The University of Bergen
The System Dynamics Group, Department of Geography

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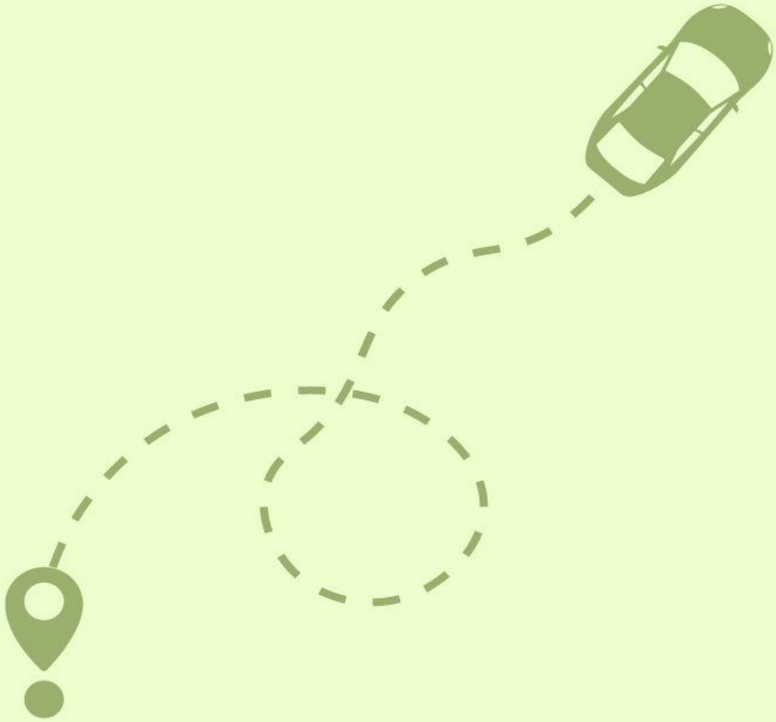
Candidates: 130, 157, 135

Can the car-sharing concept be expanded to Sogndal?



Acknowledgement

We would like to thank our client Klimapartnere Vestland (KV), and especially Hannah Emilie Rørslett Johansson, for participating in this project. The entire process from developing our model to adjusting its structure has been based on feedback from them. For example, we initially thought that price was the biggest barrier to overcome for using car-sharing. However, Hannah corrected us that it was instead the perceived price that affected the system. This also led us to change the focus of our policy recommendations.

In collaboration with KV, we have conducted interviews and participated in the car-sharing conference in Bergen to understand which barriers exist today. We have also gained insightful information about why car-sharing is hard to implement in the district of Vestland. In our report, we base our model assumptions on balancing information from Dele and KV, and other relevant literature gained from participation in the car-sharing conference that our client recommended. Our understanding has allowed us to develop policy recommendations that best fit Dele and KV's financial capacity.

It has been fun and challenging working with clients to combine qualitative information with quantitative methods. We experienced that clear communication was important when talking with the clients, to be sure we were on the same page and to avoid misunderstandings.

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1. Introduction

The nature and climate crisis requires us to make drastic changes in the way we use both land areas and energy. Private transport has a large carbon footprint and has contributed to greenhouse gas emissions and pollution. The concept of car-sharing has become a widespread phenomenon in the densely populated parts of Norway. According to Dele, a shared car is used up to 50% a day, compared to a private car that is only used 2,5% of the day. In addition, according to Klimapartnere Vestland (KV), a shared car replaces between 10-15 privately owned cars. Vestland County has set its emission goal to be net-free by 2030, and together with KV they have launched the concept campaign "Heile Vestland deler" ("All of Vestland shares").

1.1 Case description

From the campaign "All of Vestland Shares" we got the inspiration to investigate the possibility of car-sharing in the other districts of Vestland county outside of Bergen.

"How might we reduce the impact from cars on the climate and nature, without affecting the daily lives of people, businesses, and municipalities.
See if the car-sharing concept can be expanded to municipalities in the districts."

In partnership with car-sharing company Dele and KV, this project seeks to explore and expand the potential of car-sharing in Vestland. At the moment, Dele has a car-sharing fleet located in Bergen and Trondheim, with over 400 shared cars available. We aim to identify and analyze barriers that exist in more rural areas of Vestland and have specifically chosen Sogndal as a case example. The reasoning for choosing Sogndal is that it compares to Bergen in several aspects. There is a compacted city center, a high portion of the population are commuters, Vestland County has offices there, and the Western Norway University of Applied Sciences (HVL) has a campus there with 2360 students.

As part of our framing, we will only focus on the central area of Sogndalsfjøra with a 3,5km radius. We have also decided to focus on three main stakeholders; KV and Dele, the local government of Sogndal, and the part of the population who commute. Instead of including the whole population, we decided to focus on commuters as they will be the main target audience for this concept.

1.2 Problem definition

Before we started modelling, we developed a dynamic hypothesis in cooperation with the client based on our view of the situation in Sogndal. We quickly realized that this is not a problem with a single or easy solution. Addressing it requires a holistic, flexible approach that considers the needs and impacts on all stakeholders involved.

Dynamic hypothesis:
For the concept to be desirable for users, it needs to be easy to use and accessible. For the concept to be easy to use and accessible, it needs to be desirable for enough users.

Inspired by the problem definition of "All of Vestland Shares", we decided to focus our problem on how can KV and Dele make car-sharing attractive for the inhabitants of Sogndal? And how can this be increased or maximized? We then developed a research question for this:

Which drivers need to be in place to overcome the barriers for car-sharing in Sogndal, and how are they interconnected?

Based on meetings with the client and workshops, we identified barriers in the system that will need to be overcome to introduce car-sharing in Sogndal. These barriers were clustered into two main categories of accessibility and acceptance. In our model personal acceptance includes the barriers related to general acceptance, the price of owning a private car and the perceived price gap between owning/sharing. In all, we can say that these barriers reflect the perspectives of the inhabitants of Sogndal, and the likeliness of them using shared cars. Here we see that the strongest barrier is the "Perceived price gap". Accessibility includes barriers related to shared cars per user, time used to get to a shared car and the price of using a shared car. These barriers tell us something about the priorities of the inhabitants of Sogndal, what practical and logistic aspects need to be in place for them to actually use a shared car.

We see that all the barriers can also be drivers in the system, and they are part of our main reinforcing loop, which is driven by our two main KPIs, “Number of users” and “Number of shared cars”. This tells us that there are inherent possibilities within the barriers that exist in the system.

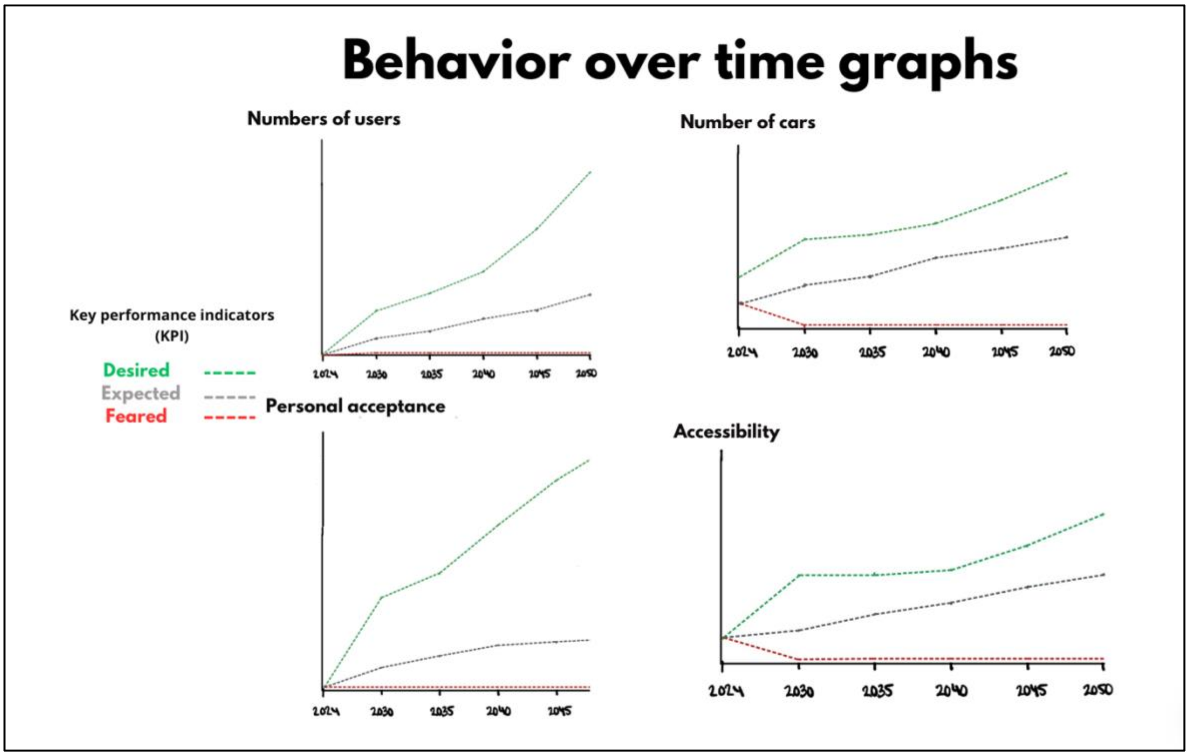

Figure. 1.3.1: *The figure shows the behavior over time for our KPIs. The y-axis of our graphs shows Number of users, number of cars, accessibility and personal acceptance from 2024 to 2050 (x-axis). Green line is desired outcome, red is feared, and grey is expected.*

Because we have no historical data on car-sharing in Sogndal, we have hypothesized three possible future behavior modes for our KPIs. The expected behavior is the base case from our model. In our base case we start out with 5 cars, and 20 users. Both the expected and desired behaviors can be defined as good results as we are trying to introduce a new concept. The foundation for the expected behavior is good accessibility, which has to be in place to reach the desired behavior. To get from expected to desired behavior, increased acceptance is key. With the desired level of accessibility in place, an increased acceptance will drive the desired behavior of number of users. In the assumed feared behavior, we can see a linear relationship between accessibility and number of cars, as 0 cars would give 0 accessibility, and vice versa. This results in low acceptance, and 0 users.

1.3 Main loops and Causal loop diagram (CLD)

To understand how our system is linked we have developed a causal loop diagram (CLD) and identified our main loops as reinforcing (R_1, R_2 and R_3).

