Shared Car Use in Bergen: A Driving Alternative

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GEO-SD 325 : Client Based Modelling

May 31, 2024

Table of contents

1. Introduction

In a world shifting towards a greener future, recent data has shown an increase in privately owned cars in Norway (Statistics Norway, 2024b). 87% of Norwegian households owned a car in 2018, with driving a car being the dominant mode of travel (Rokseth et al., 2021). An explanation for this increase in private cars could be the population growth of roughly 1.1% that Bergen has experienced in the last decade, with future projections indicating continued growth of the population and with that the likelihood of more private cars (OECD, 2022; Statistics Norway, 2022). An alternative to private car use should be considered to decrease the necessity of owning one. Car sharing is a concept where people can rent locally available cars at any time (Frenken, 2013). Car sharing was first introduced in Norway in the 1990s but has increased in recent years (Wangsness, Ciccone, & Nenseth, 2023). However, a problem may arise when the car sharing services grow and the increase in buying private cars continues. This leads to the problem statement: *How can individuals be incentivized to use shared cars as an alternative in Bergen?*

The goal of the project is to build a model that replicates the behaviour of the real-life circumstances of car sharing in Bergen. This is part of a directive from Klimapartnere Vestland to increase the use of shared cars in Bergen and Vestland as an effort to get Vestland to net zero emissions. The simulation will run until the year 2050 in order to visualise the long term impacts of car sharing. Model simulations will offer a clearer understanding of what drivers encourage people to use car sharing services and the main factors that discourage people from using them. Therefore, the System Dynamics method is deemed appropriate for this problem as it is dynamic, meaning that it is changing over time. The model represents historical data while also providing results in different sets of realistic political and cultural environments. This ensures that we have a more complete understanding of shared car use in Bergen.

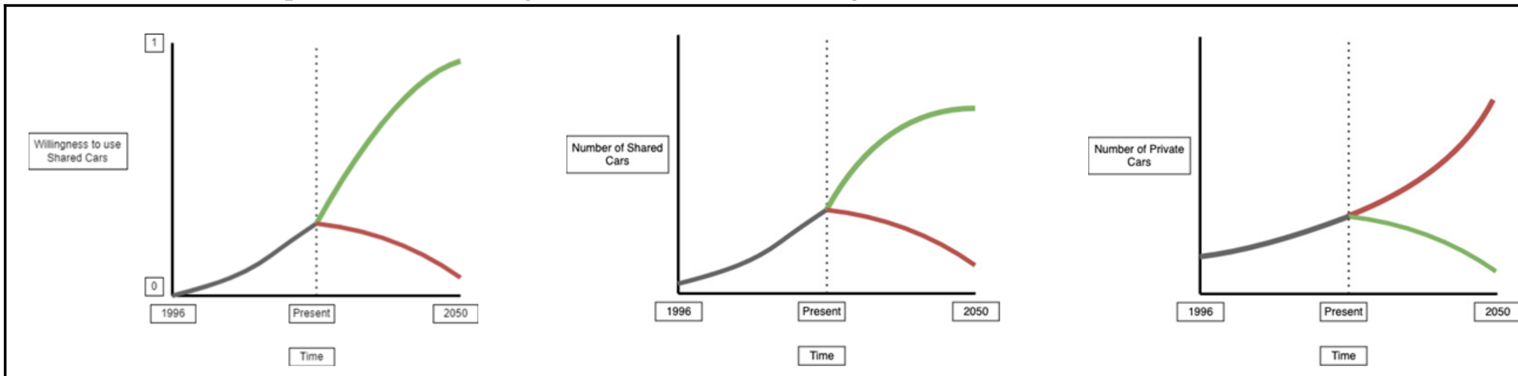

Figure 1: Key Performance Indicators (KPIs)

The key performance indicators (KPIs) for this model are Willingness to use Shared Cars, the Number of Shared Cars, and the Number of Private Cars, see Figure 1. Shared cars have been increasing over time (Wangsness, Ciccone, & Nenseth, 2023), the green line depicts a desired trend where shared cars will increase to the capacity as defined by available spaces in Bergen. The fear is that shared cars will decrease, see the red line. Congruently, the number of private cars have also increased in Bergen (Statistics Norway, 2024b). The fear is that this trend will continue, but the hope is that with more shared cars, the number of private cars will begin to decrease. Lastly, the Willingness to use Shared Cars has been increasing (Nenseth, 2019; Nenseth & Ellis, 2022). This willingness is hoped to rise until nearly all people are willing to use a shared car instead of a private car. It is feared that shared cars do not catch a lasting foothold and people will discard them.

2. Dynamic Hypothesis

The following Hybrid Stock Flow Diagram (HSFD) introduces the loops that most significantly impact the model. This model was built using information from government reports, statistical databases, and academic sources. Two sources that proved especially helpful in the model conceptualization include Struben and Sterman (2008), and interviews with the client Rørslett Johansson (2024). Struben and Sterman built a system dynamics model looking at the innovation, diffusion of electric vehicles. Meanwhile, Rørslett Johansson has introduced the overall concept of car sharing in Bergen and has confirmed the causal structure of the model.

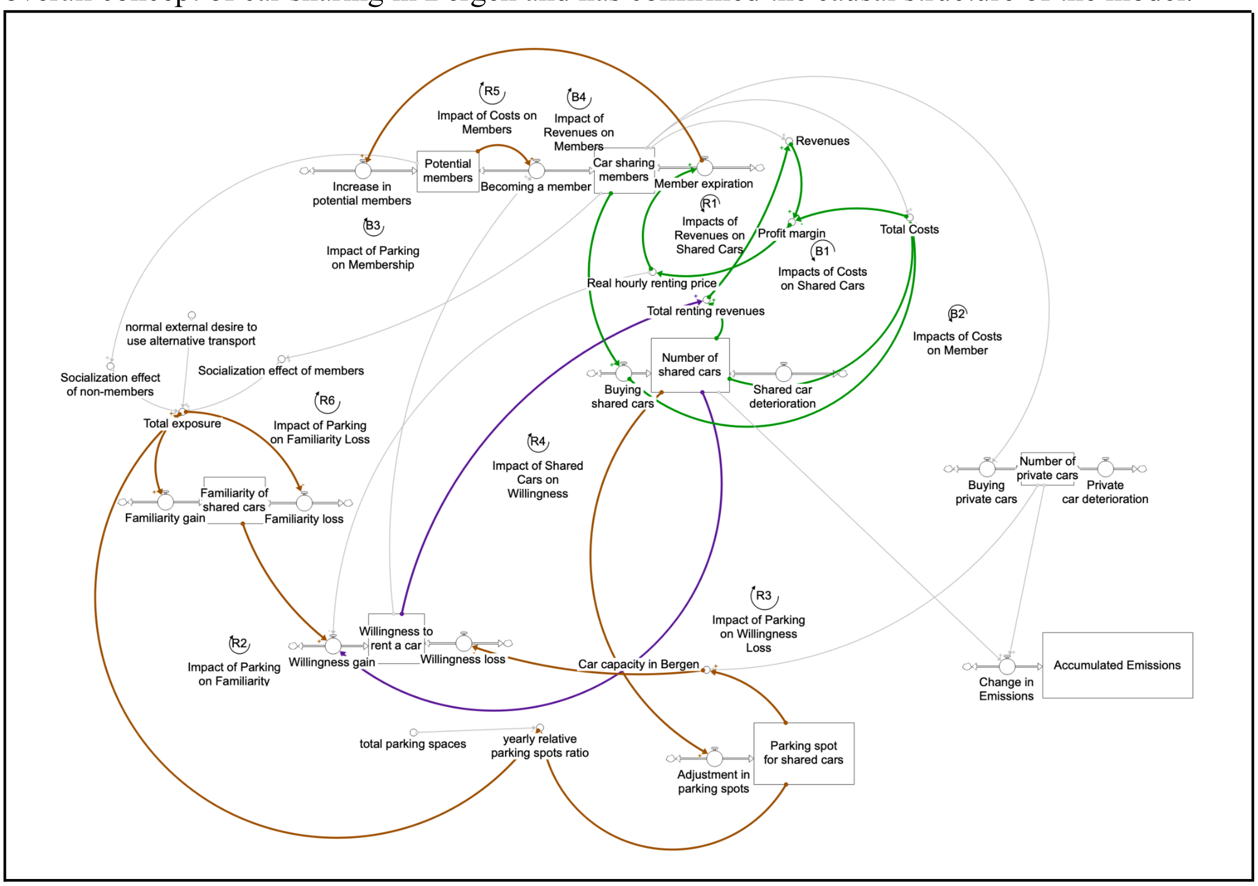

Figure 2: Hybrid Stock Flow Diagram of the Car Sharing Model

This model is most heavily influenced in two categories: Impactful Parking and Eye on the Money. <u>Impactful Parking Loops</u> incorporate reinforcing loops Impact of Parking on Familiarity (R2), Impact of Parking on Willingness Loss (R3) and Impact of Parking on Familiarity Loss (R6), and balancing loop Impact of Parking on Membership (B3). Loops R2 and R6 indicate how more shared cars leads to more spots for shared cars. With more spots, people are exposed more to shared cars as they see it around the city, increasing the "familiarity". With more "familiarity", people are more willing to rent shared cars and thus use them more. This increases the revenues, lowering the prices of renting a shared car which increases the number of total members as members are less inclined to leave as quickly as before. With more members, more shared cars are purchased and total shared cars increase.

R3 indicates that with more shared cars and more parking for shared cars, people remain more willing to rent a shared car as Bergen's capacity for private cars decreases. A lower capacity indicates more traffic and congestion. With more willingness to rent, shared cars are used more, increasing revenues, increasing members and further increasing the number of shared cars. B3 counteracts this by indicating that as revenues are increased due to more shared cars, prices are lowered ensuring less people leave, this results in a smaller pool of potential members, meaning that the increase in members is less than it would be otherwise. This leads to less shared cars to be bought than there would be otherwise because of a smaller increase in members.

The Eye on the Money Loops include reinforcing loops Impacts of Revenues on Shared Cars (R1) and Impacts of Costs on Members (R5). It also includes balancing loops Impacts of Costs on Shared Cars (B1), Impacts of Costs on Member Expiration (B2), and Impact of Revenues on Members (B4). The loops regarding revenues, R1 and B4, indicate that as there are more members, there are more shared cars, and therefore, more revenues leading to more members. In contrast, the loops regarding costs, B1, B2 and R5, indicate that as there are more members, there are more shared cars being bought, increasing the costs, leading to an increase in rental prices, and resulting in fewer members. The revenue and cost loops counteract each other to regulate the number of shared cars in the model.

Another loop that is impactful but not considered a part of either category is the reinforcing loop Impact of Shared Cars on Willingness (R4). As there are more shared cars, people are more willing to rent a shared car as it is more convenient. As such, shared cars are used more, increasing the total revenue and the total members, and resulting in more shared cars.

These loops were supported by a literature review and information from our client. It was apparent that new innovations are spread through word of mouth (Luan & Neslin, 2009; Struben & Sterman). However, the physical exposure to new innovations is also an important indicator of how innovations are spread (Ferreira et al., 2023; Struben & Sterman, 2008). There were barriers as people often lost willingness and familiarity with these new innovations regardless of how much they were exposed(Endo et al., 2017). This is particularly true for shared cars due to Norwegian cultural sense of independence (Rørslett Johansson, 2024; Wangsness et al., 2023). This information, along with the data gathered for the model, we were able to confirm causal structure to build our model.

3. Model Validation

To build confidence in the model and the simulation results, a series of tests were conducted. The model validation tests were introduced by Barlas in his paper *Model validation in System Dynamics* (1994). As seen in Table 1, there are parameters that are behaviourally sensitive.

However, they are supported by literature, or were calibrated to match existing data and match the reference mode of behaviour. A brief overview of the sensitivity analysis can be found in Table 1, for more information on the sensitivity analysis and the other model validation tests see Appendix B.

Sensitivity	**Parameters**	**Table functions**
Numerically	21	7
Behaviourally	8	2
Not sensitive	7	1

Table 1: The sensitivity analysis results

In the construction of the model, there were several assumptions made with the support of client information and literature review. Key assumptions in the model center around the table functions. Literature supports the direction and causal link of the table functions, but the shape was assumed through client discussion. Of these functions, only two proved to be behaviourally sensitive: Effect of Social Exposure on Forgetting, and Effect of Relative Hourly Price on Membership Time.

Other assumptions in the model are the rates in which people become members and stop being members, rate at which both shared and private cars are bought and deteriorated, and the rate at which familiarity and willingness are changed. These variables are calibrated to match the reference modes for this model. It has also been determined through a sensitivity analysis that many of these variables are only numerically sensitive. The eight behaviourally sensitive parameters were also used as a part of inserting the Foresight scenarios and policy recommendations into the model. The behaviourally sensitive variables and those used for scenario and policy implementation will be explained further in Appendix B.

4. Scenarios and Policies

Through a Foresight scenario development, it was identified that two major areas of high impact and high uncertainty surrounded the cultural and political environments. Discussions with Rørslett Johansson (2024) indicated that Norwegians valued driving private cars, but as a society, they are shifting towards shared transit alternatives. Additionally, Bergen and Vestland have politically been supportive of the transition to a greener society. Rørslett Johansson provided information that Bergen municipality helps to subsidise the tolls and parking fees for shared cars. It is possible that they will increase these subsidies even further (2024). However, the strong presence of the oil industry in Vestland can also introduce political resistance towards this green transition. This was coupled with finding sensitive parameters surrounding price and the change in willingness in the model. This created the foundation for scenario development. These scenarios were then implemented in the model using sensitive variables.

Policies were developed from conversations with Rørslett Johansson (2024). She indicated that Klimapartnere Vestland and Dele are looking to further market shared cars.

Klimapartnere Vestland are developing a campaign titled *Hele Vestland deler,* or All of Vestland shares. Meanwhile, the overarching goal of Klimpartnere Vestland is to cultivate private business partnerships. As such, it is very feasible that they could introduce a company partnership policy. Lastly, Dele has a model in which shared cars must be returned to the same spot. This is a barrier to use, as it is deemed more expensive and inconvenient (Rørslett Johansson, 2024). As such, a policy allowing cars to be parked throughout Bergen could make car sharing more appealing.

In the model, the marketing policy was inserted into the willingness gain inflow as the willingness sector was found to be sensitive. Meanwhile, company partnerships could be introduced by decreasing the threshold from willingness in becoming a member. This was a sensitive parameter and it was identified that through company partnerships, people more readily become members. Free-floating parking, an ability to park a shared car at multiple locations, could be introduced in the sensitive parking sector. As there were more parking spaces allocated to shared cars, people were more exposed in the familiarity section of the model. The scenario and policy stories will be discussed more specifically below.

Scenarios

Scenario 1: **Green Independence**

Society is pushing for a green future. Yet, individuals lean towards owning an electric vehicle as a sustainability choice rather than choosing shared transport. Bergen municipality reduces tolls for shared cars. Regardless, the community values the freedom of individual choice to travel as they see fit. The Norwegian inclination towards independence and personal mobility contributes to a low acceptance of shared transit. However, while people continue to buy private cars to replace older ones, they occasionally use shared cars instead of acquiring a second vehicle.

Scenario 2: **Green Tinted Glasses**

Driven by a strong public policy push for a greener future, the local government provides subsidies to diminish private car usage. Bergen municipality supports this by reducing tolls for shared cars, encouraging their adoption. Public sentiment favouring shared transit increases, leading to an increased willingness to use alternative transportation methods over private cars. As a result, there is a significant rise in shared car usage in Bergen.

Scenario 3: **Working Together Against the Odds**

Despite the public's high willingness to use shared transport, Bergen municipality resists incentivizing shared cars by maintaining tolls at the same level as private cars. This resistance is a result of the influence of the gas and oil industry in Vestland. Consequently, individuals seek other alternatives, like carpooling or public transit, instead of using shared cars.

Scenario 4: **Blindfolded to Reality**

With low willingness from the public to use shared transit and a resistance from Bergen municipality to incentivize shared cars in Bergen. Tolls are equal for shared and private cars, and people continue buying and using private cars, following the historical trend.

Policies

Marketing: With a marketing campaign, Dele can create awareness about the shared car concept and increase familiarity with Dele as a brand. This campaign is coupled by Klimapartnere Vestland's push for a more sharing community as part of their own campaign, *Hele Vestland deler*. This will increase the willingness of potential members to join, driving increased membership rates and fostering growth for Dele.

Company Partnerships: By collaborating with businesses in Bergen Municipality, businesses can offer their employees Dele car memberships instead of a private company car. This collaboration is expected to reduce the minimum required willingness to become a member and as a result, boost member acquisition for Dele.

Free-Floating Parking: With this policy, members can drive the shared car to different locations rather than returning it to the initial pick-up point. This concept requires that more parking spaces are needed for shared cars, reducing the capacity for private cars. This change provides increased freedom for the members and reduces pollution per kilometer per car by eliminating the need to backtrack to the initial pick-up location.

