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The Green Electric Mobility Tool:
An ex-ante assessment tool contributing to the advancement of eMobility in urban areas in middle-income countries

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Abstract

This paper introduces the Green Electric Mobility (GEM-) tool, an ex-ante decision-making support tool to contribute to the successful implementation of electric mobility (eMobility) in urban areas in middle income countries. It provides a method to obtain an overview and evaluation of the local context before the introduction of eMobility, based on identified preconditions relevant for the successful introduction and diffusion of eMobility. Its application enhances the understanding of the (performance of the) local system, forming an essential first step in determining an optimal policy strategy. This knowledge can be used as starting point for the introduction of eMobility, therefore enhancing the chance of eMobility to become embedded in the local context and leading to a structural transition towards an eMobility. The GEM-tool can be accessed online at evconsult.nl/gem-tool.

Keywords: electric mobility, middle-income countries, local innovation system, technical innovation systems approach

1 Introduction

Mobility can be seen as one of the fundamental characteristics of modern society as it contributes to social and economic welfare [1, 2, 3]. However, the current motorized road transportation system, based on automotive vehicles powered by fossil-fuels, also comes with adverse side-effects, the main ones being local air pollution, green-house gas (GHG-) emissions and a dependency on fossil fuels [4,1,5]. These problems are most pressing in cities in developing countries, which face the dilemma between social and economic development fostered by transportation on the one hand, and the ambition towards a more sustainable future on the other [1, 6].

As part of a larger transition towards sustainable mobility, electric mobility (eMobility) represents one of the most promising pathways and is seen as the main alternative to traditional internal combustion engine (ICE) vehicles [7, 8, 9, 10]. eMobility relates to the electrification of the propulsion of vehicles used for road transport. It can reduce GHG-emissions and local air pollution, improve energy security by diversifying energy sources and reducing the dependency on fossil fuels, increase fuel efficiency and stimulate innovation and new industries [11, 9]. This advances both social and economic development, without many of the negative side-effects on the environment caused by ICE vehicles. It therefore provides the desired solution to the posed dilemma between social and economic prosperity fostered by transportation and sustainable development [7, 1].

The development, introduction and diffusion of eMobility and its related charging infrastructure have mostly taken place in industrialized countries such as Norway, the U.S. and the

Netherlands [7]. Small scale pilots can be found in developing countries e.g. South Africa, the Philippines and Colombia [12]. However, they often lack a comprehensive, long term vision and fail to consider the systematic change, taking into account the local context, needed for a structural transition towards eMobility [13, 14]. Yet, it is essential for the diffusion of a technological innovation like eMobility that technological change is linked to a process of innovation, referring to the development of technology in interaction with the (innovation) system in which the technology is embedded [15]. Within developing countries, the maturity of such an innovation system lags behind the maturity of the technology. Experience from the last decades of transferring western technologies to developing countries shows that introducing these technologies and carrying out top-down interventions will often lead to the failure of these initiatives, as local capacities and knowledge on (the performance of) the local innovation system is lacking or not taken into account [16, 17]. Key for a successful introduction of an innovation, however, is a high level of understanding of the local context, which can form a starting point of its deployment [18]. With regards to the introduction of eMobility, this is especially true for middle income countries (MICs). MICs still face the issues caused by motorized transportation and the hinder of a lack of knowledge about the local system, but do have the means and willingness to solve these issues [2, 19].

1. 1 Research objective and question

This paper aims to contribute to the advancement of the successful implementation of eMobility in middle income countries by designing an ex-ante assessment tool which can provide an overview and evaluation of the existing local innovation system before the introduction of eMobility, based on identified preconditions relevant for the introduction and diffusion of eMobility. Its application will result in insights which provide local policy makers with the opportunity to understand and make use of the local context, including the local barriers and opportunities. This can then form a starting point for a systematic introduction of eMobility, increasing the chance of eMobility to become embedded in the local context and leading to a structural transition towards eMobility.