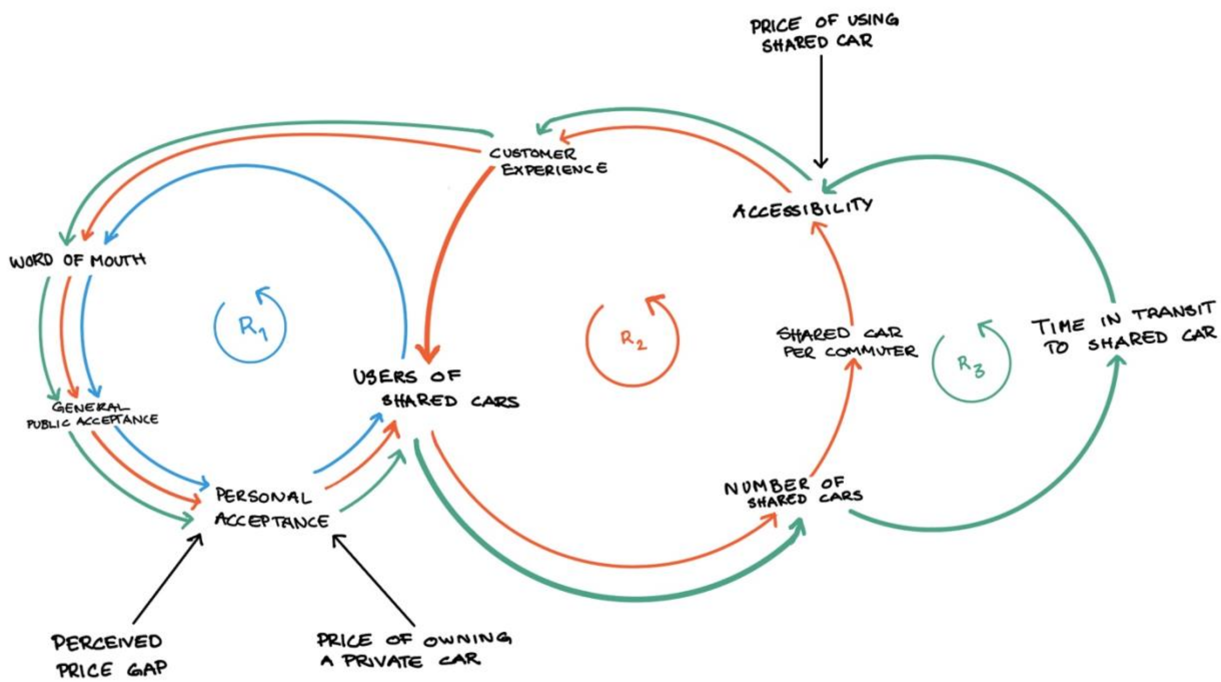

Figure 1.4.1 *Shows the Causal loop diagram (CLD) for our main loops in the model.* R_1, R_2 and R_3

1.4 Model behavior in base case

Usually, model behavior is based on past behavior over time. Our choice to look at introducing car-sharing to Sogndal provides us with a problem, as there is no historical data. When analyzing base case, we will be looking at what we assume to be the behavior in the years between 2024-2050 and call this our base case scenario. We must underscore the fact that this behavior is based on assumptions about Sogndal gathered from SSB, and numbers from Dele from their experiences in Bergen.

We observe that customer experience functions as a leverage point in our model. If customer experience is 50% and above, the customer will be satisfied, thus remain as users, and the contact rate of how many people they will talk to will highly increase. However, if customer experience is below 50%, their contact rate would be very low, and 20% of the user base would leave due to dissatisfaction. In this case, the loop will function as a balancing loop, which can be observed in scenario 2 (see Appendix). In our base case, the initial values make the customer experience just below 50% from the start. Because of this, we only observe three years of slightly lower growth in users, before it increases. After passing this leverage point, word of mouth is increased, thus boosting the strong R1 loop. This, in turn, gives power to R2, thus strengthening the R3 loop.

The result of these strong loops boosting each other is that we see increased growth from year 3 to year 4. After this, we have a steady linear growth in the number of users. For the number of cars, we observe a similar behavior in the first 5 years, as the stock of cars is directly influenced by the stock of users. From year 3 to year 5, an exponential growth is observed. However, as the life expectancy of a shared car in Deles system is 4 years, we experience a drop in the number of cars after this. As the removal of cars continues throughout the time period, we observe a slightly weaker growth of this stock. Ten years into the model, we see the number of cars doubled, leading to the time in transit to a shared car being cut in half. As the time in transit is so low, we believe this is a strong influence on good customer experience which is driving the word of mouth.

For the word of mouth, we observe a slight exponential growth throughout the whole time period. We believe this is because of an increased customer experience, which increases the number of contacts per user. The combined effect of increased number of users and increased contact rate per users will result in exponential growth.

There are some uncertainties outside our model that could work as balancing forces to the system i.e. politics related to infrastructure and parking spaces, and the economic choices and priorities of the municipality.

2. Scenario analysis

Scenario analysis is important for decision-making as it improves the clients' understanding of future challenges and opportunities. In this exercise, we used our key variables to test which exogenous factors our model is most sensitive to. Specifically, the variables “time to adopt” and “weight (price of private car)” were identified as crucial, as they will influence the users of car-sharing in Sogndal in the future (See sensitivity analysis in appendix).

Accordingly, we identified our first main driver as societal values, specifically are we moving towards a more individualistic or a more collaborative society? Sogndal is a municipality in the district of Norway and is affected by national political and economic instability. For example, a political landscape characterized by inflation and international conflicts could support the individualistic society by increasing personal wealth and enabling a high level of consumption. On the other hand, the political landscape could support a collaborative society by facilitating for sharing economy and green solutions. Another important driver in developing mobility solutions in Sogndal is the perceived purchasing power of individuals. In the future, international instability and conflicts will influence the economic stability in Norway. This could lead to a political shift on a national level, as well as in regions like Sogndal, which could affect economic choices.

The above-mentioned drivers were presented to our client and confirmed as exogenous factors beyond their control. Following this, we have developed 4 different future scenarios (Fig. 2.1.1). These scenarios were implemented in our model by adjusting key variables accordingly. Results can be found in the Appendix.

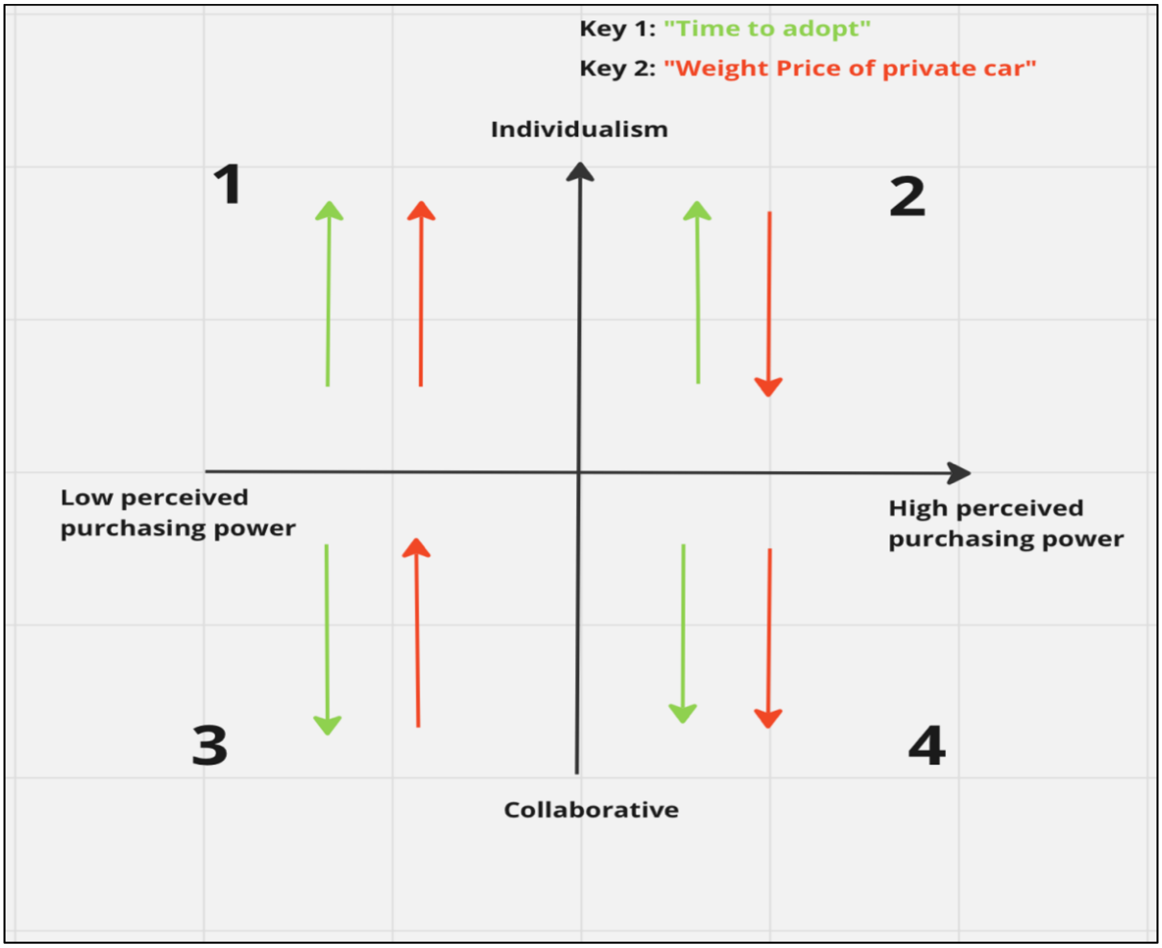

Figure 2.1.1 *The figure shows a 2x2 matrix with an overview of possible future scenarios 1-4. The x-axis shows the first driver "perceived purchasing power". The y-axis shows the second driver a collaborative versus individual society.*

Scenario 1: "Need for self-reflection?"

In this scenario we envision a world influenced by political instability and international conflicts and climate change. This has led to a political shift in the municipality of Sogndal where the society promotes individualism and a consumer driven culture. Furthermore, the economic situation is influenced by inflation, and to stabilize the economic change and instability the central bank has introduced a zero-interest-rate policy aimed to encourage spending among the inhabitants. The banks are also extending more loans to businesses to help them survive the economic situation. On the individual level, the inhabitants of Sogndal are experiencing the direct effects of inflation. The media coverage heavily emphasizes the increased cost of living, contributing to the perception that purchasing power is low. Despite the governmental effort and subsidies people feel the pressure of higher bills and expenses. There is also a slight rise in unemployment.

