An analysis of car passengers modal choice on car-free days

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Technical University Delft

Department of Transport and Planning

Transport and Planning BEP group 2

Bachelor end project

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Summary

This paper is written to report the findings of an investigation on the influence of car-free day policies on car drivers' behaviour in the Netherlands. More specifically, a model was used to predict the car user's modal choice when such a policy would be implemented. The results of the paper could be used to estimate the effectiveness of such policies. The predicted modal choice informs policymakers on whether or not the policy will result in the desired behaviour. Will car drivers choose more sustainable alternatives when cars are forbidden? Or will they choose to postpone their travels? This report describes the process of answering these questions.

To predict car drivers' behaviour, road traffic is split up into 3 subclasses: Freight, work-related travel and recreational or personal travel. Because goods need to be transported, it is assumed that car-free day policies have minimal impact on freight transport

A logit model will be used to predict the other two classes' behaviour. This model first evaluates all possible alternatives for travelling. After which it attributes a generalised cost to all alternatives. Based on the difference in generalised cost between the alternatives, the model predicts how the examined population will distribute itself over the alternatives. The model will need to be modified to include not going or travelling on a later day. To ensure the model is acceptably objective a sensitivity test will be performed. This way it can be shown whether the results are highly dependent on assumed values.

For work-related travel and commuting the results were conclusive. The model predicts that all the car drivers who can, will choose to work from home. That is a 20 to 30 % increase. Those who can't, will choose to take small electric vehicles or e-bikes if those are available. The rest will choose to take the train. Almost no one would choose to postpone their trip.

The model for personal transport indicates that more people would plan their trip on another day. However, these results were not conclusive as the model showed high sensitivity to changes in the assumed variables.

To conclude, the model suggests that car-free days would reduce car usage. It might also be more effective on working travellers than those who travel for personal reasons. Thus a workday might be a better option than a Sunday. However, more research is needed to substantiate the model for personal travel.

Contents

1 Introduction

This chapter Introduces the reader to the research topic. This rapport will look at how car-free day policies influence car drivers in the mode of transportation they chose. Section 1.1 gives an brief introduction in to the problem. After this section 1.2 formulates the research question and its sub questions to find a solution to this problem. Section 1.3 describes the current circumstances and the relevance of the problem. Finally section 1.4 gives an overview of the rest of the report.

1.1 Motivation and Problem Statement

Currently, the Netherlands and more generally the European Union are trying to reduce fuel and energy consumption for multiple reasons. One of the ideas that are being discussed in the Netherlands is to reintroduce car-free Sundays, a day on which all cars are banned from using public roads. Because the Dutch government has the power to do so during an energy crisis [NUn22a].

To properly access whether car-free days are a viable solution (or part of it), it must first be determined whether car-free days reduce car travel or if it just postpones it. For example, if you would state that one car free day per week reduces the amount of car travel by one-seventh, you would neglect the possible increased travel during the rest of the week. It seems plausible that a certain percentage of travelers would simply postpone their travel to another day.

It also seems possible that this percentage is different for different types of car travel. It can be reasoned that freight is very hard to prevent. Freight transport that is prevented on one day could just be moved to another day. This doesn't prevent any fuel consumption and could causes a whole host of undesirable side effects like congestion. However, Other transport might react differently. This is what this report wants to look in to.

There are also different solutions that are being discussed. One of those is the odd and even licence plate scheme. In this scheme on certain days only the odd numbered licence plate cars would be allowed to drive and then on another day only the even numbered licence plate cars could drive. In theory cutting the car traffic in half. However, research has shown this method only shows reductions in the short term [Nie17] . The theory is that people start using two cars or swap licence plates to be able to drive on both days.

1.2 Research question

Thus, there are still questions about car-free days that need to be answered before policymakers are able to decide whether the policy is warranted. This leads to the topic of this report. Do car-free days actually make people use other modes of transport or do they postpone their travels? The research question is formulated as follows:

How do car-free days influence the modal choice of car users?

To answer this question the research question is split up in several sub-questions:

1. What different types of car users are there?
2. What alternatives do these car users have?
3. What is the generalised cost of alternatives the driver?
4. Is a work day or the weekend the best time to implement the policy?
5. Does the purpose of the driver affect his choice of alternatives and how?

To predict the behavior of a car driver, one first needs to identify the motives of the driver. Question 1 does this by dividing the read traffic into subclasses. Questions 2 and 3 inventory the possible alternatives and how they compare to each other. Lastly, Questions 5 and 6 then look at how circumstances affect the choice of the driver.

1.3 Circumstances

To explain the necessity of reducing fuel consumption, this paragraph delves deeper in the current circumstances. At the time of writing of this report, Europe is experiencing a whole host of problems. It is recovering from a major pandemic. Europe is struggling to meat its emissions targets [IPC19]. Meanwhile Russia has invaded Ukraine. In response Europe has implemented unprecedented sanctions on Russian energy [Eur22]. This in turn has lead to record high inflation and a continent wide cost of living crisis [eur22].

All these circumstances have lead the political leaders of Europe to conclude that Europe needs to reduce its energy consumption and especially that of fossil flues that are largely imported from Russia [eur20] . There is a need to become more self sufficient when it comes to energy. There are also initiatives to import energy from other countries and diversify the energy imports, but specialists agree that reducing consumption needs to be part of the solution [NUn22b].

1.4 Thesis Structure

In chapter 2 the method of analysis in explained. All the necessary input data and assumptions are laid out. The workings of the simulation model are explained and an explanation for weights and parameters is provided. the last paragraph elaborates on how the results of the model will be processed.

Chapter 3 shows the modal splits for both the recreational drivers and work related travels. It also includes a general overview of influence of a car-free day on the car users modal choice.

Next, chapter 4 discusses the results. It evaluates possible reductions in car traffic, the influence of the day and the location of the measures. The chapter also includes a discussion on the reliability of the paper and its possible flaws. It ends on a general conclusion

Lastly, chapter 5 builds further on the conclusion. It suggests further research is needed and how this obtained knowledge could inform policy decisions in the future.

2 Methodology

In this chapter the methodology of the research will be outlined. To predict the behavior of car users when they have to chose an alternative, a model will be constructed based on the logic of a Logit model (the workings of this model will be further explained in section 2.1). To set up this model a multitude of input data is required and several assumptions will have to be made. Secondly the model will be set up. This will require weights and variables to be determined. This will need more assumptions that need to be based on literature. With the model, the modal splits can be determined. These in turn need to be processed to determine the efficacy of a car-free day and its impact.

2.1 Model description

To determine how car users will react to the implementation of car-free days, several logit models will be used. Each Logit model will simulate the decision of one of the types of car-users. The goal of the model is to determine what alternative the types of car-users referenced in chapter 1.2 will chose. The model will provide a distribution (in percent) of the car users over the alternatives. When this is known for all types of car-users the impact of car-free days can be assessed.

2.1.1 Logit model

To explain how the Logit model will be modified, it must first be explained how a Logit model works. A Logit model is generally used to estimate how a population will divide itself over different modes of transport. One assumes a number of travelers and based on the cost of each transport method the model divides the travelers over the different modes of transport.

Thus, the first step is to identify all modes of transportation that are available to the population in question. The second step is to calculate the cost of all transportation methods. This does not only include the actual cost of the trip but could also include inconveniences or other circumstances affecting the choice of the user. It is thus more like a generalized cost or the value of a transport method. The formula below shows an example of how a value calculation could look like:

$$V_{scooter} = VOT * (2,2 * T_{Searching} + T_{driving} + T_{parking}) + Cost_{scooter} \tag{2.1}$$

In equation 2.1, VOT stands for the value of time. For the models in this paper, the modal income (this is the most common income in the Netherlands, also known as the modus of all incomes) of the Netherlands is used. The modal income of in the Netherlands is 3167 euro per month or 0.3 euro per minute [Lok22]. T

indicates the time required for a certain action and Cost indicates possible costs of the transportation mode in question. Notice Not all time is weighted equally. In this example the time required to search for the rental scooter is weighed higher. This indicates users find this time more cumbersome than the time driving. Once the value of each mode of transport is calculated the following formula determines how many travelers (fraction) will use a given transportation method

$$p_i = \frac{e^{V_i}}{\sum_{j=1}^{n} e^{V_j}} \tag{2.2}$$

In equation 2.2, P_i stands for the fraction of travelers that will use method i. V still represents the value of a certain transportation method.

As previously mentioned, a Logit model will be used to simulate the choice of the car-driving population. Normally this model is only used to calculate a modal split (a distribution of the likelihood this person will choose a certain mode of transport) for someone who has decided to travel. It does not usually involve the option of not traveling ore postponing the traveling. By attributing a monetary value to these options it could be included in the calculations.

This however introduces a degree of subjectivity to the prediction. To minimise this, calculations and assumptions will be supported by research as much as possible. Further more, these assumed variables will be tested with a sensitivity test. This test is further elaborated in chapter 2.1.2. It must be stated that the results will only be a preliminary indication of the outcome and not an accurate prediction.

2.1.2 Driver Types

As mentioned in section 2.1 our model will consider different types of car drivers. The CBS distinguishes between 8 different reasons for transportation with an added category for others [CBS21]. These include commuting, services and healthcare, education, hobbies, business, groceries, visitation, and touring. For simplicity, this report distinguishes between 2 types: commuting or Work-related travel, and recreational or personal travel. Freight is also a contributing factor to road use but is excluded from the model for reasons that are explained below.

Freight

Freight will not be considered in this model because it would increase the scope of the paper too much. The assumption is made that goods will need to be transported, so the transport would just be postponed to another day. therefore it is left out of the Logit analysis. However its fraction of road use is still subtracted from the overall road occupancy.

Modal choice for commuting and work related travel

For commuting and work-related travel six alternatives are considered, namely: Public transport, bicycles, e-bikes, small electric vehicles (maximum velocity of

45 km/h), working from home, or postponing the trip to a different day. Small electric vehicles include electric scooters and other compact electric vehicles like monowheels, motorized skateboards, etc. It is assumed large electric vehicles are still banned because the political backlash would be too large if electric cars would be favored so aggressively. However small electric vehicles to facilitate last-mile transport would be allowed. Table 2.1 shows the values calculations of all possible options.