To guide the design of this tool, the following question has been put central: What should an ex-ante assessment tool encompass to contribute to the advancement of electric mobility in urban areas in middle-income countries? In order to answer this question we proceed to build an ex-ante assessment tool called the Green Electric Mobility (GEM-) tool that we hope will eventually stimulate the change from a fossil-fuel based transport system towards a sustainable, green transport system based on electric mobility.

1.2 Paper structure

After having presented the research problem and objective within chapter 1, the paper continues to describe the methodology used for the development of the GEM tool in chapter 2. In chapter 3 we will present the theoretical foundation of this paper. Chapter 4 will then elaborate upon the findings relating to the development of the GEM-tool. Chapter 5 shows the application of the GEM-tool. Next, chapter 6 will give the overall conclusions. Finally, chapter 7 provides room for an overall discussion and chapter 8 offers recommendations for the further development of the GEM tool.

2 Methodology

Figure 1 shows the steps we took to develop the GEM tool, and provided details on the corresponding methodology.

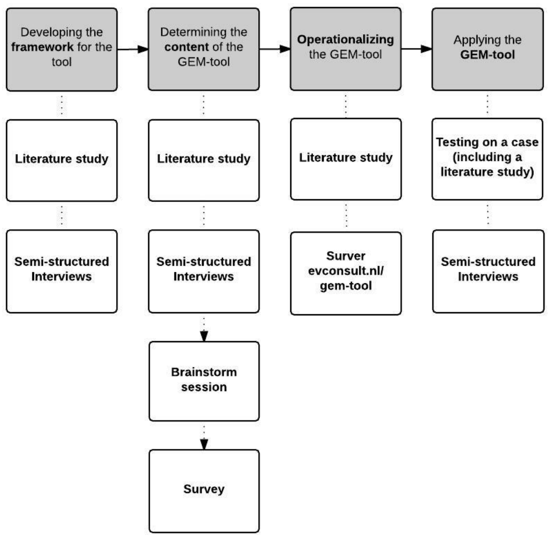

Figure 1: Methodology

An extensive literature study is performed analyzing the Technical Innovation System (TIS) approach which forms the theoretical foundation of the GEM-tool. Additionally, an analysis of literature on eMobility is carried out, including the review of best practices and lessons learned, as well as barriers and opportunities and policy recommendations regarding the introduction and diffusion of eMobility. Additionally, semi-structured interviews are held with experts on the innovation theory approach, on the introduction of innovations in MICs and with experts from the field of eMobility. Furthermore, a brainstorm session is organized with experts from EVConsult, a Dutch consultancy working on the national and international advancement of sustainable mobility and in particular electric mobility. The output of this session is used for the development of the GEM-tool. Moreover, an online survey is set-up and filled in by international and national experts on eMobility and innovations (within the context of MICs) to rank the identified preconditions from highest to lowest, giving each precondition a specific weight. Finally we applied the GEM-tool to the illustrative case of Delhi, to test and validate it.

3 Theoretical framework

Innovation can be seen as the development and adoption of new and improved ways of addressing social, environmental and economic needs and wants. Since the 1980s, both innovation researchers and policy makers have adopted a system perspective on innovation, which recognizes that innovation processes take place within a context of co-evolution of technology and society [20, 21]. We therefore base ourselves on the Technical Innovation System (TIS) approach to understand the dynamics and performance of a system focused on a specific technology, including both the technology and the components that influence the innovation process of that technology [22, 23] . The TIS approach provides an analytical framework to determine the various factors influencing the innovation and diffusion of the technologies and has been developed for the use by policy makers who intent to support an emerging technology [24, 25]. Its application can identify systemic weaknesses and strengths within a TIS, defined as "*a set of actors, interactions, institutions and infrastructure that jointly interact in a specific technological field and influence the generation, diffusion and utilization of variants of a new technology and/or a new product*" (adaptation of Markard & Truffer 2008 [26]). The following components of the TIS approach have been included within this research:

1 Delineation of TIS: the TIS needs to be delineated according to the desired focus, including the focus of attention, the breath or depth of interest, the spatial domain and the phase of development [23, 27] .