5. Policy Analysis

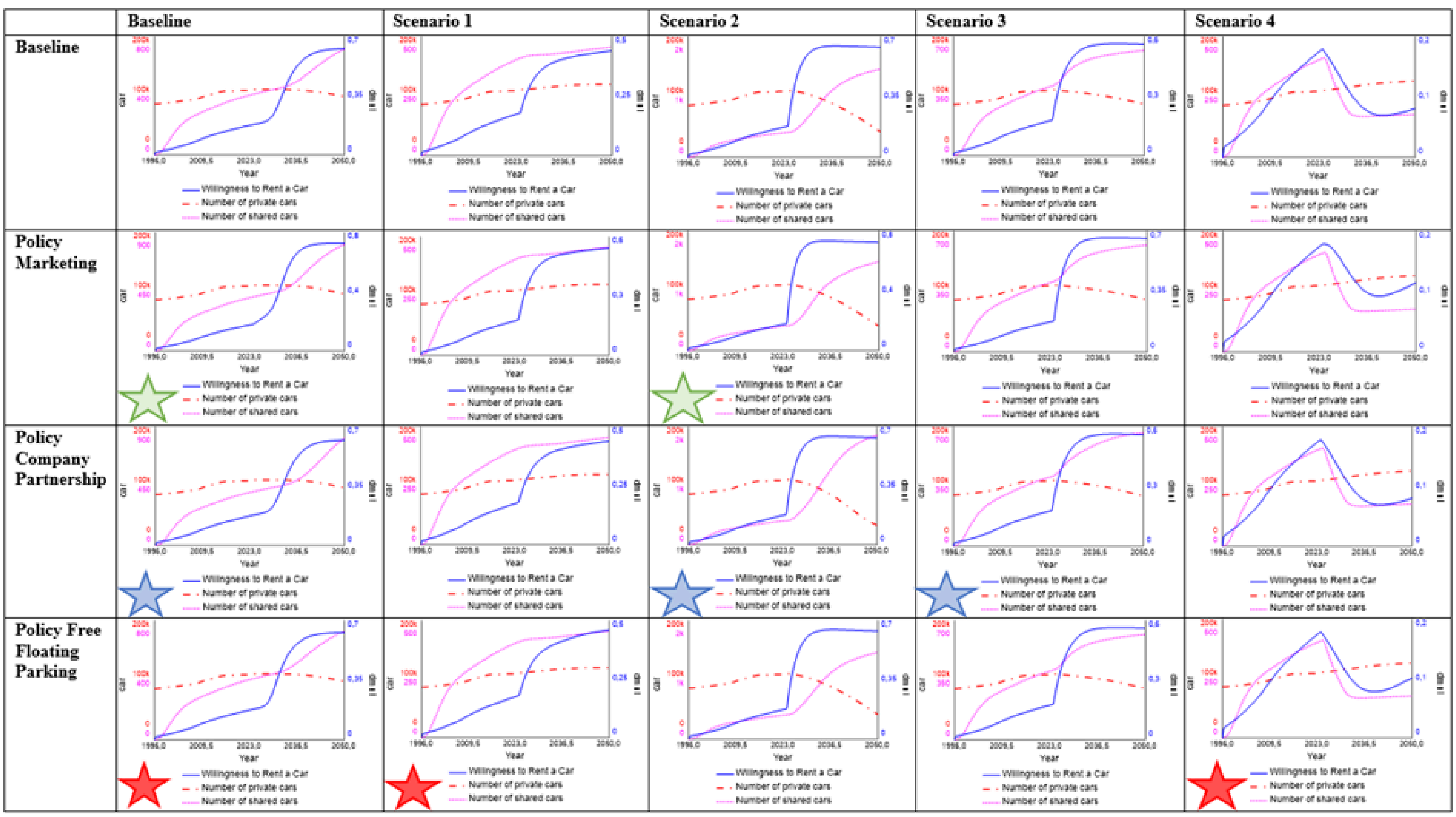

Table 2: Scenario and Policy Outcome Comparison

The three policies were all separately tested for the baseline scenario and with the four different scenarios activated. Table 2 gives an overview of the policy outcomes for each separate scenario.

The three KPIs are put together in one graph for each scenario. The solid blue line shows the "Willingness to rent a car" and has its values on the right Y-axis between 0 and 1. The red dashed-dotted line displays the "Number of private cars", and the dotted pink line depicts the "Number of shared cars". Both value ranges are shown on the left Y-axis with the range of private cars in red between 0 and 200.000, and the range of shared cars in pink between 0 and 2000. Throughout the various scenarios the policies either have a positive effect or no effect, none of the policies lead to worse results.

The marketing policy aims to increase the willingness of people to become a member and start using shared cars. It directly impacts the willingness gain, which is visible in the increase in "Willingness to rent a car" in all scenarios. When the willingness increases, more people will become members of the car sharing service. Through the increase in members, more shared cars will be purchased. This will lead to higher revenues, resulting in lower renting prices and longer membership times (see the Impact of Revenues on Shared Cars (R1)). The increase in shared cars means that more parking spaces need to be allocated towards shared cars. Seeing more shared cars in parking spaces throughout Bergen increases people's familiarity with the concept, also adding to the willingness and members (see the loop Impact of Parking on Familiarity (R2)). The allocation of parking space towards shared cars leads to less space for private cars, making the usage of shared cars more attractive, and decreases the willingness loss (see the loop Impact of Parking on Willingness Loss (R3)). This is especially noticeable when the Base Run and Scenario 2 are impacted by the marketing policy. The graphs are highlighted with a green star. Willingness and number of shared cars are higher and the number of private cars are lower in comparison to the runs without policy implementation for the respective scenarios. While the willingness to become a member increases in the other scenarios, the number of shared cars remains similar to that of the baseline. This is consistent with the circumstances of the other scenarios where shared car usage is not encouraged because of higher renting prices, this leads to lower membership time and less shared cars needed. Increasing the willingness does not rival the impact that prices have on becoming a member.

The company partnership policy introduces a collaboration between the shared car service and companies in the Bergen municipality. It affects the threshold that needs to be reached for the "willingness to become a member" to turn into actually becoming a member. If companies began a partnership with the car sharing service and offer a membership instead of a regular company car, it will lower the threshold and there will be more members, more shared cars and less private cars. The Baseline Run, Scenario 2 and Scenario 3 all show a higher number of shared cars and a lower number of private cars when influenced by this policy. This is seen when comparing the graphs highlighted with a blue star in comparison to the runs without policy implementation for the respective scenarios. The reinforcing loop R1 is dominant in the beginning. More members lead to more shared cars, higher revenues and lower renting prices, incentivizing people to extend their membership time. Eventually the reinforcing loops R2 and R3 take over to become dominant. The increase in shared cars means more parking spaces for shared cars and less for private cars, making it more convenient and accessible to use shared cars. The policy does not impact Scenarios 1 and 4. These are scenarios where the emphasis is on ownership of private cars and less on a sharing society, there is a lower willingness to use shared cars.

The free-floating policy aims to increase the allocated parking spaces for shared cars and to facilitate the “free-floating concept” where the car does not have to be brought to the renting place but can be left at a different location. This policy therefore aims to increase the parking spaces and, as a result, the willingness to become a member. The policy increases the willingness and the number of shared cars as compared to the Base Scenario. There is also an increase in willingness in Scenarios 1 and 4, however in these scenarios this does not lead to a noticeable increase in shared cars. The graphs representing these changes are highlighted by red stars in Table 2. In these scenarios the emphasis is on buying private cars instead of sharing cars. The reinforcing loop R2 is the dominant loop, which through the expansion of parking spaces increases the familiarity and willingness to become a member, and eventually more members. Through the reinforcing loop R1, more members leads to more shared cars, higher revenues and lower renting prices. Through the lower renting prices, members increase their membership time. This is however, not greater than in the scenarios with no policy implemented.

Looking at all the scenarios and all the policies, an increase in willingness does not automatically lead to a noticeable increase in shared cars or a decrease in private cars. In that case, if willingness is disregarded, the marketing policy only has a significant effect on the number of shared cars and a noticeable effect on the number of private cars in comparison to the Baseline Simulation, and a noticeable effect for both in Scenario 2. The free-floating policy only has a noticeable increasing effect on the number of shared cars when compared to the Baseline Scenario. The company partnership policy, however, has a significant effect on the number of shared cars when comparing to the Baseline Scenario, and Scenarios 2 and 3 without policies. This policy also lowers the number of private cars in Scenario 2.

When implementing policies, the combination of marketing and company partnerships, and a combination of all three policies results in the best possible outcomes, see Table 3. The combination of the company cars and free-floating policies is the next best fit, followed by the marketing and free-floating policies together. It should be noted that the company partnership policy both individually and in combination with other policies proved to consistently have the best outcomes. This includes a higher number of shared cars, a higher willingness to rent shared cars and a lower number of private cars as compared to the original scenarios.

Policies	Base	Scenario 1	Scenario 2	Scenario 3	Scenario 4
M	"+"	?	"+"	?	?
C	"+"	?	"++"	"+"	?
FF	"+"	?	?	?	?
M+C	"++"	"+"	"++"	"++"	?
M+FF	"+"	?	?	?	?
C+FF	"+"	?	"++"	"+"	?
M+C+FF	"++"	"+"	"++"	"++"	?

M = Marketing policy	? = No change
C = Company partnerships policy	"+" = Positive change
FF = Free floating policy	"++" = Super positive change

Table 3: The results of policy implementations for all scenarios

6. Recommendations and Conclusion

The most recommended policy implementation is to apply marketing and company partnership policies at the same time. This will have the most positive effect in all scenarios except Scenario 4, where only willingness is increased but not reaching the threshold required to have an effect on the number of shared or private cars. If only one policy is to be implemented, then the company partnerships policy should be applied. The combination of all three policies will have a similar impact as the marking and company partnership policy combination, but it would require more financial and administrative resources than that of only implementing two policies. The policy implementations show non-linear behaviour when more policies are implemented simultaneously. Therefore, it is recommended to implement two or more policies as they have a strengthening effect on each other.

Seeing as the main goal for Klimapartnere Vestland is to reduce emissions, this model also measures the emissions generated to provide added insight. Emissions measures the amount produced from both private and shared cars accumulated over time. Emissions were not a KPI for this model as it was the focus of the model to better understand how shared cars can be a preferred alternative to private cars. Yet, it was found that each scenario with each policy and policy combinations implemented produced a significant amount of emissions. In other words, shared cars do little to push Vestland toward a goal of net zero emissions. Total emissions from all policy outcomes can be seen in Figure 3.

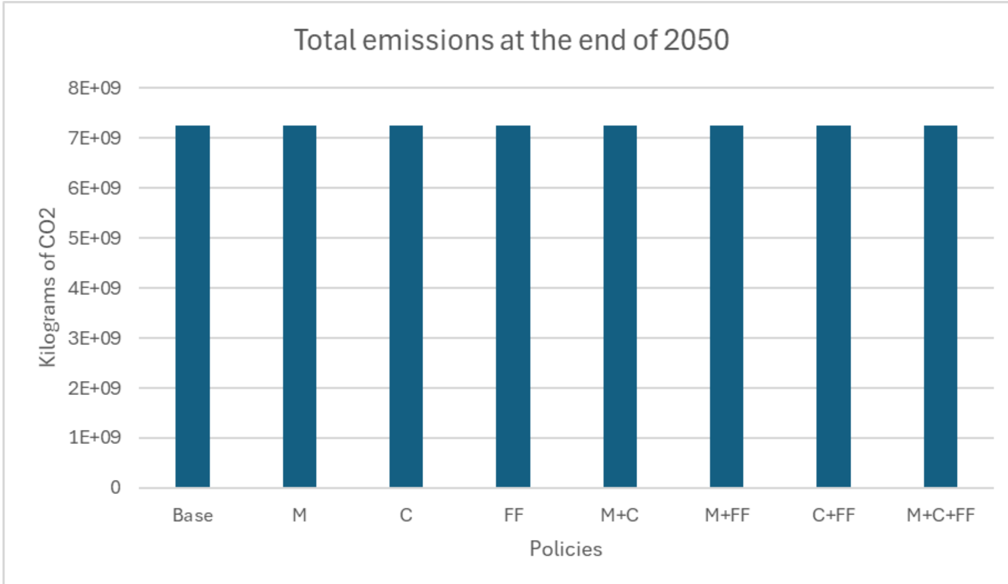

Figure 3: Total emissions from all policy implementations

The model was constructed to run up until 2050. Total population in Bergen is based on historical data until present time, and of projections until 2050. If the time horizon were to be extended, then the population in Bergen would keep the same number as that of 2050. When extending the time horizon, further projections would have to be implemented. The model could be further expanded with the addition of alternative public transit than shared cars, but given the time scale for this project, those parameters were kept outside of the model boundary. However, in consideration of emissions, it would be a useful factor to see how furthering public transit would prove beneficial to the overarching goal of net zero emissions. Additionally, the cost implementation of the policies can be another avenue for further research as Klimapartnere Vestland and its partners are looking to introduce net zero emissions under certain financial constraints.

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Appendix

Appendix A: Model documentation

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Cars:

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Additional_cars_needed = perceived_shared_cars_required-Number_of_shared_cars

UNITS: car

DOCUMENT: This variable represents the desired number of cars needed to be purchased. This is determined through a goal gap, or the difference between the perceived shared cars and the number of shared cars.

average_hourly_renting_price = 70

UNITS: kr/hour/car

DOCUMENT: This is the hourly renting price for a shared car. It is determined through calibration of a rental price within the prices currently set by Dele (2024).

Buying_private_cars = MAX(0, (private_car_purchases/Time_to_buy_private_car) + Private_cars_deterioration - (car_reduction/Time_to_buy_private_car))

UNITS: car/Year

DOCUMENT: This is the inflow into the stock of Number of private cars. This equation of the flow indicates that private cars are purchased as determined at the rate of increase of private car purchase divided by the time to buy a private car. Cars are also purchased to replace the private cars which are no longer in use, or have deteriorated. However, the number of new cars purchased will decline at a rate determined by car reduction divided by time to buy a private car. A MAX function is included to prevent the flow from going negative. The minimum number of cars that can be purchased per year is zero.

Buying_shared_cars = MAX(0, (Additional_cars_needed/Time_to_buy_shared_cars)*effect_of_relative_profit_margin_on_buying_shared_cars+shared_car_deterioration)

UNITS: car/Year

DOCUMENT: This is the inflow into the stock of Number of shared cars. This equation of the flow indicates that cars are increased at a rate of additional cars needed divided by time to buy shared cars. This rate is impacted by the effect of relative profit margin on buying shared cars. This effect determines that a fraction of additional cars needed will be purchased based on the profit margin. Buying shared cars is also increased by the shared car deterioration. Shared cars will be replaced once they are no longer used. A MAX function is included to prevent the flow from going negative. The minimum number of cars that can be purchased per year is zero.

car_reduction = Car_sharing_members*reduction_in_cars_bought_per_member

UNITS: car

DOCUMENT: This variable indicates that the number of private cars purchased will decrease based on the number of car sharing members and the rate of reduction in cars bought per member. This variable indicates that as more people use shared cars, fewer people will look to purchase a private car.

cars_per_capita = 0.64

UNITS: Car/person

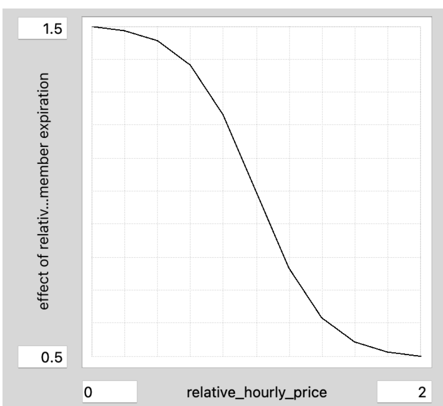
DOCUMENT: This value is based on the total vehicles per capita in Norway in 2020 according to data gathered by ACEA (2022). We assume this is a reasonable representation of cars per capita for the model as there has been trends of increasing cars per capita (ACEA, 2022).

Cost_per_new_car = 670000

UNITS: kr/car

DOCUMENT: This is an assumed value of what the typical car would cost for Dele. It is the value of the most expensive car in its current lineup, the Peugeot Traveller 9-Seater, in 2024 (Peugeot, 2024).

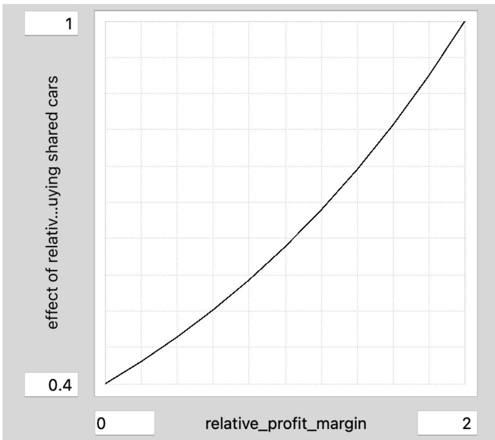
effect_of_relative_hourly_price_on_membership_time = GRAPH(relative_hourly_price)
Points: (0.000, 1.500), (0.200, 1.487), (0.400, 1.457), (0.600, 1.383), (0.800, 1.232), (1.000, 1.000), (1.200, 0.7676), (1.400, 0.6165), (1.600, 0.5434), (1.800, 0.5126), (2.000, 0.500)



UNITS: dmnl

DOCUMENT: This variable represents an effect function which indicates that relative hourly price has an effect on the indicated membership time. When relative hourly pricing is 1, the membership time would not be affected. However, an increase in the relative hourly pricing, or the price of renting a car becomes more expensive, the indicated membership time will increasingly decrease towards a minimum effect of 0.5. The membership time will be 50 percent less than it normally is, or people are members for half of the time they normally are. As the relative hourly price decreases, or the price of renting a car becomes less expensive, the indicated membership time will increase decreasingly towards a maximum effect of 1.5. The membership time will be 50 percent greater than it normally is, or people will be members 50 percent longer than they normally are. We base this shape and ranges on the assumptions of price dynamics of members. Through interviews with our client, she indicated that price was an important barrier to consider (Rørslett Johansson, 2024). Members would quickly stop or become less likely to be a member with prices, but when prices were lower, adoption would occur but slowly as many Norwegians prefer to drive private cars.

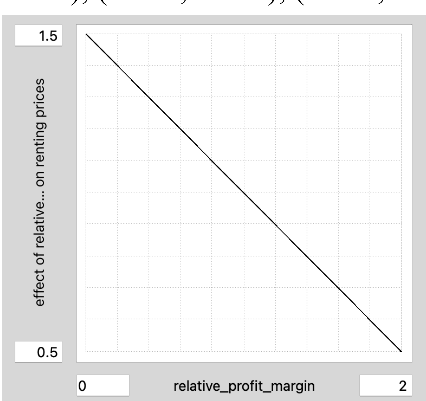
effect_of_relative_profit_margin_on_buying_shared_cars = GRAPH(relative_profit_margin)
Points: (0.000, 0.4000), (0.200, 0.4367), (0.400, 0.4773), (0.600, 0.5222), (0.800, 0.5717), (1.000, 0.6265), (1.200, 0.6871), (1.400, 0.7540), (1.600, 0.8279), (1.800, 0.9097), (2.000, 1.0000)



UNITS: dmnl

DOCUMENT: This variable is an effect function of relative profit margin on buying shared cars. When the relative profit margin is 0 and no profit is made, we assume the minimum effect to be 0.4. Some cars will continue to be purchased regardless but 40 percent of what is desired to be purchased to ensure that there are cars to be rented. Shared car purchases will increase increasingly as relative profit margin surpasses its 1 value. When profit margin is 2 or twice the reference profit margin, the effect on buying shared cars is 1. Shared cars will be purchased at the desired level. The effect will increase increasingly as shared cars can be more readily purchased.

effect_of_relative_profit_margin_on_renting_prices = GRAPH(relative_profit_margin)
Points: (0.000, 1.500), (0.200, 1.400), (0.400, 1.300), (0.600, 1.200), (0.800, 1.100), (1.000, 1.000), (1.200, 0.900), (1.400, 0.800), (1.600, 0.700), (1.800, 0.600), (2.000, 0.500)



UNITS: dmnl

DOCUMENT: This variable represents the effect of relative profit margin on renting prices. This indicates that at a relative profit margin of 1, the effect on renting prices is 1 or no effect. However, as the profit margin grows to a maximum of 2, rental prices will drop to a minimum of 0.5, or 50 percent of the original value. As profit margin decreases to zero, prices are increased by an effect of 1.5, or 50 percent greater than normal. The linear shape was chosen as the direction of the effect was confirmed, but the rate of change was uncertain. Additionally, through sensitivity analysis, this variable had little effect on the model.

high_hourly_renting_price = 120

UNITS: kr/hour/car

DOCUMENT: This is the hourly renting price with the scenario switch for a society that is unwilling to subsidize car sharing. This value was chosen as it was significantly higher than the indicated hourly renting price and it showed sensitivity in the model.