Tab. 2.1.: Value formulas for work related traffic

Mode of transport	Value formula
Train	$V_t = VOT * F_a * (2,2 * T_{walking} + T_{train} + 13 * N_{conection}) + Cost$
Bicycle	$V_b = VOT * F_a * T_{bike}$
E-bike	$V_{e-b} = VOT * F_a * T_{e-b} + cost * distance$
Small electric vehicle	$V_{sev} = VOT * F_a * T_{e-v} + cost * distance$
Working from home	$V_{wfh} = cost$
Car (other day)	$V_{car} = VOT * T_{driving} + distance * cost + 0,8 * daywage$

In these formulas F_a is the factor of annoyance. This factor indicates the reluctance of car-drivers to take other modes of transport. For both types of drivers, work and personal travel, this factor is determined with a baseline model. This model assumes no time penalty for driving to simulate the current situation (no car-free day implemented yet). As the goal is to simulate the car drivers behavior, this model should predict that almost the entire population travels by car. However, the annoyance factor should be kept as low as possible. Otherwise it will always overrule the results in later models.

T always indicates time spent on an activity and N stands for the number of times something occurs.The travel distance is 35 kilometers, the average distance traveled by car for commuting purposes [PBL21]. Some methods were given a shorter distance because they can take a more direct route (80 % of the driven distance). To calculate the time spent traveling, the average speed of each transport method is needed. Finally also the cost of each method must be known. Table 2.2 shows the assumed speed, cost and the respective sources for each method.

Tab. 2.2.: Respective speeds and cost for transport methods. Methods indicated with * can take the more direct and shorter route (sources are named in the appendix A table A.1 to keep the table readable).

Mode of transport	Average speed (km/h)	Cost (Euro)
Train	120	$0,891 + distance * 0,169$
Bicycle *	12	No cost
E-bike *	25	0.177 per km
Small electric vehicle *	45	0.3 per km
Working from home	No distance	3
Car (other day)	80	$0.614 - 0.19$ (compensation) per kilometer

With this information the value of each method can be calculated. After which the distribution is calculated with formula 2.2. However there are a few complications. Some alternatives are not available to the entire population. Working from home is only an option for about 65 % of the population [PBL21]. Electric scooters and e-bikes might also not be available to all travelers due to a high up front cost. If the model suggests that a certain method will be chosen more often than the upper limit

(65 % for working from home for example), it is assumed that all people who can, use this method. After that a second model is made without this option to estimate the behavior of the rest of the population. This is repeated until the total population is distributed.

Finally the model is checked for sensitivity to assumed factor. This is done by changing the assumed values by 25% (both up and down) and comparing the results. The results should not vary by more than 5%. The variables that are tested are the factor of annoyance, the reduction factor for direct routes and the penalty for postponing the trip.

Modal choice for recreational or personal travel

For recreational travel the same options will be considered. Only working from home is left out and the penalty for driving on another day is formulated differently. Also the distance will be different. On average people travel less for personal reasons. The average distance is 10 kilometers [PBL21]. Also the cost of driving is higher because it is no longer compensated by the employer (0.614 euro per kilometer). Formula 2.3 shows new value formula for car travel on another day.

$$V_{car} = VOT * T_{driving} + distance * cost + VOT * T_{planning} \tag{2.3}$$

The penalty for postponing the trip is no longer related to a loss in wages but a cost for the inconvenience. The cost of this inconvenience is quantified by the time required to plan the delayed trip.

Another value formula that has changed is that of public transport. Seeing as the distance is so short it is no longer assumed the the traveler will need make a switch during his trip. This results in the following formula:

$$V_{pt} = VOT * F_a * (2,2 * T_{walking} + T_{train}) + Cost \tag{2.4}$$

Other than these differences the model and the process of determining the distribution is done in the same way as for work-related travel. The factor of annoyance is determined with a baseline model. Upper limits are considered and distributions will be adjusted accordingly. The sensitivity analysis will also be performed with the same demands.

Finally it is still important to mention a few assumptions that may cause discrepancies between the models and reality. This model assumes the prices of the alternative transport methods stay equal even though it is reasonable to believe that prices will increase due to increased demand. One of the important variables in these calculations is the value of time (VOT). For this the modal income of the Netherlands is used. It could be argued that car owners would on average earn more than the average citizen, However this difference is hard to quantify.

Lastly it is assumed that car-free days are introduced and announced well in advance to allow people and companies to plan around the car-free days. This is important when evaluating the cost of postponing a trip. Furthermore the government will allow at least one day of the designated days to travel by car. For example, if Sunday was to be designated as a car-free day, the government would leave at least one Sunday each month where traveling by car is allowed. This is don so that people can plan a trip that is only possible on that day. This means most trips are still possible. If this were not the case it would greatly impact the calculations as a new option would need to be created for people who all together cancel the trip.

2.2 External data and related assumptions

The model output is not the only data required to generate valuable insight into the problem. To say something about the best day of implementation, one needs to know why people drive on what day. The ideal would be to compare the model output to a dataset that shows the occupational distribution of drivers on different days.

For example, suppose the model suggests that people who drive for personal reasons are more likely to postpone their trip instead of finding an alternative. And the dataset showed that on weekends people travel more for personal reasons. This would indicate that the weekend is the wrong day to implement car-free days. As it would mainly postpone car travel, not prevent it. Say work-related travel is less likely to postpone trips, and work-related travel is more common during the week. This would indicate that weekdays are better candidates for a car-free day.

Sadly no such dataset was available. However, more generic data about traveler numbers and road occupation can be collected from the Kennisinstituut voor Mobiliteitsbeeld(KIM) and Nationaal Dataportaal Wegverkeer(NDW) government platforms. NDW even identifies vehicle classes, based on the length of the vehicle [NDW19]. This however does not yet give the full description of the purpose of the driver. It can help in making informed guesses about occupations. How this is done will be discussed shortly, but first a representative sample must be collected.

NDW provides hourly data on specific measuring points in the Netherlands. The data provides hourly intensities, distributions based on vehicle length and average speeds. At the NDW dexter terminal one has the option to request data from a maximum of 20 measuring stations. Data from 10 locations (2 measuring stations per location, one for each direction), distributed over the whole country, were requested. The locations were chosen in such a way that they would be well distributed over the Netherlands so the data would be representative of the driving population. The locations are shown in figure 2.1. The data was requested twice. Once for the first week (Monday to Friday) of February 2019 and once for the following weekend (Saturday and Sunday).

This data gives an percentage split of the traffic based on length. The subdivisions are as follows: 1.85m-2.4m, 2.4m-5.6m, 5.6m-11.5m, 11.5m-12.2m and larger than 12.2m. In figure 2.2 a part of the data is shown. Even tough freight is not modeled during this research, it is still valuable to know how large its contribution is to the overall occupation of the road. It is assumed all vehicles longer than 11.50 meters

Fig. 2.1.: Locations of the gathered NDW data

are freight because the maximum length of a vehicle for drivers licence class B is 12 meters. Based on the NDW data and these assumptions one can easily calculate the occupational percentage of freight for the work week and the weekend. The average of the percentages larger than 11.5 meters was taken for both the workweek and the weekend.

One other assumption this data can help with is the ratio of work-related traffic and personal traffic. The data cannot give an exact ratio but it can indicate differences during the workweek and the weekend. More specifically the vehicle section of 5.6 meters to 11.5 meters refers to vans. 91 % of vans are owned by companies [Pri20]. Thus this vehicle class can be a good indicator of work-related traffic. It would not be accurate to assume that a 50 % decrease in van traffic during the weekend would mean an overall 50 % decrease in work-related traffic. However it is not

Gemiddelde voertuigverdeling per uur van 2019-02-04 00:00:00 tot 2019-02-08 23:59:59 voor A7 naar Den Oever na afrit 12 ri afrit 13 thv hmp 51.8 (GEO0B_R_RWSTI263) op weekdagen

uur op de dag	Intensiteit	tussen 1,85 m en 2,40 m	tussen 2,40 m en 5,60 m	tussen 5,60 m en 11,50	tussen 11,50 m en 12,20	groter dan 12,20 m (%)	onbepaald (%)
00:00 - 00:59	83	2,4	83,4	3,1	0,5	6,7	3,9
01:00 - 01:59	44	1,4	76,8	4,5	0,5	14,5	2,3
02:00 - 02:59	33,4	0	44,9	6,6	0	45,5	3
03:00 - 03:59	24,2	0	43	6,6	0	48,8	1,7
04:00 - 04:59	46	0	40,6	14,4	0	41,1	3,9
05:00 - 05:59	183	0,7	61,3	8,7	0,8	24,8	3,7
06:00 - 06:59	700	0,8	79	8,9	0,2	8,9	2,3
07:00 - 07:59	1010,4	1	80,7	8,2	0,4	7	2,7
08:00 - 08:59	911,6	0,9	80,9	7,6	0,2	7,9	2,4
09:00 - 09:59	739,6	1,2	78,9	8,3	0,3	9	2,4
10:00 - 10:59	698,4	1	76,2	8,4	0,5	11,2	2,7
11:00 - 11:59	741,3	1	75,8	9,3	0,3	11	2,7
12:00 - 12:59	795,3	1,1	78,1	8,3	0,4	9,7	2,4
13:00 - 13:59	823,6	0,9	78,2	7,9	0,3	10,3	2,4
14:00 - 14:59	905,2	1	78,3	9	0,4	8,8	2,5
15:00 - 15:59	1219,8	0,9	81,3	9,3	0,3	5,7	2,5
16:00 - 16:59	1321,4	1	85,2	6,9	0,2	4	2,7
17:00 - 17:59	1335,4	0,9	89,8	4	0	3	2,3
18:00 - 18:59	812,6	0,8	88,5	3,6	0,1	4,7	2,3
19:00 - 19:59	536	0,8	88,7	3,5	0	4,8	2,2
20:00 - 20:59	364,4	0,5	88,9	3,5	0,3	4,9	1,9
21:00 - 21:59	297,4	0,6	88,3	2,8	0,1	5,1	3,1
22:00 - 22:59	250	0,3	91,2	2,8	0,1	3,3	2,3
23:00 - 23:59	188,6	0,4	90,9	2,7	0,5	3,9	1,6
Totaal	14064,6	0,9	81,9	7	0,3	7,5	2,5

Fig. 2.2.: NDW data of one location

unreasonable to state that this would indicates les work traffic during the weekend. The results of the NDW data analysis are shown in chapter 3.3.

