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EV-share development: speed vs interest to adopt

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Abstract

Transport is a notable source of greenhouse gas emissions. While the mobility habits of people have an effect on a large share of the emissions, the development of the car fleet also plays a major role. In this study, Finnish SALAMA-model is used to calculate nine different scenarios, examining how changes in both the car fleet turnover speed and interest towards electric vehicles (EVs) affect the amount of EVs and total emissions from the passenger cars in Finland up to the year 2040. With the baseline scenario (normal interest and car fleet turnover speed) 28% of cars in use would be EVs (total of PHEVs and BEVs) by 2030. In contrast, scenario with higher interest and faster turnover suggest that nearly half of all cars could be EVs. When focusing on CO_2 emissions, only the scenario with the fastest turnover speed with high interest aligns with the Finnish targets for 2030. Thus, car fleet development is only a part of the emission reduction, and other measures are also needed. Based on the results, it should be noted that even though many current and past policies are often focused on increasing interest towards EVs, any solutions driving faster turnover of the car fleet would also significantly impact emission reduction.

Key points

- Car fleet development has a major impact on mobility emissions.
- High interest towards EVs and faster car turnover rate are both needed to reach the targets.
- Encouraging a faster car turnover rate has major effect on emissions.

Keywords Car fleet development, Scenario model, Emissions, Electric vehicles, Turnover speed

1 Introduction

Transport is a notable source of greenhouse gas emissions in whole Europe. In Finland, one fifth of the greenhouse gas emissions come from transport. While affecting the mobility habits of people affects a large share of these emissions, it is important to recognise that the type of cars individuals use also contributes to this impact. Therefore, it is important to acknowledge that the car fleet and its development also plays a major role in emission reduction. In addition to changing mobility habits, increasing the share of electric vehicles (*EVs*) has been one of the key targets to achieve emission reduction targets.

1.1 The aim and structure of the study

To increase the number of EVs, a common method is to drive up the consumers' interest towards EVs with for example tax benefits, pricing incentives or advertising. This leads to more and more car buyers to choose EVs instead of conventional petrol or diesel cars when changing to a new car. However, this only applies when the person is changing the car, as an EV interest does not

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necessarily lead to an EV purchase, if there is no other reason to purchase a new car at that time. In Finland, the average turnover age of cars is fairly high compared to European average. Therefore, policies that shorten the turnover time could also have a significant impact on increasing the share of EVs.

The aspect of studying the effect of turnover speed in comparison to the actual interest towards EV purchased in passenger car market is not commonly researched together, and thus, the aim of this study is to focus on how both the increased interest towards EVs as well as faster turnover time will affect the share of EVs and passenger car CO_2 emissions up to the year 2040, both individually and together. This is an important approach, as currently the turnover age of Finnish car fleet is still slowly increasing, and therefore, turning this development could resolve in possible increase of EV-share. The research focuses on this topic and the actual content can be summarised into three research questions:

RQ1 How can the EV-interest and passenger car fleet turnover speed be influenced?

RQ2 How does the EV-interest and fleet turnover speed affect the number of EVs in Finnish passenger car fleet up to 2040 in different development scenarios?

RQ3 How do the projected CO2 emissions in these scenarios align with EU's emission reduction targets?

Further in this chapter, the different measures of influencing both EV-interest and turnover speed are explained to answer the first research question. Second chapter explains shortly the method that is used in this study to calculate the car fleet development based on turnover speed and EV-interest changes. In addition, the second chapter introduces the different scenarios that are used in this study. Then, in the third chapter, the results based on both EV-share (RQ2) as well as CO_2 emissions (RQ3) are presented. The results are then concluded in the fourth chapter in additions to other lessons learned in this study.

1.2 Background

There have been multiple studies regarding different actions that can influence car users to switch to EVs. These can be divided at least into three different aspects, which are financial actions, improving the infrastructure, and providing better information. However, since these actions only have an influence when a car owner has already decided to switch to a new car, it is as important to consider actions that aim to shorten the time between car changes. This will make the prospect of buying of a new car relevant for more people at a faster rate, therefore expediting the development. There have been calculations by the Finnish Information Centre of Road Transport [9] that changes in taxation together with EV purchase incentives and scrapping bonuses could accelerate the Finnish car fleet turnover by three to four years.

