. CONCLUSIONS AND FUTURE WORK

This research study has focused on developing and validating a strategic framework for the transition to SM. To achieve this goal, multiple aspects of the problems were considered, including previous research, government policies and initiatives, and the perspective of users and mobility experts. This multisectoral and all-inclusive approach was adopted to ensure that the resulting framework is robust and transferable.

Based on the literature review, the SM ecosystem was developed for the study objectives. A strategic perspective on the SM transition was acquired by going through the national and regional policies, strategies, and the published white papers by various government agencies. Moreover, questionnaire surveys were developed for the common users and mobility experts for their opinions and reviews regarding the current and future mobility systems. In the end, the following conclusions were drawn from this study:

- The review showed a clear preference for public transport solutions, which have been receiving equal importance in the international literature and national policies and plans further transformed into projects and master plans.

- Public transport was also found to be the most preferred smart solution by the stakeholders in literature, and this study proved that this preference is found among both common users and mobility suppliers.
- The response analysis highlighted the issue of the “Attitude-Behavior Gap” among survey respondents who prefer cars for their personal trips over other mobility options despite their affinity for public transport as a system. This could be due to long-term car dependency inside the Kingdom. The literature provides evidence of such disparity in other countries that are much further progressed in terms of adoption of smart mobility, proving it as a global phenomenon.
- The survey results showed that mobility suppliers think the integration of stakeholder systems is the biggest challenge for achieving SM, followed by public policies and development costs. The finding is supported by empirical evidence from other studies in the literature.
- Experts consider safety to be one of the most important aspects of SM, which aligns with international sustainability goals and national strategic focus.
- On the basis of the above validated findings, the strategic framework consists of 4 main streams (vision and policies, stakeholders, smart mobility options, and smart mobility transition valuables).
- There is consensus among experts regarding the elements of the proposed framework providing its practical validation, which is in addition to its alignment with scholarly evidence.

The robust approach of the research, implementing a mixed-method multisectoral combination of qualitative and quantitative analysis, makes it likely to be implemented in other circumstances. This strategic framework is expected to help the Saudi Arabian government in its future planning with a strong possibility to be adopted by other countries in the region.

Some of the limitations of this research include limited sample sizes and condition assessment of present transportation systems in car-dependent cities, especially in Saudi Arabia and surrounding countries. With regards to the collected data, the sample was male-dominated and had a high proportion of respondents within 24-35 years, which limits the generalization of the results of the survey. Another limitation of the study is related to its time of data collection, which was in 2020-2021; hence, its results would need further validation in the purview of the latest developments in the car-dependent countries. Possible future directions of research may include evaluating the effects of different policy measures on the transformation to smart mobility. Moreover, performance and evaluation indices could be developed to measure the effectiveness of different strategies for transitioning to smart mobility.

References

1. Aldalbahi M., G. Walker. 2015. „Attitudes and policy implications of urban growth boundary and traffic congestion reduction in Riyadh, Saudi Arabia”. In: *International Conference on Data Mining*.
2. Alonso-Munhoz P.A., et al. 2025. „Exploring the future of Mobility as a Service (MaaS): A co-design approach to scenario planning in European cities”. *Journal of Urban Mobility* 8: 100133. DOI: https://doi.org/10.1016/j.urbmob.2025.100133.

