A Delphi-based Analysis to Identify Barriers and Solutions in Adoption of Electric Vehicles Sharing System

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Abstract. *Electric vehicles and shared mobility services are regarded as the means of reaching a transition to sustainable low-carbon emission transportation systems This study aimed to identify and assess the barriers in adoption of electric vehicle sharing system (EVSS) and the potential policy measures that can aid in improving the demand of EVSS. We employed a Delphi-method based expert opinion survey in order to characterise the selected barriers and policy measures with respect to EVSS demand using three parameters – expected probability of occurrence of each barrier while selecting EVSS as transport mode, impact of barrier in choice and that of policy measure in overcoming barrier, and desirability in framing policies. Our results depict barriers related to technological, policy & governance, and infrastructure related aspects are most impactful in hindering EVSS demand. Further, the potential policy measures were identified which can help city authorities to improve the EVSS mode-share.*

Keywords. Shared mobility, electric mobility, consumer adoption, sustainable transportation, Delphi

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1 Introduction

Large metropolitan cities around the world have been facing an exacerbating growth of trips through fossil fuel-powered vehicles which is often cause for the urban traffic congestion, climate change, and depletion of the natural resources [1]. This has led the global economies to think towards restructuring the urban mobility systems and regulations. Electric vehicles and shared mobility services are regarded as the means of reaching a transition to sustainable low-carbon emission transportation systems [2].

The challenges involved in this process are not only to look for innovative vehicle design and service models, but to also understand the demand and adaptation of such services, which is imperative to ease effective market penetration. There are still only a small number of trips currently made using the electric vehicle sharing services (EVSS) [3]. The city authorities currently have little knowledge on how to efficiently systematise the EVSS system. This study tries to find the potential barriers affecting the demand and adaptation of EVSS and to recognize the possible policy measures to overcome the barriers. Specifically, this paper presents the early results achieved using the Delphi-based experts' opinion survey. We adopted a modified Delphi-method in which selected experts were asked to assess the barriers and policy measures with respect to the expected probability of occurrence in real case scenarios, impact, and desirability at strategic level of planning, and experts' confidence level in this assessment. This is particularly valuable in policy making and analysis since it is possible to understand the variance in the opinions of different experts.

2 Data Collection and Analysis

The Delphi method has proven to be an efficient survey method when there is a limited amount of data is available [4]. It seeks to achieve consensus and stable results on an issue by the structured group of experts. In this study, we have identified thirty-seven sub-barriers based on an extensive literature review, which are then categorized into five major category barriers namely, behavioural, policy & governance, infrastructural, technological, and external barriers based on their characteristics. Subsequently, twenty-three possible solutions and policy measures were identified which can aid in overcoming the barriers in the adaptation of EVSS. A panel of experts identified for this study were selected from – academic institutions, city authorities, and industry representative bodies. We approached 22 such experts who have minimum 5 years of associated experience (looking to the newness of the topic) associated with the subject matter while 10 of them agreed (response rate of 45%) and responded to our questions. In the questionnaire, experts were asked to assess each sub-barrier regarding their expected probability (EP) of occurrence which depicts whether a particular barrier will arise against the users when they consider travelling with EVSS (scaled on 0-100%), impact (I) of sub-barrier on user's choice and that of solution to aid the adaptation of EVSS (5-point Likert scale), desirability (D) in strategic level of planning (5-point Likert scale). For solutions, similar questions were asked except EP. Additionally, experts were asked to rate their confidence level in assessing sub-barriers and potential solutions. A similar Delphi-based approach is frequently adopted in studies related to market behaviour and risk analysis [5], however the application of the same in context of travel behaviour analysis has not been explored before.

Table 1 and Table 2 respectively demonstrate the list of sub-barriers and solution adopted and their quantitative evaluations. We show the mean values of the assessments for estimated EP and geometric weighted average for I and D since it showcases more logical aggregated value than mean [6]. Please note that in Likert's scale, a set of rating {1,2,3,4,5} corresponds to the linguistic set {Not-so, Less-so, Neutral, More-so, Most-so}.