2 Structural factors: within a TIS, the structural factors should be identified, referring to the static components within a system that are relatively stable over time. These include:

- Actors: any organization contributing to the emerging technology based on their presence, skills and willingness to take action. They can be categorized based on their role in the economic activity: governmental & non- governmental organizations, civil society actors, companies, knowledge institutes and other parties [22, 28].

- Interactions: the relationships between actors which can be analyzed at the level of networks or individual contacts. These facilitate the exchange and diffusion of knowledge and are an important drivers for learning and the formation of coalitions [22, 23, 28].

- Institutions: the 'rules of the game in a society', which can be both formal and informal. They include policy programs, as well as the responsibility and expectations of certain actor groups [28].

- Infrastructure: material (e.g. roads), financial (e.g. grants), and knowledge (e.g. expertise) factors relevant to the TIS [22].

3. System functions: In order to understand and capture the dynamics of the TIS, the activities that take place within the TIS are mapped [15]. These activities are called system functions (see table 1) and can be seen as a checklist of key activities that need to be present in a TIS in order for it to develop. Furthermore, the most common interaction between system functions in each development phase of a TIS have been translated into trajectories called the motors of innovation [28].

Table 1: System functions within a TIS [22, 28]

System function	Description
F1 Guidance of the search	Those activities that shape the needs, requirements and expectations of actors with respect to their support of the emerging technology
F2 Resource mobilization	The allocation of human, financial and material capital used for the technology to develop and diffuse
F3 Knowledge development	The learning mechanisms which are the heart of an innovation process, including learning by doing and learning by searching
F4 Knowledge diffusion & networks	The facilitation of knowledge between all actors involved, including learning by using and learning by interacting
F5 Entrepreneurial activities	The translation of knowledge into actions and business opportunities
F6 Market	The creation of a demand and

formation	supply for the new technology
F7 Creation of legitimacy	The creation of legitimacy for an innovation through advocacy coalitions

4. Functional-structural analysis: each system function can be examined through the perspective of its structural factors. This relationship leads to the identification of system problems as both the presence and the quality of the structural factors can lead to systemic problems (see table 2).

Table 2: systemic instrument goals [22]

Systemic problem	Goals of systemic instrument
Actor (presence)	Stimulate and organise participation of relevant actors
Actor (capabilities)	Create space for actors capability development
Interaction (presence)	Stimulate occurrence of interactions
Interaction (quality)	Prevent too strong and too weak ties
Institution (presence)	Secure presence of hard and soft institutions
Institution (capacity)	Prevent too weak and too stringent institutions
Infrastructure (presence)	Stimulate physical, financial and knowledge infrastructure
Infrastructure (quality)	Ensure adequate quality of infrastructure

This offers a map of all possible blocking mechanisms that may occur in a TIS due to the malfunctioning of the structural factors. Based on these structural barriers, eight systemic instrument goals have been developed by Wieczorek & Hekkert (2012). These instruments should be addressed to improve the functioning of the system functions and therefore the system as a whole [22].

4 The GEM-tool

The TIS approach serves as a guide in the development of the GEM-tool as it provides insights in the essential factors for the uptake of an innovation such as eMobility. It is, however, adapted to fit a more practical and ex-ante application focusing on the pre-development phase of eMobility and the existing local innovation system beforehand. The following steps represent the subsequent parts of the GEM-tool. The GEM-tool can be found online at evconsult.nl/gem-tool.