The political situation in this scenario could affect the willingness to adopt the concept of shared cars. The inhabitants have a higher degree of individualism and pride themselves on owning a private car. Followingly, we have increased the time to adopt from 1 year to 2 years in our model. In addition, the scenario could affect the variable “weight (price of private car)” because the cost owning a private car is more noticeable and feels less accessible. In our model we show this by increasing the variable “weight (price of private car)” from 0,2 to 0,3.

Scenario 2: “Lykkeland”

In this scenario, we assume that the municipality of Sogndal is growth-oriented and affected by a high level of national prosperity, due to i.e., high oil prices. On both local and national levels, governments have implemented policies that further enhance individual wealth and personal freedom. Society is defined by low unemployment, and the politicians have made substantial tax cuts on e.g., electric vehicles and introduced incentives for obtaining higher loans, fostering a culture of financial independence. As a result, inhabitants in this society could exhibit a strong preference for owning property and private vehicles such as a car.

The situation in this scenario could increase the time to adopt the concept of car-sharing as people are leaning more towards owning a private car and can very easily afford to own both one and two cars. In the model we have shown this by increasing the variable “time to adopt" from 1 year to 2 years. In addition, we assume that the political events in this scenario will decrease the perceived cost of private cars. Additionally, the prevailing culture of individualism promotes private ownership, making car ownership a high priority for the public. We have shown this in our model by decreasing the variable "Weight (price of private cars)" from 0,2 to 0,1.

Scenario 3: "Sharing is Caring"

In this scenario we assume that the realization of the consequences of climate change steers the world in the direction of greener and more environmentally friendly governance. This has also led to a political shift in the municipality of Sogndal, where we see that the municipality has evolved into a community-centered society characterized by strong strategies that prioritize collective goods over individual gains. Political strategies support and promote sharing services and a circular economy through close cooperation between local and national institutions. Economically, Sogndal focuses on community-based initiatives and promotes local production, and reduces taxes on goods, facilitating collaboration among the inhabitants. On an individual level, the people of Sogndal experience a strong sense of community and trust and they are embracing the benefits of a sharing economy. Furthermore, people are conscious of how they use their resources due to a low perceived purchasing power.

This future scenario could potentially decrease the time to adopt car-sharing from 1 year to 6 months. There is a high focus on collaboration in the community and a strong sense of trust among the inhabitants. In addition, the willingness to adopt and use concepts that focus on sharing resources increases. Specifically related to car-sharing, we assume that the perceived price of owning a private car is high. In the model, we have shown this by increasing the "Weight (price of private cars)" from 0,2 to 0,3.

Scenario 4: "Manifesting green economy"

This is a world defined by weak sustainability characterized by high levels of well-being and economic production. We assume there is a strong sense of community and trust, and policies that support economic growth, social welfare, and environmental sustainability. As in scenario 3, the political strategies in the municipality promote a sharing economy. In addition, there is a higher perceived purchasing power. However, compared to scenario 3 there may be less consciousness of the amount of money spent but rather more focus on how it is spent, as general consensus is to pay it back to society.

We predict that the willingness to adopt the concept of car-sharing is high in this scenario. In the model we have therefore decreased the variable "time to adopt" from 1 year to 6 months. On the other hand, we assume that the variable "weight of price of private cars" will decrease from 0,2 to 0,1 because of a high perceived purchasing power. This means that people can afford to buy a private car, but they want to contribute to the collective good and therefore choose to share cars.

3. Policy recommendations

In the following chapter we will describe potential policies that our client can implement to influence car-sharing in Sogndal. We will consider how the different policies affect the situation in the base case as we assume this is what resembles Sogndal today. The robustness of the policies is later measured against scenarios (Chapter 4.2). Details on the changed variables in each policy can be found in the appendix.

Policy 1: Collaborating with HVL

Our first recommendation involves a collaboration between Dele and HVL in Sogndal. HVL is a regional institution with 449 employees in Sogndal distributed between different departments ("Tilsette ved HVL," n.d.). Among these, we assume that 15% will use car-sharing as a part of their workdays when presented with the concept. By partnering with HVL, the number of shared car users in 2024 could rise from an initial 20 users to 67. This projection assumes that Dele adds 5 new cars to its car fleet, placed near campus to be easily accessible for the employees. This policy effectively boosts the number of users from the starting phase, and it could help create a more stable start-up for Dele, thus helping to avoid bankruptcy, as this seems to be a reoccurring problem for car-sharing establishments in smaller cities. The partnership could also potentially increase the visibility of shared cars as there are many students at HVL. However, this is not implemented in our model and does not affect our shown results.

Policy 2: Car nudging by email

The TØI report from the research project in Oslo highlighted “Nudging” as a concept that could increase the number of shared car users (Ciccone, 2024). The research project involves emailing private car owners that own a car that is 4 years or older, and that has driven under 10,000 km a year. The email includes a link to a price calculator showing how much you can save each year by changing to a shared car. In the model, we introduce a one-time policy where Sogndal municipality applies for national funding to conduct the project in the beginner phase of the car-sharing start-up. This policy strengthens R1by increasing word of mouth and changing the perceived price gap from negative to positive. We observe that the perceived price gap has the largest effect on the change in users, and therefore suggest focusing on this aspect. The second policy will effectively double the number of users from 2024-2050.

Policy 3: Car nudging by app

A more effective way of implementing the price calculator is to introduce it in the “Dele app”. In our third policy, we suggest that our client implement a permanent price calculator in their app, for example, showing users how much they have spent on car-sharing this year compared to the total yearly price of owning a private car. This is implemented in the model by changing the perceived price gap, as well as adding to word of mouth. Followingly, we see this policy as a more effective way of implementing the concept of car nudging as the effect continues throughout the time period. By giving the users something tangible and relatable to talk with friends and family about, this policy will also reach non-users. Even though we see this as the most effective policy, we believe that this could be more financially demanding to implement as it requires investment from Dele in further development of the app.

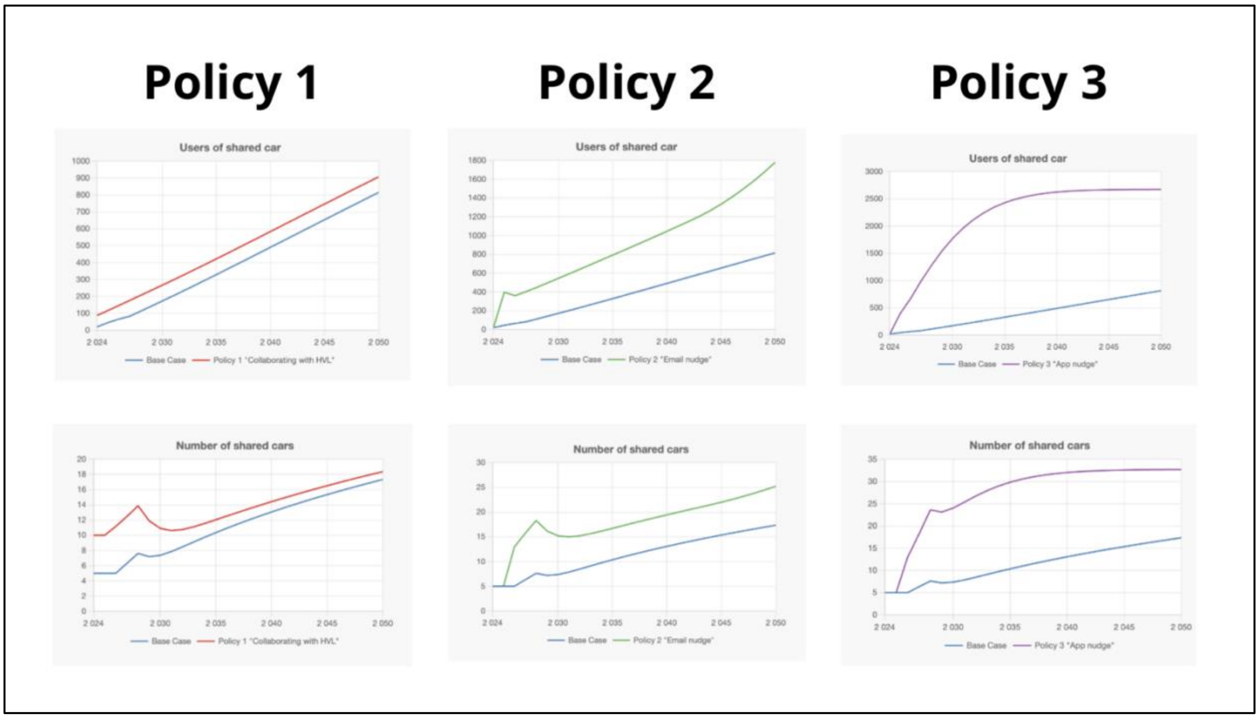

Figure 3.1.1 *This figure shows what happens when policy 1, 2 and 3 are applied individually to the base case.*

4. Discussion

4.1 Options for policy implementations

Based on the effectiveness of our policies in the base case, we have developed two recommendations for our client depending on their financial capacity. Option 1 is to implement both the partnership with HVL (policy 1) and the car nudge by email (policy 2). This will ensure a stable start-up phase for Dele while increasing the number of users over time. This option is less financially dependent because it would be a part of a research project that would receive funding. However, this would be a more time-consuming option because it would require data gathering and reporting of results.

The second option for policy implementation is to only apply car nudge by app (policy 3), as this is the most effective way of increasing the number of shared car users over time. On the other hand, this is a more financially dependent option than the first one, as it requires Dele to invest more money in developing their app. We see this as an obstacle for our client considering that low financial capacity is a reoccurring problem for car providers. We suggest that our clients base their decision on their financial capacity.