Hours_in_a_year = 8760

UNITS: Hour

DOCUMENT: These are the number of hours in a year.

Hours_per_year_in_use = Hours_in_a_year*utilization_rate

UNITS: Hour/year

DOCUMENT: This indicates how many hours in a year a shared car is used.

Initial_private_cars = 86000

UNITS: car

DOCUMENT: This is the initial number of private cars. It is the number of passenger cars per 1000 people in 1995 multiplied by the amount of people in Bergen in 1996.

Initial_shared_cars = 1

UNITS: car

DOCUMENT: This is determined by the car that started what is now Dele. It was one car shared amongst five families (Dele, 2024).

low_hourly_renting_price = 40

UNITS: kr/hour/car

DOCUMENT: This is the hourly renting price with the scenario switch for a society that is willing to subsidize car sharing. This value was chosen as it was significantly lower than the indicated hourly renting price and it showed sensitivity in the model.

Maintenance_costs_per_car_per_year = 100000

UNITS: kr/car/year

DOCUMENT: This is an assumed value which indicates the maintenance costs for a shared car per year. This is based on information from the client who mentioned that an average car requires 100000 NOK per year to maintain (Rørslett Johansson, 2024).

Members_per_car = 10

UNITS: person/car

DOCUMENT: We are basing this off of given information from our client. She noted that a Dele car replaces 10-15 private cars. If we assume that each car has one driver per member, we can say that one car equals 10 members (Rørslett Johansson, 2024).

No_Green_Scenario_SWITCH = 0

UNITS: dmnl

DOCUMENT: This is a switch that indicates a scenario in which the Bergen municipality is unwilling to further invest or subsidize in the green transition, especially when it comes to car sharing which it currently dolls through reduced tolls and parking costs (Rørslett Johansson, 2024). When this is one, the switch introduces a higher hourly renting price. When at zero, the indicated hourly renting price is used.

normal_reduction_in_cars_bought_per_member = 0.22

UNITS: car/person

DOCUMENT: Based on survey data, it was found in Oslo that on average a car sharing member leads to a reduction of somewhere between 0.22 and 0.45 privately owned cars (Wangsness et al., 2023). We assume that 0.22 cars are no longer bought per car sharing member as it is a more conservative yet reasonable assumption.

Normal_utilization_rate_shared_cars = 0.5

UNITS: dmnl/year

DOCUMENT: Through information provided by our client, it was indicated that shared cars are currently used up to 50 percent (Rørslett Johansson, 2024). This determined the normal utilization rate of a shared car.

Number_of_private_cars(t) = Number_of_private_cars(t - dt) + (Buying_private_cars - Private_cars_deterioration) * dt

INIT Number_of_private_cars = Initial_private_cars

UNITS: car

DOCUMENT: This is the stock, or accumulated number, of private cars. It is influenced by the inflow of buying private cars and the outflow of private cars deterioration. If the inflow were to increase/decrease, the stock would be greater than/less than it otherwise would be. If the outflow were to increase/decrease, the stock would be less/greater than it otherwise would be. The initial value is determined by the initial private cars.

Number_of_shared_cars(t) = Number_of_shared_cars(t - dt) + (Buying_shared_cars - shared_car_deterioration) * dt

INIT Number_of_shared_cars = Initial_shared_cars

UNITS: car

DOCUMENT: This is the stock, or accumulated number, of shared cars. It is influenced by the inflow of buying shared cars and the outflow of shared car deterioration. If the inflow were to increase/decrease, the stock would be greater than/less than it otherwise would be. If the outflow were to increase/decrease, the stock would be less/greater than it otherwise would be. The initial value is determined by the initial shared cars.

parking_per_car = 1

UNITS: parking/car

DOCUMENT: This is a parameter that indicates that each parking spot can only take one car.

perceived_shared_cars_required = SMTH1(Total_shared_cars_required, 1)

UNITS: car

DOCUMENT: This is a delay converter that indicates that it takes one year for the company to perceive the total of shared cars required to meet the demands of members.
private_car_purchases = change_in_population*cars_per_capita
UNITS: car
DOCUMENT: This is the normal number of private car purchases. It is determined by the change in population multiplied by the number of cars per capita.
Private_cars_deterioration = Number_of_private_cars/time_for_private_cars_to_deteriorate
UNITS: car/Year
DOCUMENT: This is the outflow from the stock of number of private cars. It is determined by the number of private cars divided by the time for private cars to deteriorate.
private_parking_required = Number_of_private_cars*parking_per_car
UNITS: parking
DOCUMENT: This is the number of parking spots needed for the private cars in Bergen. It is determined by multiplying the number of private cars by the parking per car.
real_hourly_renting_price =
(average_hourly_renting_price*effect_of_relative_profit_margin_on_renting_prices)*(1-scenario_in_effect:_no_green)*(1-scenario_in_effect:_green_low_prices) +
high_hourly_renting_price*scenario_in_effect:_no_green*(1-scenario_in_effect:_green_low_prices) +
low_hourly_renting_price*scenario_in_effect:_green_low_prices*(1-scenario_in_effect:_no_green)
UNITS: kr/hour/car
DOCUMENT: This is the hourly renting price. It is determined by multiplying the indicated hourly renting price by the effect of relative profit margin on renting prices. As the effect increases, the hourly renting price will be larger than indicated. As the effect decreases, the indicated hourly renting price is less than indicated. This variable is sensitive and used in two scenarios. One in which the price is lowered in a scenario where subsidies for shared cars are increased, and another in which the price is increased in a scenario where subsidies are not as much as they are now.
reduction_in_cars_bought_per_member =
normal_reduction_in_cars_bought_per_member*(1-scenario_in_effect:_freedom_society)*(1-scenario_in_effect:_sharing_society) +
reduction_of_cars_freedom_society*scenario_in_effect:_freedom_society*(1-scenario_in_effect:_sharing_society) +
reduction_of_cars_shared_society*scenario_in_effect:_sharing_society*(1-scenario_in_effect:_freedom_society)
UNITS: car/person
DOCUMENT: This is the number of reduction in private cars bought per member. It is normally determined by the normal reduction in cars bought per member. However, this variable is used for two scenarios. When the freedom society scenario is activated, the reduction of cars

will be lowered as people are less willing to use shared cars. In a sharing society scenario, this value will be higher as people are more willing to share.

reduction_of_cars_freedom_society = 0.1

UNITS: car/person

DOCUMENT: This is the assumed number of private cars reduced per shared car member in a society that is less willing to drive shared cars. This value was determined through sensitivity analysis.

reduction_of_cars_shared_society = 0.3

UNITS: car/person

DOCUMENT: This is the assumed number of private cars reduced per shared cara member in a society that is more willing to drive shared cars. This value was determined through sensitivity analysis.

relative_hourly_price = real_hourly_renting_price/average_hourly_renting_price

UNITS: dmnl

DOCUMENT: This is the relative hourly price as determined by the real hourly renting price divided by the indicated hourly renting price.

scenario_in_effect:_green_low_prices = IF TIME >= Start_year THEN Green_Scenario_SWITCH ELSE 0

UNITS: dmnl

DOCUMENT: This variable determines when the scenario where the Bergen municipality is willing to increase subsidies through lowered tolls is active.

scenario_in_effect:_no_green = IF TIME >= Start_year THEN No_Green_Scenario_SWITCH ELSE 0

UNITS: dmnl

DOCUMENT: This variable determines when the scenario where the Bergen municipality is less willing to provide subsidies through tolls is active.

shared_car_deterioration = (Number_of_shared_cars/Time_for_shared_cars_to_deteriorate)

UNITS: car/Year

DOCUMENT: This is the outflow from the stock of shared cars. It is determined by taking the number of shared cars and dividing it by the time for cars to deteriorate to provide a yearly rate at which shared cars are removed from the fleet each year.

time_for_private_cars_to_deteriorate = 12

UNITS: year

DOCUMENT: This value is assumed. It is also determined through calibration. It determines that it takes 12 years for a private car to deteriorate.

Time_for_shared_cars_to_deteriorate = 8

UNITS: year

DOCUMENT: This is an assumed value. It is determined through calibration. It indicates that a shared car will last 8 years before deteriorating.

Time_to_buy_private_car = 1

UNITS: Year

DOCUMENT: This is an assumed value that indicates how long it takes to buy a private car. We assume it will take approximately one year to get a new car to add to the stock of private cars.

Time_to_buy_shared_cars = 1

UNITS: year

DOCUMENT: This is an assumed value that indicates how long it takes to buy a shared car. We assume it will take approximately one year to get a new car to add to the fleet of shared cars.

Total_car_maintenance_costs = Number_of_shared_cars*Maintenance_costs_per_car_per_year

UNITS: kr/Years

DOCUMENT: This is the total maintenance cost per year for shared cars. It is determined by multiplying the number of shared cars by the maintenance costs per car per year.

Total_costs_for_new_cars = Cost_per_new_car*Buying_shared_cars

UNITS: kr/Years

DOCUMENT: This is the total cost of buying new shared cars per year. It is determined by multiplying the cost per new car by the number of shared cars bought.

total_number_of_cars = Number_of_private_cars+Number_of_shared_cars

UNITS: car

DOCUMENT: The total number of cars represents the total number of cars in Bergen by adding the number of private cars and the number of shared cars.

Total_renting_revenues = Number_of_shared_cars*Hours_per_year_in_use*real_hourly_renting_price

UNITS: kr/year

DOCUMENT: The total renting revenues is the amount of money generated from shared cars. It is determined by multiplying the number of shared cars by the hours they are used per year by the real hourly renting price.

Total_shared_cars_required = Car_sharing_members/Members_per_car

UNITS: car

DOCUMENT: This is the total shared cars required. It is determined by dividing car sharing members by members per car. It indicates that the total number of members need a certain number of shared cars as determined by the members per car.

utilization_rate = MIN(1, Normal_utilization_rate_shared_cars*effect_of_relative_willingness_for_utilization_on_utilization_rate)

UNITS: dmnl/year

DOCUMENT: The utilization rate is the amount a car is used per year. It is determined by multiplying the normal utilization rate for shared cars by the effect of relative willingness for utilization on utilization rate.

****
Emissions_Sector:
****
Accumulated_Emissions(t) = Accumulated_Emissions(t - dt) + (Change_in_Emissions) * dt
INIT Accumulated_Emissions = Initial_Emissions
UNITS: Kilogram of CO2
DOCUMENT: This is a stock showing the accumulation of emissions in Co2 per kilograms from shared and private electric, fossil fuel and hybrid cars based on change in the amount of the different cars and the difference in utilization between shared and private cars and kilograms of Co2 per kilometer. It is increased by the inflow of change in emissions. The initial value is described in the variable called initial emissions.
Average_KMs_per_Car_Multiplier = utilization_rate/Normal_utilization_rate_private_cars
UNITS: dmnl
DOCUMENT: This variable indicates how much more shared cars are used in comparison to private cars. It serves as a multiplier to the average number of kilometers driven by shared cars.
Average_KMs_per_Private_Car_Electric = 13234
UNITS: Kilometer/Car/Year
DOCUMENT: This variable shows the average kilometers traveled per private electric car per year (Statistics Norway, 2024d).
Average_KMs_per_Private_Car_Fossil_Fuel = 7333
UNITS: Kilometer/Car/Year
DOCUMENT: This variable shows the average kilometers traveled per private fossil fueled car per year (Statistics Norway, 2024d).
Average_KMs_per_Private_Car_Hybrid = 13483
UNITS: Kilometer/Car/Year
DOCUMENT: This variable shows the average kilometers traveled per private hybrid car per year (Statistics Norway, 2024d).
Average_KMs_per_Shared_Car_Electric = Average_KMs_per_Car_Multiplier*Average_KMs_per_Private_Car_Electric
UNITS: Kilometer/Car/Year
DOCUMENT: This variable shows the average kilometers per Electric shared car per year and is determined by the Average KMs per Private Car Electric multiplied by the added utilization rate for shared cars.
Average_KMs_per_Shared_Car_Fossil_Fuel = Average_KMs_per_Private_Car_Fossil_Fuel*Average_KMs_per_Car_Multiplier
UNITS: Kilometer/Car/Year
DOCUMENT: This variable shows the average kilometers per Fossil Fuel shared car per year and is determined by the Average KMs per Private Car Fossil Fuel multiplied by the added utilization rate for shared cars.

Average_KMs_per_Shared_Car_Hybrid =
Average_KMs_per_Private_Car_Hybrid*Average_KMs_per_Car_Multiplier

UNITS: Kilometer/Car/Year

DOCUMENT: This variable shows the average kilometers per Hybrid shared car per year and is determined by the Average KMs per Private Car Hybrid multiplied by the added utilization rate for shared cars.

Change_in_Emissions = Emissions_Fossil_Fuel+Emissions_Hybrid+Emissions_Electric

UNITS: Kilogram of CO2/Year

DOCUMENT: This is the flow of change in emissions in kilograms of CO2 per year from all cars in Bergen. It is an inflow to the stock of accumulated emissions.

Emissions_Electric =
Emissions_per_KM_Electric*(KMs_traveled_Private_Car_Electric+KMs_Traveled_Shared_Car_Electric)

UNITS: Kilogram of CO2/Year

DOCUMENT: This variable shows emissions of private and shared electric cars in kilograms of CO2 per year. It is calculated by emissions of electric cars per km given by DNB (2022), which is 0, multiplied with emissions per km for shared and private electric cars.

Emissions_Fossil_Fuel =
Emissions_per_KM_Fossil_Fuel*(KMs_traveled_Private_Car_Fossil_Fuel+KMs_Traveled_Shared_Car_Fossil_Fuel)

UNITS: Kilogram of CO2/Year

DOCUMENT: This variable shows emissions of private and shared Fossil Fuel cars in kilograms of CO2 per year. It is calculated by emissions of Fossil Fuel cars per km given by (EPA, 2023), multiplied with emissions per km for shared and private Fossil Fuel cars.

Emissions_Hybrid =
Emissions_per_KM_Hybrid*(KMs_traveled_Private_Car_Hybrid+KMs_Traveled_Shared_Car_Hybrid)

UNITS: Kilogram of CO2/Year

DOCUMENT: This variable shows emissions of private and shared Hybrid cars in kilograms of CO2 per year. It is calculated by emissions of Hybrid cars per km given by (Transport & Environment, 2022), multiplied with emissions per km for shared and private Hybrid cars.

Emissions_per_KM_Electric = 0

UNITS: Kilogram of CO2/Kilometer

DOCUMENT: Emissions from Electric cars in kilograms of CO2 per kilometer. As we are measuring C02 released per km and not measuring cradle to grave emissions, we chose to set the number of C02 per km for electric cars to 0, as the electricity produced in Norway is 99% renewables. Even if Norway is connected to the European electric market and may use a small percentage of fossil energy, we assume the percentage is so small it is of no relevance in this case (DNB, 2022).

