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# Process to support strategic decision-making: Transition to electromobility

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**Abstract**

The shift to electromobility is an anticipated transition intended to combat the grand challenges of climate change and air pollution. This paper introduces a process designed to support strategic decision-making and policy-planning to facilitate such a transition. We demonstrate the process by a case study that explores electric vehicles as the solution to the vision of emission free transport in cities in 2050.

The working process begins with scoping of the decision-making situation. For our case study we selected the policy target of phasing out conventionally fuelled passenger cars in urban transport by 2050, as stated in the White Paper on transport by the European Commission. Having further processed this vision that defines the desired future state, the socio-technical entity of the urban transport system in the Helsinki metropolitan area in Finland is analysed, and three alternative yet combinable paths towards the vision with suitable policy measures are mapped. One path focuses on public transport, and the other two investigate passenger cars powered by electricity or biofuels. In this paper we focus on presenting the vision path facilitating the shift from internal combustion engines to the electric drive. The process continues by build-up of a system dynamics model, and a series of simulations are run to study designed vision paths.

The case study proved the developed process a success and ready to be applied in real-life decision-making situations.

*Keywords: decision-making, policy-planning, electromobility, vision, modelling*

## 1 Introduction

Large-scale introduction and uptake of electric vehicles signifies a major transition in the current transport system. Such a transition in a complex socio-technical system necessitates systemic changes, and all components of the transport system are involved: transport vehicles, infrastructure and users. This can be facilitated by proactive transport system governance, and strategic transport planning could be used to enable, speed up and steer the incremental changes leading to the ultimate transition.

This paper introduces a process, where the multi-level perspective (MLP) approach is used to link and combine various aspects and tools from the fields of foresight, impact assessment, modelling and embedding. This process to support strategic decision-making and policy-planning in systemic transitions can be applied to various societal contexts, but we showcase it by a tailor-made case study in the transport sector. The case study explores electric vehicles as the potential solution to the vision of emission free transport in cities in 2050.

The methodological work and the case study contribute to a better understanding of societal and systemic changes and transitions. The main outcome is a methodological framework to address transitions in the transport sector: a process with tools to support decision-making and policy-planning.

## 2 Methodological approach

Figure 1 gives an overview of the working process (that is demonstrated by the electromobility case study in Chapter 3). The developed process consists of methodological steps that support strategic decision-making and policy-planning, and it can be applied various decision-making situations and policy context with minor adjustments. Choice of specific research methods and tools along the steps; how these are linked and sequenced; and who are involved in the working process are some of the characteristics that need to be determined case-by-case.

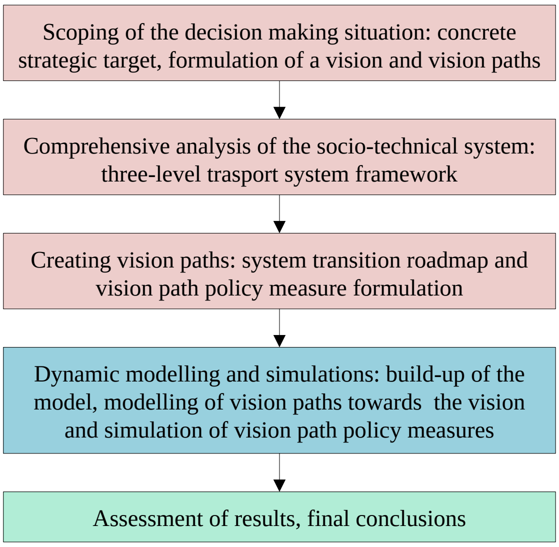


Figure1: Overview of the working process

The multi-level perspective (MLP) approach (for a brief description and references for further information see [1]) is used as an integrating theoretical platform through the working process (Figure 1). The MLP distinguishes three analytical levels: niche level, socio-technical regime level and socio-technical landscape. In the context of transport systems we translate these levels to the level of technologies and solutions, the level of transport system and the landscape level. In our case study on electromobility the landscape pressure to reduce transport-induced emissions and the technological innovations in electric vehicle related industries contribute to the system-level transition in urban passenger transport. Incremental changes towards the transition, and e.g. the measures designed to speed them up, are studied against the MLP in all five steps of the working process.