2.3 Model output processing

Withe the modal split for each traveler type, the impact can be determined. To be able to consult the government on a diversity of car-free day applications, the different impact on several locations and times will be analysed. This will inform a decision on how car-free days would be implemented. Is Sunday the best day? can a more local approach work? is it even effective at all?

To answer the last question is relatively simple. If the model show most people chose to postpone there travel, a car-free day has minimal effect. If the model shows a large fraction of the car users chooses a more environmentally friendly alternative, the car-free day has a positive effect on pollution.

To determine which day is most effective, there needs to be a reference to the distribution of traffic during the work week and the weekend. It is assumed that the results of the Logit models are not influenced by the day of the week. However the fraction of the type of users is different. Say for example that commuting travelers are much more likely to chose the train on a car-free day than recreational travelers. If there are more commuters during the work week, the effect of a car-free day during the week is different than during the weekend.

Finally the question of a more local approach is more difficult. But with some assumptions an informed guess could be made. If it is assumed that most commuters work in city centers. And the model shows that the largest impact is found in the commuting population. One could suggest that only making city centers car free still results in similar reductions with less drastic measures. Of course this is not certain. But it can certainly indicate interesting new research topics.

dblfloatfix

Results

3

This chapter will lay out the results of the models that were produced. It will show the determined distributions for both work-related travel and personal travel accompanied by the sensitivity analysis of each model. The next paragraph will show the processed data from NDW and the differences in work-week and weekend traffic.

3.1 Modal split commuters and work related travel

With the baseline model, it was determined that the factor of annoyance (F_a)would need to be around 1.5. Figure 3.1 shows the baseline model predictions with F_a of 1.5 and the sensitivity test on the variable F_a. The variance test shows some deviance on the lower limit of the variable F_a. This is to be expected as the baseline model is set up to find a value of F_a that predicts car travel is the favorite option of the population. This deviation in the baseline model does not affect the results of the model, as will be shown in later plots. A full overview of the results and their variance for the 3 variables (factor of annoyance, reduction factor, and postponing penalty) is given in appendix B.

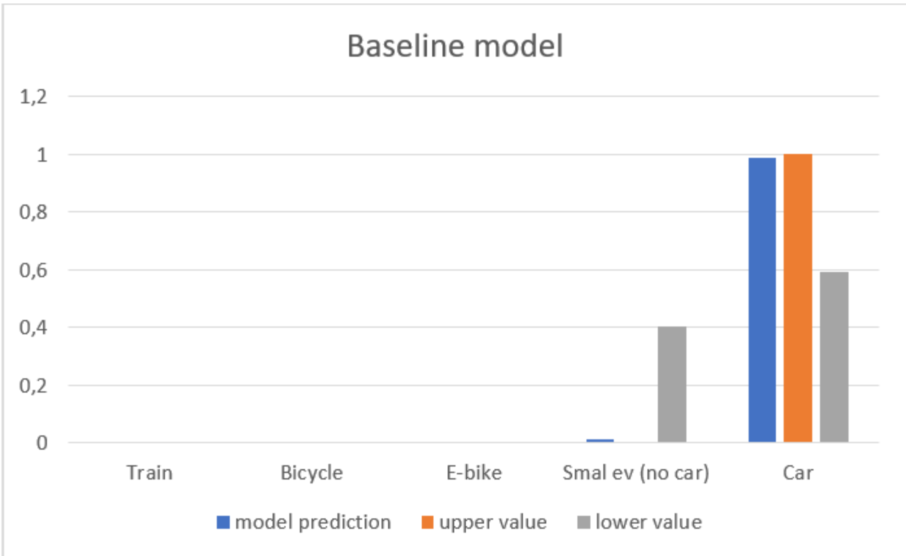

Fig. 3.1.: Logit model for work related and commuting traffic: Baseline and variance in factor of annoyance

According to the model, all those who are able (65 %) will work from home when car-free days are implemented. Those who do not have the option of working from home will use small electric vehicles and e-bikes. These are also not available to the entire population as the upfront cost is high. These people will take public transport. According to the model people who usually drive to work will not take a bicycle.

Postponing the trip is by far the least favorite of the options as the cost of missing a day's work is just too high. Appendix A shows the structure of both models. Figure 3.2 shows how all those who have the option will work from home. The upper and lower value again show the variance in F_a.

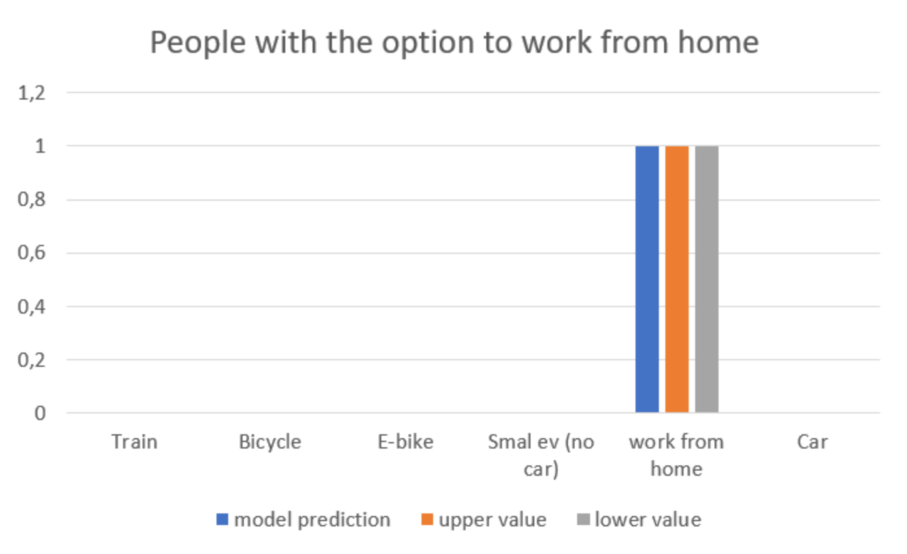

Fig. 3.2.: Logit model for work related and commuting traffic: People who can work from home and variance in factor of annoyance

The results show that all people who normally go to work by car and can work from home will do so on the day that the car-free day would be implemented. This would constitute a 20 to 30 % gain. According to the figures from Planbureau voor leefomgeving (PBL) currently between 40 and 45 % of people partially work from home [PBL21]. PBL states that between 65 and 70 % could partially work from home. These statistics are represented in figure 3.3 an figure 3.4

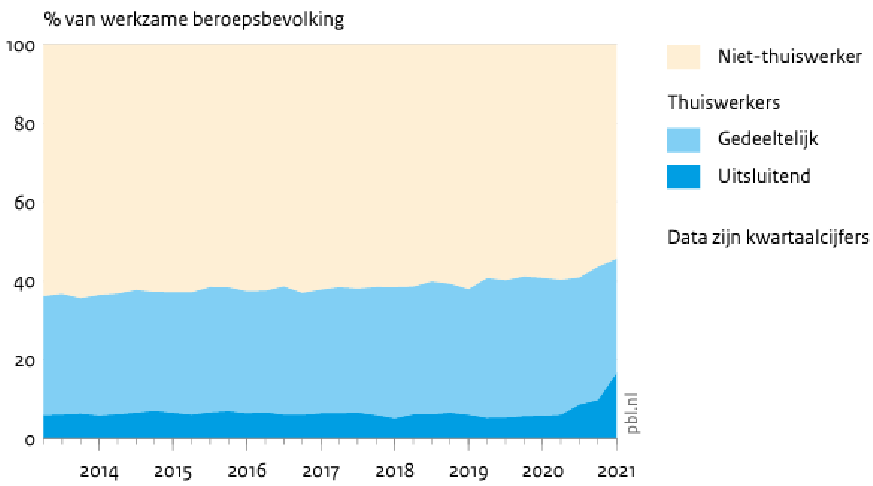

Fig. 3.3.: Percentage of people working from home: dark blue indicates people who work exclusively from home, light blue those who do so partially [PBL21].

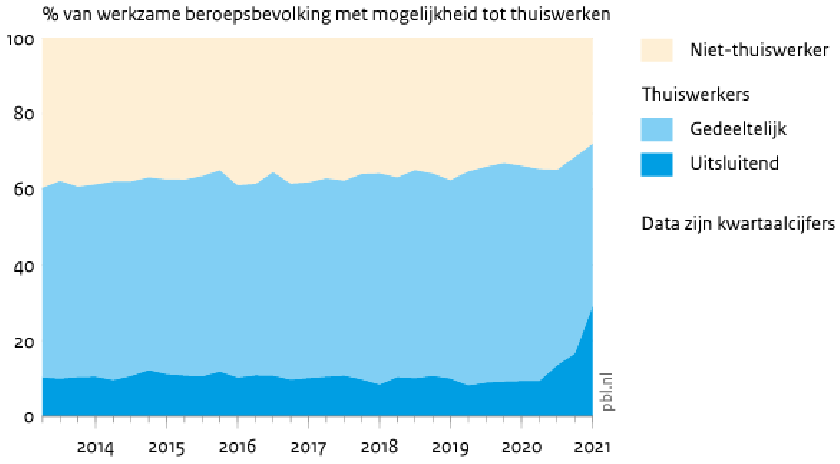

Fig. 3.4.: Percentage of people that can work from home: dark blue indicates people who can work exclusively from home, light blue those who can do so partially [PBL21].

3.2 Modal split recreational and personal travel

The baseline model indicated that for recreational travel the factor of annoyance should be higher, around 2.2. The model suggests that a significant fraction of the population would choose to postpone the trip. However this result is very sensitive to changes, so it is not reliable. Figure B.18 shows how the baseline value is stable under variation of the time penalty. This is logical as it is not included in this model. However figure B.19 shows how the predictions vary significantly when the time penalty changes.