Emissions_per_KM_Fossil_Fuel = .250
UNITS: Kilogram of CO_2/Kilometer
DOCUMENT: Emissions from fossil fuel cars in kilograms of CO_2 per kilometer (EPA, 2023).
Emissions_per_KM_Hybrid = 0.190
UNITS: Kilogram of CO_2/Kilometer
DOCUMENT: Emissions from hybrid cars in kilograms of CO_2 per kilometer (Transport & Environment, 2022).
Initial_Emissions = 0
UNITS: Kilogram of CO_2
DOCUMENT: Emissions at the start of Dele in 1996.
KMs_traveled_Private_Car_Electric = Average_KMs_per_Private_Car_Electric*Private_Cars_Electric
UNITS: Kilometer/Year
DOCUMENT: This variable shows how many kilometers per year is traveled with private electric cars. Calculated by multiplying stock of private electric cars with the average kilometers each private electric car drives a year.
KMs_traveled_Private_Car_Fossil_Fuel = Average_KMs_per_Private_Car_Fossil_Fuel*Private_Cars_Fossil_Fuel
UNITS: Kilometer/Year
DOCUMENT: This variable shows how many kilometers per year is traveled with private Fossil Fuel cars. Calculated by multiplying stock of private Fossil Fuel cars with the average kilometers each private Fossil Fuel car drives a year.
KMs_traveled_Private_Car_Hybrid = Average_KMs_per_Private_Car_Hybrid*Private_Cars_Hybrid
UNITS: Kilometer/Year
DOCUMENT: This variable shows how many kilometers per year is traveled with private Hybrid cars. Calculated by multiplying stock of private Hybrid cars with the average kilometers each private Hybrid car drives a year.
KMs_Traveled_Shared_Car_Electric = Average_KMs_per_Shared_Car_Electric*Shared_Cars_Electric
UNITS: Kilometer/Year
DOCUMENT: This variable shows how many kilometers per year is traveled with shared electric cars. Calculated by multiplying stock of shared electric cars with the average kilometers each shared electric car drives a year.
KMs_Traveled_Shared_Car_Fossil_Fuel = Shared_Cars_Fossil_Fuel*Average_KMs_per_Shared_Car_Fossil_Fuel
UNITS: Kilometer/Year

DOCUMENT: This variable shows how many kilometers per year is traveled with shared Fossil Fuel cars. Calculated by multiplying stock of shared Fossil Fuel cars with the average kilometers each shared Fossil Fuel car drives a year.
KMs_Traveled_Shared_Car_Hybrid = Shared_Cars_Hybrid*Average_KMs_per_Shared_Car_Hybrid
UNITS: Kilometer/Year
DOCUMENT: This variable shows how many kilometers per year is traveled with shared Hybrid cars. Calculated by multiplying stock of shared Hybrid cars with the average kilometers each shared Hybrid car drives a year.
New_private_electric_cars = Buying_private_cars*Percentage_of_Private_Cars_Electric
UNITS: car/Year
DOCUMENT: This is the flow of new private electric cars. It goes into the stock of private cars electric. The formula is the flow of buying private cars multiplied by the percentage of electric cars bought at each time.
New_private_fossil_fuel_cars = Buying_private_cars*Percentage_of_Private_Cars_Fossil_Fuel
UNITS: car/Year
DOCUMENT: This is the flow of new private fossil fuel cars. It goes into the stock of private cars fossil fuel. The formula is the flow of buying private cars multiplied by the percentage of fossil fuel cars bought at each time.
New_private_hybrid_cars = Buying_private_cars*Percentage_of_Private_Cars_Hybrid
UNITS: car/Year
DOCUMENT: This is the flow of new private hybrid cars. It goes into the stock of private cars hybrid. The formula is the flow of buying private cars multiplied by the percentage of hybrid cars bought at each time.
New_shared_cars_electric = Percentage_of_Private_Cars_Electric*Buying_shared_cars
UNITS: car/Year
DOCUMENT: This is the flow of new shared electric cars. It goes into the stock of shared cars electric. The formula is the flow of buying shared cars multiplied by the percentage of electric cars bought at each time
New_shared_cars_fossil_fuel = Percentage_of_Private_Cars_Fossil_Fuel*Buying_shared_cars
UNITS: car/Year
DOCUMENT: This is the flow of new shared fossil fuel cars. It goes into the stock of shared cars fossil fuel. The formula is the flow of buying shared cars multiplied by the percentage of fossil fuel cars bought at each time.
New_shared_cars_hybrid = Percentage_of_Private_Cars_Hybrid*Buying_shared_cars
UNITS: car/Year
DOCUMENT: This is the flow of new shared hybrid cars. It goes into the stock of shared cars hybrid. The formula is the flow of buying shared cars multiplied by the percentage of hybrid cars bought at each time.
Normal_utilization_rate_private_cars = 0.03

UNITS: dmnl/year

DOCUMENT: This variable shows the normal utilization rate of private cars. The number 0.03 indicates that a normal car is used approximately 3% of the time in a year. Numbers gathered from Dele's webpage where they claim that a private car is parked 97% of the time (Dele, n.d-a).

Percentage_of_Private_Cars_Electric = GRAPH(TIME)

Points: (1996.00, 0.000301961), (1997.00, 0.000156861), (1998.00, 0.00026441), (1999.00, 0.000630999), (2000.00, 0.001427048), (2001.00, 0.001188563), (2002.00, 0.00195654), (2003.00, 0.001700218), (2004.00, 0.000818716), (2005.00, 0.000914501), (2006.00, 0.001374677), (2007.00, 0.000642741), (2008.00, 0.001904234), (2009.00, 0.00142564), (2010.00, 0.002528626), (2011.00, 0.012064414), (2012.00, 0.024813765), (2013.00, 0.057389783), (2014.00, 0.12492617), (2015.00, 0.178911352), (2016.00, 0.172322372), (2017.00, 0.23143896), (2018.00, 0.342213441), (2019.00, 0.424769565), (2020.00, 0.534372034), (2021.00, 0.638258734), (2022.00, 0.792182404), (2023.00, 0.811), (2024.00, 0.828), (2025.00, 0.832), (2026.00, 0.838), (2027.00, 0.842), (2028.00, 0.845), (2029.00, 0.845), (2030.00, 0.849), (2031.00, 0.849), (2032.00, 0.849), (2033.00, 0.849), (2034.00, 0.852), (2035.00, 0.856), (2036.00, 0.856), (2037.00, 0.859), (2038.00, 0.863), (2039.00, 0.866), (2040.00, 0.869), (2041.00, 0.873), (2042.00, 0.876), (2043.00, 0.883), (2044.00, 0.883), (2045.00, 0.887), (2046.00, 0.887), (2047.00, 0.890), (2048.00, 0.893), (2049.00, 0.895), (2050.00, 0.897)

UNITS: dmnl

DOCUMENT: These are the total percentages of electric cars being bought each year. This is based on data until 2024 and the percentages until 2050 are based on our own assumptions following trends from the past years (Statistics Norway. 2024e).

Percentage_of_Private_Cars_Fossil_Fuel = GRAPH(TIME)

Points: (1996.00, 0.999698039), (1997.00, 0.999843139), (1998.00, 0.99973559), (1999.00, 0.999369001), (2000.00, 0.998572952), (2001.00, 0.998811437), (2002.00, 0.99804346), (2003.00, 0.998299782), (2004.00, 0.999181284), (2005.00, 0.999085499), (2006.00, 0.998625323), (2007.00, 0.999351469), (2008.00, 0.998081917), (2009.00, 0.998558694), (2010.00, 0.996489746), (2011.00, 0.979065908), (2012.00, 0.94610733), (2013.00, 0.883304372), (2014.00, 0.800735937), (2015.00, 0.696661804), (2016.00, 0.589460591), (2017.00, 0.464985044), (2018.00, 0.38112117), (2019.00, 0.313602863), (2020.00, 0.162591163), (2021.00, 0.079587086), (2022.00, 0.055899236), (2023.00, 0.045402865), (2024.00, 0.045), (2025.00, 0.041), (2026.00, 0.034), (2027.00, 0.034), (2028.00, 0.031), (2029.00, 0.027), (2030.00, 0.024), (2031.00, 0.021), (2032.00, 0.021), (2033.00, 0.017), (2034.00, 0.017), (2035.00, 0.017), (2036.00, 0.017), (2037.00, 0.017), (2038.00, 0.017), (2039.00, 0.017), (2040.00, 0.014), (2041.00, 0.014), (2042.00, 0.014), (2043.00, 0.014), (2044.00, 0.014), (2045.00, 0.010), (2046.00, 0.010), (2047.00, 0.010), (2048.00, 0.007), (2049.00, 0.007), (2050.00, 0.007)

UNITS: dmnl

DOCUMENT: These are the total percentages of fossil fuel cars being bought each year. This is based on data until 2024 and the percentages until 2050 are based on our own assumptions following trends from the past years (Statistics Norway. 2024e).
Percentage_of_Private_Cars_Hybrid = GRAPH(TIME)
Points: (1996.00, 0.000), (1997.00, 0.000), (1998.00, 0.000), (1999.00, 0.000), (2000.00, 0.000), (2001.00, 0.000), (2002.00, 0.000), (2003.00, 0.000), (2004.00, 0.000), (2005.00, 0.000), (2006.00, 0.000), (2007.00, 0.00000579046), (2008.00, 0.000013849), (2009.00, 0.0000156664), (2010.00, 0.000956777), (2011.00, 0.008869677), (2012.00, 0.029078905), (2013.00, 0.059300091), (2014.00, 0.074331987), (2015.00, 0.124426845), (2016.00, 0.238211197), (2017.00, 0.303575995), (2018.00, 0.276665389), (2019.00, 0.261627571), (2020.00, 0.303036803), (2021.00, 0.28215418), (2022.00, 0.15191836), (2023.00, 0.1431373), (2024.00, 0.127), (2025.00, 0.127), (2026.00, 0.128), (2027.00, 0.124), (2028.00, 0.124), (2029.00, 0.128), (2030.00, 0.127), (2031.00, 0.130), (2032.00, 0.130), (2033.00, 0.134), (2034.00, 0.131), (2035.00, 0.127), (2036.00, 0.127), (2037.00, 0.124), (2038.00, 0.120), (2039.00, 0.117), (2040.00, 0.117), (2041.00, 0.113), (2042.00, 0.110), (2043.00, 0.103), (2044.00, 0.103), (2045.00, 0.103), (2046.00, 0.103), (2047.00, 0.100), (2048.00, 0.100), (2049.00, 0.098), (2050.00, 0.096)

UNITS: dmnl

DOCUMENT: These are the total percentages of hybrid cars being bought each year. This is based on data until 2024 and the percentages until 2050 are based on our own assumptions following trends from the past years (Statistics Norway. 2024e).
Private_Cars_Electric(t) = Private_Cars_Electric(t - dt) + (New_private_electric_cars - Private_electric_car_deterioration) * dt

INIT Private_Cars_Electric = 0

UNITS: car

DOCUMENT: This is the stock of total private electric cars. It is increased by the inflow of new private electric cars and decreased by the outflow of private electric car deterioration. The initial value of the stock is 0 because it is assumed that in the start year of 1996 there were no electric cars in use.
Private_Cars_Fossil_Fuel(t) = Private_Cars_Fossil_Fuel(t - dt) + (New_private_fossil_fuel_cars - Private_fossil_fuel_car_deterioration) * dt

INIT Private_Cars_Fossil_Fuel = Initial_private_cars

UNITS: car

DOCUMENT: This is the stock of total private fossil fuel cars. It is increased by the inflow of new private fossil fuel cars and decreased by the outflow of private fossil fuel car deterioration. The initial value of the stock is 86000 because it is assumed that in the start year of 1996 all the initial private cars were fossil fuel cars.
Private_Cars_Hybrid(t) = Private_Cars_Hybrid(t - dt) + (New_private_hybrid_cars - Private_hybrid_car_deterioration) * dt

INIT Private_Cars_Hybrid = 0

UNITS: car

DOCUMENT: This is the stock of total private hybrid cars. It is increased by the inflow of new private hybrid cars and decreased by the outflow of private hybrid car deterioration. The initial value of the stock is 0 because it is assumed that in the start year of 1996 there were no hybrid cars in use.

Private_electric_car_deterioration = Private_Cars_Electric/time_for_private_cars_to_deteriorate

UNITS: car/Year

DOCUMENT: This is the flow of private electric car deterioration. It goes out of the stock of private cars electric. The formula is the stock of private cars electric divided by the time for private cars to deteriorate.

Private_fossil_fuel_car_deterioration = Private_Cars_Fossil_Fuel/time_for_private_cars_to_deteriorate

UNITS: car/Year

DOCUMENT: This is the flow of private fossil fuel car deterioration. It goes out of the stock of private cars fossil fuel. The formula is the stock of private cars fossil fuel divided by the time for private cars to deteriorate.

Private_hybrid_car_deterioration = Private_Cars_Hybrid/time_for_private_cars_to_deteriorate

UNITS: car/Year

DOCUMENT: This is the flow of private hybrid car deterioration. It goes out of the stock of private cars hybrid. The formula is the stock of private cars hybrid divided by the time for private cars to deteriorate.

Shared_Cars_Electric(t) = Shared_Cars_Electric(t - dt) + (New_shared_cars_electric - shared_electric_car_deterioration) * dt

INIT Shared_Cars_Electric = 0

UNITS: car

DOCUMENT: This is the stock of total shared electric cars. It is increased by the inflow of new shared cars electric and decreased by the outflow of shared electric car deterioration. The initial value of the stock is 0 because it is assumed that in the start year of 1996 there were no electric cars in use.

Shared_Cars_Fossil_Fuel(t) = Shared_Cars_Fossil_Fuel(t - dt) + (New_shared_cars_fossil_fuel - Shared_fossil_fuel_car_deterioration) * dt

INIT Shared_Cars_Fossil_Fuel = 1

UNITS: car

DOCUMENT: This is the stock of total shared fossil fuel cars. It is increased by the inflow of new shared cars fossil fuel and decreased by the outflow of shared fossil fuel car deterioration. The initial value of the stock is 1 because it is assumed that in the start year of 1996 the only car that Dele started with is a fossil fuel car.

Shared_Cars_Hybrid(t) = Shared_Cars_Hybrid(t - dt) + (New_shared_cars_hybrid - Shared_hybrid_car_deterioration) * dt

INIT Shared_Cars_Hybrid = 0

UNITS: car

DOCUMENT: This is the stock of total shared hybrid cars. It is increased by the inflow of new shared cars hybrid and decreased by the outflow of shared hybrid car deterioration. The initial value of the stock is 0 because it is assumed that in the start year of 1996 there were no electric cars in use.

shared_electric_car_deterioration = Shared_Cars_Electric/Time_for_shared_cars_to_deteriorate

UNITS: car/Year

DOCUMENT: This is the flow of shared electric cars deterioration. It goes out of the stock of shared cars electric. The formula is the stock of shared cars electric divided by the time for shared cars to deteriorate.

Shared_fossil_fuel_car_deterioration = Shared_Cars_Fossil_Fuel/Time_for_shared_cars_to_deteriorate

UNITS: car/Year

DOCUMENT: This is the flow of shared fossil fuel cars deterioration. It goes out of the stock of shared cars fossil fuel. The formula is the stock of shared cars fossil fuel divided by the time for shared cars to deteriorate.

Shared_hybrid_car_deterioration = Shared_Cars_Hybrid/Time_for_shared_cars_to_deteriorate

UNITS: car/Year

DOCUMENT: This is the flow of shared hybrid cars deterioration. It goes out of the stock of shared cars hybrid. The formula is the stock of shared cars hybrid divided by the time for shared cars to deteriorate.

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Familiarity:

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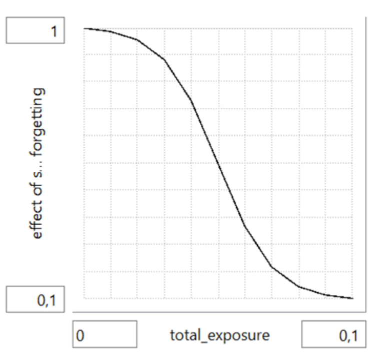
effect_of_social_exposure_on_forgetting = GRAPH(total_exposure)

Points: (0, 1.0000), (0.01, 0.9886), (0.02, 0.9609), (0.03, 0.8951), (0.04, 0.7592), (0.05, 0.5500), (0.06, 0.3408), (0.07, 0.2049), (0.08, 0.1391), (0.09, 0.1114), (0.1, 0.1000)



UNITS: dmnl

DOCUMENT: This is a graphical function, it shows the effect that social exposure has on the rate that people forget about shared cars. If the total exposure of people talking about shared cars increases, the forgetting rate will decrease. This means that it will take longer for people to forget about the concept of shared cars. If the total exposure of people talking about shared cars diminishes, the effect on the forgetting rate will be greater. People will forget about shared cars at the normal forgetting rate. The graphical function has a Z-shape, with a minimum of 0,1 and maximum of 1 at the y-axis. This means that the effect of social exposure can only decrease the normal forgetting rate. With no social exposure, the normal forgetting rate will be used. On the x-axis, the minimum is 0 and the maximum is 0.1, due to the small values of the social exposure variable.

effective_contact_rate_for_members = 0.25

UNITS: dmnl/year

DOCUMENT: The variable effective contact rate for members is a constant, and is set at 0.25. It represents how effective the effect of meeting a shared car member is on an individual to become familiar with the concept. The range of 0-0.3 was found in research conducted by Struben and Sterman (2008) and Ferreira et al. (2022). The value of 0.25 was chosen based on hand calibration.

"effective_contact_rate_for_non-members" = 0.15

UNITS: dmnl/year

DOCUMENT: The variable effective contact rate for non-members is a constant, and is set at 0.15. It represents the idea that even non-members still talk about the concept of shared cars, and how effective this contact is on becoming familiar with the concept. The range of 0-0.3 was found in research conducted by Struben and Sterman (2008) and Ferreira et al. (2022). The value of 0.25 was chosen based on hand calibration.

familiarity_gain = total_exposure*(maximum_familiarity-Familiarity_of_shared_cars)/maximum_familiarity

UNITS: 1/year

DOCUMENT: Familiarity gain is the inflow of the stock of "familiarity of shared cars". It is the increase in familiarity of the concept of shared cars. It is calculated by multiplying the total exposure to the shared car concept, by the remaining gap of the maximum familiarity minus the accumulated familiarity in the stock divided by the maximum familiarity.

familiarity_loss = effect_of_social_exposure_on_forgetting*Familiarity_of_shared_cars*normal_forgetting_rate

UNITS: 1/year

DOCUMENT: Familiarity loss is the outflow of the stock "familiarity of shared cars". It shows the decrease in familiarity of the concept of shared cars. It is calculated by multiplying the stock of familiarity of shared cars by the normal forgetting rate and the effect of social exposure on forgetting.

Familiarity_of_shared_cars(t) = Familiarity_of_shared_cars(t - dt) + (familiarity_gain - familiarity_loss) * dt

INIT Familiarity_of_shared_cars = Initial_Familiarity

UNITS: dmnl

DOCUMENT: This is a stock and displays the accumulated familiarity of shared cars. It increases with the inflow “familiarity gain” and decreases due to the outflow “familiarity loss”. The initial value is the variable “Initial Familiarity”. It is set at 0, assuming that in 1996 no one in Norway had heard of shared cars.

freedom_society_SWITCH = 0

UNITS: dmnl

DOCUMENT: This is a switch used to turn on the scenario of the “Freedom society”. If it is 0, the scenario is off and the baseline scenario is used. If it is 1, the Freedom scenario is in effect.

high_minimum_familiarity_required = 0.5

UNITS: dmnl

DOCUMENT: This variable is part of the “Freedom society” scenario. If this scenario is in effect, a higher threshold is needed for familiarity to start having an effect on the willingness of people to become a member and use shared cars. The threshold is set at 0.5

Initial_Familiarity = 0

UNITS: dmnl

DOCUMENT: This is the initial value of the stock “familiarity of shared cars”. The value is set at 0, based on the assumption that in 1996 no one in Norway had heard of shared cars.

low_minimum_familiarity_required = 0.1

UNITS: dmnl

DOCUMENT: This variable is part of the “Sharing society” scenario. If this scenario is in effect, a lower threshold is needed for familiarity to start having an effect on the willingness of people to become a member and use shared cars. The threshold is set at 0.1.

maximum_familiarity = 1

UNITS: dmnl

DOCUMENT: This variable displays the maximum familiarity that can be reached, and it is set at 1 or 100%.