The first three steps of the process (Figure 1) aim at analysing and structuring the challenge being addressed. Firstly, the decision-making situation is scoped to ensure thorough understanding of the strategic target that is being sought after. A statement describing the desired future, i.e. a *vision* is formulated. In addition, the first drafts of one or several ways how to reach the vision, i.e. *vision paths*, are generated. Next, the socio-technical system such as that of urban transport is analysed. Various methods and tools are available, and i.e. *three-level transport system framework* [2] provides the means to systematically identify and address transport system elements, components and stakeholders that play a role in the pursue of the vision. Relationships between different objects and subjects in the system can then be further studied and illustrated using *causal loop diagrams*. The third step revisits the vision path descriptions from the beginning, and an action plan and expected developments are structured on the *system transition roadmap* [3]. The core of this step is to design actions and policy measures to catalyst, speed up and push forward the changes that are required. If successful and effective enough, the incremental changes resulting from the mix of policy measures add up to the ultimate systemic transition of the socio-technical system and the envisioned future state can be reached.

Step four gathers the knowledge from preceding tasks of the working process (Figure 1). Based on the causal loop diagrams, the relevant section of the socio-technical system is brought to a *system dynamics model*. The vision paths are then put to a test when simulations employing the measures described in the system transition roadmaps are run. The simulation model shows the impacts of the policy measures and whether these actions are sufficient enough to reach the vision. At this point a critical evaluation of the preliminary simulation results is crucial, and if they do not meet the target satisfactorily, the previous three steps of the working process could be revisited. Minor needs to adjust and sequence the policy measures could be done by returning to step three. More substantial alterations e.g. to redefine the system boundary of the socio-technical system would require a visit back to step two. Or if the simulation results suggested that the desired impacts were not even closely within reach with the chosen approach, the process could be repeated from step one to formulate a new vision path as a more efficient alternative to the original ones failing to meet the targets.

The last, fifth step of the process (Figure 1) proceeds to assess the results along the entire process, including the possible iterations to adjust and refine the vision paths, the model and the simulations. If the simulation results are satisfactory, the final conclusions may typically be communicated as policy recommendations or suggested policy actions. Providing that the working process actively involved participation of (1) the stakeholders critical to the legitimacy and authorisation of the decision-making situation as well as (2) the stakeholders critical to the implementation of the actions described in the preferred vision path, the final step could go as far as concrete planning of how to introduce the vision path policy measures.

# 3 Case study set-up

## 3.1 Vision

As a demonstration to showcase the developed process (see Figure 1), this paper explores electric vehicles as the potential solution to the vision of emission free passenger transport in cities in 2050. The topic was selected from the goals set by the European Commission [4] in the White Paper on transport, where a reduction of at least 60% of GHG (greenhouse gas) emissions is targeted by 2050, compared to 1990. As benchmarks for this target, the White Paper lists ten goals, the first of which addresses new and sustainable fuels and propulsion systems in urban environments. This specific target sets a goal to halve the use of conventionally fuelled cars in urban transport by 2030 and to phase them out completely in cities by 2050.

Based on the aforementioned White Paper targets and goals, a primary vision and three alternative vision paths leading to the envisioned image of the future were formulated. The primary vision “emission free transport in cities 2050” proposes that in 2050 passenger transport produces no greenhouse gas emissions in cities. The three vision paths emphasising three different solutions to reach the ultimate vision were defined as public transport, electric vehicles and biofuels. All three paths were studied as stand-alone solutions as well as in different combinations. In this paper we present the second vision path where conventionally fuelled cars are replaced by electric vehicles in the regional settings of the Helsinki metropolitan area. In the following sections of the paper we focus on the topic of electromobility and the parts of the working process where electromobility vision path was highlighted. A comprehensive overview of the development and demonstration of the methodological process [3] will be accessible as well as a detailed description of the simulation model [5].

## 3.2 Electric vehicle vision path

The electric vehicle vision path presents electromobility as the technological solution in reaching the vision of emission free passenger transport in Helsinki area in 2050. The developments towards mass introduction and uptake of electric vehicles and the policy measures supporting these developments are outlined in Figure 2, using the *system transition roadmap*. The rows represent a modified approach to the MLP, where the transport sector compliant levels of technologies and services, the transport system and landscape are distinguished. The horizontal division into three columns gives the roadmap frame temporal dimension, comprising phases of emergence, diffusion and consolidation. Drivers and changes are placed on the roadmap as text boxes: technological innovations initiating the change (red), related trends contributing to favourable environment for change (yellow) and policy measures to support the desired development path (blue) steer development towards the envisioned future of 2050 (green).