4.1 Delineation of GEM-tool

Before the development of the tool, its focus should be made clear. Firstly, the GEM-tool is based on the concept of eMobility, which refers to the electrification of the propulsion of vehicles used for road transport. The GEM-tool is applicable to battery- electric vehicles (BEVs), hybrid- electric vehicles (HEVs) and plug- in hybrid vehicles (PHEVs) which can be two, three four and four+ vehicles. However, to ensure the general application of the GEM-tool, it will not distinguish between the types of vehicles, modes of transport or the range of applications of eMobility as it is not known beforehand which type of vehicle or vehicle usage is suitable for electrification in the local context. It merely provides information to support local policy makers in their decision making process [6, 11].

Secondly, the GEM-tool has been designed for local policy makers, as they often struggle to develop policies to support the transition towards an innovation [15]. This is particularly the case for developing countries, which generally have the least technical and institutional capabilities to develop and introduce technical innovations [18]. The GEM-tool therefore aims to provide insights regarding the local innovation system to local policy makers. However, we advise that the GEM-tool is employed by an independent party with expertise regarding eMobility in order to increase the reliability and validation of the information used as input for the GEM-tool as well as the interpretation and application of its outcomes.

Thirdly, the GEM-tool aims to provide an overview of the local innovation system *before* the introduction of eMobility. This provides an overview of the existing system beforehand, leading to knowledge on the local system which can form a starting point for the introduction of eMobility. This enhances the chance of it to become embedded in the local context and to lead to a structural transition towards a transport system based on eMobility.

Fourthly, the GEM-tool focuses on urban areas as they are favorable regions to deploy an innovation. An urban region is defined as a city and its surrounding peri-urban areas. Furthermore, urban areas experience the worst direct effects of traditional transport in the form of local air pollution [29].

Fifthly, the GEM-tool focuses on Middle-Income Countries (MICs), defined as countries with a Gross National Income between $1,046 and $12,735 US dollars per capita [30]. Generally, MICs are still faced with the various challenges caused by the motorized road transport sector but their growing economies also provide the opportunities to invest in sustainable mobility [2]. Furthermore, MICs have made the most reference to eMobility as means towards the reduction of their transport emissions [19]. The incentive and willingness of MICs are therefore assumed to be present, which forms a starting point for the introduction of eMobility.

4.2 Online questionnaire

4.2.1 Developing the questionnaire and its outcome

The core of the GEM-tool consists of preconditions which are identified according to the seven system functions as defined within the TIS approach (see table 1). The preconditions represent the conditions that should be present within the innovation system. To identify these preconditions for each system function, general questions were used as guidance (see table 3), indicating the overarching activities that need to be present for a TIS to develop.

Table 3: main questions per system function

System function	Main question
F1 Guidance of the search	What kind of guidance and stimulation is given to the introduction of eMobility?
F2 Resource mobilization	What kind of resources (financial, human & material) are mobilized for the introduction of eMobility?
F3 Knowledge development	What is the level of existing knowledge and where can it be found?
F4 Knowledge diffusion & networks	What (f)actors enable the diffusion of knowledge?
F5 Entrepreneurial activities	Which actors can be identified that can perform the entrepreneurial activities regarding eMobility?
F6 Market formation	What kind of policies are present which influence the development of a market for eMobility?
F7 Creation of legitimacy	What kind of support for and resistance to eMobility can be identified and by whom, which can influence the development of eMobility?

The TIS approach forms the basis of the identification of factors that determine the introduction of eMobility, as the description of the system functions within the TIS literature indicates the necessary conditions for the system functions to develop [15, 31, 32, 33, 28]. Furthermore, articles on the practical application of the TIS approach give examples of indicators [28, 34], guiding questions [27, 35], data types [24], evaluative questions [22], analytical goals to assess the strengths and weaknesses [36] and inducement and blocking mechanisms for the dynamics within and between system functions [28, 32]. Additionally, studies on the application of technical innovation system studies in emerging economies are included [37, 38]. This information was used as input for the various components within the GEM-tool.