Minimum_familiarity_required_to_have_an_effect_on_willingness_gain = 0.3

UNITS: dmnl

DOCUMENT: This variable represents a threshold that needs to be reached for familiarity to start having an effect on the willingness gain. It is set at 0.3.

normal_external_desire_to_use_alternative_transport = 0.005 + STEP(0.03, 2014)

UNITS: dmnl/year

DOCUMENT: This variable represents an external desire that people might have to start using alternative modes of transport. The year 2014, when this will go into effect, is chosen because of the founding of Uber. This is also a form of sharing a car in a way and would have been a pulse for people to start becoming familiar with the concept of car sharing.

normal_forgetting_rate = 0.8

UNITS: dmnl/year

DOCUMENT: This variable represents the rate at which people forget information. Range the value was tested was 0.5 to 3 (Struben & Sterman, 2008). The value of 0.8 was chosen after hand calibration to match historical data.
probability_of_contact_with_a_member = Car_sharing_members/Total_eligible_drivers
UNITS: dmnl
DOCUMENT: This variable represents the probability that an individual comes into contact with a car sharing member. It is calculated by dividing the stock of car sharing members by the total number of eligible drivers.
"Probability_of_contact_with_a_non-member" = Potential_members/Total_eligible_drivers
UNITS: dmnl
DOCUMENT: This variable represents the probability that an individual comes into contact with a non car sharing member. It is calculated by dividing the stock of potential members by the total number of eligible drivers.
relative_familiarity =
(Familiarity_of_shared_cars/Minimum_familiarity_required_to_have_an_effect_on_willingness_gain)*(1-scenario_in_effect:_sharing_society)*(1-scenario_in_effect:_freedom_society) + (Familiarity_of_shared_cars/low_minimum_familiarity_required)*(scenario_in_effect:_sharing_society)*(1-scenario_in_effect:_freedom_society) + (Familiarity_of_shared_cars/high_minimum_familiarity_required)*(scenario_in_effect:_freedom_society)*(1-scenario_in_effect:_sharing_society)
UNITS: dmnl
DOCUMENT: The relative familiarity divides the familiarity which has accumulated in the stock by the threshold that is needed for familiarity to start having an effect on the willingness gain. There are three scenarios, where the threshold changes. The baseline scenario has the variable minimum familiarity required to have an effect on willingness gain. The Freedom society has a high minimum familiarity and the Sharing society has a low minimum familiarity.
scenario_in_effect:_freedom_society = IF TIME >= Start_year THEN freedom_society_SWITCH ELSE 0
UNITS: dmnl
DOCUMENT: This variable indicates that if the freedom society scenario policy switch is at 1, then it will be enabled in the year 2024. If the policy switch is at 0, then this policy will not be in effect at any time.
scenario_in_effect:_sharing_society = IF TIME >= Start_year THEN sharing_society_SWITCH ELSE 0
UNITS: dmnl
DOCUMENT: This variable indicates that if the sharing society scenario policy switch is at 1, then it will be enabled in the year 2024. If the policy switch is at 0, then this policy will not be in effect at any time.
sharing_society_SWITCH = 0

UNITS: dmnl

DOCUMENT: This is a switch used to turn on the scenario of the “Sharing society”. If it is 0, the scenario is off and the baseline scenario is used. If it is 1, the Sharing scenario is in effect.

Socialization_effect_of_members = probability_of_contact_with_a_member*effective_contact_rate_for_members

UNITS: dmnl/year

DOCUMENT: The variable socialization effect of members represents the probability of coming into contact with a member and how effective that contact was on an individual becoming familiar with the shared car concept.

"Socialization_effect_of_non-members" = Familiarity_of_shared_cars*"effective_contact_rate_for_non-members"*"Probability_of_contact_with_a_non-member"

UNITS: 1/year

DOCUMENT: The variable socialization effect of nonmembers represents the probability of coming into contact with a non-member and how effective that contact was on an individual becoming familiar with the shared car concept.

total_exposure = (Socialization_effect_of_members+"Socialization_effect_of_non-members") + normal_external_desire_to_use_alternative_transport + yearly_relative_parking_spots_ratio

UNITS: dmnl/year

DOCUMENT: The total exposure variable accounts for the socialization effect of members and non-members. The external desire to use alternative transport is added to this, as well as the perceived parking space ratio. This all together makes up for the total exposure of shared cars.

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Membership_Sector:

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Average_membership_time = 5

UNITS: year

DOCUMENT: This variable represents the average time an individual is a member of a shared cars service. The value is assumed at 5 years and remains constant over time.

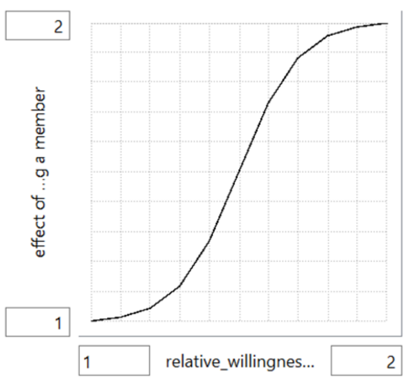
becoming_a_member = Potential_members*membership_rate*effect_of_relative_willingness_on_becoming_a_member

UNITS: Person/Year

DOCUMENT: This is the inflow of people becoming a member of a car sharing service. It goes into the stock of "Car sharing members”. It is the stock of potential members multiplied by the membership rate and the effect of the willingness on becoming a member.

Car_sharing_members(t) = Car_sharing_members(t - dt) + (becoming_a_member - member_expiration) * dt

INIT Car_sharing_members = Initial_members
UNITS: Person
DOCUMENT: This is a stock which accumulates the number of people who have active subscriptions with a car sharing service, and are thus car sharing members. The stock increases with the inflow of becoming a member and decreases with the outflow of member expiration. The initial value is given by the variable “initial members”, and is set at 0.
change_in_population = population_Bergen-HISTORY(population_Bergen, TIME-1)
UNITS: person
DOCUMENT: This variable represents the change in population in Bergen. It is calculated by looking at the population of Bergen and subtracting the population of Bergen in the previous year. That will give the change in the population.
effect_of_relative_willingness_on_becoming_a_member = GRAPH(relative_willingness_for_membership)
Points: (1.000, 1.000), (1.100, 1.013), (1.200, 1.043), (1.300, 1.117), (1.400, 1.268), (1.500, 1.500), (1.600, 1.732), (1.700, 1.883), (1.800, 1.957), (1.900, 1.987), (2.000, 2.000)

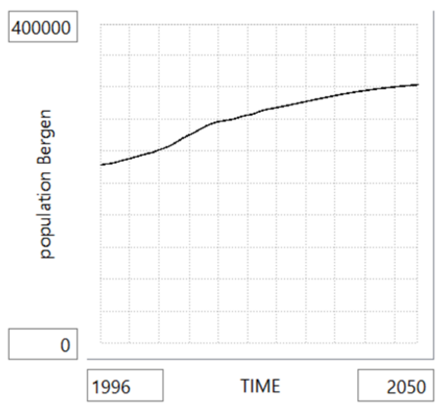


UNITS: dmnl
DOCUMENT: This is a graphical function, it shows the effects that willingness has on becoming a member. If the willingness increases it will have a greater effect on the normal membership rate, which will increase. If the willingness remains constant around the initial value it will not have an effect on the membership rate, which will keep its initial value. The graphical function is s-shaped and both the x-axis and y-axis go from 1 to 2.
fraction_people_with_drivers_license = 0.64
UNITS: dmnl
DOCUMENT: The fraction of people with a driver’s license represents the fraction of the people that have a driver’s license. It is set a little lower than the national fraction of people with a driver’s license, which is around 82% (Woodgate, 2014), due to the assumption that less people have a driver’s license when growing up/living in a big city.
increase_in_potential_members = (Total_eligible_drivers-Potential_members-Car_sharing_members)/time_to_become_a_potential_member+member_expiration
UNITS: Person/Year

DOCUMENT: This is the inflow to the stock of "potential members". It is calculated by subtracting the people who are either a potential member or already a car sharing member from the total eligible drivers which is divided by the time to become a potential member. The people who are no longer a member are also added to this, because when leaving the membership the become potential members again.
indicated_membership_time = membership_time*effect_of_relative_hourly_price_on_membership_time
UNITS: Year
DOCUMENT: The indicated membership time is the normal membership time multiplied by the effect that the relative hourly price has on member expiration. If the relative price increases the membership time will decline.
Initial_members = 0
UNITS: person
DOCUMENT: Initial members is a variable that displays the number of members the car sharing service had in 1996, it is assumed to be 0.
initial_potential_members = 143000
UNITS: person
DOCUMENT: Initial potential members is the initial value of the stock potential members. It is the population in Bergen that had a driver's license in 1996, which is roughly 143000.
member_expiration = (Car_sharing_members/indicated_membership_time)
UNITS: Person/Year
DOCUMENT: This is the outflow of the stock "car sharing members", it accounts for the people who are no longer a member. It is calculated by the number of car sharing members divided by the indicated membership time.
membership_rate = (normal_membership_rate*(1-scenario_in_effect:_sharing_society)*(1-scenario_in_effect:_freedom_society)) + (membership_rate_sharing_society*scenario_in_effect:_sharing_society*(1-scenario_in_effect:_freedom_society)) + (membership_rate_freedom_society*scenario_in_effect:_freedom_society*(1-scenario_in_effect:_sharing_society))
UNITS: dmnl/year
DOCUMENT: This variable represents the rate at which potential members become actual members. If there are no scenario;s in effect, this is calculated by the normal membership rate. If the Sharing society scenario is in effect, it is calculated by the membership rate sharing scenario. If the Freedom society is in effect, the membership rate freedom society gives the value.
membership_rate_freedom_society = 0.0055
UNITS: dmnl/year

DOCUMENT: This variable only goes into effect when the Freedom society scenario is switched on. Then the membership rate will become 0.0055, which is lower than the normal membership rate. Indicating that in a freedom society, less people will want to become a member of a car sharing service
membership_rate_sharing_society = 0.0085
UNITS: dmnl/year
DOCUMENT: This variable only goes into effect when the Sharing society scenario is switched on. Then the membership rate will become 0.0085, which is higher than the normal membership rate. Indicating that in a sharing society, more people will want to become a member of a car sharing service
membership_time =
Average_membership_time*(1-scenario_in_effect:_freedom_society)*(1-scenario_in_effect:_sharing_society) +
membership_time_freedom*scenario_in_effect:_freedom_society*(1-scenario_in_effect:_sharing_society) +
membership_time_sharing*scenario_in_effect:_sharing_society*(1-scenario_in_effect:_freedom_society)
UNITS: year
DOCUMENT: The membership time is the amount of time that people will be a member of a car sharing service. In the baseline scenario this will be the average membership time. In the Freedom society scenario the membership time is indicated by the membership time freedom and will be lower. In the Sharing society scenario, it is depicted by the membership time sharing and will be longer than in the baseline scenario.
membership_time_freedom = 3
UNITS: year
DOCUMENT: This variable only goes into effect when the Freedom society scenario is switched on. Then the membership rate will become 3 years, instead of 5 years. Indicating that people won’t want to be a member as long as in the base scenario.
membership_time_sharing = 7
UNITS: year
DOCUMENT: This variable only goes into effect when the Sharing society scenario is switched on. Then the membership rate will become 7 years, instead of 5 years. Indicating that people will want to be a member longer than in the base scenario.
normal_membership_rate = 0.007
UNITS: dmnl/year
DOCUMENT: This variable represents the rate at which potential members become actual members. The value of 0.007 was chosen after calibration to represent historical data on members as best as possible.
population_Bergen = GRAPH(TIME)

Points: (1996.00, 223238), (1997.00, 224308), (1998.00, 225439), (1999.00, 227276), (2000.00, 229496), (2001.00, 230948), (2002.00, 233291), (2003.00, 235423), (2004.00, 237430), (2005.00, 239209), (2006.00, 242158), (2007.00, 244620), (2008.00, 247746), (2009.00, 252051), (2010.00, 256600), (2011.00, 260392), (2012.00, 263762), (2013.00, 267950), (2014.00, 271949), (2015.00, 275112), (2016.00, 277391), (2017.00, 278556), (2018.00, 279792), (2019.00, 281190), (2020.00, 283929), (2021.00, 285601), (2022.00, 286930), (2023.00, 290032), (2024.00, 292286), (2025.00, 293736), (2026.00, 295167), (2027.00, 296621), (2028.00, 298094), (2029.00, 299631), (2030.00, 301200), (2031.00, 302776), (2032.00, 304341), (2033.00, 305891), (2034.00, 307415), (2035.00, 308901), (2036.00, 310340), (2037.00, 311732), (2038.00, 313038), (2039.00, 314269), (2040.00, 315426), (2041.00, 316515), (2042.00, 317535), (2043.00, 318495), (2044.00, 319400), (2045.00, 320251), (2046.00, 321054), (2047.00, 321806), (2048.00, 322514), (2049.00, 323176), (2050.00, 323799)



UNITS: person

DOCUMENT: This is a graphical function, it displays the total population in Bergen starting from 1996 up until the year 2050. It is based on historical data and future projections made by Statistics Norway (2022).

Potential_members(t) = Potential_members(t - dt) + (increase_in_potential_members - becoming_a_member) * dt

INIT Potential_members = initial_potential_members

UNITS: Person

DOCUMENT: This is a stock of accumulated potential members for the car sharing service. The stock increases through the inflow of increase in potential members and decreases through the outflow of becoming a member. The initial value is given by the variable initial potential members, and is set at 143000.

time_to_become_a_potential_member = 1

UNITS: year

DOCUMENT: This variable depicts the time it takes a potential member to become an actual member. It is assumed that, because it is a serious consideration, it takes a year.

Total_eligible_drivers = fraction_people_with_drivers_license*population_Bergen

UNITS: person

DOCUMENT: This variable shows the total number of eligible drivers in Bergen. It is calculated by multiplying the population of Bergen by the fraction of people with a driver's license.

****

Money:

****

Average_employee_salary = 600000

UNITS: kr/person/year

DOCUMENT: The average salary for each employee at the company for each year. The average salary for a Norwegian is around 630000kr but for this model we assume that it's a bit lower than that due to the employees not needing higher education to do the work (McGarvie, 2023).

baseline_indicate_hourly_renting_price = 69

UNITS: kr/hour/car

DOCUMENT: The average price for one hour of renting a car from the company. This value is taken as a mean for the hourly prices on Dele's website (Dele, 2024).

baseline_total_revenue = baseline_indicate_hourly_renting_price*Hours_per_year_in_use*Number_of_shared_cars

UNITS: kr/year

DOCUMENT: This is the calculated total revenues each year for the company in a baseline scenario. That means that no matter what the change in average renting would be, this would always calculate the revenues as if the renting prices stayed at 69 for the whole model.

Costs = Total_costs_for_new_cars+Total_car_maintenance_costs

UNITS: kr/Years

DOCUMENT: This is the total cost for the company's cars each year. It is the sum of costs for new cars and total maintenance cost each year.

Employee_salary_costs = Total_employees*Average_employee_salary

UNITS: kr/year

DOCUMENT: This is the total cost for employees. It is a multiplication of total employees and the average salary for each employee.

Employees_per_member = 0.001

UNITS: dmnl

DOCUMENT: These are the employees needed per car sharing member. It is an assumed value that was deemed appropriate for a normal member/employee ratio for a company such as this one.

government_subsidies = baseline_total_revenue-Total_renting_revenues

UNITS: kr/year

DOCUMENT: These are the total subsidies that the government would give the car sharing company when the green scenario is in effect. If the prices would be lowered to increase customer willingness, then the company would make less money, the government subsidies would cover the rest of the potentially lost revenues, so that the company would be making the same amount of money as if they wouldn't have lowered the prices.

Green_Scenario_in_Effect = IF TIME >= Start_year THEN Green_Scenario_SWITCH ELSE 0

UNITS: dmnl

DOCUMENT: This variable indicates that if the green scenario switch is at 1, then it will be enabled in the year 2024. If the policy switch is at 0, then this scenario will not be in effect at any time.

Green_Scenario_SWITCH = 0

UNITS: dmnl

DOCUMENT: This variable indicates if the green scenario is in effect or not. If it is at 0, then it is not in effect and if it is at 1, then it is in effect.

member_price = 1200

UNITS: kr/person/year

DOCUMENT: This is the total membership price per person per year. The value of 1200kr is taken from Dele's website as a membership for half a year is 600kr (Dele, 2024).

Perceived_profit_margin = SMTH1(Profit_Margin, time_to_perceive_profit_margin, 0.2)

UNITS: dmnl

DOCUMENT: This is the perceived profit margin for the car sharing company's management. It is a smooth function because the time it takes to acquire new information and take it as the absolute truth with no regard to profit margins of previous years takes longer than the actual profit margin would be. The initial value of 0.2 was hand calibrated in the model. It is a delay variable.

Profit_Margin = (revenues-total_costs)//total_costs

UNITS: dmnl

DOCUMENT: The profit margin indicates how much percentage the total accumulated finances would be of the costs for each year. This helps the company observe how much money they are making, and helps them determine how much they can lower their car renting prices to increase customers' willingness.

Reference_profit_margin = 0.2

UNITS: dmnl

DOCUMENT: This is the lowest desired profit margin for the company for each year for the company to believe it's making a healthy profit. If the profit margin is under the desired value, then the company would increase their renting prices to reach the profit margin. If the profit margin is over the desired profit margin, then the company would lower their renting prices to increase people's willingness and get more customers.

relative_profit_margin = Perceived_profit_margin/Reference_profit_margin

UNITS: dmnl

DOCUMENT: The relative profit margin shows if the company is making its desired profits for each year. As the perceived profit margin is higher than the reference profit margin, then this value would be more than 1. If the perceived profit margin is lower than the reference profit margin, then this value is less than 1.

revenues = (Total_renting_revenues + Car_sharing_members*member_price) *(1-Green_Scenario_in_Effect) + (Total_renting_revenues + Car_sharing_members*member_price+government_subsidies)*(Green_Scenario_in_Effect)

UNITS: kr/year

DOCUMENT: This variable shows the revenues. It is determined by adding the renting revenues from the cars and the membership prices. The government subsidies are also added when the green scenario is in effect to make sure that the company wouldn't go bankrupt when they lower their renting prices.

Start_year = 2024

UNITS: year

DOCUMENT: This is the start year for the policies to be implemented into the simulation.

time_to_perceive_profit_margin = 1

UNITS: year

DOCUMENT: This is the time it takes for the company's management to perceive their profit margins. The value is assumed to be 1 because every year they get a new report for the company's finances and would then take the numbers from that report into consideration when perceiving their profit margins.

total_costs = Costs+Employee_salary_costs

UNITS: kr/year

DOCUMENT: This variable is the total costs. It is the sum of total car purchases, maintenance and employee costs.