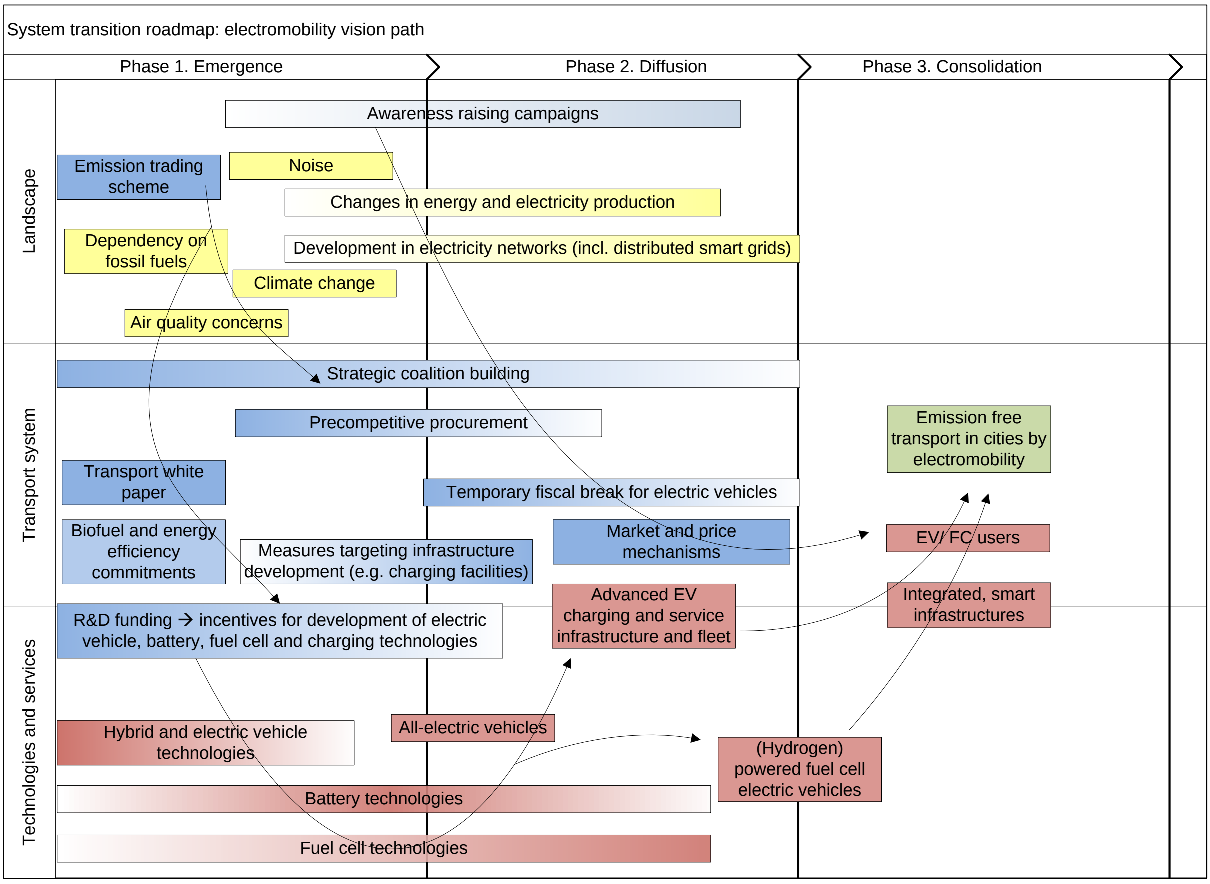


Figure2: System transition roadmap of the electric vehicles vision path

In the emergence phase (Figure 2) there are a number of drivers which are perceived to urge to look for alternative vehicle and fuel options to passenger vehicles running on fossil fuels. Climate change and air quality concerns particularly in urban environments have emerged as two of the grand challenges of our time. These are connected to dependence on fossil fuels. On one hand oil reserves are shrinking despite the growing demand, on the other hand there are issues relating to energy security and political instabilities. Population growth, urbanisation and emergence of megapoleis on global scale as well as continuously growing number of transport volume and vehicles in use are all accentuating the need to find ways to decrease and eventually get rid of fossil fuel use and the resulting emissions in the transport sector. Against this, electric vehicles provide a viable solution to eliminate local emissions and to combat climate change, presuming that electricity is produced from non-fossil, sustainable sources. Changes in energy and electricity production as well as in development of electricity networks are called for, and international efforts such as emission trading schemes have been initiated.