The input of the TIS literature on the advancement of innovations in general has been combined with the input of eMobility literature. Reports and articles relating to sustainable mobility, electric mobility and urban transportation (within the context of MICs), have been analyzed for input in the GEM-tool. These articles include studies on barriers & opportunities, best practices & lessons learned, national and local policy measures and incentives regarding the advancement of eMobility in urban areas. This also includes policy measures of more than 70 cities regarding eMobility, stemming from the EV City Casebook and the EV 50 Big Ideas report [12, 39]. Furthermore, reports of international institutions that keep track of the developments relating to sustainable transport and electric vehicles have been included in the research e.g. the International Energy Agency, the Clean Energy Ministerial, the International Council on Clean Transportation and the Electric Vehicle Initiative.

Additionally, eight semi-structured interviews were conducted with experts on innovations and electric mobility and used as input for and validation of the GEM-tool.

Lastly, a brainstorm session was held with experts from EVConsult, a Dutch consultancy firm working on the national and international advancement of sustainable mobility. This resulted in 65 statements on blocking and inducing factors regarding the introduction of eMobility which were used as input for the GEM-tool.

4.2.2 The content of the questionnaire

The above mentioned practices resulted in a total of 49 preconditions which have been included in the tool. They range from essential prerequisites to indications for relevant information beforehand to stimulate the development of the innovation system. To differentiate between the importance of the preconditions, an individual weight is given to each precondition within the overarching system function. Additionally, the tool includes local, national and international oriented preconditions, as the local innovation system is influenced by (inter)national factors. Furthermore, the preconditions have been linked to the four structural factors identified within the TIS approach. This link makes it possible for the systemic instrument goals (see table 2) to form a basis for the policy recommendation for each precondition,.

All preconditions have been translated into a question with corresponding answer categories. These answers categories are scored using a consistent scoring system (unless indicated otherwise within the tool):

-1 = a negative score forming a barrier
0 = a neutral score forming an area of focus
+1 = a positive score forming an opportunity in need of additional focus
+2 = an excellent score forming an opportunity

Both the preconditions as their corresponding answers and scores take into account the pre-development phase of the system within the context of MICs. However, it should be noted that the scores should be used mainly as an indication and the user of the tool is advised to take into account the specific local context for each score. Additionally, examples of possible answers were identified for each precondition to steer the question in a certain direction, while still keeping the generic applicability of the tool in mind. Lastly, possible data sources are identified and given to facilitate the gathering of the essential information for the use of the GEM-tool, and to increase the overall reliability and verification of the answers.

4.3 Outcome of GEM-tool

Submitting the answers to all online questions results in an automated generation of a PDF document, representing the outcome of the GEM-tool. It includes the scores, policy implications and recommendations for the individual preconditions and their overarching system functions. It furthermore includes a score of the entire innovation system.

4.3.1 Scoring system and evaluation

The scores of the preconditions are given within the questionnaire, and are shown within the outcome of the GEM-tool.

The performance of the system functions is derived from the scores of the individual preconditions times their corresponding weight (see 4.2.2.), using the following formula:

$$\text{Score} = \frac{\sum_{1}^{rp=N}((S_p - S_{mi})/(S_{ma} - S_{mi}) * R_p)}{\sum_{1}^{rp=N} R_p} * 100$$

Sp = score of precondition
Smi = minimal score precondition
Sma = maximal score precondition
Rp= weight of precondition
rp=1 for the precondition with the lowest weight
rp = N for the precondition with the highest weight (differs per system function)

The score is given in standardized percentages to allow for a comparison between the system functions, as they do not have the same amount of preconditions. Furthermore, the weight of each precondition is taken into account, as the performance of a system function is influenced more by the performance of preconditions with a high weight. As the total number of appointed weights differs for each system function, the lowest and highest weight for each system function is taken into account within the formula. Based on the four possible scores, the following evaluation is proposed:

< 33% = a weak system function
33-66% = an intermediate system function
> 66% = a strong system function

The total score of the GEM-tool shows the performance if the innovation system in the predevelopment phase of eMobility in the local context. It is calculated based on the scores and corresponding weights of all preconditions. The same formula is therefore used for the scoring of the total GEM-tool and thus, the same evaluation method can be applied as well for the entire system.