Total_employees = Car_sharing_members*Employees_per_member

UNITS: person

DOCUMENT: These are the employees required for the company. As the company gains more members, they will need to increase their numbers of employees to service both the members and the cars.

****

Parking_space_sector:

****

Adjustment_in_parking_spots = MIN(Gap_in_parking_spots, Potential_maximum_gap)/Time_to_adjust_parking_spots_for_shared_cars

UNITS: parking/Year

DOCUMENT: This is the flow of adjustment in parkings spots for shared cars. It flows into the stock of parking spots for shared cars. This flow represents the increase in designated parking spots for shared cars as the shared car fleet increases. The MIN function in the equation represents that if the gap between shared cars and their parking spots is more than the potential maximum gap, then the maximum gap is used instead. This is because there is a maximum of how many parking spots can be changed to being only for shared cars. The remaining parking spots are privately owned and can not be changed into a shared car parking spot.

Desired_parking_spots_per_shared_car = 1

UNITS: Parking/Car

DOCUMENT: The variable Desired parking spots per shared car shows how many parking spots Dele wants per shared car. We assume they want at least one spot per car because each car needs at least one parking spot.

Desired_total_parking_spots = Number_of_shared_cars*Desired_parking_spots_per_shared_car*(1-Policy_in_effect:_Free_Floating) + Number_of_shared_cars*Free_floating_desired_parking*Policy_in_effect:_Free_Floating

UNITS: parking

DOCUMENT: The variable shows the total parking spots Dele wants to have. The total number of spots they desire depends on how many shared cars they have and the desired parking spots for each shared car. It is calculated by Number of shared cars multiplied by how many parking spots they desire per spot. The value of the desired parking spot per shared car can change if the free floating policy is put in effect, thus increasing the desired total parking spots.

Free_floating_desired_parking = 8

UNITS: Parking/Car

DOCUMENT: The variable Free floating desired parking shows the number of desired parking spots in the free floating policy. By adding 7 extra parking spots, the members can choose to park the car in 7 other places other than the original one space where they picked the car up.

Free_Floating_Policy_SWITCH = 1

UNITS: dmnl

DOCUMENT: The switch for the policy Free floating. The switch is on when it shows 1 and off when it shows 0. The policy allows members to not be as restricted as the current policy Dele is operating with, where members have to pick up the car at A and bring it back to A. It allows members to drive from A to B, and B is now several other parking options, depending on area and how many other members or shared car customers are parked in the same area.

Gap_in_parking_spots = Perceived_desired_total_parking_spots-Parking_spot_for_shared_cars

UNITS: parking

DOCUMENT: The gap between how many parking spots Dele wants and how many parking spots they have for shared cars. This is shown through subtracting the parking sports for shared cars from the perceived desired total parking spots

Initial_parking_spots_for_shared_cars = 1

UNITS: parking

DOCUMENT: Assumed based on Dele's webpage where they explain they started with 1 car, shared between 5 families (Dele, n.d). We can assume that in 1996. Each family had their own parking for their private home. However, any number above 1 is irrelevant as we assume they were neighbors and therefore parked the car in the same area.

Parking_spot_for_shared_cars(t) = Parking_spot_for_shared_cars(t - dt) + (Adjustment_in_parking_spots) * dt

INIT Parking_spot_for_shared_cars = Initial_parking_spots_for_shared_cars

UNITS: parking

DOCUMENT: This is a stock showing the amount of parking spots per shared car, it is increased by the inflow of adjustment in parking spots. The initial value is described in the variable above, called initial parking spots for shared cars.

Perceived_desired_total_parking_spots = SMTH1(Desired_total_parking_spots, Time_to_percieve_parking_spots)

UNITS: parking

DOCUMENT: This variable indicates the perceived desired total parking spots. This acts as a delay for how many parking spots are required for the shared cars. The smooth function acts as an information delay because it takes time for people to realize the total needed parking spots from the shared cars than they do need in real time.

Policy_in_effect:_Free_Floating = IF TIME >= Start_year THEN Free_Floating_Policy_SWITCH ELSE 0

UNITS: dmnl

DOCUMENT: This variable decides when the policy will be in effect, IF TIME means that - if the start year is 2024, THEN= then the free floating policy switch will be turned on, if not - ELSE=0 Meaning, if the start year is not 2024, the policy switch is off. Making sure the policy does not start before 2024 when turned on.

Potential_maximum_gap = Potential_parking_spots_for_shared_cars-Parking_spot_for_shared_cars

UNITS: parking

DOCUMENT: This is the maximum gap in parking spots that can be turned into parking spots for shared cars. Parking spots for shared cars are subtracted from the potential parking spots for shared cars to calculate how many additional parking spaces can be turned into parking spots for shared cars.

Potential_parking_spots_for_shared_cars = 4000

UNITS: parking

DOCUMENT: Number assumed because Dele today has 400 cars (Dele, n.d-b). Since they started with one car in 1996, 36 years ago, we chose 4000 as an assumption for the maximum number of parking spots because most car parking spaces are privately owned and can not be turned into a designated parking spot for shared cars.

Time_to_adjust_parking_spots_for_shared_cars = 1/4

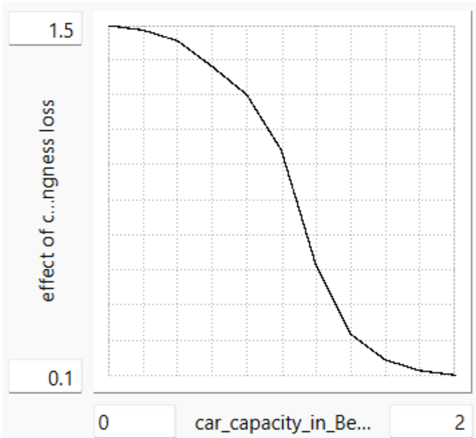
UNITS: year

DOCUMENT: This variable shows an assumed number which is ¼ of a year = 3 months. We assume it takes 3 months to get a new parking spot from Bergen municipality, businesses or private persons.
Time_to_percieve_parking_spots = 1
UNITS: year
DOCUMENT: This is the time it takes on average for people to perceive the change in how many parking spots are needed for the fleet of shared cars. One year was taken as an assumption.
yearly_relative_parking_spots_ratio = (Parking_spot_for_shared_cars/total_parking_spaces)/Time_to_percieve_parking_spots
UNITS: dmnl/year
DOCUMENT: This is the ratio of designated parking spots for shared cars to the total car parking spots in Bergen every year. The shared parking spots are divided by the total parking spots to find that ratio. That ratio is then divided by a year to get the yearly parking spots ratio.

****
policy_switches:
****

****
scenario_switches:
****

****
Willingness_Sector:
****
car_capacity_in_Bergen = (private_parking_required/Spaces_for_private_car)
UNITS: dmnl
DOCUMENT: This value determines if the cars in Bergen are over capacity or not. If the private parking required goes above the spaces for private cars, then the value of this variable goes above 1 and indicates that the cars are over capacity.
company_partnerships:_SWITCH = 0
UNITS: dmnl
DOCUMENT: This is the policy of company partnerships. If the value of this variable is 0, then the policy is not in effect. If the value is at 1, then the policy is in effect.
effect_of_car_capacity_in_Bergen_on_willingness_loss = GRAPH(car_capacity_in_Bergen)
Points: (0.000, 1.500), (0.200, 1.48196603774), (0.400, 1.43882641509), (0.600, 1.33618490566), (0.800, 1.223), (1.000, 1.000), (1.200, 0.539), (1.400, 0.263705283019), (1.600, 0.161149056604), (1.800, 0.117830566038), (2.000, 0.100)

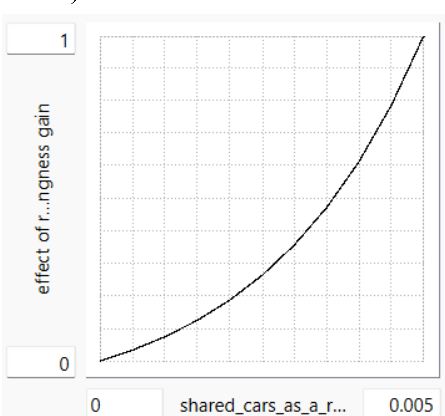


UNITS: dmnl

DOCUMENT: This is a graphical function of how the car capacity affects the willingness loss. It is Z-shaped. When car capacity is at 1, then this effect would be 1. As the car capacity in Bergen lowers, people lose willingness in using shared cars because there's more room for private cars in the city. When the car capacity increases, people lose their willingness at a slower rate because it becomes more desirable to use shared cars. The minimum value of the x-axis is 0 and the maximum value is 2. The minimum value of the y-axis is 0.1 and the maximum is 1.5.

effect_of_ratio_of_shared_cars_on_willingness_gain = GRAPH(shared_cars_as_a_ratio_of_total_cars)

Points: (0, 0.000), (0.0005, 0.03341), (0.001, 0.07447), (0.0015, 0.1249), (0.002, 0.1869), (0.0025, 0.2631), (0.003, 0.3567), (0.0035, 0.4717), (0.004, 0.613), (0.0045, 0.7866), (0.005, 1.000)

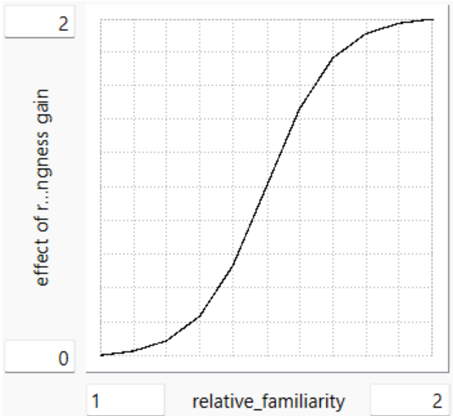


UNITS: dmnl

DOCUMENT: This is a graphical function of how the ratio of shared cars of the total cars in Bergen has an effect on willingness gain. This indicates that as there are relatively more shared cars in the city, then people find it more convenient to use. The shape of the graphical function is an exponential growth as we assume that when the ratio of shared cars increases then people would be more willing to use them at a faster rate. The minimum value of the x-axis is 0 and the maximum value is 0.005. The minimum value for the y-axis is 0 and the maximum is 1.

effect_of_relative_familiarity_on_willingness_gain = GRAPH(relative_familiarity)

Points: (1.000, 0.000), (1.100, 0.02526), (1.200, 0.08682), (1.300, 0.2331), (1.400, 0.5352), (1.500, 1.000), (1.600, 1.465), (1.700, 1.767), (1.800, 1.913), (1.900, 1.975), (2.000, 2.000)

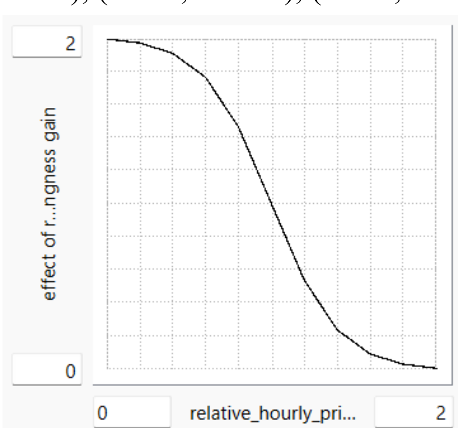


UNITS: dmnl

DOCUMENT: This is a graphical function of how familiarity has an effect on willingness gain. It is an S-shaped growth because we assume that familiarity would start to have an effect on willingness slowly in the beginning, but as familiarity increases, the effect would start to increase as well until it reaches a max point where it plateaus out. As familiarity increases, so does the effect on willingness gain. When familiarity decreases, it has a less of an effect on willingness gain. The minimum value of the x-axis is 1 and the maximum is 2. The minimum value of the y-axis is 0 and the maximum value is 2.

effect_of_relative_hourly_price_on_willingness_gain = GRAPH(relative_hourly_price)

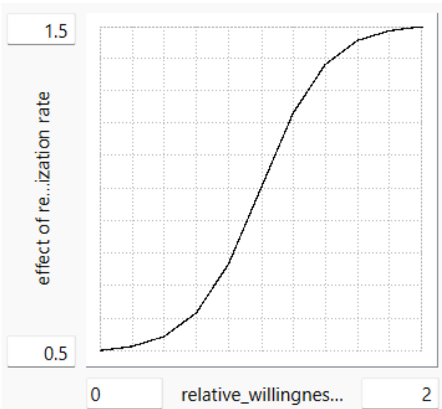
Points: (0.000, 2.000), (0.200, 1.975), (0.400, 1.913), (0.600, 1.767), (0.800, 1.465), (1.000, 1.000), (1.200, 0.5352), (1.400, 0.2331), (1.600, 0.08682), (1.800, 0.02526), (2.000, 0.000)



UNITS: dmnl

DOCUMENT: This is a graphical function that shows how the relative hourly prices affect the willingness gain. It is Z-shaped. As prices go below the indicated hourly price, people's willingness increases at a faster rate. If the prices go above the indicated hourly price, the people's willingness increases at a slower rate. The minimum value for the x-axis is 0 and the maximum value is 2. The minimum value for the y-axis is 0 and the maximum is 2.

effect_of_relative_willingness_for_utilization_on_utilization_rate = GRAPH(relative_willingness_for_utilization)
Points: (0.000, 0.500), (0.200, 0.5126), (0.400, 0.5434), (0.600, 0.6165), (0.800, 0.7676), (1.000, 1.000), (1.200, 1.232), (1.400, 1.383), (1.600, 1.457), (1.800, 1.487), (2.000, 1.500)



UNITS: dmnl

DOCUMENT: This is a graphical function of how willingness has an effect on shared cars' utilization rate. It is an S-shaped growth that has an increasing effect in one direction, and a decreasing effect in the other direction. When the relative willingness on utilization rate is at 1, then this effect is at 1. As willingness increases, people would use the shared cars more every day. This means that each shared car is more in use per day. If willingness lowers, then people use each car less per day. The minimum value for the x-axis is 0 and the maximum value is 2. The minimum value for the y-axis is 0.5 and the maximum is 1.5.

Initial_Willingness = 0

UNITS: dmnl

DOCUMENT: The initial willingness is assumed to be at 0 at the start of the simulation because this was the first time car sharing was introduced to Bergen. Only after the car sharing company started did people's willingness increase.

marketing_effect = 1.5

UNITS: dmnl

DOCUMENT: The marketing effect determines by how much the inflow of willingness gain increases. It is a part of the marketing policy. The value of 1.5 is an assumed value that the policy would put in effect.

marketing_policy:_SWITCH = 0

UNITS: dmnl

DOCUMENT: This variable indicates if the marketing policy is in effect or not. If it is at 0, then it is not in effect and if it is at 1, then it is in effect.

Maximum_Willingness = 1

UNITS: dmnl

DOCUMENT: This is the maximum value of the stock of willingness. When it is at 1, it is at 100% and can only decrease from there.

minimum_willingness_required_to_have_an_effect_on_becoming_a_member = normal_minimum_willingness_required_to_have_an_effect_on_becoming_a_member*(1-policy_in_effect:_company_partnerships) + minimum_willingness_required_to_have_an_effect_on_becoming_a_member_through_company_partnerships*policy_in_effect:_company_partnerships

UNITS: dmnl

DOCUMENT: This is the minimum willingness required to have an effect on the membership rate increasing. When the company partnership policy is turned on, then the value of this variable takes the given number for that policy scenario. If the policy is turned off, then this variable takes the value of the normal minimum willingness required to have an effect on membership rate.

minimum_willingness_required_to_have_an_effect_on_becoming_a_member_through_company_partnerships = 0.45

UNITS: dmnl

DOCUMENT: This is the minimum willingness required to have an effect on people becoming members when the company partnership policy is turned on. The value of 0.45 is an assumed value that was hand calibrated from looking at the results of the base simulation.

normal_minimum_willingness_required_to_have_an_effect_on_becoming_a_member = 0.65

UNITS: dmnl

DOCUMENT: This is the normal minimum willingness required to have an effect on people becoming members. This value is taken when the company partnership policy is turned off, and is therefore used in the baseline scenario. The value of 0.65 is an assumption that was hand calibrated to match existing data.

Normal_Willingness_Gain_Rate = 0.15

UNITS: dmnl/year

DOCUMENT: This is the normal willingness gain rate. This would be the increase in willingness each year if no effects would be applied to the inflow of willingness gain. This is an assumed value that was hand calibrated to match existing data.

Normal_Willingness_Loss_Rate = 0.1

UNITS: dmnl/year

DOCUMENT: This is the normal willingness loss rate. This would be the rate of willingness loss each year if no other effect would be applied to the outflow of willingness loss. This is an assumed value that was hand calibrated to match existing data.

policy_in_effect:_company_partnerships = IF TIME >= Start_year THEN company_partnerships:_SWITCH ELSE 0

UNITS: dmnl

DOCUMENT: This variable indicates that if the company partnerships policy switch is at 1, then it will be enabled in the year 2024. If the policy switch is at 0, then this policy will not be in effect at any time.

policy_in_effect:_marketing_policy = IF TIME >= Start_year THEN marketing_policy:_SWITCH ELSE 0

UNITS: dmnl

DOCUMENT: This variable indicates that if the marketing policy switch is at 1, then it will be enabled in the year 2024. If the policy switch is at 0, then this policy will not be in effect at any time.

Relative_weight_of_Familiarity = 0.7

UNITS: dmnl

DOCUMENT: This is the relative weight of familiarity compared to the weight of accessibility. This is an assumed value that was hand calibrated to match existing data.

relative_willingness_for_membership = Willingness_to_Rent_a_Car/minimum_willingness_required_to_have_an_effect_on_becoming_a_member

UNITS: dmnl

DOCUMENT: This variable determines when an effect variable is applied. When the willingness is lower than the threshold of minimum willingness required to have an effect on becoming a member, then the value of this variable is under 1. When this variable is under 1, then the effect function does not take it into consideration on people becoming members.

relative_willingness_for_utilization = Willingness_to_Rent_a_Car/Willingness_threshold_on_utilization_rate

UNITS: dmnl

DOCUMENT: This variable indicates whether the willingness is higher or lower than the threshold to have an effect on utilization rate. When the willingness is lower than the threshold, then the value of this variable is under 1 and when the willingness is higher than the threshold, then the value of this variable is over 1.

shared_cars_as_a_ratio_of_total_cars = Number_of_shared_cars/total_number_of_cars

UNITS: dmnl

DOCUMENT: This variable calculates what the ratio of the shared cars is to the total numbers of cars in Bergen. It divides the number of shared cars with the total number of cars to get that ratio.