At the transport system level, the identified landscape level drivers are increasingly included into the policy guidelines and white papers setting the framework for development of transport system in coming years. Seeing electromobility as a viable solution to tackle emissions, there is a need for strategic coalition building initiatives which bring together actors representing e.g. car manufacturing, legislators, infrastructure planning, companies providing charging and service infrastructures and research on electric vehicles, batteries, fuel cells and charging technologies. The strategic coalition building should continue through the emergence and diffusion phases to allow different actors to coordinate and orchestrate their actions as well as to provide fertile soil to common interests emerge around diffusion and take-up of electric vehicles.

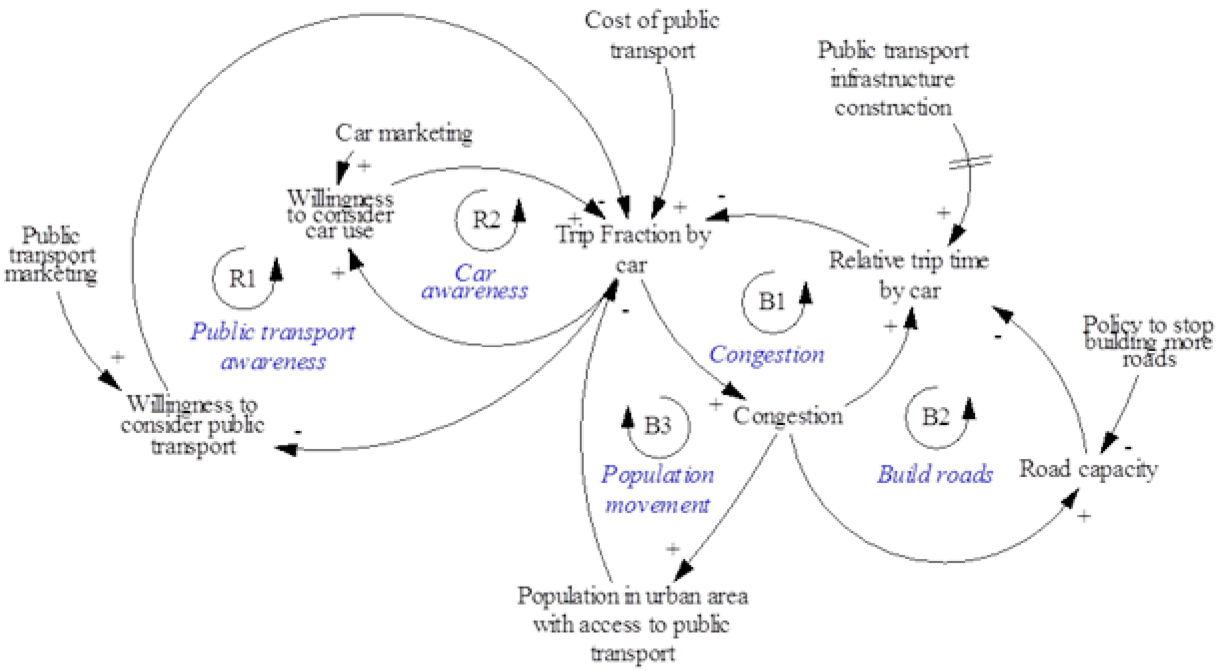


Figure3: Simple representation of the main causal loops in the model.

In the level of technology and service development, there is a need to use research and development funding and other suitable policy measures to solve problems related for example to battery, fuel cell and charging technologies. The progress and diffusion of technologies can be supported on system level by drafting targeted measures for infrastructure development as well as public procurement. The public sector can provide an important testing environment and lead market for new solutions related to electric vehicles.

The diffusion phase (Figure 2) is characterised by the need to ensure continuity of activities launched in the earlier stage in order to prepare ground for the mass take-off of electric vehicles. Landscape level key drivers (air pollution, climate change, dependence on fossil fuels) continue to be relevant and may even ask for more radical support actions. At system and niche levels the diffusion of electric vehicles should be continued through well focused research and development funding for technology, infrastructure and service development. Also use of temporary fiscal breaks for electric vehicles should be considered in order to support demand and to nurture the new electric vehicle based transport system. In addition, opportunities to use market and price mechanisms for advancement of the new electric vehicle transport system should be evaluated.