Regarding different financial actions, there is evidence that pricing subsidies and direct feebates are most effective, as up-front savings are favoured over lifecycle savings [1] and in general, it has been noted that EV purchase subsidies will increase the number of new EV sales through a competitive pricing against conventional cars [5, 11]. Financial benefits for EVs can also be achieved through different taxation schemes, such as the Swedish malus-system [18] or with development of different use costs, such as fuel prices, and a larger increase to fuel prices has been seen as a factor moving more people towards EVs [8, 11].

However, infrastructure is as important as financial measures, and both Mukherjee & Ryan [13] and Scorrano et al. [16] presented that while financial benefits may be the major reason to switch to EVs, the home charging possibility is still the critical establisher that should be solved, as it allows the possibility to the lower use costs. There are also studies showing that increase of charging points in general will affect the number of EVs [7, 11]. In addition, the development of charging infrastructure may encourage the use of EVs. Developing new charging infrastructure technologies, e.g., wireless charging systems, can increase the convenience and safety of charging [4]. Dynamic wireless charging systems can help to reduce range anxiety by enabling EVs to charge wirelessly while in motion, eliminating the need for sops for charging. [4]. However, the speed and scale of implementation of these technologies remain uncertain.

It is also important to consider the effect of correct information as people using conventional cars need the knowledge of the different financial benefits as well as how the infrastructure supports the EVs to actually make the switch, and there are studies showing that a large gap exists between consumer expectations and reality [2]. When the users are more trusting and confident about the EVs, they have more motivation to purchase EVs [3, 10]. One potential solution to provide more information and experience with EVs is to promote car sharing services and MaaS (Mobility as a Service) featuring electric vehicles. The promotion of car sharing services with EVs can provide possibilities for consumers to test and gain more experience with EVs, thereby addressing potential barriers to acceptance [15].

2 Method

To calculate the car fleet development in Finland under different EV-uptake and turnover speed scenarios, the SALAMA car fleet model by Viri et al. [19] is used. The concept of the calculation is further presented in this chapter and a more throughout description of the car fleet model can be found in Viri et al. [19]. In addition to the model, this chapter explains how the CO_2 calculation is implemented on top of the model and what kind of scenarios are used in the study. A more specific explanation of the CO_2 calculation can be found in Viri & Mäkinen [20].

2.1 Baseline and scenarios

The baseline scenario used in the study is developed to fulfil the Finnish national target to have 750 000 EVs by the year 2030. In this target, both battery electric vehicles (*BEV*) and plug-in vehicles (*PHEV*) are counted as EVs. In the model used in the study, the probability to change from a specific driving power to a new driving power is annually set to different area types (urban, semiurban, rural) individually, which the model then uses to calculate the actual car fleet development. In the baseline, the probability to switch from petrol- or diesel-powered car to either a BEV or a PHEV is set according the 2020 and 2021 sales figures to follow that trend to 2025. After 2025, depending on the area type, 70 to 75 percent of the PHEV interest will move towards BEV interest, as it is estimated that closer price parity and broader selection of BEVs will start to largely impact the demand of PHEVs. This trend continues to the end of 2029. Then, starting from 2030, all of the other probabilities will start to drop gradually towards 0 percent, allowing BEV to have a 100% new car market share in the start of 2035 as per the set EU targets.

To create variation for the scenarios, a high- and low-adoption scenarios were created for the EV-interest. The actual method of calculating the probabilities is the same as in the baseline, but the probability to switch to an EV from petrol or diesel is changed. For *high*, a total of 10%-point increase is made to the probabilities to switch to PHEV and BEV up to end of 2029 and it is done in the expense to probability of petrol. The increase is divided between PHEV and BEV interest based on the baseline values, so that their interest stays on the same level related to each other. Then, from the start of 2030 onwards, the values start to gradually drop to 0 percent, as in the baseline. For *low*-adoption scenario, the same method was used as above, but the probability was decreased for a total 10%-point instead, divided between BEV and PHEV as in the high scenario. As the interest towards EVs is now lower in total, all the remaining interest is now calculated to go towards petrol.