4.3.2 Policy implications & recommendations

For every precondition, the score is presented as well as brief policy recommendations, aiming to get to the optimal situation. They are based on the operationalization and identified optimal performance of the innovation system in the predevelopment phase of eMobility in the local context. How the precondition should evolve from a negatively to a positively or even excellent scored precondition is not elaborated upon in detail as this is very context specific. Therefore the policy advice focuses on a general improvement of the TIS. Furthermore, as each precondition has been defined as being an actor, interaction, institution or infrastructure – one of the four structural factors (see section 3) – the preconditions can be connected to the systemic instrument goals which have been designed for each structural factor (see table 2). This forms the basis of the policy recommendation and has been adapted to the local innovation system before the introduction of eMobility for each precondition. Additionally, the policy recommendations are in part based on the lessons learned and opportunities identified within frontrunner countries regarding the implementation of eMobility. Over 70 initiatives regarding eMobility were analyzed during this research, which resulted in advice within the GEM-tool which gives examples of possible measures to stimulate the introduction of eMobility.

For each overarching system function, overarching policy implications and recommendations are included as well. Furthermore, the motors of innovation of a TIS [28] have been translated into a GEM-motor for the GEM-tool, taking into account the interactions corresponding to the pre-development phase (see figure 2). The system functions interact with each other, therefore influencing their performance which leads to policy implications. For example, figure 2 shows a direct relationship between Resource Mobilization and Knowledge Development because the lack of funding for R&D or pilot projects will affect the knowledge development.

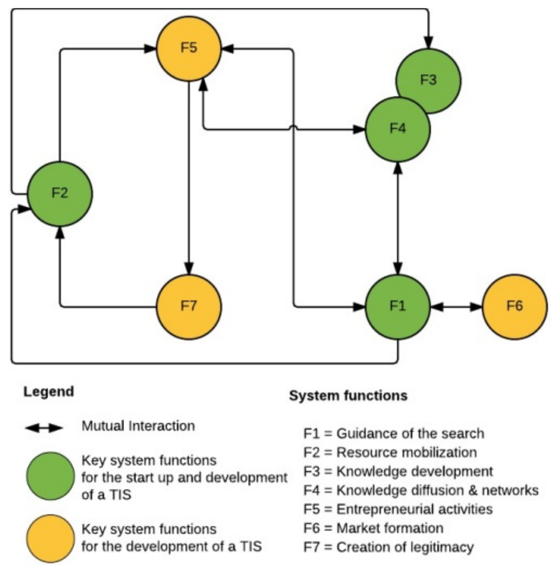

Figure 2: GEM-motor

No policy implication or recommendation has been developed for the performance of the innovation system as a whole, as this is based on the performance and dynamics of the system functions and preconditions which are described within the outcome of the GEM-tool.

5 Application of the GEM-tool

The GEM-tool has been tested by applying it to an illustrative case. Its application on a real-world case helps to understand the functioning of the tool, to test its applicability and to increase its validity. As the GEM-tool aims to be generically applicable for all MICs, the tool should be applied to a set of representative cases for its (empirical) validation from a methodological point of view. However, due to practical reasons, in particular time- and resource constraints, only one case has been analyzed to test the GEM-tool.

For the selection of the case, a number of criteria have been applied. Firstly, the case should be an urban area located in a MIC, following the spatial delineation of the GEM-tool. Secondly, eMobility should be on the political agenda and a start of the implementation should be made. Having a case which is expected to score well shows the relevance of the identified preconditions and the potential gaps or excessive use of elements within the tool. Furthermore, it shows whether a country scores well using the GEM-tool when it is considered to perform well in general.