Table 1. Quantitative Evaluation of the EVSS Sub-barriers

Barriers	Code	EP	I	D
Behavioural Barriers	**B1**			
Poor tech-savvy level – little awareness about the EVSS technology	B11	70.56	3.58	4.14
Negative perception towards the EVSS	B12	62.22	2.90	2.91
Habit of using private modes – stigma to not giving up the private-vehicle ownership or use (Due to personal or household circumstances)	B13	67.78	3.67	3.73
Social stigma – thinking about others' views, showing-off wealthy status, etc.	B14	38.89	2.60	2.76
Lack of sustainability awareness	B15	36.11	2.05	3.12
Performance and Range anxiety among users	B16	68.89	3.96	4.46
Higher perceived cost to the users – generally compared with public transport	B17	71.67	3.67	4.19
Lack of knowledge of perceived benefits among users	B18	54.44	3.09	3.27
Policy & Governance Barriers	**B2**			
Lack of future visions, priorities, and coherent & nationwide policy – limited growth prospects	B21	66.67	3.70	3.70
Lack of marketing strategies to promote the use	B22	66.67	3.52	3.85
Poor interventions with the local authorities and regulations	B23	67.78	3.70	3.79
Lack of required capital investments for developments and operations	B24	73.33	3.91	3.77
Difficulties in incentivizing users	B25	64.44	3.34	3.24
Poor team and government involvements in implementation	B26	66.67	3.15	3.13
Time based tariffs limit the use – multiple stops enroute incur higher costs	B27	46.67	2.53	2.70
Infrastructural Barriers	**B3**			
Unsuitable city infrastructure at current levels	B31	86.67	4.39	4.28
Lower utilization rate – due to charging layover – limits the supply	B32	73.89	3.91	3.91
Reliability of vehicles as well as operator support	B33	66.11	3.45	3.74
Uncertain availability – availability in real time when needed	B34	73.33	3.96	4.39
Access to and availability of EVSS at origin	B35	73.33	3.84	3.93
Access to and availability of EVSS at destination	B36	71.11	3.84	3.93
Unavailability of required space – stations, charging points, separate lanes (where needed)	B37	68.89	3.65	3.77
Poor/Unsuitable physical conditions of roads and Road network (including terrain) – safety	B38	62.78	3.13	3.47
Poor intersection management – safety	B39	52.78	2.53	2.84
More number of cross streets – safety and travel time	B310	41.11	2.15	2.01
Higher land-use density	B311	36.11	1.74	1.66

Barriers	**Code**	**EP**	**I**	**D**
Highly congested road network	B312	52.22	2.81	2.46
Technological Barriers	**B4**			
Lack of know-how for planning EVSS	B41	67.78	3.67	3.72
Inefficient charging infrastructure (when vehicles are not in working order) – limits the supply	B42	66.67	3.31	3.51
Poor integration with public transport systems – accessibility and fare system	B43	73.33	3.82	3.91
Unavailability of real-time vehicle data – evaluation and improvement of system	B44	60.00	2.33	2.97
Easiness of using service – IT based services	B45	75.00	3.84	3.93
External Barriers	**B5**			
Less suitable according to the individuals' demographics	B51	59.44	3.47	3.07
No fulfilments of trip requirements – higher trip length, greater travel time, multiple destinations enroute	B52	74.44	3.44	3.47
Unfavourable weather conditions	B53	71.11	3.17	3.36
Increasing levels of pollution	B54	50.00	2.46	2.39
Concerns about cleanliness of sharing vehicles	B55	44.44	2.47	2.36