3. Bagloee S. A., M. Tavana, M. Asadi, T. Oliver. 2016. „Autonomous vehicles: Challenges, opportunities, and future implications for transportation policies". *Journal of Modern Transportation* 24(4): 284-303. DOI: https://doi.org/10.1007/s40534-016-0117-3.
4. Boin R., T. Möller, V. Pokotilo, A. Ricotti, N. Sandri. 2023. *Infrastructure technologies: Challenges and solutions for smart mobility in urban areas.* McKinsey & Company: Travel, Logistics & Infrastructure.
5. Butler L., T. Yigitcanlar, A. Paz. 2020. „Smart urban mobility innovations: A comprehensive review and evaluation". *IEEE Access* 8: 196034-196049. DOI: https://doi.org/10.1109/ACCESS.2020.3031918.
6. Caragliu A., C.F. Del Bo, P. Nijkamp. 2023. „'Smart cities in Europe' revisited: A meta-analysis of smart city economic impacts". *Journal of Urban Technology* 30(4): 51-69. DOI: https://doi.org/10.1080/10630732.2023.2246477.
7. Caragliu A., C. Del Bo, P. Nijkamp. 2011. „Smart cities in Europe". *Journal of Urban Technology* 18 (2): 65-82. DOI: https://doi.org/10.1080/10630732.2011.601117.
8. Chng S., S. Anowar, L. Cheah. 2022. „Understanding shared autonomous vehicle preferences: A comparison between shuttles, buses, ridesharing and taxis". *Sustainability* 14(20): 13656. DOI: https://doi.org/10.3390/su142013656.
9. European Commission. 2024. *Sustainable urban mobility planning and monitoring. Directorate-General for Mobility and Transport*. Available at: https://transport.ec.europa.eu/transport-themes/urban-transport/sustainable-urban-mobility-planning-and-monitoring_en.
10. Fatorachian H., H. Kazemi. 2025. „Sustainable optimization strategies for on-demand transportation systems: Enhancing efficiency and reducing energy use". *Sustainable Environment* 11(1): 2464388. DOI: https://doi.org/10.1080/27658511.2025.2464388.
11. Galal H., H. Wimmer, A. Khurana. 2022. *Smart cities: Mobility ecosystems for a more sustainable future*. strategy+business, a PwC publication.
12. Golzar J., S. Noor, O. Tajik. 2022. „Convenience sampling". *International Journal of Education and Language Studies* 1(2): 72-77.
13. Graziotin D. 2013. „An analysis of issues against the adoption of dynamic carpooling". *arXiv preprint*. Available at: https://arxiv.org/abs/1306.0361.
14. Guzman L.A., V.A. Cantillo-Garcia, J. Arellana, et al. 2023. „User expectations and perceptions towards new public transport infrastructure: Evaluating a cable car in Bogotá". *Transportation* 50: 751-771. DOI: https://doi.org/10.1007/s11116-022-10275-w.
15. IEEE Standards Association. 2024. Three mobility trends to watch for in 2024. IEEE Beyond Standards. Available at: https://standards.ieee.org/beyond-standards/2024-mobility-trends/.
16. Kendziorra J., M. Barmann, K. Kusanke, A.K. Witte. 2025. „Gender and mobility – A literature review on women's (non-) use of shared mobility services". In *International Conference on Wirtschaftsinformatik*: 355-373. Springer, Cham. DOI: https://doi.org/10.1007/978-3-031-61057-5_25.
17. Kim K. 2015. „Can carsharing meet the mobility needs for the low-income neighborhoods? Lessons from carsharing usage patterns in New York City". *Transportation Research Part A: Policy and Practice* 77: 249-260. DOI: https://doi.org/10.1016/j.tra.2015.04.017.