Table 1 The scenarios used in this study

Speed and interest	Basic	High	Low
100%	Basic 100—*baseline*	High 100	Low 100
85%	Basic 85	High 85	Low 85
70%	Basic 70	High 70	Low 70

To vary the speed of the development process, three different speed coefficients are used in the model. By design, the car fleet model used in the study estimates that the average age of the cars is stable throughout different areas and user groups through the whole model timeframe. For the baseline scenario, speed is used as it is, thus the average age of the car fleet fluctuates at above 11 years. For the other two scenarios, a speed coefficient of 85% and 70% is used, denoting that the speed new cars are introduced is faster, by either being 85% or 70% of the original speed, resulting into average ages fluctuating at around 9.5 and 7.8 years, respectively. The prior calculations of the Finnish Information Centre of Road Transport [9] stated that three to four years drop in average age could be reached through a major change in taxation, which would be on par with the 70% scenario.

By using the three different interest -scenarios with the three different speed -scenarios, a set of 9 combination scenarios (1 baseline and 8 modifications) can be created to be used in this study, as shown in Table 1.

2.2 Car fleet model

The development of the different scenarios is calculated through SALAMA, a Finnish car fleet model for passenger cars. It is built on top of Finnish car fleet data, and it contains the main technical information of every car in use in Finland with basic information of the registered car user, such as their age group and location. This data is then used to categorised all the cars into their appropriate user groups based on their driving power, location, and registered user. The average age of these groups is then used to estimate the probable end of life for all the cars that are in use, and when the end of life is reached, the probability based on the driving power for that year is used to form the probabilities of the driving power of the replacement car. The model is run and repeated on generated cars as long as the target year of 2040 is achieved. Based on the scenarios presented in previous chapter, the average age for end of life -calculation is varied based on the development speed and the probability to switch driving power per different year is varied based on the EV-interest, thus making the model ran 9 times to cover all scenarios and therefore, creating 9 different car fleet development scenarios in total for this study.

As a results, the car fleet model provides a full list of cars with their specifications from the model start year to year 2040 consisting of every car estimated to exist during that timeframe, for every different scenario. The technical information of these cars includes information of their CO_2 emissions either from the original dataset for the original cars or estimated from the model to the new, model-introduced cars. In addition, there is information about the recorded mileage in the last inspection, allowing the calculation of average annual mileage for the cars in the dataset.

The model assumes that the car ownership per capita will stay stable during the upcoming years, and therefore, all replaced cars will generate a new version throughout the timeframe of the model. However, since the location and user group of the cars is known, this information is used to calculate a coefficient for every car to exist based on the future population projection [17], thus correcting the results to follow the estimated changes of population of different areas of Finland. In the end, this allows the calculation of the number of both BEVs and PHEVs in any given year during the model timeframe.

2.3 CO_2 calculation

Based on both the CO_2 and mileage information coming from the SALAMA car fleet model, a mileage-weighted CO_2 average is calculated annually for every Finnish subregion based on the model results, for each scenario. The average is chosen to be weighted by mileage, as it will give more weight on the cars that are realistically driven more based on the data. Since only tank-to-wheel emissions are focused, BEVs are calculated to produce 0 g/km CO_2 and PHEVs are calculated based on their registered CO_2-value. During the average calculation, the plans of biofuel uptake in Finland [12] are considered to align the results with other national statistics. Moreover, the values are corrected to better respect real world emissions based on the results from Dornoff et al. [6]. This whole process is further described in Viri & Mäkinen [20].

Then, by using Finnish National Travel Survey data (NTS 2018) [14], the passenger car mileage for every subregion is calculated based on the data and the sample is extended to represent whole subregions. The total CO_2 emissions are then calculated as driven kilometres in the subregion times the subregional average of CO_2 g/km, totalling into CO_2 emission development of whole Finland. The CO_2 averages vary annually as the car fleet develops, but as with cars per capita, annual mileage is estimated to stay on the same level as the NTS-data but corrected with the population development coefficient per year.

3 Results

Based on the methods described above, the annual development for both EV fleet (both BEVs and PHEVs included) and CO_2 emissions are presented for Finland up to the year 2040. The results are shown first to the year 2030 and for 2030 to 2040, as the next EU level target is set to 2030, when the emissions should be reduced 45% compared to 2020 level. For the next ten years, the figures are shown separately, as the car fleet development is forced to go towards full electricity in 2035 thus making the development in all the scenarios closer to each other.

Due to the model dataset currently being from 2018, 2019 is already a modeled year in the results, and as a result of this, the development speed affects slightly already in the 2019 thus causing the starting points between different speed to slightly vary at the start of 2020 in the figures.