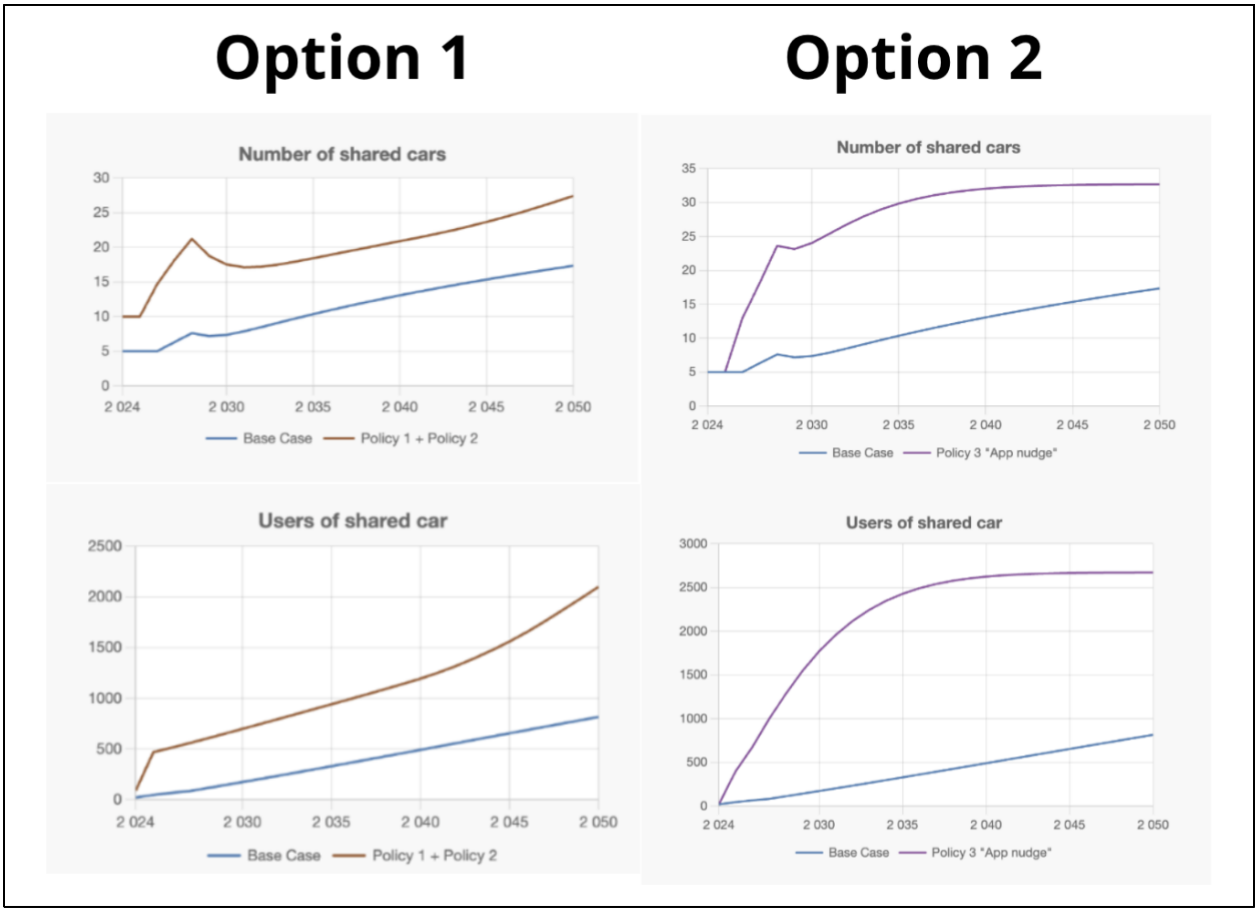

Fig. 4.1.1 *This figure shows the change in the number of users and number of shared cars. The left side shows the option to implement policy option 1 in base case. The right side shows the implementation of option 2.*

4.2 Robustness of policies: testing policies in scenarios

The above-mentioned results are based on how the policies will affect the base case. However, there is no certainty that the political and societal situation in Sogndal will stay like this in the future. With this in mind, we have checked the robustness of our policies by implementing them in our 4 future scenarios.

In this section, we show them in scenario 1 and 3 as we find these to be most likely in the future (See Appendix for policies in all scenarios). Today, Sogndal is a municipality with relatively low average income and people are experiencing the high living costs in Norway.

Based on this, we believe it is more likely that the inhabitants of Sogndal will experience a perceived low rather than high purchasing power in the future. However, this is uncertain due to a complex interplay of subjective and objective elements surrounding the perception of purchasing power.

Regarding society's state of individualism, we believe that Sogndal is currently at a crossroad between an individualistic or a collaborative society. The community plan of Sogndal facilitates for sharing economy, and it is clearly a part of their strategy to increase activities supporting a collaborative society. However, from previous experiences with our nation in "dyrtid", for example during covid, we saw that political and financial institutions incentivized and subsidized individualistic behavior, such as mentioned in scenario 1. Therefore, the political choices of Sogndal, in addition to national politics, will affect whether they would move forward towards scenario 1 or scenario 3.

By implementing policy options 1 and 2 in scenario 1 we observe a less effective result than in the base case. However, we still see an increased growth over time. This is because the time to adopt is decreased in scenario 1 due to the high level of individualism. Followingly there is a delay in people's willingness to become users. As a result, the policy does not effectively boost the users over time, but instead they increase steadily.

On the other hand, by implementing the policy options in scenario 3, we see steady growth over time, and the results are better than in base case. This is because the variable time to adopt is effectively boosted by policy 3, due to the collaborative society.

With this, we conclude that both policy options are robust in a dynamic society.

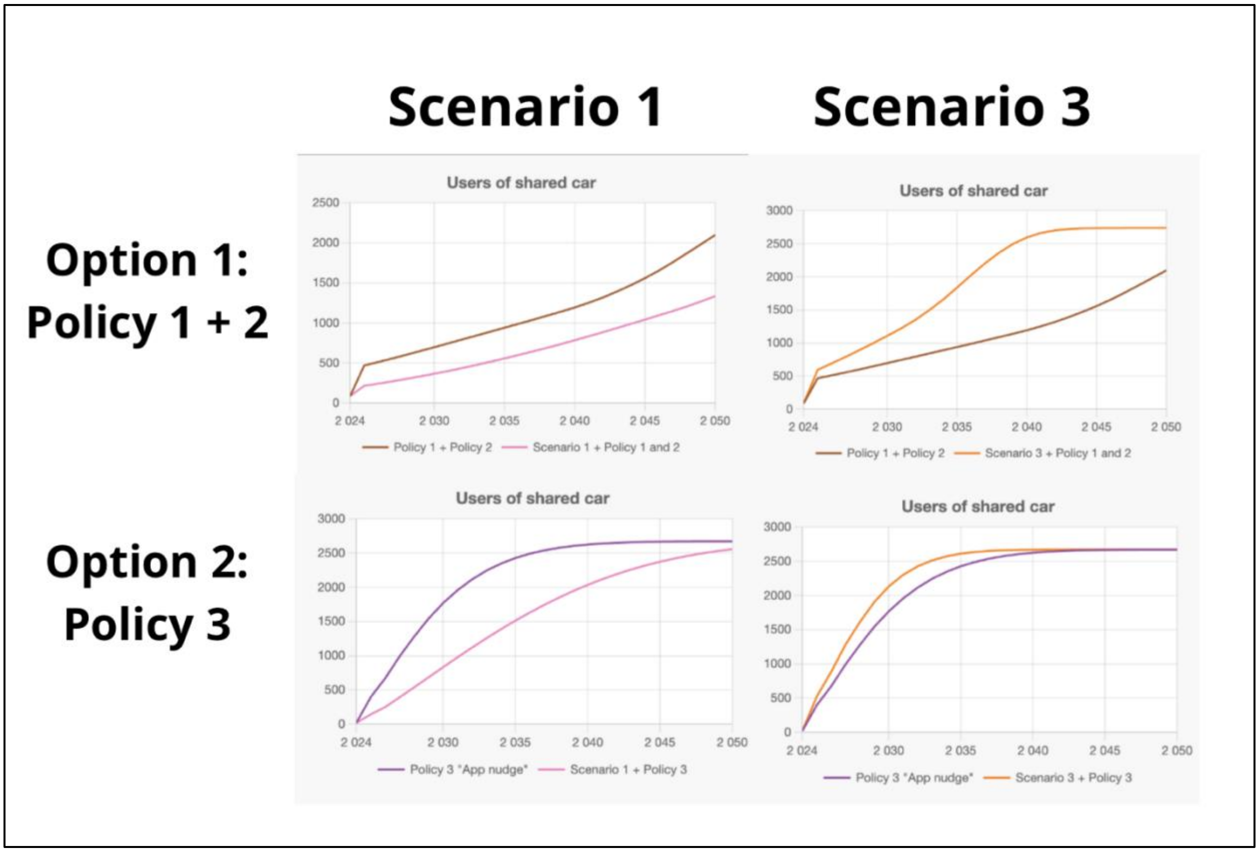

Fig. 4.2.1: *This figure shows the implementation of policy option 1 and option 2, in scenario 1 (left). It also shows what happens when option 1 and option 2 are implemented in scenario 3 (right).*

4.3 Possible synergies and tradeoffs related to the implementation of car-sharing in Sogndal

KV seeks to facilitate the expansion of the car-sharing concept to other municipalities. Both Dele and Sogndal municipality are partners in KV, and we see some possible synergies related to this. In Sogndals community plan, they have established quality of life, being an innovative force, and environmental consciousness as objectives for the municipality towards 2030 (Sogndal Kommune, n.d.). Based on this, we argue that car-sharing fits well into their plan for becoming a "5-minute city". They emphasize reducing car traffic and parking in the city center and say that they will be an instigator for mobility solutions (Sogndal Kommune, n.d.). Dele's objective is to reduce the need for private cars and thus contribute to the green transition in passenger transport. Another synergy of car-sharing for Sogndal is that it can contribute to their goal of establishing more areas for physical and recreational activities, as it frees up space used for private car parking.

On the other hand, we see possible tradeoffs related to investment in both cars and the infrastructure needed for parking and charging stations. The introduction of car-sharing could also be seen as an attempt to green wash on a political level, as car-sharing still contributes to the demand for cars. This is just one aspect that makes this problem difficult to solve and there are several complex interdependencies related to establishing car-sharing.

5. Conclusion

The introduction of car-sharing in Sogndal could create synergies with the community. However, the barriers that exist in the system today could negatively affect the general acceptance of the concept, making it hard to overcome. The convenience of owning a car, and the perceived price gap between owning a car and using a shared car drive people's habits towards owning cars. We believe that Sogndal can overcome the existing barriers by implementing our policy recommendations, which can accelerate car-sharing in the municipality. We recommend that our clients base their decision on financial capacity.