18. Kleinberg J., S. Mullainathan, M. Raghavan. 2024. „The challenge of understanding what users want: Inconsistent preferences and engagement optimization". *Management Science* 70(9): 6336-6355. DOI: https://doi.org/10.1287/mnsc.2023.4932.
19. Kurani K.S., N. Caperello, J. TyreeHageman. 2016. *New car buyers' valuation of zero-emission vehicles: California*. UC Davis Research Reports. Available at: https://escholarship.org/uc/item/28v320rq.
20. Maldonado Silveira Alonso Munhoz P.A., F. da Costa Dias, C. Kowal Chinelli, A.L. Azevedo Guedes, J.A. Neves dos Santos, W. da Silveira e Silva, C.A. Pereira Soares. 2020. „Smart mobility: The main drivers for increasing the intelligence of urban mobility". *Sustainability* 12(24): 10675. DOI: https://doi.org/10.3390/su122410675.
21. Moura F., J. de Abreu e Silva. 2019. „Smart cities: Definitions, evolution of the concept, and examples of initiatives". In: *Industry, Innovation and Infrastructure*: 989-997. Springer, Cham. DOI: https://doi.org/10.1007/978-3-319-95867-5_116.
22. Noy K., M. Givoni. 2018. „Is 'smart mobility' sustainable? Examining the views and beliefs of transport's technological entrepreneurs". *Sustainability* 10(2): 422. DOI: https://doi.org/10.3390/su10020422.
23. Paiva S., M.A. Ahad, G. Tripathi, N. Feroz, G. Casalino. 2021. „Enabling technologies for urban smart mobility: Recent trends, opportunities and challenges". *Sensors* 21(6): 2143. DOI: https://doi.org/10.3390/s21062143.
24. Radu L.D. 2020. „Disruptive technologies in smart cities: A survey on current trends and challenges". *Smart Cities* 3(3): 1022-1038. DOI: https://doi.org/10.3390/smartcities3030051.
25. Risher J., J.F. Hair Jr. 2017. „The robustness of PLS across disciplines". *Academy of Business Journal* 1: 47-55.
26. Russo F., C. Rindone. 2023. „Smart city for sustainable development: Applied processes from SUMP to MaaS at European level". *Applied Sciences* 13(3): 1773. DOI: https://doi.org/10.3390/app13031773.
27. Safarpour H., Z.D. Khorasani, H. Soori, L.K. Bagheri, Z. Ghomian, R. Mohammadi. 2020. „Vision Zero: Evolution history and developing trend in road safety: A scoping review". *Trauma Monthly* 25(6): 275-286. DOI: https://doi.org/10.30491/tm.2020.240217.1083.
28. Shvetsova O., A. Bialevich, J. Kim, M. Voronina. 2022. „Behavioral model deployment for the transportation projects within a smart city ecosystem: Cases of Germany and South Korea". *Processes* 11(1): 48. DOI: https://doi.org/10.3390/pr11010048.
29. Slowik P., D. Hall, N. Lutsey, M. Nicholas, S. Wappelhorst. 2019. *Funding the transition to all zero-emission vehicles*. White paper, International Council on Clean Transportation.
30. Sourbati M. 2020. „Age and the city: The case of smart mobility". In *International Conference on Human-Computer Interaction*: 312-326. Springer, Cham. DOI: https://doi.org/10.1007/978-3-030-50252-2_24.
31. Sourbati M., F. Behrendt. 2021. „Smart mobility, age and data justice". *New Media & Society* 23(6): 1398-1414. DOI: https://doi.org/10.1177/1461444820910411.
32. Syed J., F. Ali, S. Hennekam. 2018. „Gender equality in employment in Saudi Arabia: A relational perspective". *Career Development International* 23(2): 163-177. DOI: https://doi.org/10.1108/CDI-01-2018-0010.