3.1 Development to the year 2030

Figure 1 shows the development of EV fleet per year, and quite reasonably, the scenario producing most EVs is the one that has highest interest towards EVs and the fastest turnover speed. However, when looking towards 2030, scenario with basic EV-interest and fast turnover speed will catch the development of scenario with regular turnover speed and high interest.

However, when looking at the results of CO_2 emissions in Fig. 2, the results are a bit different for 2030. Here, the scenario with fastest development and high interest to EVs still results into highest CO_2 reduction, but even the scenario with basic interest and fastest speed will provide larger emission reduction than the scenario with15%-point slower speed and high interest. This is because, despite the higher number of EVs in the alternative scenario, all the conventional cars in the scenario with fast turnover speed are replaced with more fuel-efficient vehicles.

The speed of the development has a much larger effect when looking into total emissions. However, when comparing to the 2030 target level, only high interest, high speed scenario provides a substantial emission reduction, and for every other scenario, changes to mobility habits (i.e., less driven mileage) should be implemented to reach the target.

3.2 Continuing to the year 2040

When looking the development of EV-fleet from 2030 to 2040, as seen in Fig. 3, it can be seen that due to all of the scenarios starting to gradually focus towards fully BEVs in 2035, the turnover speed starts to be a much more critical component, as in the results for 2040, the three scenarios that provide most EVs are the 3 ones with fast turnover speed.

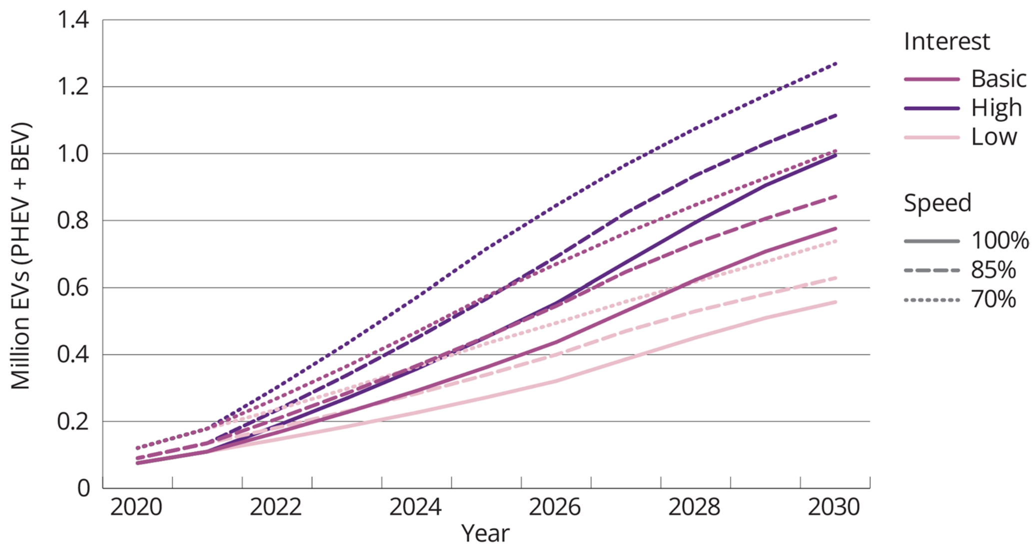

Fig. 1 The number of EVs (PHEV + BEV) over years in Finnish fleet in different scenarios up to the year 2030