Table 2. Quantitative Evaluation of the EVSS Solutions

Solutions/Policy Measures	Code	I	D
Provisions for congestion pricing / road pricing strategies for private vehicles	P1	3.67	3.69
Establishment of parking restriction policies	P2	3.88	3.98
Creating awareness campaigns for sustainable transport amongst the citizens	P3	2.94	3.76
Making people aware of the benefits of using electric shared-vehicles – at individual and societal levels	P4	3.01	3.86
Perform initial assessments and benchmarks from the foreign (other successful) examples	P5	3.26	3.45
Prior assessment for the optimal locations for EVSS stations – access/egress to O&D, PT locations, mobility needs & demand	P6	4.39	4.61
Provision for High taxations for private vehicle ownership – include environment and CO2, NOx emission taxes	P7	3.67	3.79
Formulating transport pricing on the basis of the 'polluter-pays' and 'user pays' principles – to ensure fair treatment of PV users, shared users and PT users	P8	3.27	3.21
Improvements in charging infrastructure and its availability – to decrease the layover (The idle time between trips when it is required to charge the vehicles)	P9	3.61	3.91
Established policies towards transit-oriented development and 15-minutes city	P10	3.19	3.60
Development of financial strategies to implement qualitative network for micro-mobility routes and to eliminate missing links	P11	3.38	3.17
Establishment of PPP mechanisms for infrastructural works	P12	2.71	2.79
Provisions to obtain real time data of service use to ensure quality and reliability	P13	3.58	3.72
Develop tools & techniques to evaluate the services at frequent time intervals	P14	3.00	3.13
Improving digital accessibility to EVSS services	P15	3.65	3.68
Provisions for supportive local authorities and policies for effective operations	P16	3.70	3.62

Solutions/Policy Measures	Code	I	D
Consideration of social equity while planning new infrastructure – to ensure the transport needs of communities irrespective of their social and economic characteristics	P17	3.05	3.15
Ensure tuning between the federal policies and local & regional level policies	P18	2.92	3.07
Decent coordination between local authorities and operators to better understand the market conditions and requirements and efficient operations	P19	3.61	3.65
Provisions should be in favour of the unified planning and control systems at authority level	P20	2.98	3.05
Provision of single fare policy	P21	3.65	3.91
Increased accessibility to low/medium income households	P22	3.33	3.47
Increased accessibility to the areas with mobility issues (not well served by PT)	P23	3.25	3.38

3 Results and Discussion

The quantitative estimations in the Tables 1 and 2 express the perceptions of different experts towards various sub-barriers and policy measures. On the basis of these data, planners and policy makers can develop strategies and measurements to aid the adaptation of EVSS. It is to be noted that all the parameters i.e., EP, D, and I should not be considered separately, rather it is imperative to assess them conjointly for an appropriate derivation of strategies. For example, a parameter with high probability (i.e., higher EP) with low impact value would make it less desirable to be considered. On the other hand, a parameter with similar EP and high impact value would be required due attention and thorough examination.

Table 1 reveals that technological barriers have the highest probability of occurrence overall (mean value) in users' travel decisions regarding the choice of EVSS followed by the policy & governance barriers and infrastructural barriers which have nearly similar EP values. Behavioural barriers and external barriers have been rated lowest by the experts in their overall judgements. However, looking at the individual level, it is seen that eight infrastructure sub-barriers have EP values greater than 60% with the highest EP value of 87% for B31. The sub-barrier B45 is rated as second most influencing barrier in EVSS demand. Along with the higher EP values, it can be noted that the associated impact values are also higher (i.e., above 3), which states the relevance of those sub-barriers while conducting a detailed examination for the policy framework. It is noteworthy that, though the EP values are comparatively lower for the behavioural barriers, the impact values are relatively higher. It means that the effect of behavioural barriers can act as a decider when users consider riding with shared e-mobility options, which can also be supported by past studies [7]. In terms of desirability factor, our results show that policy & governance barriers are most desirable to be considered for strategies formulation which can corroborate a systematic market penetration and operations of EVSS. The mean of desirability values of technological barriers seems to closely be following the policy & governance barriers.

Our study also considers the potential policy measures (Table 2) that city authorities can adopt to overcome the above discussed barriers. It can be noticed that the measure P6 has the highest impact and desirability values, both being above 4, showing the importance of selecting optimum locations of EVSS stations which ultimately affects the access/egress characteristics of the EVSS. Better the access/egress characteristics of EVSS, higher the usage of the services [8], [9]. Apart from this, P2, P4, P9 and P21 have been rated as more impactful and desirable solutions which can help in increasing EVSS demand by means of – restricting private car usage, raising awareness, availability of shared vehicles when required, and single fare policy to avoid series of payments and inconvenience respectively.

Overall, we focused our research on the contribution of Delphi-method based analysis to understand how to improve the market share of the EVSS through the expert opinion survey. We identify the highly impactful barriers hindering the EVSS adoption and the possible solution to overcome them, which can be further examined in-detail to help achieving the target mode-share of EVSS.

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