33. Thøgersen J., A. Vatn, M. Aasen, R.E. Dunlap, D.R. Fisher, O. Hellevik, P. Stern. 2021. „Why do people continue driving conventional cars despite climate change? Social-psychological and institutional insights from a survey of Norwegian commuters". *Energy Research & Social Science* 79: 102168. DOI: https://doi.org/10.1016/j.erss.2021.102168.
34. Tomaszewska E.J., A. Florea. 2018. „Urban smart mobility in the scientific literature – Bibliometric analysis". *Engineering Management in Production and Services* 10(2): 41-56. DOI: https://doi.org/10.2478/emj-2018-0012.
35. Tutak M., J. Brodny. 2025. „Stakeholder collaboration and open innovation in smart cities: A Quattro Helix model for technological and social transformation". *Journal of Open Innovation: Technology, Market, and Complexity*: 100594. DOI: https://doi.org/10.1016/j.joitmc.2025.100594.
36. Usami D.S., et al. 2017. *Inventory of assessed infrastructure risk factors and measures*. Deliverable 5.4 of the H2020 project SafetyCube. Loughborough University: SafetyCube.
37. Verma R., M.M. Agarwal. 2025. „A systematic review on road accident prediction: A special attention towards machine learning and deep learning approaches". *Journal of Circuits, Systems and Computers*. DOI: https://doi.org/10.1142/S0218126625502198.
38. Viechnicki P., A. Khuperkar, T. Fishman, W. Eggers. 2015. *Smart mobility: Reducing congestion and fostering faster, greener, and cheaper transportation options*. Deloitte Smart Mobility Research Report. Available at: https://www2.deloitte.com/content/dam/insights/us/articles/smart-mobility-trends/DUP_1027_Smart-Mobility_MASTER1.pdf.
39. Xydis G., L. Pagliaricci, Ž. Paužaitė, V. Grinis, G. Sallai, P. Bakonyi, R. Vician. 2021. „SMARTIES project: The survey of needs for municipalities and trainers for smart cities". *Challenges* 12(1): 13. DOI: https://doi.org/10.3390/challe12010013.
40. Zhu J., N. Xie, Z. Cai, W. Tang, X. Chen. 2023. „A comprehensive review of shared mobility for sustainable transportation systems". *International Journal of Sustainable Transportation* 17(5): 527-551. DOI: https://doi.org/10.1080/15568318.2022.2077772.

Appendix

Tab. A1

Demographic frequency table – user survey result

Question	Categories	Count	Percentage %
Q1 - Are you	Male	126	61.5%
	Female	79	38.5%
	Prefer not to answer	0	0.0%
Q2 - What is your age	Under 18	0	0.0%
	18-24	50	24.4%
	25-34	81	39.5%
	35-44	42	20.5%
	45-54	16	7.8%
	55-64	9	4.4%
	Above 64	7	3.4%
Q3 - I am based in	Saudi Arabia	202	98.5%
	Other	3	1.5%
Q4 - My region in Saudi Arabia is	Riyadh	45	22.0%

	Eastern Province	107	52.2%
	Makkah/Jeddah	19	9.3%
	Madina/Tabuk	9	4.4%
	Asir	3	1.5%
	Jizan	5	2.4%
	Tabuk	3	1.5%
	Ha'il	1	0.5%
	Najran	0	0%
	Northern Region/Al Jawf	2	1.0%
	Other	11	5.4%
Q5 - What is the highest degree or level of school you have completed	High school	19	9.3%
	Some college	22	10.7%
	Trade/vocational/technical	6	2.9%
	Bachelors	122	59.5%
	Masters	32	15.6%
	Doctorate	4	2.0%
Q6 - Were you familiar with the term "SM" before this survey	Yes	93	45.4%
	No	112	54.6%

Tab. A2

Demographic frequency table – supplier survey result

Question	Categories	Count	Percentage %
Q1 - Are you	Male	41	91.1%
	Female	3	6.7%
	Prefer not to answer	1	2.2%
Q2 - What is your age	Under 18	0	0.0%
	18-24	0	0.0%
	25-34	23	51.1%
	35-44	13	28.9%
	45-54	5	11.1%
	55-64	4	8.9%
	Above 64	0	0.0%
Q3 - I am based in	Saudi Arabia	45	100.0%
	Other	0	0.0%
Q4 - My region in Saudi Arabia is	Riyadh	15	33.3%
	Eastern Province	26	57.8%
	Makkah/Jeddah	2	4.4%
	Madina/Tabuk	2	4.4%
	Asir	0	0.0%
	Jizan	0	0.0%
	Tabuk	0	0.0%
	Ha'il	0	0.0%
	Najran	0	0.0%
	Northern Region/Al Jawf	0	0.0%
	Other	0	0.0%
	High school	1	2.2%

Q5 - What is the highest degree or level of school you have completed	Some college	0	0.0%
	Trade/vocational/technical	0	0.0%
	Bachelors	28	62.2%
	Masters	8	17.8%
	Doctorate	8	17.8%
Q6 - Were you familiar with the term “SM” before this survey	Yes	39	86.7%
	No	6	13.3%

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