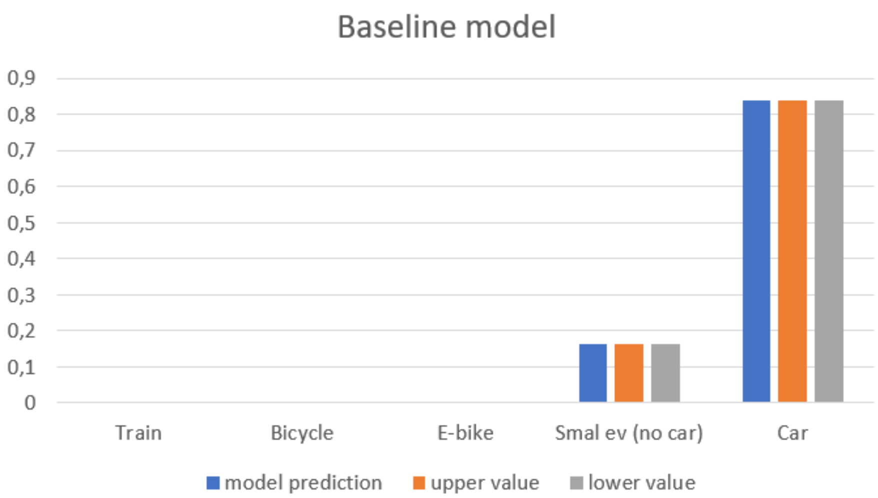

Fig. 3.5.: Logit model for recreational an personal traffic: Baseline model

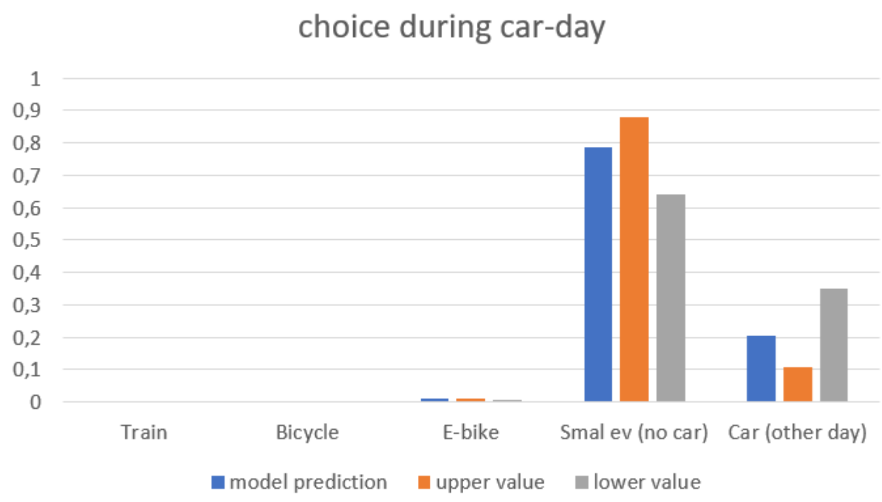

Fig. 3.6.: Logit model for recreational an personal traffic: Predictions

3.3 Road use data and differences during the week

As was mentioned in chapter 2.2 this research would require data on driver occupation and road occupancy. However, no such data was available so it was decided to analyze data from the NDW which gave road occupation based on length. The results of this data analysis are shown in Table 3.1.

Tab. 3.1.: Percentage-wise split of road use based on the length of the vehicle.

Length of the vehicle (meters)	percentage during week	percentage during weekend
1.85 - 2.40	0.63	0.65
2.40 - 5.60	75.37	87.92
5.60 - 11.50	7.98	4.14
11.50 and larger	13.66	5.48

The normal driving license held by a passenger car-driver (license class B) allows a maximum length of the vehicle of 12 meters. Thus it is assumed that section “11.5 and larger” represents freight transport. Furthermore, it is assumed that section “5.60 – 11.50” represents vans, section “2.40 -5.60” represents passenger cars, and section “1.85 – 2.40” represents motorcycles. Table 3.2 shows the change from week to weekend traffic according to these assumptions and the NDW data.

Tab. 3.2.: Change in vehicle type traffic from workweek to weekend.

Vehicle type	Change from week to weekend
Motorcycle	+ 3.08 %
Passenger car	+ 14.27 %
Van	- 92.75 %
Freight	-149.27 %

The data analysis shows that there is a significant decrease in van and freight traffic during the weekend. Following the reasoning from chapter 2.2 it is assumed that there is less work traffic during the weekends than during the work week.

4 Discussion and Conclusion

This chapter will reflect on the results. It will discuss the implications of the findings from the models and data analysis. In doing so this chapter will provide the answers to the research question and its sub-questions. For the ease of the reader the research question and its sub-questions are repeated here:

How do car-free days influence the modal choice of car users?

1. What different types of car users are there?
2. What alternatives do these car users have?
3. What is the generalised cost of alternatives the driver?
4. Is a work day or the weekend the best time to implement the policy?
5. Does the purpose of the driver affect his choice of alternatives and how?

Question 1 was answered in section 2.1.2. There were many ways to subdivide road users, but it was decided to divide road users into 3 categories: freight, work-related travel, and personal travel. For scoping reasons it was decided to not model the behavior of freight. It was assumed the cargo would need to be transported anyway, so there were no reductions to be made for this subsection.

The answer to question 2 was formulated in sections 2.1.2. The different options for the car drivers during a car-free day were required to formulate the logit model. Table 4.1 shows the options both types of car drivers have.

These first two questions mostly defined the scope of the study. The following questions required more research or computation to answer. Question 3 required setting up the value formulas of the logit model to start modeling the answers to

Tab. 4.1.: alternatives during car-free days for car drivers

Work related traffic	Personal traffic
Public transport	Public transport
Bicycle	Bicycle
E-bike	E-bike
Small Electric vehicle	Small Electric vehicle
Car (other day)	Car (other day)
Working from home	

the next questions. Table 4.2 repeats these formulas. The main difference between work-related traffic and personal traffic was the time penalty for taking the car and the value formula for public transport. These formulas are repeated respectively in formula 4.1 and 4.2.

Tab. 4.2.: Value formulas for work related traffic

Mode of transport	Value formula
Train	$V_t = VOT * F_a * (2,2 * T_{walking} + T_{train} + 13 * N_{conection}) + Cost$
Bicycle	$V_b = VOT * F_a * T_{bike}$
E-bike	$V_{e-b} = VOT * F_a * T_{e-b} + cost * distance$
Small electric vehicle	$V_{sev} = VOT * F_a * T_{e-v} + cost * distance$
Working from home	$V_{wfh} = cost$
Car (other day)	$V_{car} = VOT * T_{driving} + distance * cost + 0,8 * daywage$

$$V_{car} = VOT * T_{driving} + distance * cost + VOT * T_{planning} \tag{4.1}$$

$$V_{pt} = VOT * F_a * (2,2 * T_{walking} + T_{train}) + Cost \tag{4.2}$$

Lastly questions 4 and 5 required the model output to be answered. According to the model 20 to 30 % more people would work from home due to the implementation of the policy. The results of the model for personal travel were inconclusive, however. They suggest that personal travel is more easily delayed than work-related travel. Only, the results were very sensitive to changes in the chosen variables and thus unreliable. To fully answer question 4 more research on the perceived cost of delaying personal travel is needed (recommendations are further elaborated in chapter 5).

One thing that can be said is that there is significantly less freight transport during the weekend. If policymakers would like to minimize the disruption of this sector, weekend days would be the superior option. If further research indicates that personal travel is indeed more readily postponed this would mean that the greatest reductions in car use are to be found during the workweek. Thus, question 5 can also not be answered in full.

Therefore the main question can only be partially answered. The models show that car traffic will indeed be reduced. They also show that environmentally friendly alternatives are popular ones. The switch to these alternatives during car-free days would most likely reduce emissions. Although this needs to be researched further as this fell outside of the scope of this research paper. The behavior of work related traffic also seems to be different to that of personal traffic, but this needs to be further substantiated.

Recommendation

5

0ptIn this chapter recommendations for future research and the application of the acquired knowledge are laid out. It will discuss the unanswered questions of this report and how these could be answered in the future. After this chapter suggests how this information could be used.

0ptOne of the main shortcomings of this report is that a lot of data is collected from separate sources that don't necessarily have a one-to-one comparison. As was previously mentioned, it would be great if the logit model could be substantiated by a dataset that correlates the purpose of the driver with a whole host of properties. How far does the driver drive? How much does this cost the driver? How long does it take? A survey or other statistical test that could generate such data would greatly improve the reliability of the research described in this report.

0ptA second factor that decreases the reliability of the results in this paper is the assumptions on the perceived cost of having to delay a trip or to use alternative modes of transportation. It would be very useful to have a survey that can assess how much postponing a trip bothers people. A possible way of doing this is to ask the following question to car drivers: "Say you had a choice. You want to make a certain trip and you have two options. Either you can go today, but you have to go by this alternative or you can go tomorrow by car. How much would someone need to pay you to choose the first option?" One could repeat this for several alternatives. This would put a monetary value on the reluctance of drivers to use alternative modes of transportation.

0ptThirdly one should investigate the impact on freight. Would logistics companies choose alternatives to trucking? Are these alternatives less harmful to the environment? Could these measures cause congestion due to the displacement of freight to different days? Can a more local application of the policy have a similar effect on emissions with less interference with freight? The answers to these questions can greatly impact the decision on car-free days.

0ptLastly, this report did not look into the actual fuel consumption and emissions reductions that can be caused by car-free day policies. When the effect of the policy is predicted with a higher certainty it is valuable to actually quantify these possible savings. One can imagine that a transfer to small electric vehicles can increase the demand for electricity. How does this factor into the environmental impact? Questions such as these should be answered to be able to make an informed decision on the possible implementation of the proposed policy.