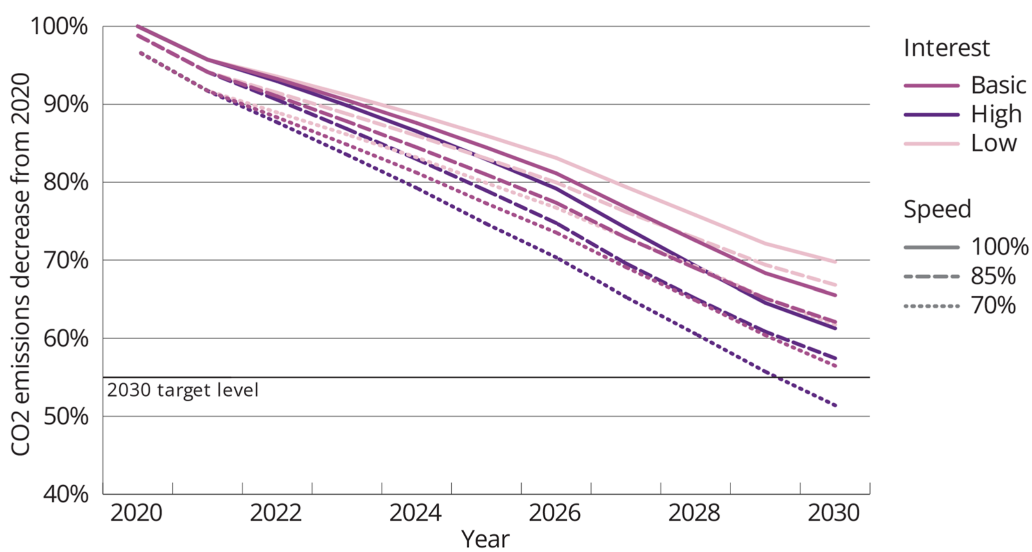

Fig. 2 CO2 emission reduction development of passenger car transport in Finland compared to the year 2020 of baseline up to the year 2030

For the CO_2 emission development presented in Fig. 4, the scenarios with faster turnover speed were already shown to have greater CO_2 reduction. Consequently, when the difference in interest slowly fades out, the scenarios with faster turnover start to provide better CO_2 reduction compared to the slower ones.

Based on the results, it should be noted that although media and different policies give a high value on EVs as a tool to reduce emissions, they are not the only answer. If the efficiency development is moved to the car fleet with faster turnover time, it could also lead to major CO_2 reduction, even with lower EV-interest.

4 Discussion and conclusions

There are measures that have been used that can increase the interest towards EVs, such as better infrastructure for charging EVs both at home and on public locations, subsidies to decrease the price gap when obtaining a new car or increasing customer awareness about EVs. Regarding turnover speed, Finnish car taxation could be modified to more effectively encourage the purchase of new cars, thereby expediting the turnover time. Scrapping bonuses and other incentives can also help to remove older cars from the fleet.

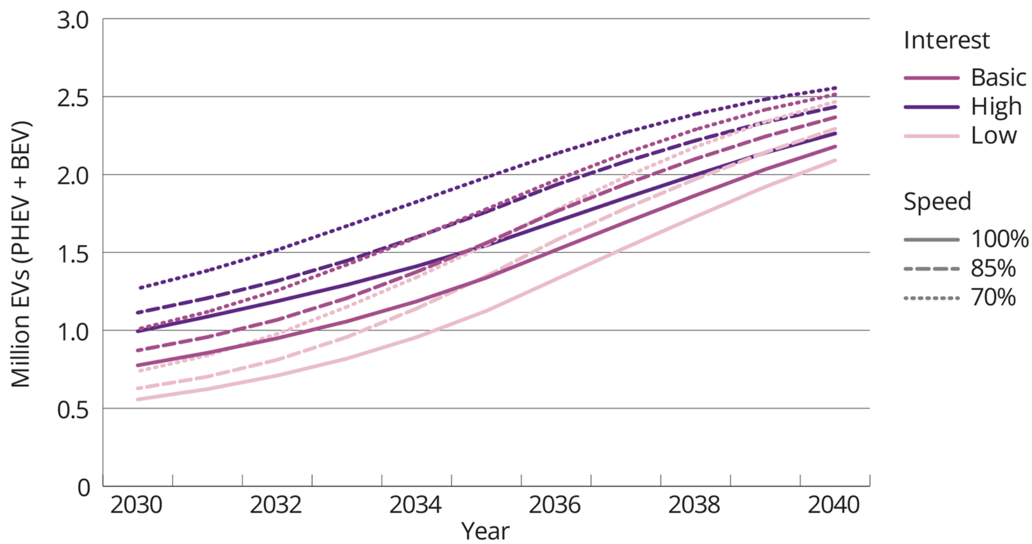

Fig. 3 The number of EVs (PHEV + BEV) over years in Finnish fleet in different scenarios up to the year 2040