6. Sources

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7. Appendix

7.1 Model documentation

All variables in the model are documented in the notes section of the variable, in silico.

Link to model: https://silico.app/@dat014/car-sharing-cbm/app?dashboard

Documentation of lookup tables:

Relation between price of owning a private car and acceptance

We believe that if the price of owning a private car becomes cheaper than it is today, the acceptance in Sogndal will be very low, as they are considered quite an individualistic society, thereby would want to own property, like a car, as long as they can afford it and it is easy. Therefore, we have put an effect on the acceptance that equals zero until the price is about 70% of what it is today. From here we believe it to be a slow growth up until the price of today, as we believe there is some acceptance around it even when owning a car is at a lower price than today. When the relative price passes 1, the effect on acceptance increases, as people become more aware of cheaper possibilities of commuting. We believe it flattens more out when you get to a certain point, as when owning a car gets too expensive, you would have high acceptance anyway. Therefore, the graph in this lookup table has an S-shape.

Relation between effect of perceived price gap and acceptance

As people believe it is more expensive to use shared cars than owning a private car, the acceptance will be low. As the perceived price gap approaches equality, the acceptance will slowly increase. At the tipping point of zero, the acceptance will start to grow faster, and will keep increasing. The public will reach an acceptance on 1 as the perceived kilometer price of private car reaches 6kr more than the kilometer price of a shared car. Due to these assumed effects, the graph behaves exponentially.

Relation between personal acceptance and adoption rate

We believe that when personal acceptance is zero, the adoption into users of shared cars would be almost equal zero. As the personal acceptance increases, the adoption rate will also increase. However, we believe if you are under 50% accepting of the concept, the likelihood of trying it is lower. Therefore, the tipping point in the curve is at about 50%, and when exceeding this, the graph grows faster. When reaching a point of 80% acceptance, we believe that the chances of trying the concept is close to a 100%. Due to this, the graph of this lookup table is of an S-shape.

Relation between time transiting and accessibility of shared cars

We believe that a low relative time in transit would lead to a low feeling of accessibility. However, we do not believe it to be zero. Therefore, it starts at about 0.05. As the relative time in transit increases, the feeling of accessibility will also increase, but as long as you have to spend over a certain amount of time in transit, the growth will be slow. We believed that the tipping point of the time you feel it is acceptable to use to get to a shared car is 15 minutes. This is an assumption based on personal experience. Therefore, the tipping point in the lookup table was put to about 0.3. After exceeding the tipping point, the growth is faster. When reaching a relative time in transit of about 0.7, the graph flattens out, as the feeling of accessibility would already be very high at this point. 100% acceptance would not be reached before the desired time in transit is reached. Due to these effects, the graph in this lookup table is as an S-shape.

Relation between relative shared car per commuter and accessibility

The variable of relative car per commuter affects two things regarding accessibility. If there are more cars per commuter, the chances of one being available when you need it is higher, and you experience higher accessibility. Also, it reflects visibility. The more shared cars per commuter, the more you will encounter them in your everyday life, and the feeling of them being everywhere will lead to an experience of high accessibility. With this in mind, we believe that when the number of cars per person is very low, you would experience low accessibility. However, we do not presume it would equal zero because as long as there is one or more cars in the area, you would feel like it is accessible, just low. Further on, we can see that the graph in this lookup table is not representing what we believe to be real-life behavior. When the car per commuter is 1, the accessibility should also be 1. However, the behavior of the graph is representable of how we think these variables interact, it is just the numbers that are a little inaccurate. We chose to have the graph going from 0 to 2 because there is a possibility that cars per person will exceed what is the desired level.

Relation between hours of use and average price

We believe that as long as the time of use is lower or equal to the initial time, the price would remain the same. The lookup table was not adjusted after an adjustment in the hours, so it is supposed to be at 1 at the x-axis when the hours are at 6 at the y-axis. As the hours of use increase, the price would go down. This we have been informed by our client KV. However, we believe that the price will not decrease more than 20%. Therefore, the effect starts stabilizing at 15 hours, as we assume this would be one of the upper limits of how many hours in the day a car is used, on average.

Relation between price and accessibility

The y-axis on this lookup table starts at 0.5, as we believe that if the price of using a shared car is half of what it is today, the feeling of accessibility would be 100%. When the price is at the level of today, the accessibility would be at a level of 80%, as we have gained information from our client that the price of today is quite good, and not really the biggest driver. With increasing price, the concept would feel less accessible and decrease more rapidly. When the price gets closer to double, the feeling of accessibility would be very low and start to flatten out. However, we do believe that even though it is very expensive, and people would not choose this type of transportation, they would not feel like it is 100% inaccessible.

Relation between customer experience and contact rate

In this lookup table, we have decided to have the y-axis go from 0 to 1.5, as we experienced when working with the model that customer experience can exceed 1. However, the effect on contact rate will not exceed 1 even when customer experience does. Therefore, the graph flattens out after 1. We also believe that even if customer experience is very low, there would still be a few persons talking about it. Also, bad customer experience can be communicated to friends and family and make people familiar with the concept, if this was a completely new thing for them. Therefore, the graph does not start at 0 at the x-axis. We believe that the behaviour of the graph is exponential, as the better experience you have with using shared cars, the more people you will talk to.

Relation between word of mouth and acceptance

We believe that even though the word of mouth (WOM) is very low, there would be some level of general acceptance in the public. This would not equal zero unless there is some specific incident making the public strongly against the public. We also believe that there is an exponential effect of spreading acceptance when more people are talking about it. When the WOM reaches around 75%, we assume that the general public acceptance would be at 100%.

7.2 Validation

7.2.1 Direct structure test

The direct structure test is performed in order to validate the structure. Structure validation is required for a model to be considered functional, and other validation tests are unnecessary if structure validation is not achieved. To gain confidence in the model, we have used the direct structure test, by comparing the model structure with knowledge about real system structures. There are four components to this test: structure confirmation test, parameter confirmation test, dimensional consistency test, and direct extreme-condition test. (Barlas, 1996).

Structure confirmation test

A structure confirmation test was performed during the documentation of the model, as all functions and behaviors are described, literature findings are given, and assumptions are stated.

We acknowledge that some of the structures in the model are not 100% representative of the real world, and would like to comment on them:

Investment rate new shared cars

For the variable investment rate of shared cars, we assumed it was based on the increase or decrease in the user base. If the number of users went up, they would invest in more cars, relating to a demand and supply function. However, when talking with the client, we understood that the investment rate is driven by many different things, and the user base was not highly weighted, but still one of the drivers. Unfortunately, the response from Dele was received very late, and due to the complexity of this part of the system, and time limitations, we decided to keep the structure as it is.

When investigating synergies and trade-offs, we became aware that there are real life trade-offs not reflected in our model, some of them due to this structure. For example, if the user base increases, the demand would increase. If Dele does not have the financial capacity to invest in more cars, the availability of cars could go down, as the ratio of users to cars would be too high. This could also affect the customer experience where an increased user base, with decreased availability, could result in low customer experience, thus a higher number of unsatisfied users.

Lookup tables

All of the lookup tables are drawn by hand and represent only the trend of the effect and not exact values. No values were given by the client; therefore, these graphs are based on assumptions from our side. However, some of the trends were confirmed by the client in our foresight exercise.

Many of the lookup tables are affecting sensitive variables, thus small alterations led to big changes in the model. This makes the results very uncertain, as we do not have exact numbers. For example, in the sensitivity analysis we see similar behavioral change in many of the variables. There appears to be a threshold of when it is passed, the growth accelerates and becomes more exponential. This was figured out to be due to the trend of the graph in the lookup table “Relation between customer experience and contact rate”.

We also acknowledge that we have not paid attention to the steps in most of the lookup tables, which could have been changed for the benefit of some of them.

Customer experience

In the sensitivity analysis, we also observed behavioral changes in variables connected to the R2 and R3 loop. In the behavior, we observed a threshold at around 150-180 users, and found it to be because of the fraction of the “minimum customer experience for staying as a customer”. Before reaching 150-180 users, customer satisfaction is below 0.5, thus some of the users will exit the userbase. When passing the threshold of users, the customer experience exceeds 0.5 and no users exit the user base. Therefore, most parameters in R2 and R3 accelerate after this point. This behavior is almost not observable in base case, as the customer experience starts at 0.492 and exceeds 0.5 within 3 years. This is due to our choice of area of interest being so small, thus we overcame the given threshold.

Distribution of shared cars

Now we do not account for that some of the shared cars will be places in the same area, for example at mobility spots, at parking spots and so on. The equal distribution results in a low time in transit, with accessibility being 1 from the beginning.

Conclusion

We believe that by doing the documentation and sensitivity test earlier, we could have discovered these structural mistakes in time to change them. Unfortunately, the time frame of this assignment is quite short, and we were not able to complete the alterations. We believe that some of them could have affected all the policy results.

Dimensional consistency test

We found one unit inconsistency in the model with the variable" Distance to closest shared car". We could not figure out how to alter the structure to achieve unit consistency with this variable, but we are confident that the formula gives the correct value for the purpose of this variable. All other variables show dimensional consistency.

Direct extreme condition test

By changing some selected exogenous parameters to represent extreme conditions, expected results were achieved, simulating possible real-life values. For example, when "Life expectancy of a shared car" decreased from 4 to 0.2, the stock of cars dropped from 17.5 to 2.4 cars. By increasing the "Area of interest" from 3,5 km^2 to 50 km^2, the distance to closest car increases from 0.2km to 5.9km. When changing "minimum customer experience for staying as customer” from 0.5 to 0.8, the stock of users dropped from 827,7 to 185,9.

Parameter confirmation test

A parameter confirmation test was performed during the documentation of the model. All parameters that have real-world counterparts are stated, as well as those that are assumptions and the reasoning behind them.

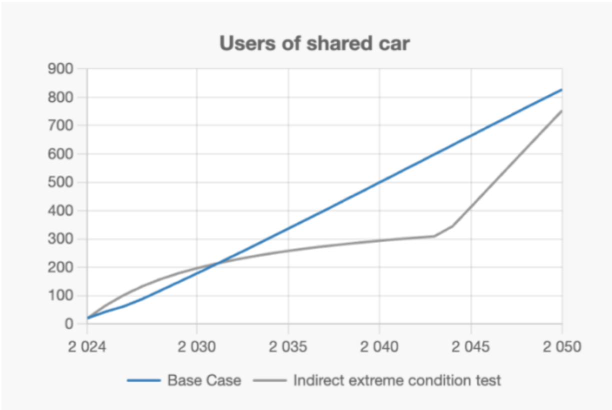
While checking for parameter confirmation, we discovered that the value of the variable “Area of interest” did not reflect the real-world situation. When we looked at the map, we discovered that the outer area of the 5km radius included mostly uninhabited areas of woods and steep mountain hills, thus not representing an area suitable for car-sharing. Therefore, it was changed from 5 km^2 to 3.5 km^2.