Spaces_for_private_car = total_parking_spaces-Parking_spot_for_shared_cars

UNITS: parking

DOCUMENT: This variable calculates how many parking spaces are allocated for private cars. It subtracts the parking spots for shared cars from the total parking spaces.

total_parking_spaces = 200000

UNITS: parking

DOCUMENT: We determined that each household in Bergen has at least one dedicated parking spot. The total number of dwellings in Bergen as of 2024 is just under 147000. Some households have more than one parking space so we made an assumption that the total value of parking spaces in Bergen are 200000 (Statistics Norway, 2024c).

Weight_of_Accessibility = (1-Relative_weight_of_Familiarity)*(1-Weight_of_Price)

UNITS: dmnl

DOCUMENT: This variable calculates the weight of accessibility by taking the remaining weights from both familiarity and price and multiplies them. That value is given to the weight of accessibility. This formulation makes sure that no matter what changes are made to the other weights, their total would always add up to 1.

Weight_of_Familiarity = (1-Weight_of_Price)*Relative_weight_of_Familiarity

UNITS: dmnl

DOCUMENT: The weight of familiarity is calculated by taking the remaining weight after the weight of price is subtracted from it and multiplied by the relative weight of familiarity.

Weight_of_Price = 0.3

UNITS: dmnl

DOCUMENT: This is the weight of price having an effect on the increase of people's willingness to rent a car. The value of 0.3 was assumed and hand calibrated to make the simulation match existing data until 2024.

Willingness_gain =
((Maximum_Willingness-Willingness_to_Rent_a_Car)/Maximum_Willingness*
Normal_Willingness_Gain_Rate*
(effect_of_ratio_of_shared_cars_on_willingness_gain*Weight_of_Accessibility+
effect_of_relative_familiarity_on_willingness_gain*Weight_of_Familiarity+
effect_of_relative_hourly_price_on_willingness_gain*Weight_of_Price)*(1-policy_in_effect:_marketing_policy)) +
((Maximum_Willingness-Willingness_to_Rent_a_Car)/Maximum_Willingness*
Normal_Willingness_Gain_Rate*
(effect_of_ratio_of_shared_cars_on_willingness_gain*Weight_of_Accessibility+
effect_of_relative_familiarity_on_willingness_gain*Weight_of_Familiarity+
effect_of_relative_hourly_price_on_willingness_gain*Weight_of_Price)*marketing_effect*policy_in_effect:_marketing_policy)

UNITS: dmnl/year

DOCUMENT: This is the flow of willingness gain going into the stock of willingness to rent a car. The flow is determined by taking the gap to fill the willingness and multiplying it with the normal willingness gain rate as well as other additional effects. When the marketing policy is turned on, then the inflow is multiplied by the marketing effectiveness to increase it further.

Willingness_loss =
Willingness_to_Rent_a_Car*effect_of_car_capacity_in_Bergen_on_willingness_loss*Normal_Willingness_Loss_Rate

UNITS: dmnl/year

DOCUMENT: This is the flow of willingness loss going out of the stock of willingness to rent a car. It takes the value of willingness to rent a car and multiplies it by the normal willingness loss rate. That is then multiplied by the effect of car capacity in Bergen on willingness loss.

Willingness_threshold_on_utilization_rate = 0.7

UNITS: dmnl

DOCUMENT: This is the threshold required for willingness to have a positive effect on utilization rate. The value of 0.7 is an assumed value that was hand calibrated to match existing data until 2024.

Willingness_to_Rent_a_Car(t) = Willingness_to_Rent_a_Car(t - dt) + (Willingness_gain - Willingness_loss) * dt

INIT Willingness_to_Rent_a_Car = Initial_Willingness

UNITS: dmnl

DOCUMENT: This is the stock of willingness to rent a car. It is increased by the inflow of willingness gain and decreased by the outflow of willingness loss. The initial value for the stock was deemed to be 0 as it is assumed that at the start of the simulation, people weren't familiar with the car sharing concept or business and would therefore not have any willingness.

Appendix B: Model validation

Structure confirmation test

The model was constructed to match the reference mode of behaviour, which was built based on literature, feedback from our client, and global trends. The structure is considered a realistic representation of how shared cars may tone down private car use and be an alternative method of transport.

Parameter confirmation test

Most parameters in the model were based on literature and data although some parameters and effects were based on our own assumptions to match existing data and show a realistic simulation into the future. For more information on the parameters and effects, see model documentation in Appendix A.

Dimensional consistency test

All the model variables show unit consistency, confirmed by Stella Architect 3.6 and have a real-life meaning behind them. The equations hold dimensional consistency, also confirmed by Stella Architect 3.6.

Behavioural pattern reproduction

The reference mode of behaviour for Willingness to Rent a Car and Number of Shared Cars have been met, but the number of Private cars plateaus instead of increasing or decreasing. This is a result of only 3.6% of the eligible driver population being members at the end of 2050. This means that by only doing the shared cars concept, the decrease in private car use is not as substantial as previously considered. While not all reference modes were met, this model is still considered valid and useful based on the simulations.

Extreme conditions test

Series of extreme conditions tests were done with the results being deemed appropriate and expected in a real-life environment. The reference mode of behaviour for shared cars and willingness were met in the model simulation, but the number of private cars stabilised in the baseline scenario. This is due to car deterioration eventually catching up to the flow of buying private cars because as car sharing members increase, car purchases will drop.

Integration error test

The model was tested with different DTs. As the smallest time unit in the model is 0.0055 dmnl/year, the most appropriate DT to use is 1/256. A higher DT shows unrealistic oscillations. The model was simulated with both Euler's method and Runge-Kutta 4. Due to there being no difference in the results with both integration methods, a DT of 1/256 was chosen with the Runge-Kutta 4 integration method.

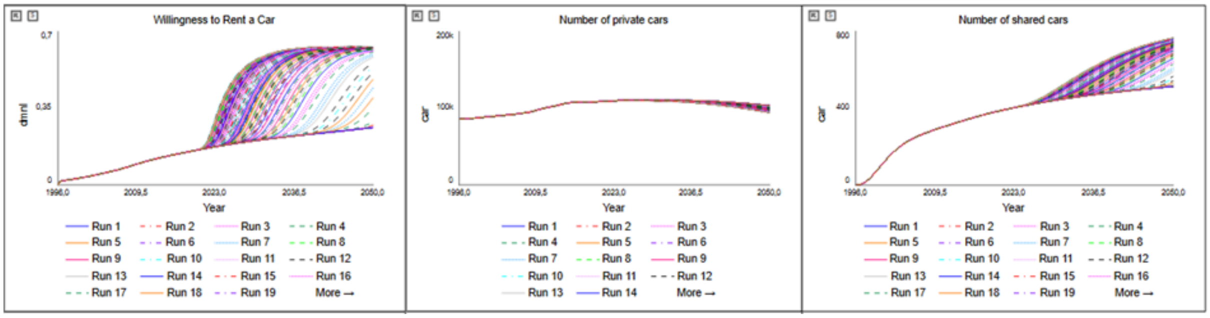
Sensitivity analysis

Sensitivity analysis was conducted for all parameters and effects in the model for the baseline scenario. It was done with Stella's Model Analysis Tool feature. Sobol sequence sampling was used with uniform distribution across a realistic range and run 200 times for each parameter. Uniform distribution proved to be best suited as more information was needed to determine the mean or standard deviation for the parameters.

Variables	Range	Results
Familiarity sector		
effective contact rate for non-member	0 - 0.3	**Behavioural**
normal external desire to use alternative transport	0 - 0.1	**Behavioural**
effective contact rate for member	0 - 0.5	Numerical
normal forgetting rate	0.5 - 3	**Behavioural**
Minimum familiarity required to have an effect on willingness gain	0 - 0.8	**Behavioural**
effect of social exposure on forgetting	Graph	**Behavioural**
Membership sector		
fraction people with drivers license	0.1 - 0.8	Numerical
time to become a potential member	0.5 - 3	Not Sensitive
normal membership rate	0.001 - 0.1	**Behavioural**
Membership time	0.5 - 20	Numerical
effect of relative willingness on becoming a member	Graph	Numerical
Willingness sector		
Normal Willingness Gain Rate	0.05 - 0.25	Numerical
Normal Willingness Loss Rate	0.05 - 0.15	Numerical
Minimum willingness required to have an effect on becoming a member	0.3 - 1	Numerical
Willingness threshold on utilization rate	0.35 - 0.85	Numerical
total parking spaces	13000 - 35000	Numerical
Weight of price	0 - 1	Numerical
Relative weight of familiarity	0 - 1	Numerical
effect of relative willingness for utilization on utilization rate	Graphs	Numerical
effect of car capacity in Bergen on willingness loss	Graphs	Numerical
effect of ratio of shared cars on willingness gain	Graphs	Numerical
effect of relative hourly price on willingness gain	Graphs	Numerical
effect of relative familiarity on willingness gain	Graphs	Numerical

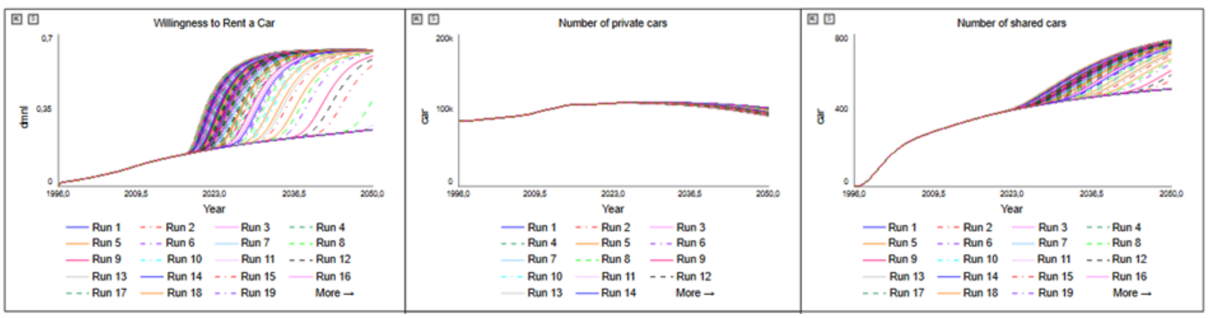
Money sector		
Employees per member	0.0005 - 0.0015	Not Sensitive
Average employee salary	450000 - 800000	Not Sensitive
member price	600-1800	Numerical
time to perceive profit margin	0.5 - 2	Not Sensitive
Reference profit margin	0.1 - 0.5	Numerical
Car sector		
Cars per capita	0.32 - 0.96	Numerical
Cost per new car	250000 - 1000000	Numerical
effect of relative hourly price on membership time	Graph	**Behavioural**
effect of relative profit margin on buying shared cars	Graph	Not Sensitive
effect of relative profit margin on renting prices	Graph	Numerical
Average hourly renting price	32 - 150	**Behavioural**
Maintenance costs per car per year	50000 - 150000	Numerical
Members per car	5 - 25	Numerical
Normal utilization rate	0.1 - 0.9	**Behavioural**
reduction in cars bought per member	0.11 - 0.33	Numerical
Time for cars to deteriorate	2 - 15	Numerical
time for private cars to deteriorate	5 - 20	Not Sensitive
Time to buy private car	0.1 - 3	**Behavioural**
Time to buy shared cars	0.1 - 3	Numerical
Parking sector		
Desired parking spots per shared car	1-20	Numerical
Potential parking spots for shared cars	500-10000	Not sensitive
Time to perceive parking spots	0.1-5	Numerical
Time to adjust parking parking spots for shared cars	0.08-1	Not sensitive

Effective contact rate for non-member



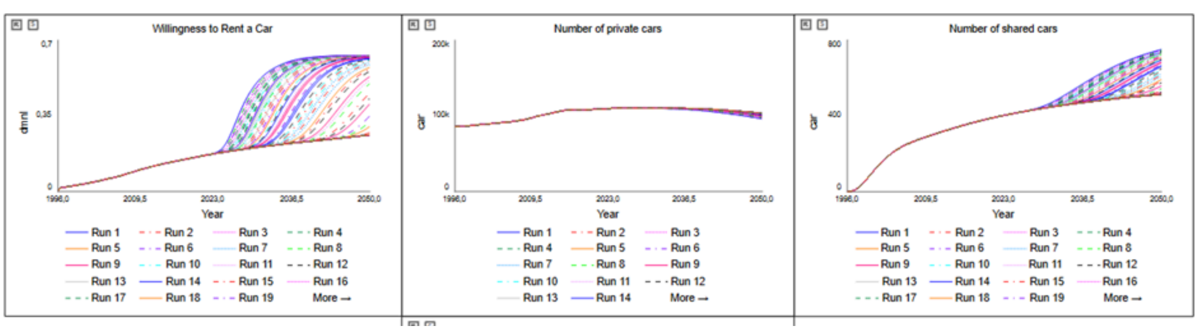
The model is behaviourally sensitive to this variable due to it having a large influence on familiarity gain. Willingness is only increased by familiarity if it exceeds the threshold required to have an effect on willingness. As familiarity gets over the threshold then the willingness increases and total members increase, resulting in fewer private cars and more shared cars. If the familiarity is under the threshold, then it would not increase the willingness.

Normal external desire to use alternative transport



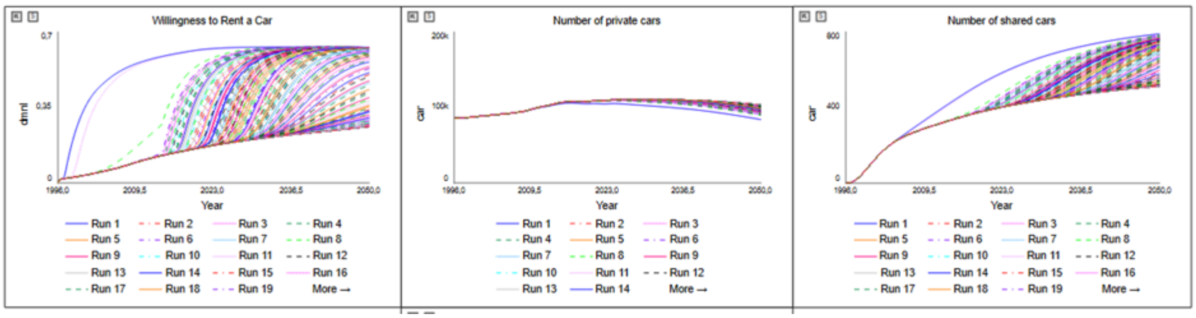
The model is behaviourally sensitive to this variable due to it having a large influence on familiarity gain. Willingness is only increased by familiarity if it exceeds the threshold required to have an effect on willingness. As familiarity gets over the threshold then the willingness increases and total members increase, resulting in fewer private cars and more shared cars.If the familiarity is under the threshold, then it would not increase the willingness.

Normal forgetting rate



The model is behaviourally sensitive to this variable due to it having the main influence on familiarity loss. Willingness is only increased by familiarity if it exceeds the threshold required to have an effect on willingness. As this variable increases, it dampens familiarity growth. As familiarity gets over the threshold then the willingness increases and total members increase, resulting in fewer private cars and more shared cars.If the familiarity is under the threshold, then it would not increase the willingness.

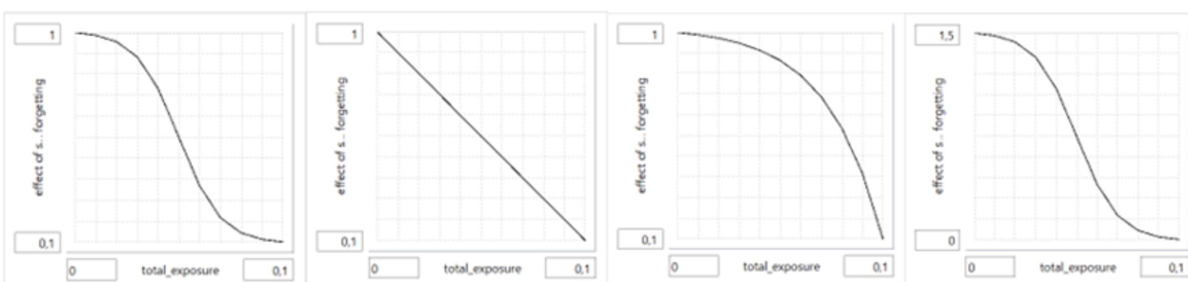
Minimum familiarity required to have an effect on willingness gain

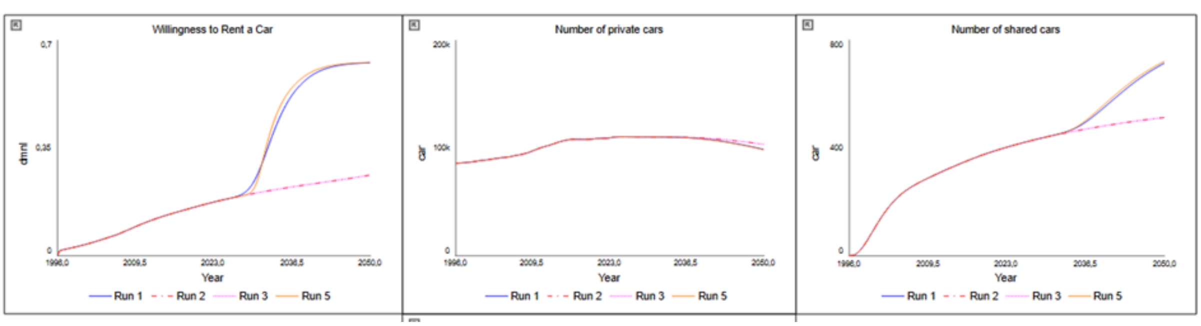


The model is behaviourally sensitive to this variable due to it being the required threshold for familiarity to exceed to increase willingness gain. As this variable increases, familiarity would have to increase to have an effect on willingness gain. As this variable decreases, less familiarity would be required to have an effect on willingness gain. When willingness increases, total members increase, resulting in fewer private cars and more shared cars.

This is used for the scenario switch between a more sharing and a more freedom seeking culture.