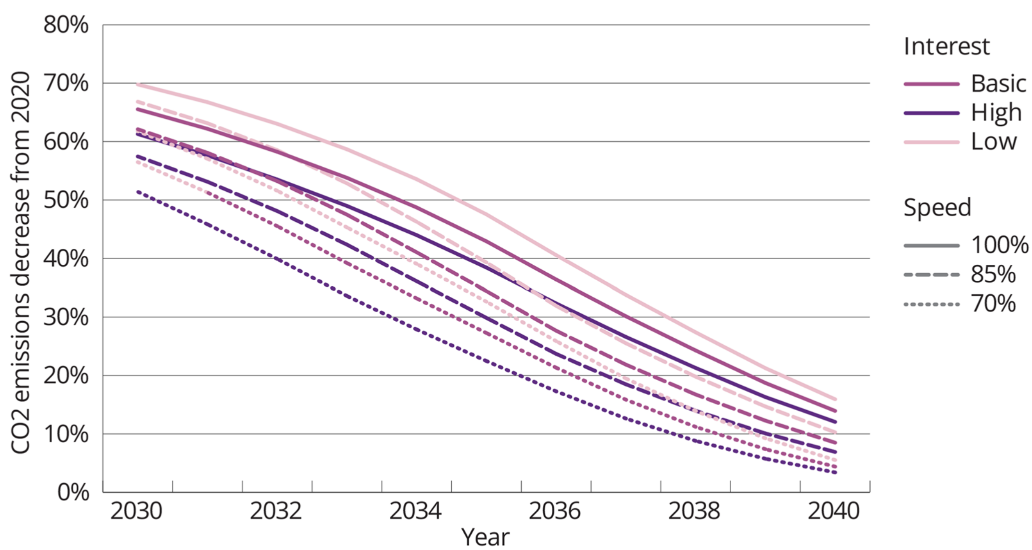

Fig. 4 CO2 emission reduction development of passenger car transport in Finland compared to the year 2020 of baseline up to the year 2040

In this study, 9 scenarios were created, where the EV-interest and car fleet turnover speed were varied. Based on these different scenarios, the results show quite unsurprisingly that higher interest towards EVs will result in more EVs in the car fleet, whereas the turnover speed of the car fleet has less effect on the development of EV-share. However, when looking at the CO_2 emissions development, the influence of turnover speed is much higher, as not only EVs provide lower emissions, but also newer car fleet in general will have lower CO_2 emissions, as the technology is more efficient.

Even though many current policies seem to focus to raise the interest towards EVs, which certainly creates CO_2 reduction, the higher turnover speed also impacts CO_2 emissions. Therefore, different actions that would encourage the users to replace their cars faster would also be viable, even if they would replace the cars with newer car with a conventional engine. The faster turnover has also other benefits than the higher efficiency of the fleet, as the newer cars tend to be safer due to the new technologies included.

In this study, the calculation assumed that both the car ownership and car use per capita will remain at a stable level. As the results showed, only 1 of the 9 scenarios fulfilled the 2030 targets for CO_2 reduction, but it should be noted that car fleet development is not the only method for emission reduction, but methods that affect car ownership and use also have an effect, and therefore, the target can be reachable even in the other scenarios. For further research, the scenarios of this study could be combined with different scenarios of car use changes in different areas to provide more detailed results. In addition, MaaS and car sharing services can affect both car use patterns and car ownership, and if these services are using EVs, this can further impact overall interest in EVs and the turnover speed. However, sufficient data concerning the effect of car sharing and MaaS was not available for analysis in this study.

Also, in this study, it was assumed that the 2035 target of only zero emission vehicles registered is filled by BEVs. There could, however, also be other driving powers that would meet the criteria, such as hydrogen vehicles, but as this study only focused on tank to wheel -emissions, they would have the same result of CO_2. However, the policies to raise interest towards hydrogen might be different than the ones for BEVs.

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Author contributions
RV: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing—Original Draft, Writing—Review & Editing, Visualization. JM: Conceptualization, Methodology, Formal analysis, Investigation, Writing—Original Draft, Writing—Review & Editing, Validation. All authors read and approved the final manuscript.

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Availability of data and materials
The model is built on top of Finnish car fleet data obtained from Finnish Transport and Communications Agency Traficom for research use. The model also uses results of Finnish National Travel Survey, which data is also obtained from Finnish Transport and Communications Agency Traficom for research use. The authors have no consent of sharing the data under the agreements made with the data provider.

Declarations

Ethics approval and consent to participate
Not Applicable.

Consent for publication
Not Applicable.

Competing interests
The authors declare that they have no competing interests.

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