7.2.2 Structure oriented behavior test

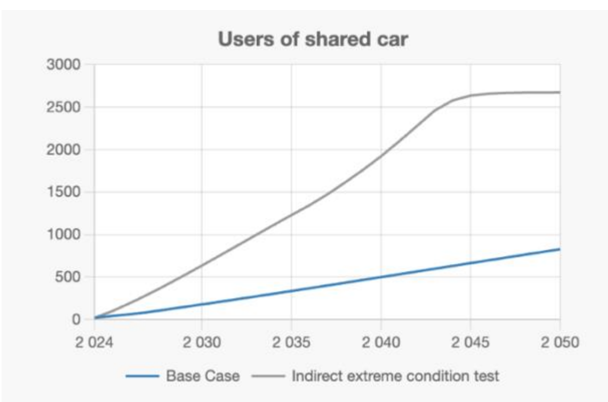
A structure-oriented behavior test, consisting of indirect extreme-condition tests, integration error tests, and behavior sensitivity tests, provides even greater validation of the model structure.

Indirect extreme-condition test

Using the extreme condition test as a proxy for structure validation, we can see that the structure behavior of the model also matches what is expected. For example, if the variable “Fraction of people commuting” is increased from 0.55 to 1, we see an expected behavioral change. By increasing the number of commuters, the relation between the number of cars and commuters becomes smaller, which lowers the accessibility. Due to this the stock “Users of shared car” has a slow growth for a while. In the year 2043, the behavior changes and the number of users increases much faster. This is due to the accessibility reaching the threshold of 0.5, which is set as the minimum customer experience for staying as a user. After this point, no users leave the user base due to dissatisfaction.



When increasing the variable “Perceived kilometer price of using private car” from 4 to 14, we see a great increase in the user base, with a slighter steeper growth from around 2037, and then flattening out a little before 2045. This is expected behavior as the perceived price gap is a strong driver of the R1 loop. The steeper increase is believed to be due to the effect of word of mouth. The more users there are, the more people will be reached. Also, as the customer experience increases, the contact rate of each user will increase. When approaching the year 2045, the user base has almost reached its limit, as there are no more potential users, thus the flattening out of the curve.



Integration error test

To avoid integrated errors, we have conducted the integrated error test described by Sternman (Sterman, 2010, p. 872). The smallest time constant in the model is 0.01. By following the method, we divided 1 by 0.01, multiplied this with ⅖, and then multiplied the results by 2 until no changes in the model output were observed. This resulted in the resolution being 80.

1/0.01*⅖ = 40
40*2 = 80

Behavior sensitivity test

In this test, we altered the values of exogenous variables and checked for the model's sensitivity to these. We evaluated the level of sensitivity, and whether it was behavioral or numerical sensitivity.

Variable	Change in value	Type of sensitivity	Level of sensitivity
Relative price adjustment	0.01 + 0.03	Numerical	Low
Initial average yearly price of owning a private car	100 000 + 100 000	None	None
Perceived kilometer price of using private car	4 + 3	Numerical	Medium to high
Perceived kilometer price of using shared car	6 - 3	Numerical	Medium
Time to reevaluate	2 + 10	None	None
Time to adopt	1 + 0.5	Behavioral	Medium to high
Users of shared car	20 + 100	Numerical	Low
Number of shared cars	5 + 50	None	None

Minimum customer experience for staying as customer	0.5 + 0.02	Numerical	Very high
Required users per shared car for investing in new cars	10 + 6	Behavioral	Medium
Life expectancy of a shared car	4 + 6	None	None
Area of interest	5 + 3	Behavioral	Medium to high
Fraction of people commuting	0.55 + 0.3	Behavioral	Medium
Desired accessability of number of cars	1/50 --> 1/40	Behavioral	High
Average time commuting per km	6 + 3	Behavioral	High
Desired time in transit to shared car	5 - 2	Behavioral	High
Hours of the day a shared car is used	5 + 15	Numerical	Low
Initial average price of shared car	200 + 200	None	None
Ideal contact rate	5+20	Behavioral	Low
Adoption fraction	0.2 + 0.6	Behavioral	Low
Initial word of mouth	1 – 0.8	Behavioral	Low
Weight (price of private car)	0.2 + 0.3	Numerical	Low
Weight (perceived price gap)	0.45 - 0.1	Numerical	High
Weight (general public acceptance)	0.35 - 0.1	Numerical	High
Weight (price of using shared car)	0.2 + 0.15	Behavioral	Medium to high
Weight (time in transit)	0.4 + 0.5	None	None
Weight (shared car per commuter)	0.4 + 0.02	Behavioral	Very high

7.3 Formulas

Policy 1:

Variables	Change
Users of shared cars	20+ (Fraction Hvl*HVL employees)
Shared cars amount	5+5
Initial average daily use	6+3

Policy 2:

Variables	Change
People reached by advertisment	“People communting” * 0.5
Percieved kM price on private cars	4+4
Word of mouth	Step function: +step("People reached by advertisement talking about it",2024)-step("People reached by advertisement talking about it", 2025) (1 år kun realt).
Fraction reached people talking about it	0.06
Adoption fraction	0,2+0,1 I base case (0.2)

Policy 3:

Variables	Change
People reached by advertisment	Users of shared car
Percieved kM price on private cars	4+4
Fraction reached people talking about it	0.3
Adoption fraction	0.2+0.1

7.4 Figures

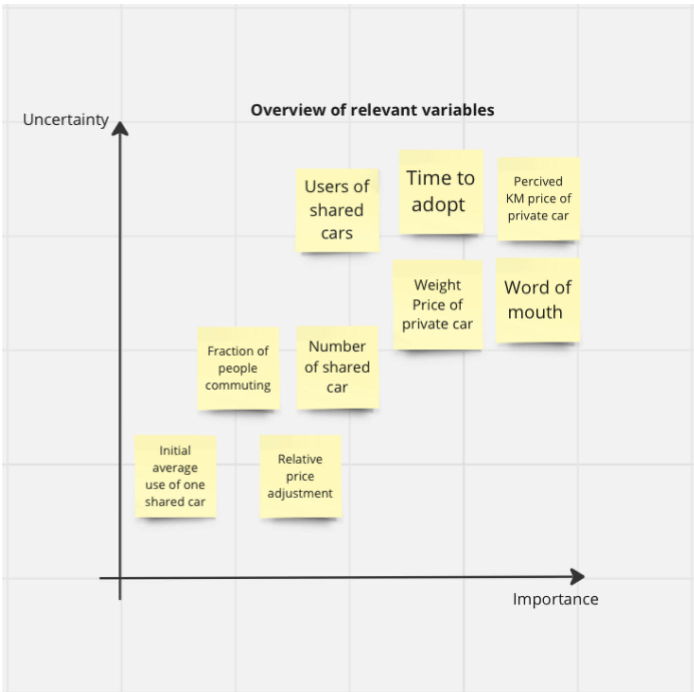
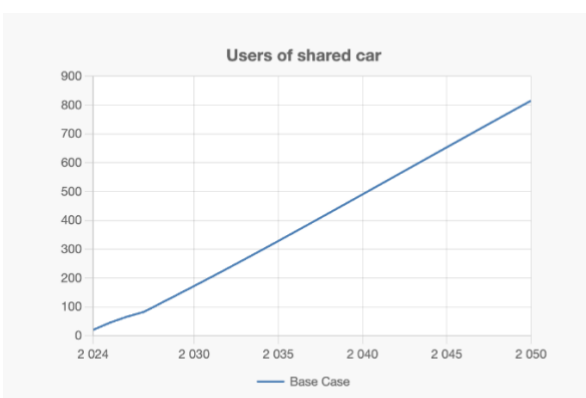
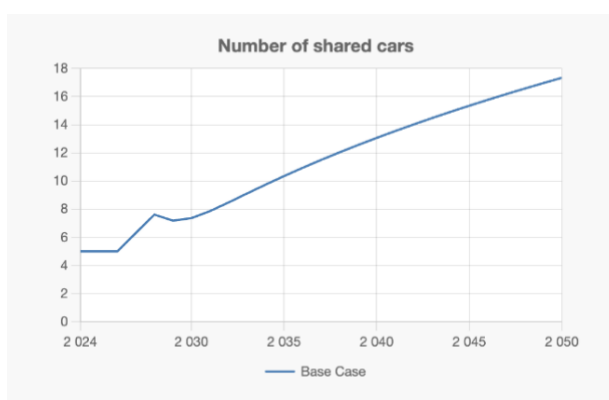


Figure. 7.7.1 The figure shows an overview of drivers sorted by uncertainty and importance. The figure is developed in the software "Miro"

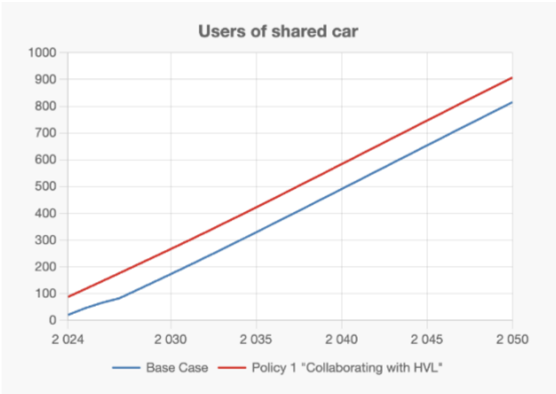
Graphs policy

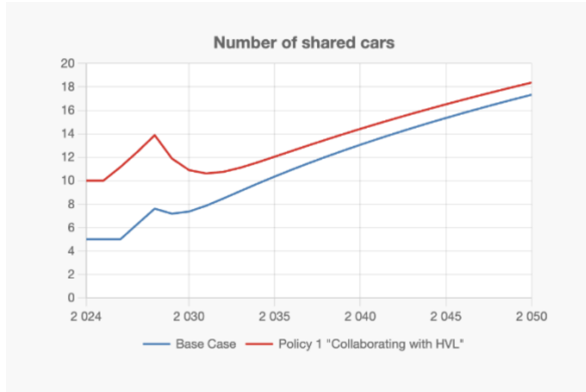
Base case:





Policy 1:





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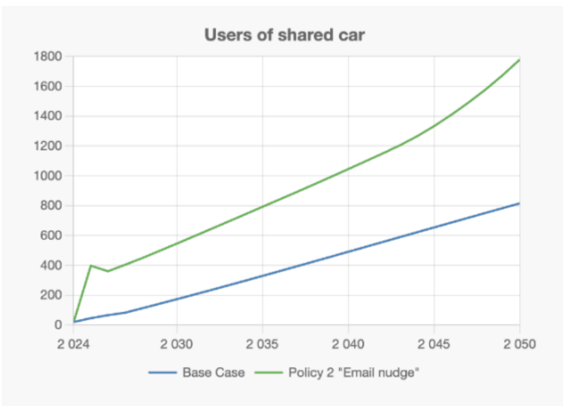

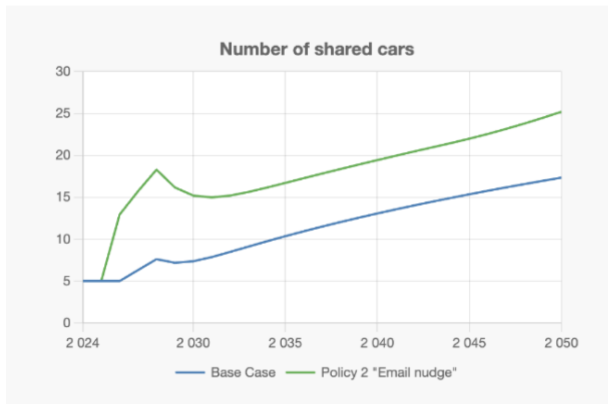

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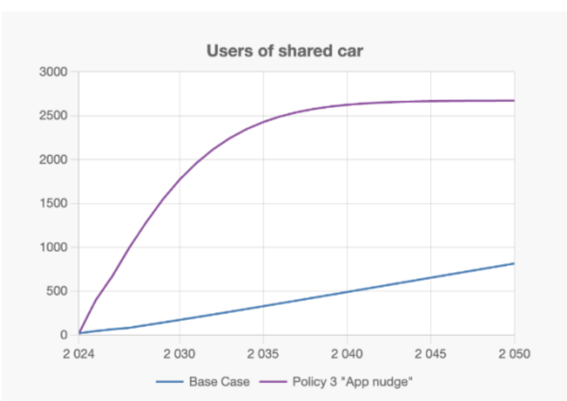
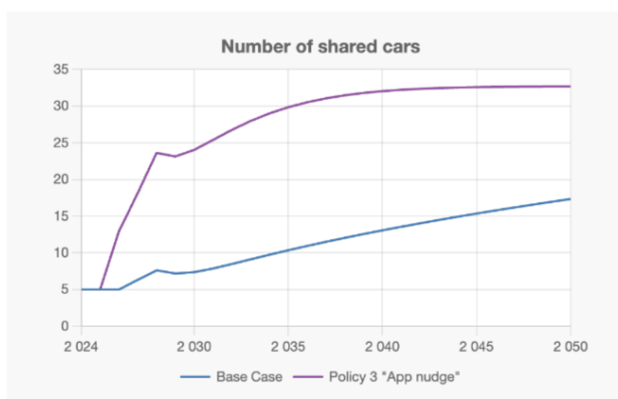
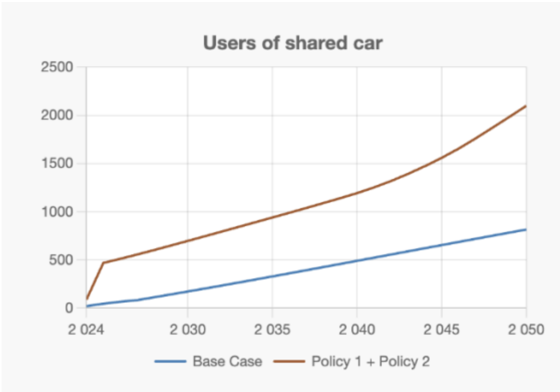
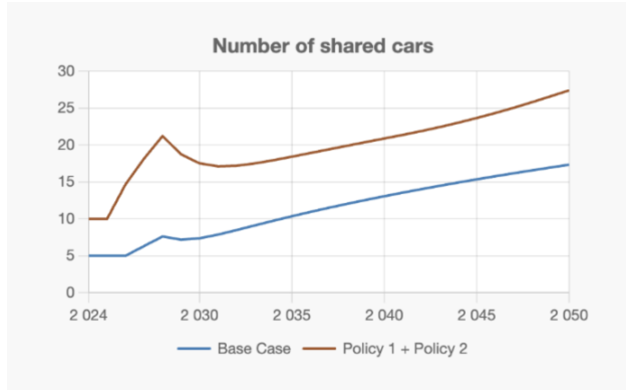




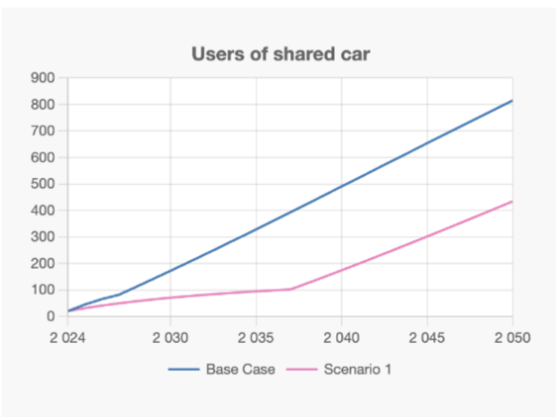
Policy 1 + policy 2:

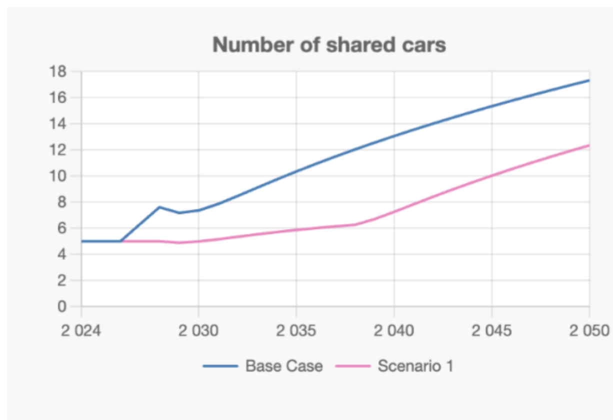




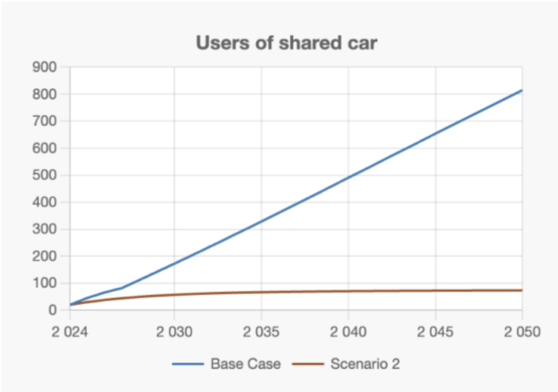
Scenarios

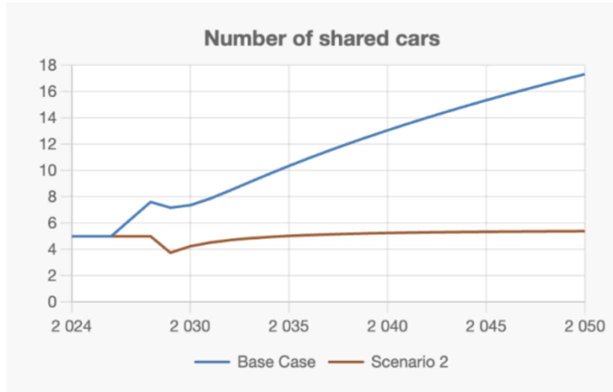
Scenario 1:





Scenario 2:





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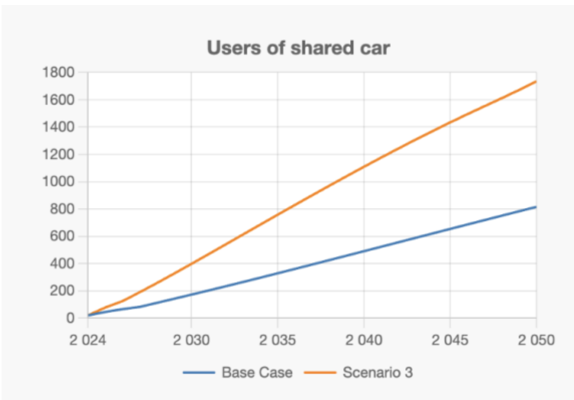
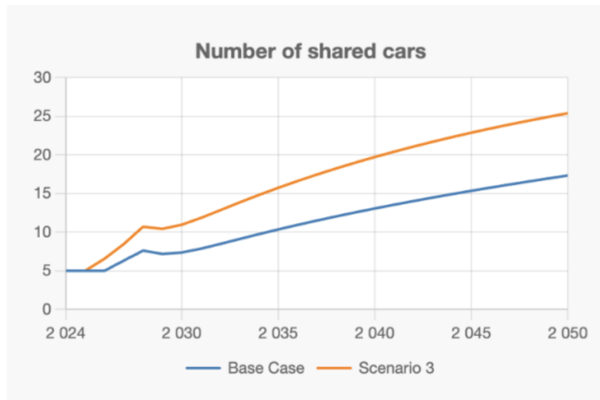
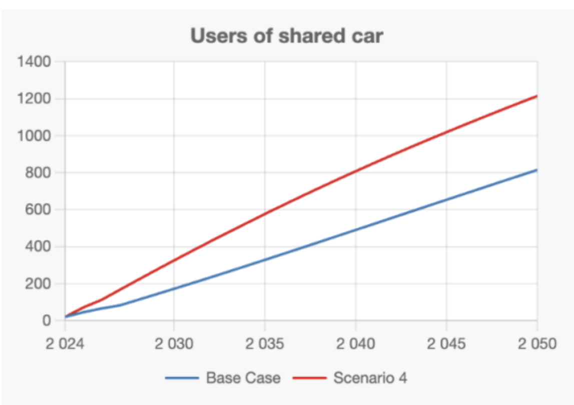
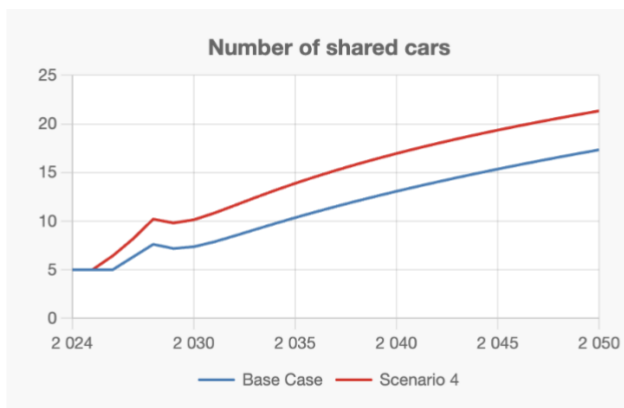