If successful, the electric vehicles replace fossil fuel driven cars in cities in the consolidation phase (Figure 2), thus contributing to the vision of emission free passenger transport in cities. In this phase there is no more need for large scale public support activities, and measures can be scaled gradually down in parallel to emergence of the new dominant system.

## 3.3 Simulation model

In order to explore the vision paths, a system dynamics simulation model was built of motorised passenger transport in the Helsinki metropolitan area (Figure 3). The objective of the model is to analyse the behaviour of transport user groups by mode (users of regular cars, users of public transport and users of electric cars) and how desired changes can be achieved. The choice of transport means and mode is influenced by a multitude of factors such as costs, availability and comfort. The details of the system dynamics simulation model are described in [5].

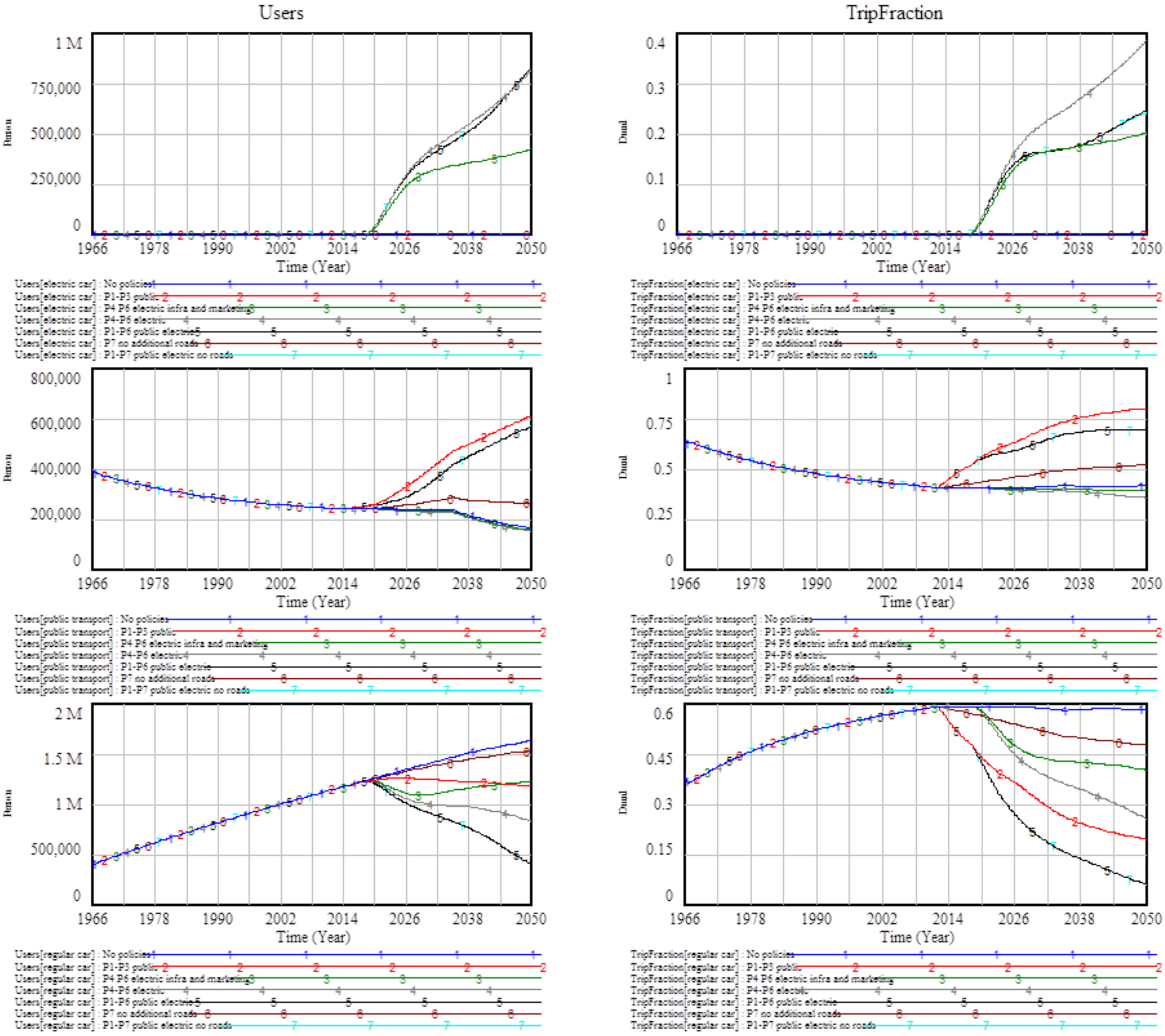


Figure4: Simulation results under different policy measures (curves 1 to 7). On the left: number of users. On the right: trip fraction. From top to bottom: electric vehicles, public transport and regular car