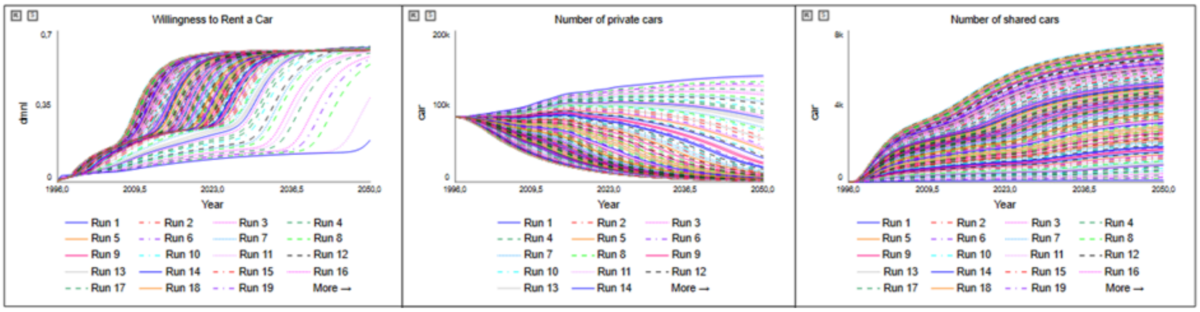
Effect of social exposure on forgetting





This graphical function indicates how total exposure has an effect on willingness loss. As this effect increases familiarity loss, familiarity may not exceed the threshold required to have an effect on willingness gain. Therefore, willingness would not grow as it would otherwise and total members would not increase as much. As there are fewer members, there are fewer shared cars. Also, as there are fewer members, there is a smaller reduction in private cars.

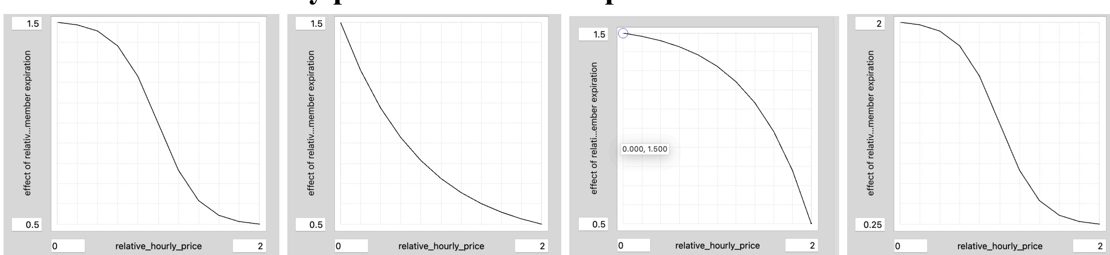
Membership rate

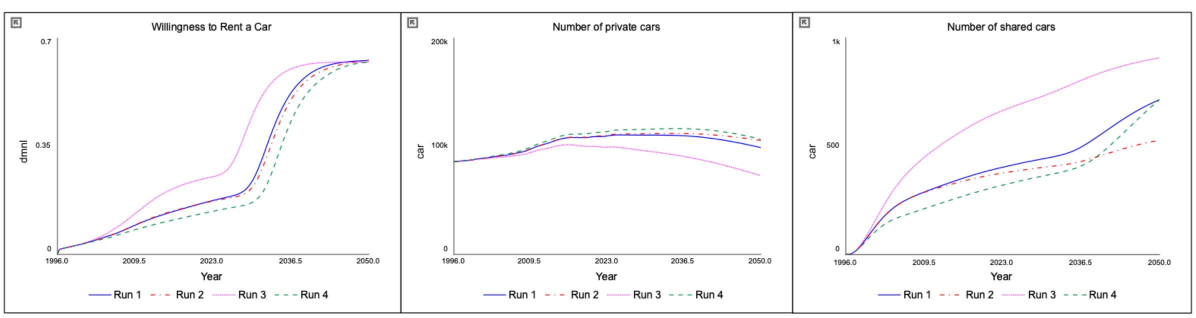


The model is behaviourally sensitive to this variable. This variable is the main influence on increase in memberships. As this variable increases, so too would total members, leading to a decrease in private cars and increase in shared cars. As this variable decreases, so too would total members, leading to more private cars and less shared cars than there would be otherwise.

This variable is used to fluctuate between a sharing versus a more free society.

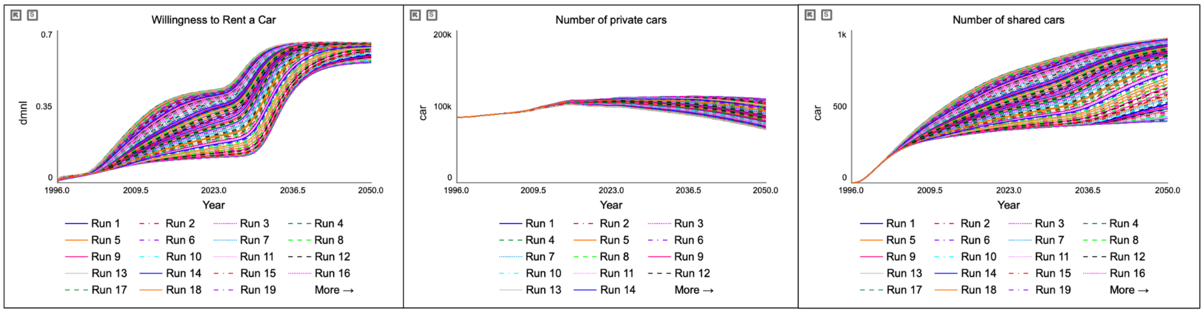
Effect of relative hourly price on membership time





This variable indicates that as hourly prices increase, the total number of members will decrease as they choose to stop being members more quickly. It is behaviourally sensitive. As the rate of change for this effect is decreased, meaning that as prices increase the membership time decreases more slowly, the number of private cars will be lower than normal and the number of shared cars higher than before.

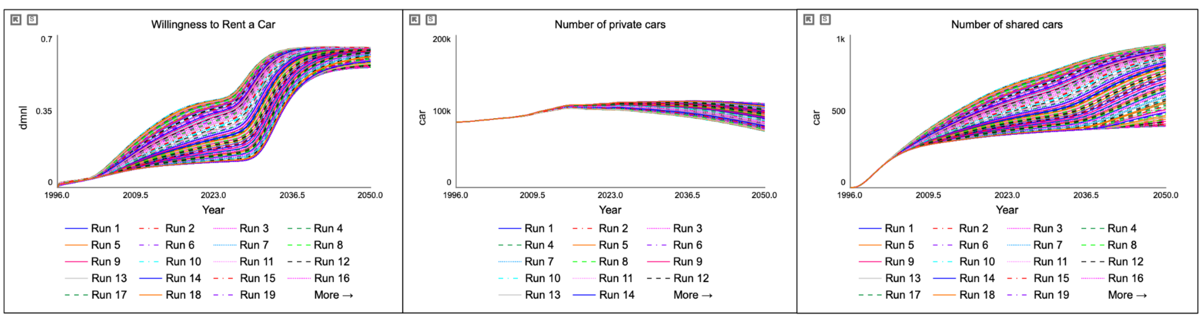
Average hourly renting price



The model is behaviourally sensitive to this parameter. As this variable increases, so too would the profit margin. As profit margin increases, more shared cars will be bought. Also, as profit margin increases, real hourly renting prices would lower, leading to increased willingness and total members. Thus, more shared cars would be required.

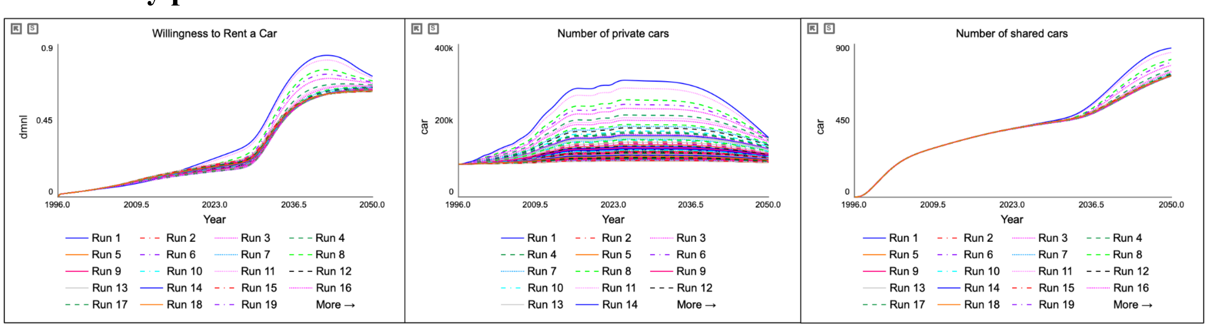
This variable determines between a more green and no green society.

Normal utilization rate shared cars



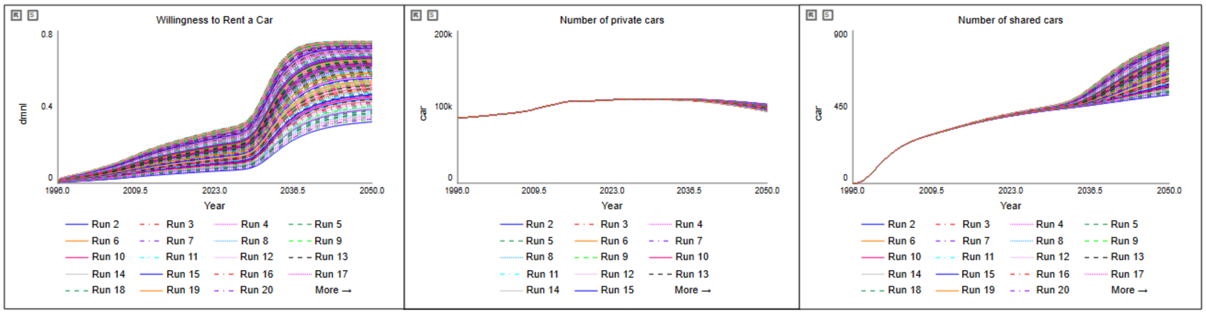
This variable is behaviourally sensitive. As the utilization rate is increased, there are more shared cars as more revenues were generated. More revenues leads to lower prices, more members and more shared cars. This also means that there are fewer private cars. Willingness is increased as more shared cars means that people are more exposed to shared cars.

Time to buy private car



The model is behaviourally sensitive to this parameter. As this variable increases, private car purchases would slow down due to the time it takes to buy a car. However, if this variable decreases, then private cars increase at a faster rate. When private cars exceed the car capacity, willingness increases, resulting in increased memberships. With more members, more shared cars will be bought, and private cars would decrease.

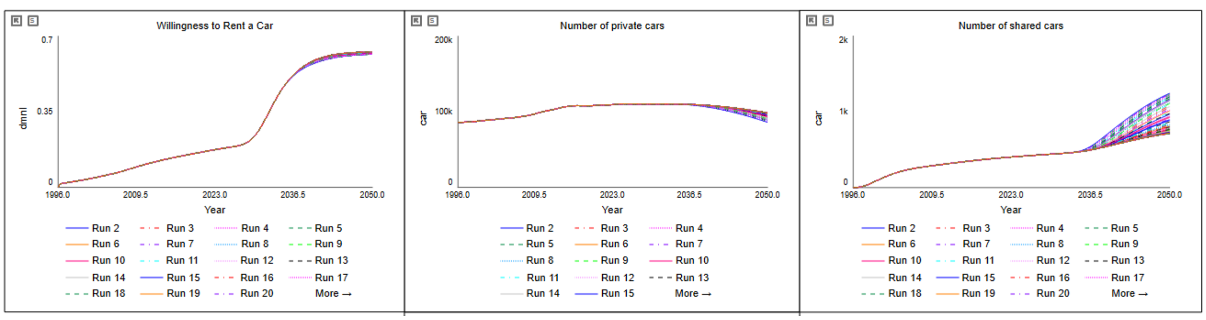
Normal willingness gain rate



This variable is numerically sensitive. It indicates the normal rate at which people gain willingness. With more willingness normally, people are willing to rent shared cars. This variable is used as the basis for the marketing policy where it is increased as people are more exposed to shared cars through advertising.

This is used for the marketing policy.

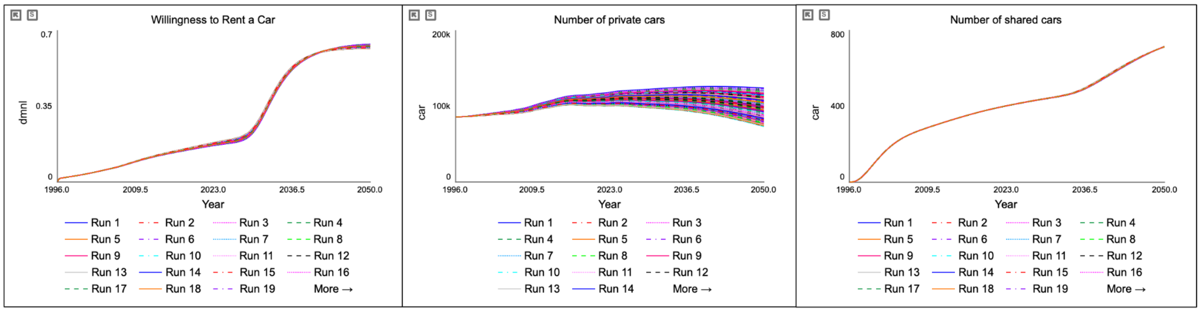
Minimum willingness required to have an effect on becoming a member



This variable is numerically sensitive. It indicates the threshold at which it is required for willingness to have an effect on becoming a member. As this threshold is lowered, people more quickly become members. With more members, there are more shared cars.

This is used for the company partnership policy through a lower threshold.

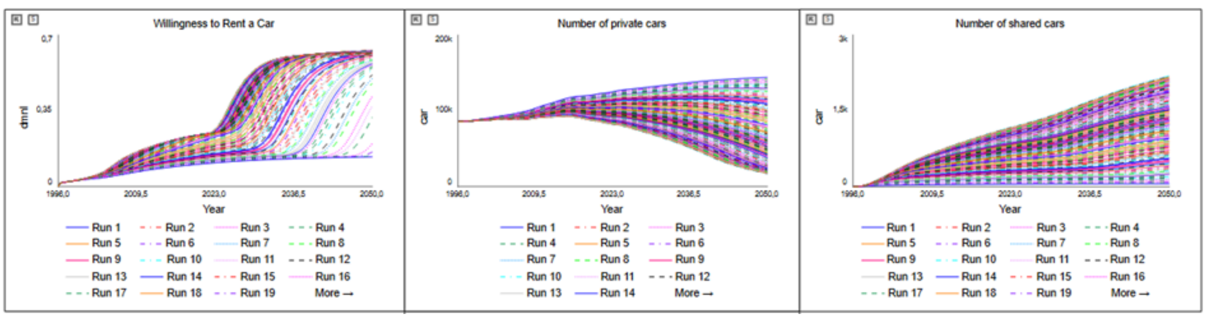
Reduction in cars bought per member



This variable is numerically sensitive. It indicates how the number of members leads to a reduction in private cars. If there is a larger reduction, there are fewer private cars. If there is a smaller reduction, there are more private cars.

This variable is used for freedom versus sharing society.

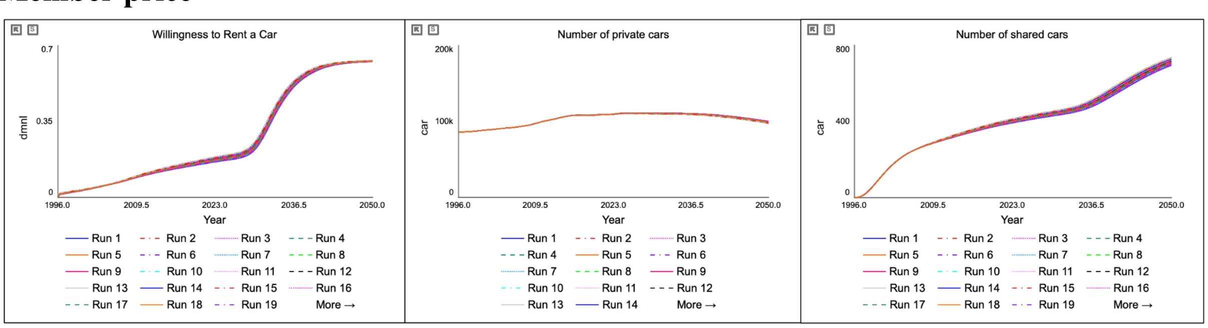
Membership time



The model is behaviourally sensitive to this parameter. As this variable increases, people will stay as members for longer, resulting in less private cars and more shared cars. Willingness would increase through familiarity and the ratio of shared cars to private cars in Bergen. As this variable decreases, people will stay as members for a shorter period of time, resulting in less reductions of private cars and less increase of shared cars. This leads to decreased willingness gain through familiarity and convenience.

This is used as a parameter to switch between a more sharing versus more free society.

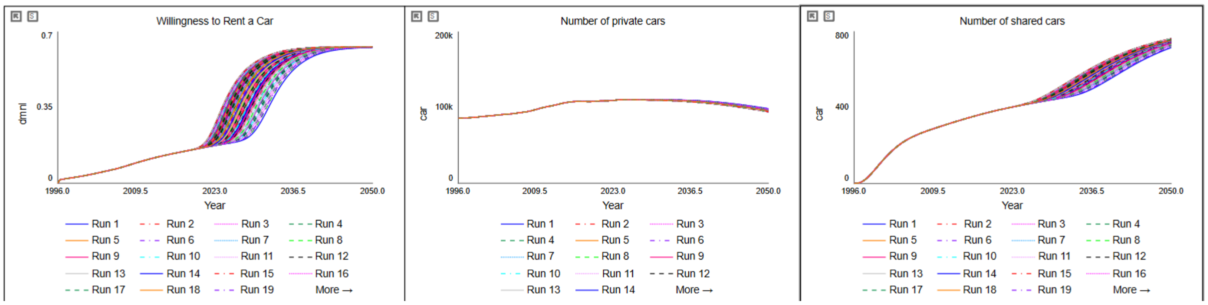
Member price



This model is numerically sensitive to this variable. It indicates that as the member price increases, there is more revenue. Renting prices are then lowered, members are increased, and there are more shared cars.

This was used for a green society scenario as a representation that the government will contribute to the revenues.

Desired parking spots per shared car



This variable is numerically sensitive in the model. It indicates that as there are more desired parking spots per shared car, there is increased willingness as people are more exposed. With more willingness, there are more shared cars.

This was used as part of a free-floating parking policy where it is increased.