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Appendix A: Logit model

A

Annoying factor	Distance (km)	Vot (euro/min)	sensitivity factor	shortening factor
1,5	35	0,3	1	0,8

car drivers do not like to use other tp

reduced distance for (E-)bike and smal ev

cost train is total

cost is partialy reinburced by employer

Transport method	speed (km/min)	cost (euro/km)	value formula	value	mu*exp(value)	distribution
Train	2	6,806	Vt = Vot*anoying factor*(2,2*Twalking + Ttrain + 13*Nconection) + Cost	-45,281	2,16128E-20	1,568E-10
Bicycle	0,2	0	Vb = Vot * anoying factor * Tbike	-63	4,35961E-28	3,163E-18
E-bike	0,416666667	0,177	Ve-b = Vot*anoying factor*Te-b + cost*distance	-36,435	1,50135E-16	1,089E-06
Smal ev (no car)	0,75	0,3	Vsev = Vot*anoying factor*Te-b + cost*distance	-27,3	1,39239E-12	0,0101007
Car	1,333333333	0,424	Vcar = Vot*Tdriving + distance*cost	-22,715	1,36459E-10	0,9898982

Car free day introduced

Delay factor
0,8

cost train is total

cost WFH is total

cost is partialy reinburced by employer

Transport method	speed (km/min)	cost (euro/km)	value formula	value	mu*exp(value)	distribution
Train	2	6,806	Vt = Vot*anoying factor*(2,2*Twalking + Ttrain + 13*Nconection) + Cost	-45,281	2,16128E-20	4,341E-19
Bicycle	0,2	0	Vb = Vot * anoying factor * Tbike	-63	4,35961E-28	8,757E-27
E-bike	0,416666667	0,177	Ve-b = Vot*anoying factor*Te-b + cost*distance	-36,435	1,50135E-16	3,016E-15
Smal ev (no car)	0,75	0,3	Vsev = Vot*anoying factor*Te-b + cost*distance	-27,3	1,39239E-12	2,797E-11
work from home	\	3	Vwfh = cost	-3	0,049787068	1
Car	1,333333333	0,424	Vcar = Vot*Tdriving + distance*cost + 0,8*day wage	-137,915	1,27138E-60	2,554E-59

People who can not work from home

cost train is total

cost is partialy reinburced by employer

Transport method	speed (km/min)	cost (euro/km)	value formula	value	mu*exp(value)	distribution
Train	2	6,806	Vt = Vot*anoying factor*(2,2*Twalking + Ttrain + 13*Nconection) + Cost	-45,281	2,16128E-20	1,552E-08
Bicycle	0,2	0	Vb = Vot * anoying factor * Tbike	-63	4,35961E-28	3,131E-16
E-bike	0,416666667	0,177	Ve-b = Vot*anoying factor*Te-b + cost*distance	-36,435	1,50135E-16	0,0001078
Smal ev (no car)	0,75	0,3	Vsev = Vot*anoying factor*Te-b + cost*distance	-27,3	1,39239E-12	0,9998922
Car	1,333333333	0,424	Vcar = Vot*Tdriving + distance*cost + 0,8*day wage	-137,915	1,27138E-60	9,13E-49

No ev

cost train is total

cost is partialy reinburced by employer

Transport method	speed (km/min)	cost (euro/km)	value formula	value	mu*exp(value)	distribution
Train	2	6,806	Vt = Vot*anoying factor*(2,2*Twalking + Ttrain + 13*Nconection) + Cost	-45,281	2,16128E-20	0,0001439
Bicycle	0,2	0	Vb = Vot * anoying factor * Tbike	-63	4,35961E-28	2,903E-12
E-bike	0,416666667	0,177	Ve-b = Vot*anoying factor*Te-b + cost*distance	-36,435	1,50135E-16	0,9998561
Car	1,333333333	0,424	Vcar = Vot*Tdriving + distance*cost + 0,8*day wage	-137,915	1,27138E-60	8,467E-45

No E-bike

cost train is total

cost is partialy reinburced by employer

Transport method	speed (km/min)	cost (euro/km)	value formula	value	mu*exp(value)	distribution
Train	2	6,806	Vt = Vot*anoying factor*(2,2*Twalking + Ttrain + 13*Nconection) + Cost	-45,281	2,16128E-20	1
Bicycle	0,2	0	Vb = Vot * anoying factor * Tbike	-63	4,35961E-28	2,017E-08
Car	1,333333333	0,424	Vcar = Vot*Tdriving + distance*cost + 0,8*day wage	-137,915	1,27138E-60	5,883E-41

Fig. A.1.: Logit model for work related and commuting traffic

Annoying factor	Distance (km)	Vot (euro/min	sensitivity factor	shortening factor
2,5	10	0,3	1	0,8

car drivers do not like to use other tp method

reduced distance for (E-)bike and smal

Transport method	speed (km/min	cost (euro/km)	value formula	value	mu*exp(value)	distribution
Train	2	2,581	Vt = Vot*anoying factor*(2,2*Twalking + Ttrain) + Cost	-22,831	1,21513E-10	4,982E-07
Bicycle	0,2	0	Vb = Vot * anoying factor * Tbike	-30	9,35762E-14	3,836E-10
E-bike	0,416666667	0,177	Ve-b = Vot*anoying factor*Te-b + cost*distance	-16,17	9,4942E-08	0,0003892
Smal ev (no car)	0,75	0,3	Vsev = Vot*anoying factor*Te-b + cost*distance	-11	1,67017E-05	0,0684709
Car	1,333333333	0,614	Vcar = Vot*Tdriving + distance*cost	-8,39	0,000227127	0,9311394

Introduction car free day

Time to plan	10

Transport method	speed (km/min	cost (euro/km)	value formula	value	mu*exp(value)	distribution
Train	2	2,581	Vt = Vot*anoying factor*(2,2*Twalking + Ttrain) + Cost	-47,581	2,16688E-21	7,71E-17
Bicycle	0,2	0	Vb = Vot * anoying factor * Tbike	-30	9,35762E-14	3,33E-09
E-bike	0,416666667	0,177	Ve-b = Vot*anoying factor*Te-b + cost*distance	-16,17	9,4942E-08	0,0033782
Smal ev (no car)	0,75	0,3	Vsev = Vot*anoying factor*Te-b + cost*distance	-11	1,67017E-05	0,5942684
Car	1,333333333	0,614	Vcar = Vot*Tdriving + distance*cost + Vot*Tplanning	-11,39	1,1308E-05	0,4023535

Fig. A.2.: Logit model for personal and recreational traffic

Tab. A.1.: Sources for the speed and cost of all evaluated alternatives.

Mode of transport	Average speed	Cost
Train	[NOS18]	[tre16]
Bicycle *	[CBS21]	No cost
E-bike *	[Kon22]	[18]
Small electric vehicle *	[War21]	[18]
Working from home	No speed	[Nib22]
Car (other day)	[Min22b]te	[18] and [Min22a]