With the above mentioned criteria in mind, Delhi (India), a major urban region in a MIC, was chosen. Furthermore, India is the frontrunner of MICs when it comes to eMobility [11]. India as a whole has high ambitions regarding eMobility and has an extensive national plan to carry out its ambition. Lastly, the problems regarding air pollution and emission in Delhi are very pressing. It is one of the most polluting cities in the world according to the World Health Organization, with the main source of pollution (70%) in Delhi being emissions from road vehicles [40, 41].

5.1 Illustrative case study

During the case, a literature study was performed and relevant experts were interviewed with extensive knowledge on the situation in India and in specific Delhi regarding eMobility.

Table 4: Scores of the illustrative case

Overall Score	65%
Guidance of the Search	79%
Resource Mobilization	68%
Knowledge Development	75%
Knowledge Diffusion & Networks	49%
Entrepreneurial Activities	68%
Market Formation	65%
Creation of Legitimacy	43%

Delhi scores just under 66%, making it an intermediate innovation system (see table 4). This score is lower than what was expected beforehand as the case was chosen because of India's front runner status. It was therefore assumed that a well performing innovation system was present within Delhi. However, during the research it turned out that even though India as a nation is promoting and introducing eMobility, Delhi lags behind. The GEM-tool helped to identify the existing barriers. For example, it showed a difficult relationship between the Indian government and Delhi government and a lack of focus on eMobility (as other fuels are promoted). Furthermore, a lack of a local plan for sustainable mobility and eMobility reduces the awareness of consumers, decreases local resources and diminishes the power to get (incumbent) companies involved. However, opportunities were identified as well, including a general trend towards sustainable and eMobility in India as a whole, resulting in national resource mobilization, knowledge development and entrepreneurial activities which Delhi can deploy. This depends, however, in how far the local government can make use of the national trend and mobilization towards eMobility as the GEM-tool has shown some a difficult relation between local and national government officials.

5.2 Evaluation case study

The illustrative case provided an excellent example of how an innovation system in its predevelopment phase can make use of the GEM-tool to give an overview of barriers and opportunities, and to help to make use of existing actors, interactions, institutions and infrastructure. The GEM-tool proved to provide practical and structural guidance to gather relevant data before the start of eMobility. It furthermore justified the relevance of all identified preconditions, as the entire set provided the desired overview of the local situation. Additionally, the case confirmed the necessity for an independent advisor to gather, analyze and validate the various data (sources) to increase the validity of the outcomes of the case. The role of an independent advisor is also important when the gathered data do not completely match with the scoring system of the GEM-tool but are still relevant for the local context. As the scoring system is used as indication, the advisor can include specific local data and decide on the final score of the precondition him or herself. In sum, the case study has proven the relevance and application of the GEM-tool and contributed to the validity of the GEM-tool.

6 Conclusion

This research responded to the need for a more structural introduction of eMobility in middle-income countries. It aimed to contribute to the advancement of electric mobility by developing an ex-ante assessment tool of which the application leads to an overview and evaluation of the local system. This resulted in the Green Electric Mobility tool. The GEM-tool includes the set of preconditions essential for the successful introduction and diffusion of eMobility. These preconditions and their corresponding components are based on the empirically verified theoretical framework of the TIS approach, combined with best practices and lessons learned from frontrunner countries regarding eMobility, also taking into account the context of urban areas in middle-income countries. The GEM-tool furthermore provides an operationalization and evaluation of the identified preconditions. This provides an assessment of the performance of the overarching system functions and individual preconditions which together make up the functioning of the local innovation system. The application of the tool therefore offers a structural method to gather, interpret and evaluate information regarding the local innovation system beforehand. Furthermore, it shows the barriers and opportunities that need to be overcome to strengthen the local innovation system in place. In addition, the GEM-tool offers policy implications & policy recommendations to stimulate the receptivity of the local situation.