## 3.4 Simulation results

Figure 4 presents the electric vehicles vision path simulation results, showing the impact of introducing the policy measures designed using the system transition roadmap. Results are extracted from the model as *fraction of trips* and as *number of users.* These are presented for each of the three transport means under study: regular cars, public transport and electric vehicles. It should be noted that users of regular cars or electric vehicles refer to vehicle ownership. These user groups do, however, overlap with that of public transport users, because car owners do choose public transport for some trips. The time frame of the simulations runs from the historical developments between late 1960s and 2012 to the vision path developments until 2050. Besides policy measures to boost electromobility, Figure 4 also shows policy measures from the public transport vision path. The authors found it important that even though this paper focuses on uptake of electric vehicles, the public transport point of view would still be partly included. The public transport vision path is explained in detail in [3]. The different vision paths, public transport, electric vehicles as well as biofuels, can be studied as exclusive attempted visionary solutions, but they can also be combined. And as suggested by intuition, our study showed that when taking into account the transport system as a whole, the most fruitful outcomes could be gained when promoting strong public transport while also supporting shift from conventionally fuelled vehicles to the electric drive.

In Figure 4 policies and policy combinations are numbered from one to seven, representing different simulation rounds. In the following, the policies behind these numbered curves are explained briefly:

- Curve 1, Policy 0: The reference situation with no specific policies.
- Curve 2, Policies P1-P3: A combination of policies from the public transport vision path, including measures on public transport infrastructure development, public transport ticket price reduction and public transport awareness raising.
- Curve 3, Policies P4 and P6: A combination of measures aiming to develop infrastructure required by electric vehicles and simultaneously implemented awareness raising campaigns.
- Curve 4, Policies P4-P6: A combination of three measures directly linked to electric vehicles vision path: infrastructure construction, electric vehicle purchase subsidies and awareness raising campaigns.
- Curve 5, Policies P1-P6: All the public transportation and electric vehicles policies bundled up.
- Curve 6, Policy 7: A separate policy measure to limit road construction.
- Curve 7, Policies P1-P7: All the public transportation and electric vehicles policies bundled up and combined to the policy measure to limit road construction.

The simulation results (Figure 4) show that implementing the policies tailored to support electric vehicle uptake (curve 3, P4 and P6 and particularly curve 4, P4-P6) enables major positive impact on electromobility both in terms of fraction of trips and number of users in coming two to three decades. Simultaneous implementation of public transportation policies alongside of policies aiming to support electromobility (curve 5, P1-P6) does not affect markedly to this scenario. Especially the number of users using electric vehicles increases with same pace no matter if only combination of the three electric vehicle policies modelled are implemented alone (curve 4, P4-P6) or if a broader policy mix combining measures promoting public transport and electric vehicles (curve 5, P1-P6) are realised. On the other hand, development of the trip fraction differs for these two scenarios, as the public transport measures (curve 5, P1-P6) encourage also electric vehicle owners to take the public transport from time to time. Such an outcome in the development of vehicle ownership (shift to electric drive) while maintaining and even improving the trip fraction in favour of public transport (contra private cars) can be considered successful.

# 4 Discussion

This paper introduced a methodological process designed to support strategic decision-making and policy-planning in systemic transitions. The process was demonstrated by a case study exploring electric vehicles as a solution to the vision of emission free transport in cities in 2050.

The systemic nature of the proposed methodological process captures the challenges of the decision-making situation of the case study as a whole, and the emphasis for the policy-design support is on the understanding of user behaviour in the socio-technical system of transport. The policy measures formulated for the vision path and the resulting simulation results from the dynamic model do not, however, remain as the only outcome of the process. Instead, an important contribution is the learning experience along the working process. The preparatory work before simulations, where the decision-making situation and the related challenges in reaching the vision along one path or another are structured, helps to understand the systemic interactions and changes taking place on the way towards the vision. In many cases this aspect could well be the most important achievement for the experts, decision-makers and other stakeholders taking part in the process.

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