Appendix B: Model output

B

B.1 Work related travel

B.1.1 Variance in factor of annoyance

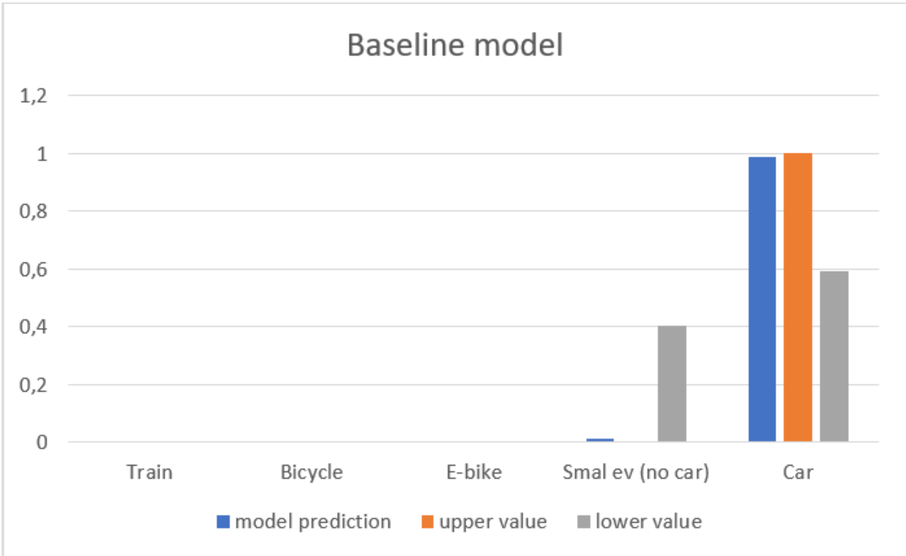

Fig. B.1.: baseline model

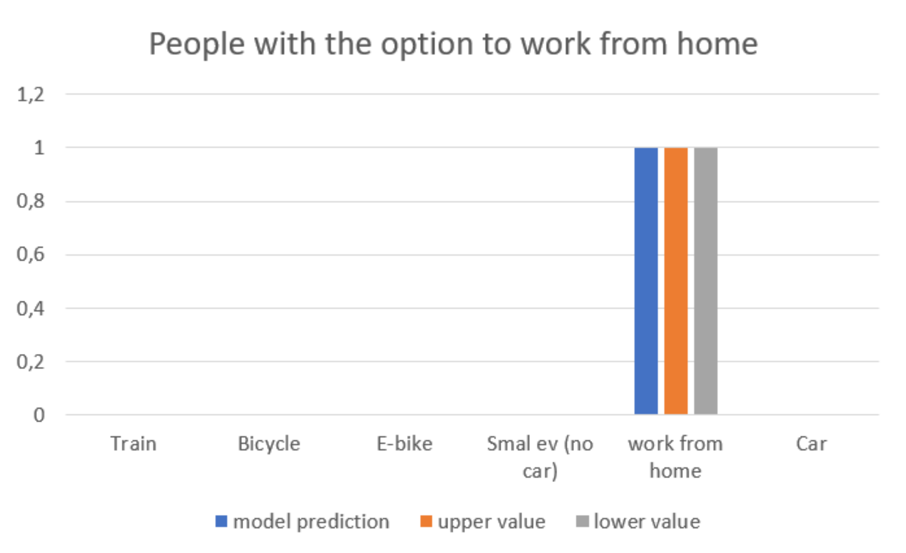

Fig. B.2.: working from home model

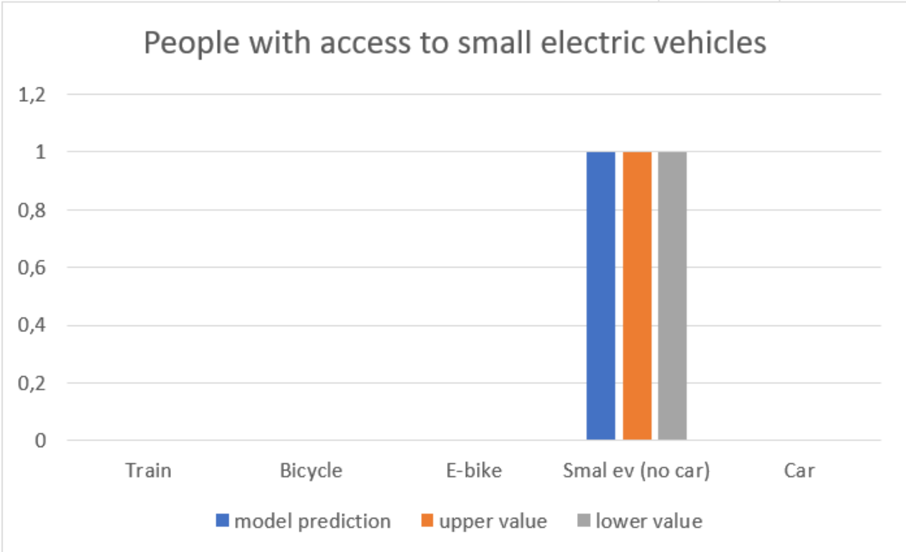

Fig. B.3.: ev model

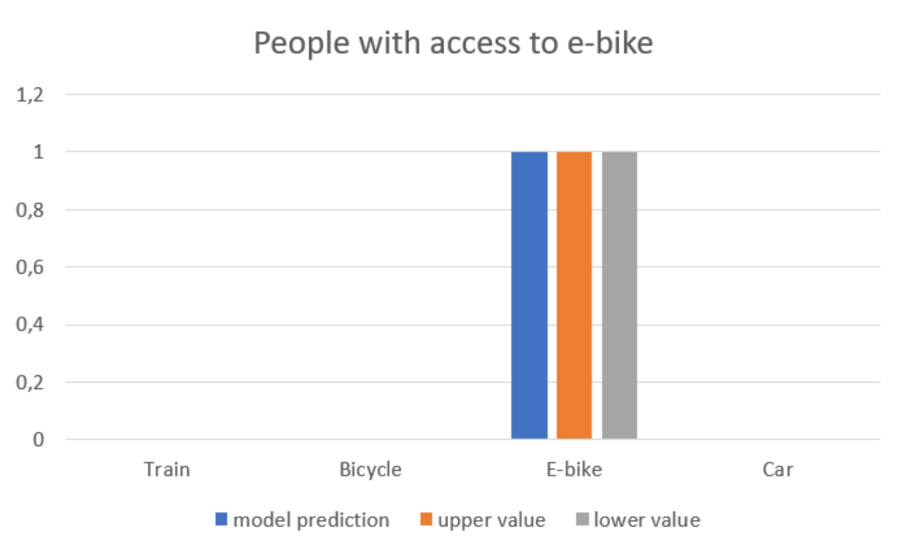

Fig. B.4.: e-bike model

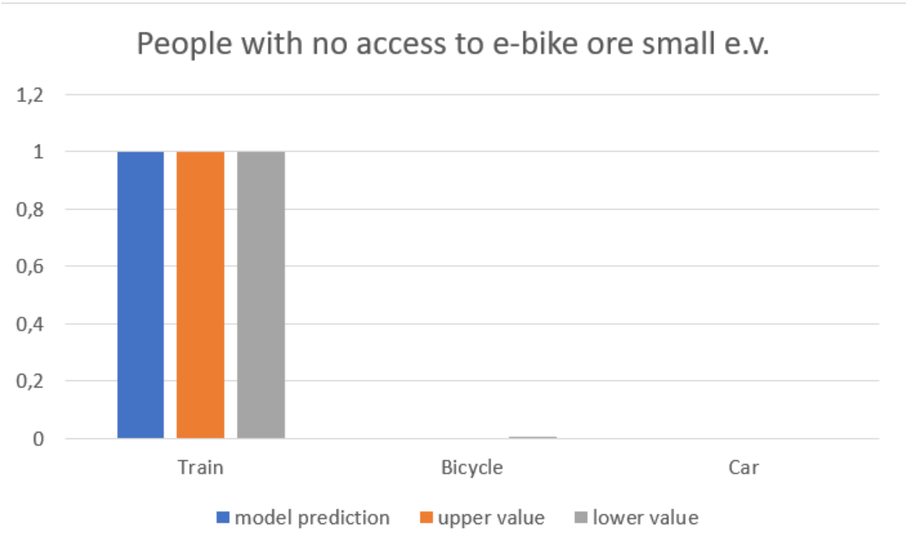

Fig. B.5.: Public transport model

B.1.2 Variance in time penalty

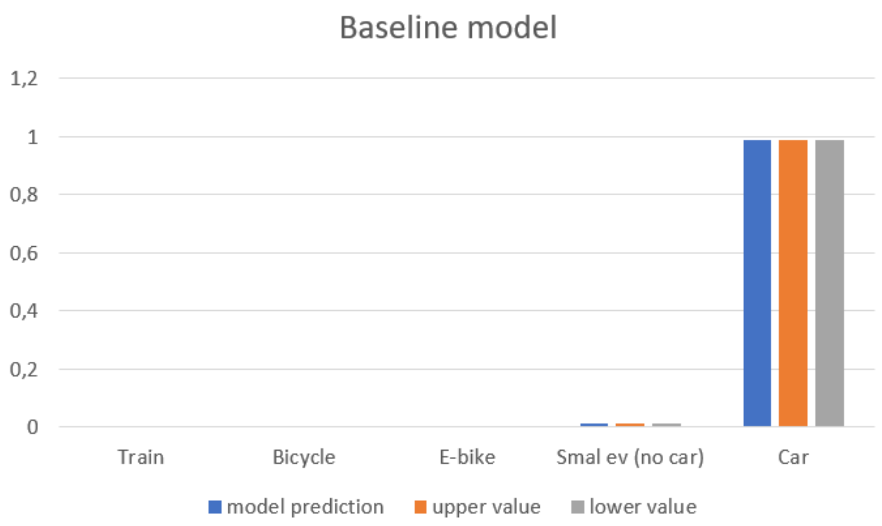

Fig. B.6.: baseline model

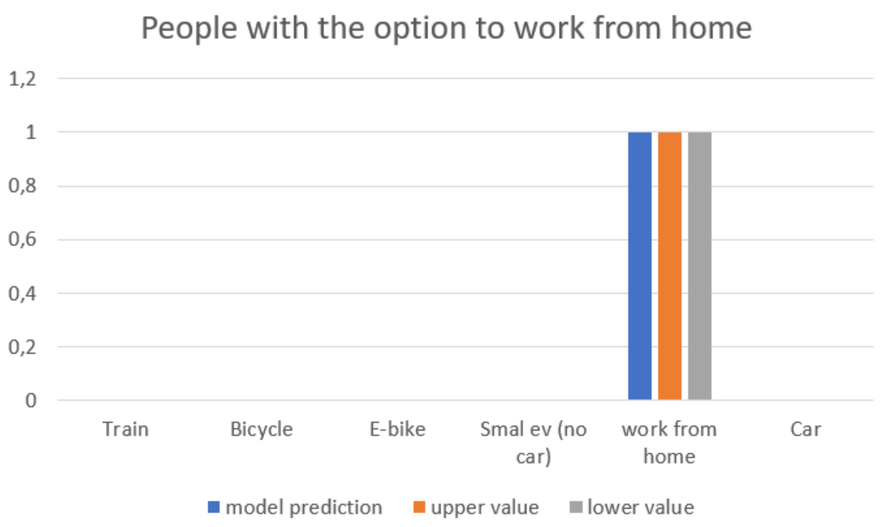