To conclude, the application of the GEM-tool leads to an overview and evaluation of the local system as well as brief policy advice. This empowers local policy makers with essential insights for the structural introduction of eMobility, taking into account the desired large scale transition as of the start of the process. This enhances the chance for the uptake and diffusion of eMobility considerably as it can become more easily embedded within the local context. It can be concluded that both the development of the GEM-tool itself as its application result in a considerable amount of new insights regarding the introduction of eMobility and the functioning of local innovation systems in urban areas in middle-income countries.

7 Discussion

This research presents the first steps in the design and application of the Green Electric Mobility Tool. Therefore, certain limitations may be found as well as questions asked regarding its reliability, validity and causality which will be discussed below leading to recommendations for further research.

Firstly, the reliability of the GEM-tool is completely dependent on the data that is gathered during its application. A first sketch of the data collection has been provided, but still subjective choices will be made which can undermine the reliability of the outcome. It is therefore recommended that the tool is used by an independent party, with experience within the field of eMobility, which is expected to apply the tool with consideration and discretion. Furthermore, the reliability of the research for the development of the GEM-tool may be lowered due to choices made based on the expert view of the researcher in determining what to include in the GEM-tool. These choices, however, were founded on an extensive literature search regarding the TIS approach and the context of eMobility, analysing eMobility initiatives of more than 70 cities. Lastly, a combination of methods and data sources has been used which enhanced the reliability of the research. Therefore, the research is still seen as reliable.

Secondly, what the GEM-tool measures, to obtain the desired conclusion on the local innovation system is based on the identified preconditions and their operationalization. It can be questioned whether or not the preconditions and the corresponding questions and operationalization are valid: do they represent the right indicators to illustrate the overview and performance of the local innovation system? To develop the GEM-tool, an extensive literature study regarding the empirical verified TIS approach has been performed, as well as a comprehensive analysis of reports and articles relating to the introduction and diffusion of eMobility. Furthermore, the extensive knowledge of experts from the field of innovations, international development, sustainable mobility and electric mobility as well as policy makers dealing with the introduction and diffusion of eMobility has been included, which has helped to develop and validate the GEM-tool. Additionally, the combination of data sources and methods has helped to increase the validity of this research. Still, the validity of the GEM-tool can be improved by testing it for empirical evidence and showing the quality of measures included. This is strongly connected to the causality of the GEM-tool. It is assumed that the preconditions will lead to a better understanding of the local innovation system, which is assumed to lead to a more successful transition towards eMobility. As the tool is based on a solid interpretation of literature and experts sources, it is expected to be applicable. Empirical research is, however, recommended to validate and if necessary improve the causality of the GEM-tool.

8 Recommendations

This research provides an innovative first step towards the development of an ex-ante, practical assessment to advance the introduction and diffusion of eMobility in middle-income countries. As the tool can be seen as work in progress and the results should be interpreted as first step in an ongoing process towards a more validated and specified tool, there are still some improvements to be made. Firstly, it is recommended that further research is performed on the specific local context within middle income countries. As this is one of the starting points of this research, it is an essential part of the GEM-tool. Further research could enhance the embeddedness of context of middle income countries within the GEM-tool, both within the preconditions as answer categories and policy recommendations, as this proved difficult in the limited time of this research. Secondly, the scoring system could be improved by making the answer categories of the preconditions more specific. Normative and qualitative options now make up most of the operationalization, as the local context needs to be taken into account as well as the general applicability of the GEM-tool in MICs. Additionally, the evaluation can be differentiated with regards to the various scores and policy implications & recommendations. Further research and empirical case studies can provide the necessary information to optimize the operationalization. Lastly, the remaining components, e.g. the data collection, possible answers and weight, could be made even more specific as the tool provides a first sketch of their inclusion. Nevertheless, taking the above stated limitations and improvements into account, the GEM-tool is seen as a successful first step in designing an ex-ante assessment tool for the advancement of eMobility. Other researchers are encouraged to take up its presented blueprint to improve the above mentioned limitations. This will lead to an advanced assessment tool.

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