Fig. B.7.: working from home model

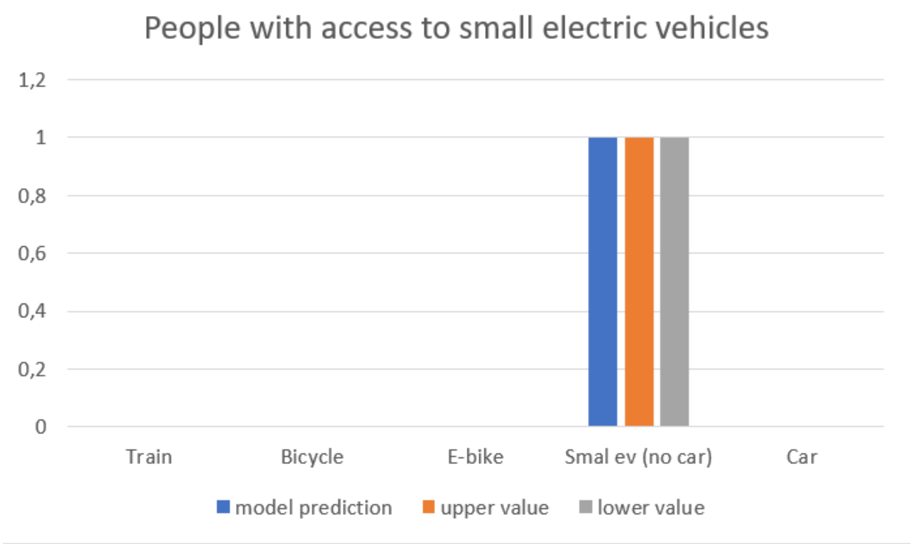

Fig. B.8.: ev model

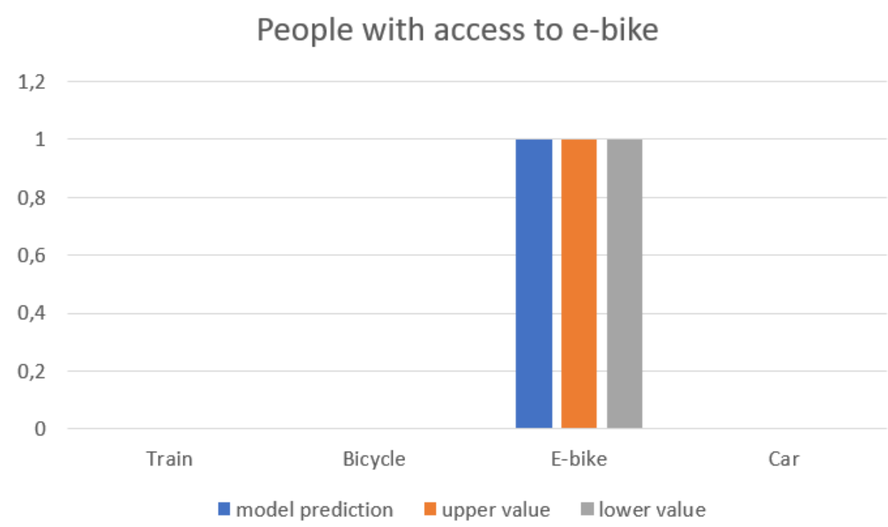

Fig. B.9.: e-bike model

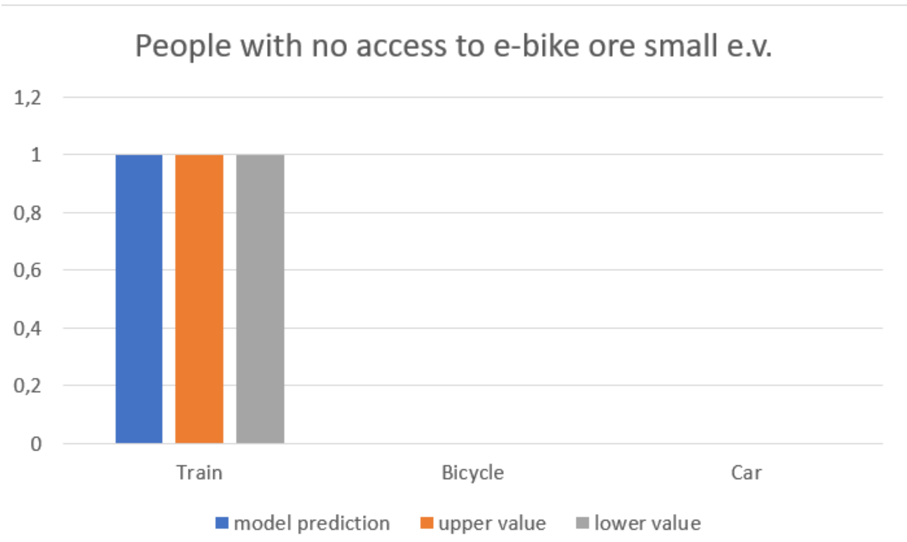

Fig. B.10.: Public transport model

B.1.3 Variance in distance reduction factor

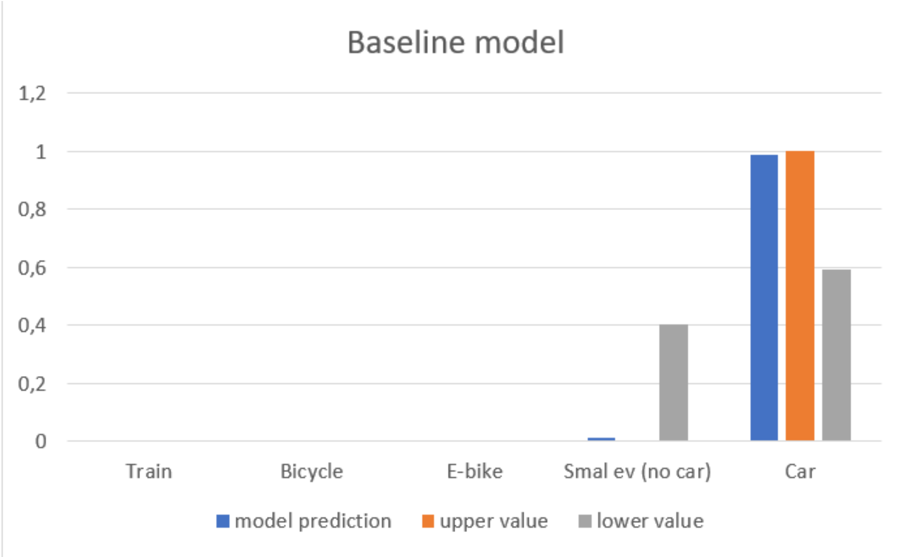

Fig. B.11.: baseline model

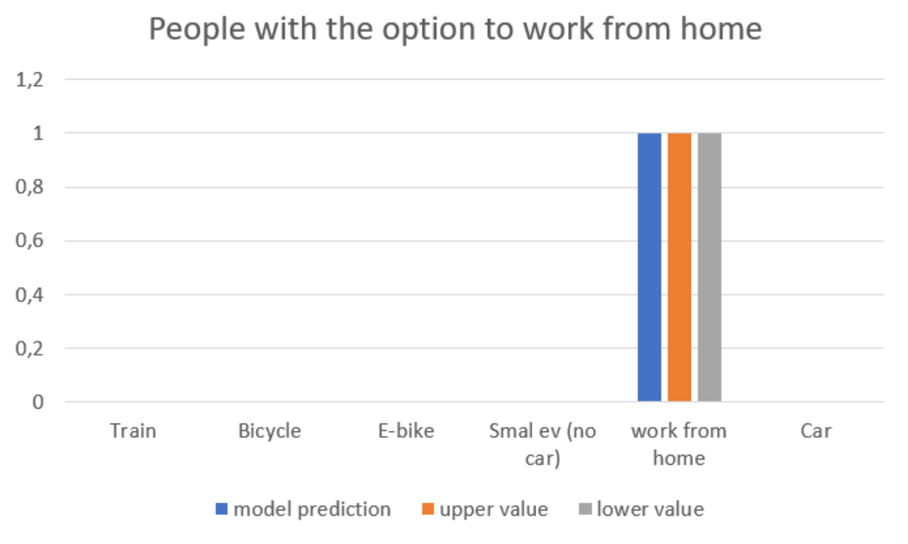

Fig. B.12.: working from home model

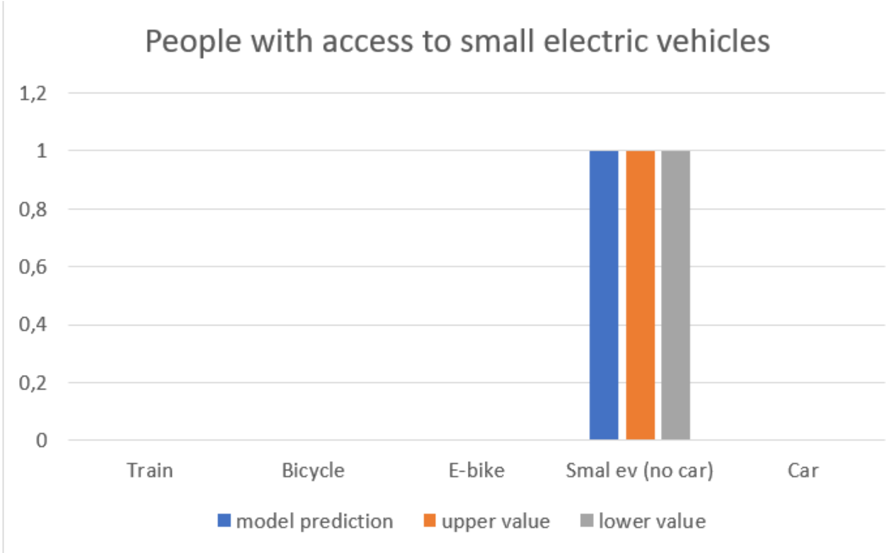

Fig. B.13.: ev model

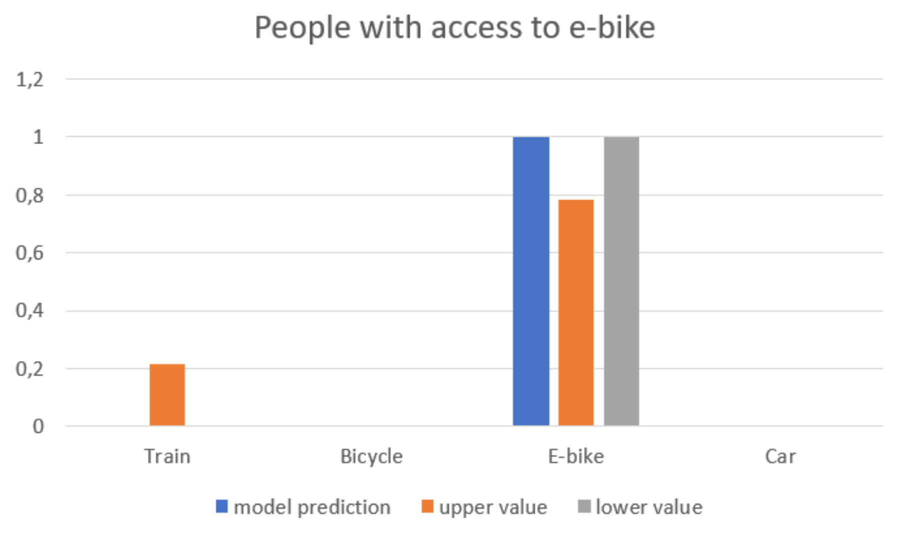

Fig. B.14.: e-bike model

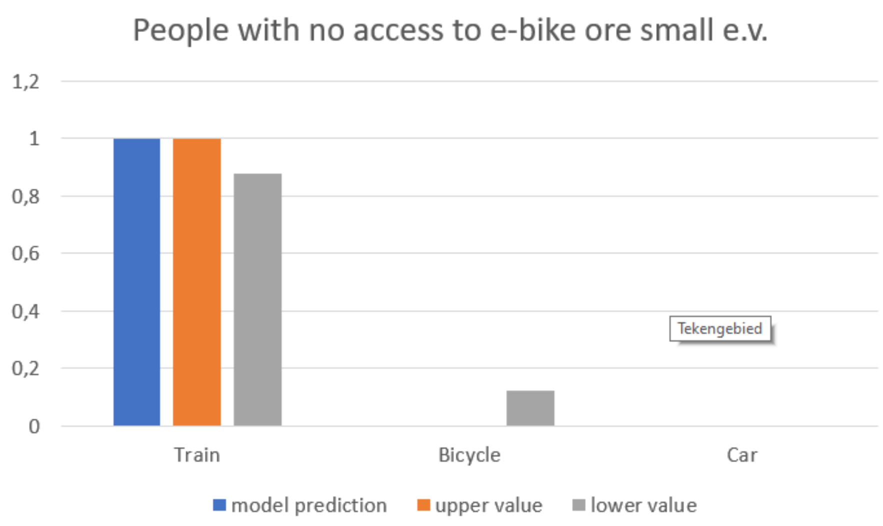

Fig. B.15.: Public transport model

B.2 Personal travel

B.2.1 Variance in factor of annoyance

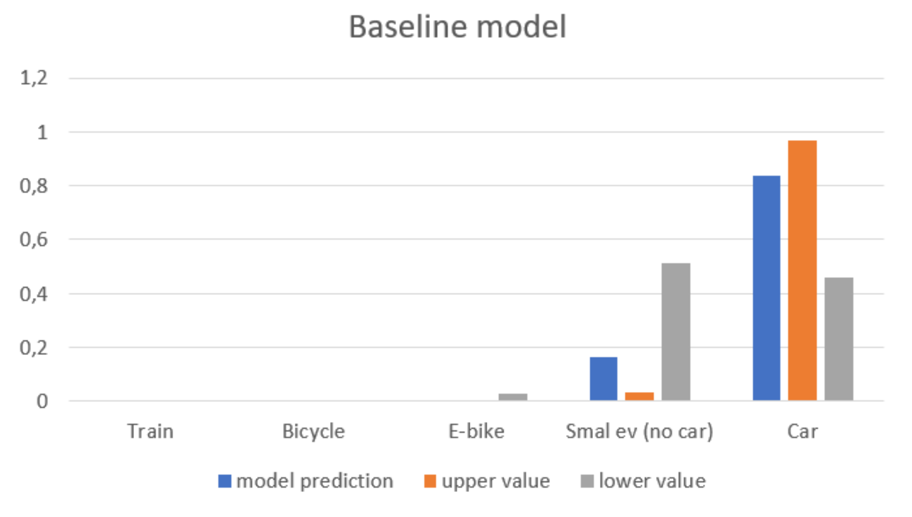

Fig. B.16.: Baseline model

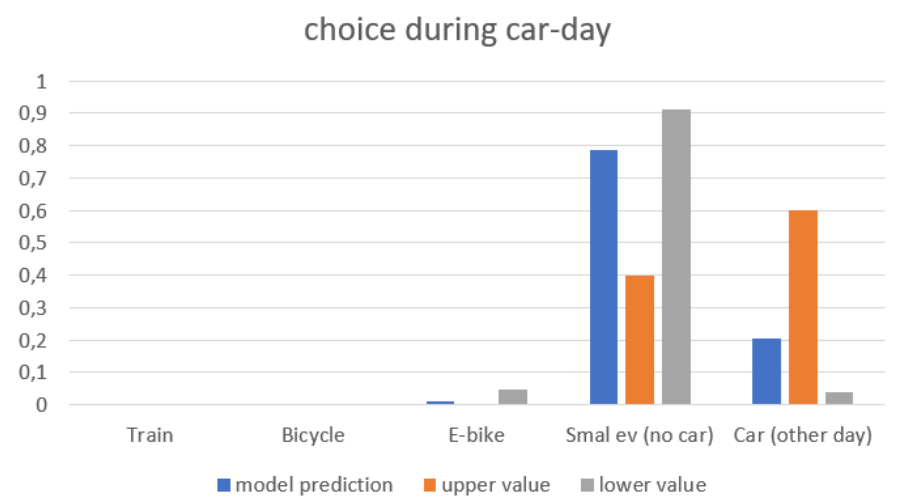

Fig. B.17.: Prediction

B.2.2 Variance in time penalty

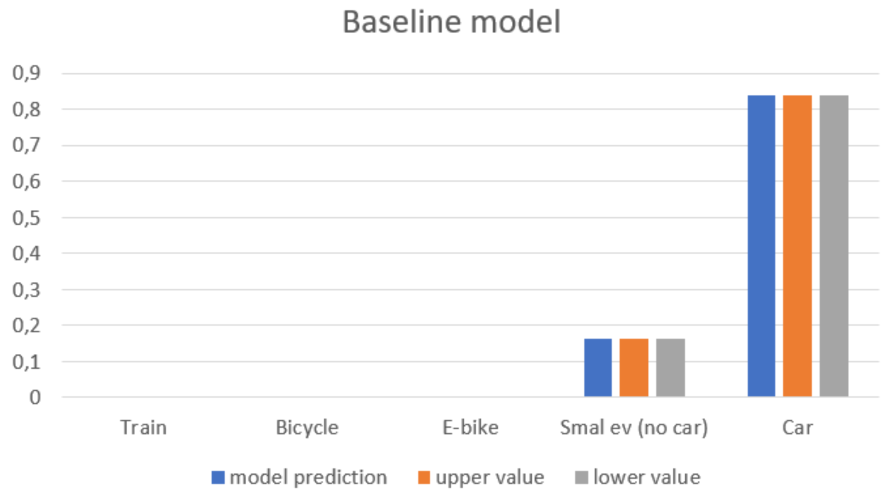

Fig. B.18.: Baseline model

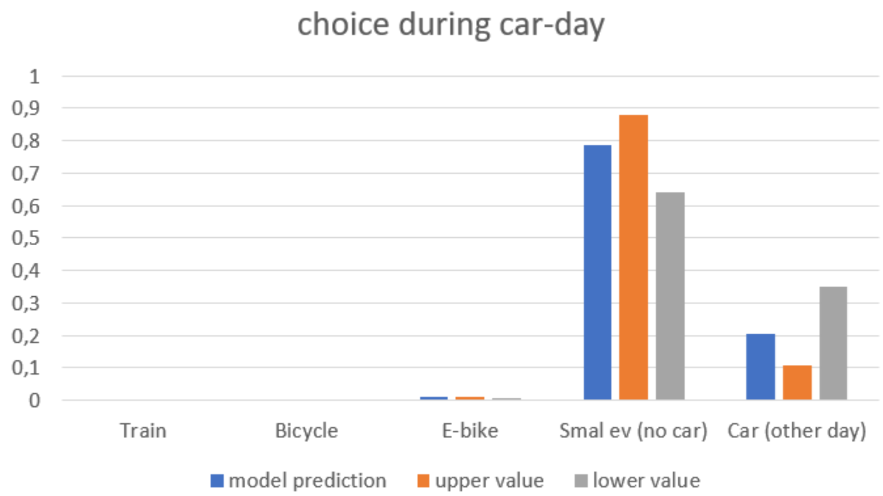

Fig. B.19.: Prediction

B.2.3 Variance in distance reduction factor

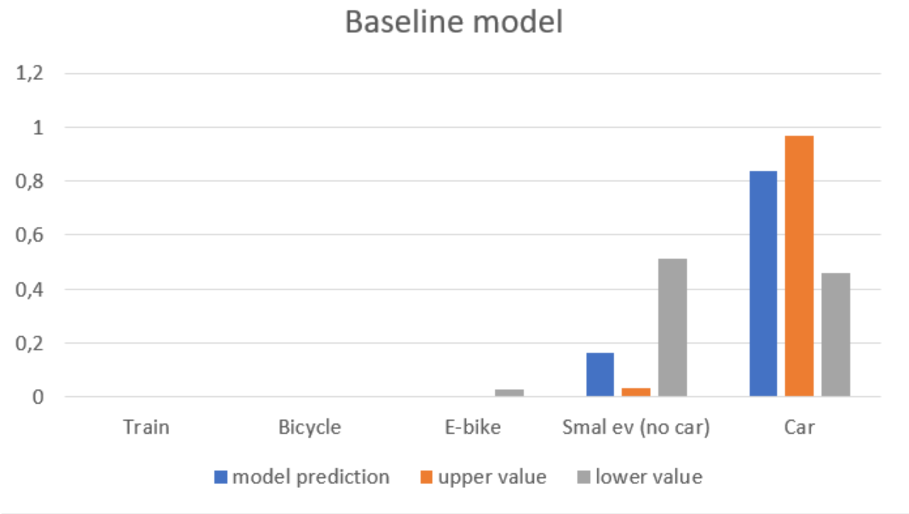

Fig. B.20.: Baseline model

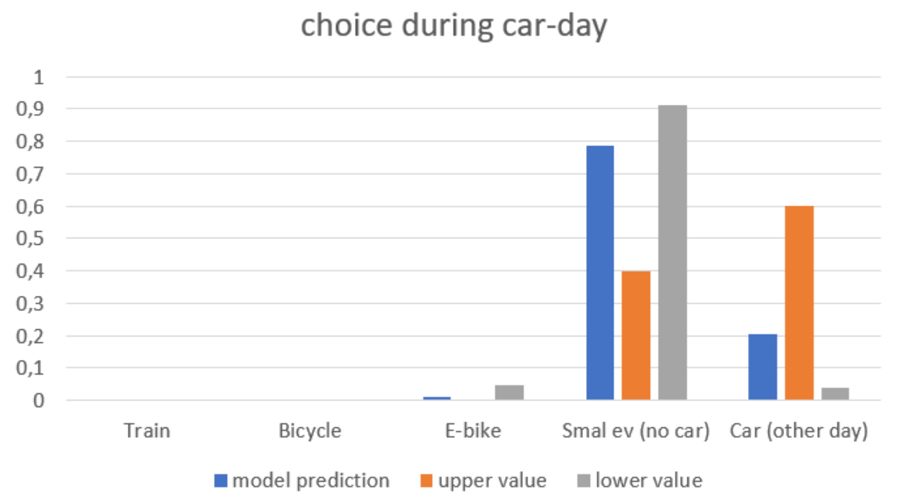

Fig. B.21.: Prediction