Scenario 4:

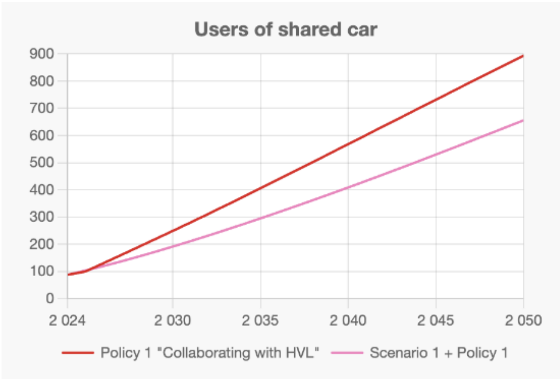


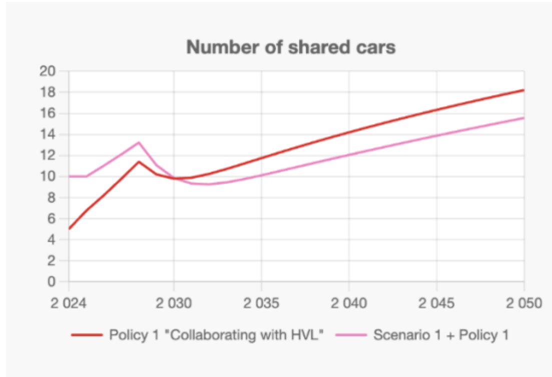


Scenarios + policies

Scenario 1

Scenario 1 + policy 1:





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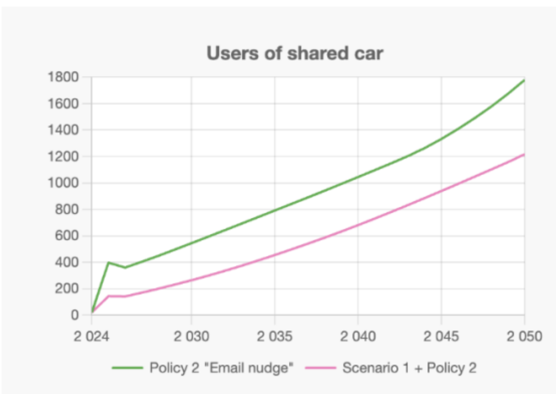
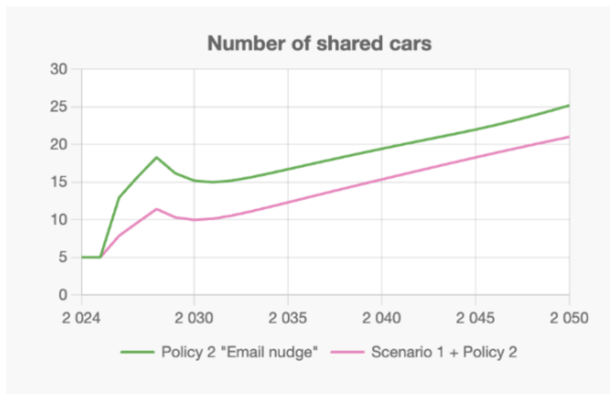
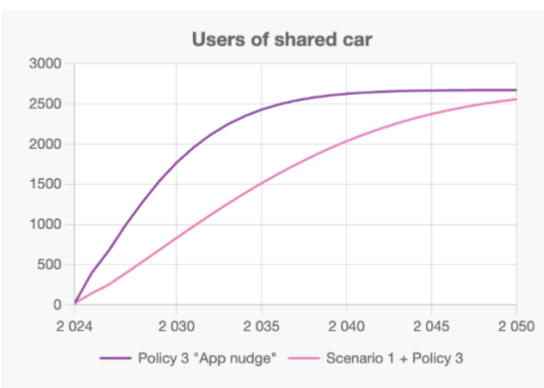
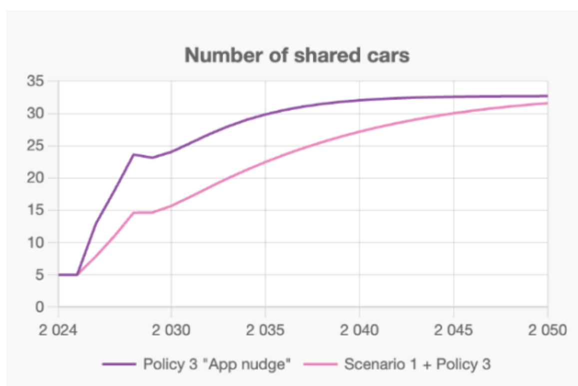


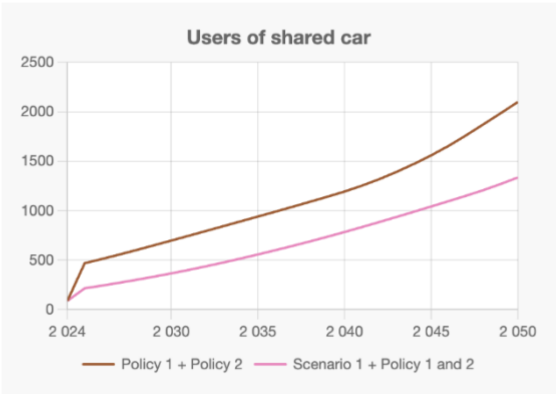


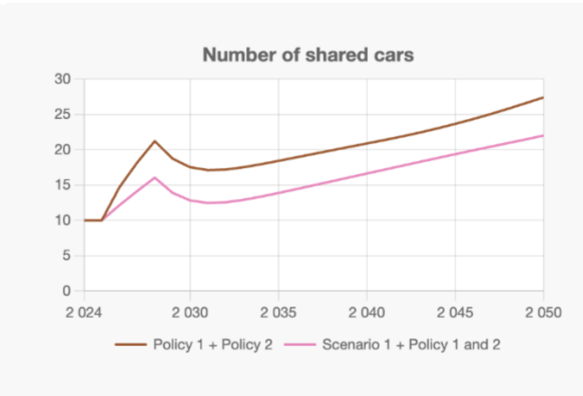
Scenario 1 + policy 3:





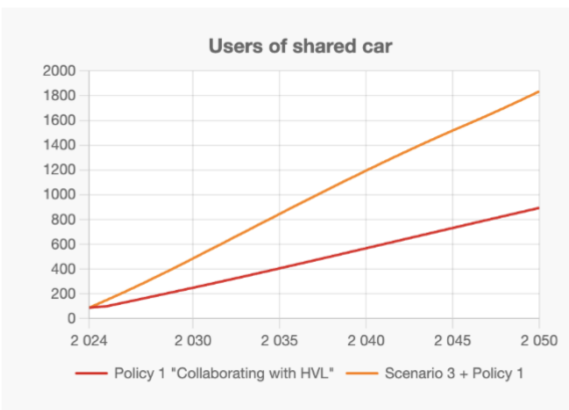
Scenario 1 + policy 1 and 2:

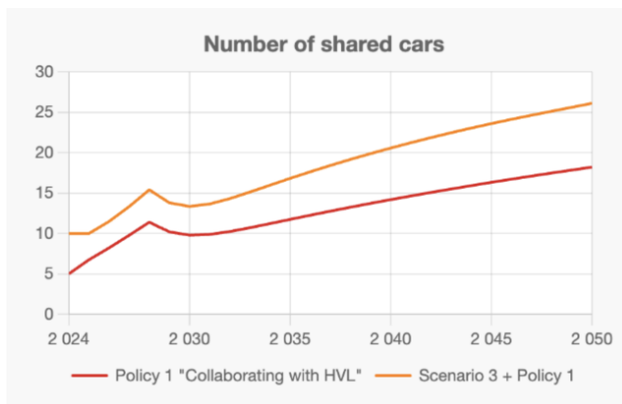




Scenario 3

Scenario 3 + policy 1:





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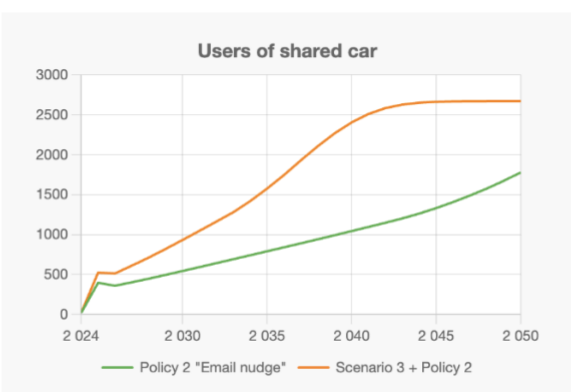
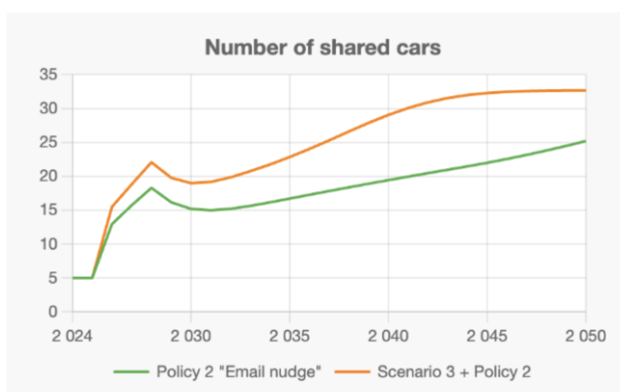
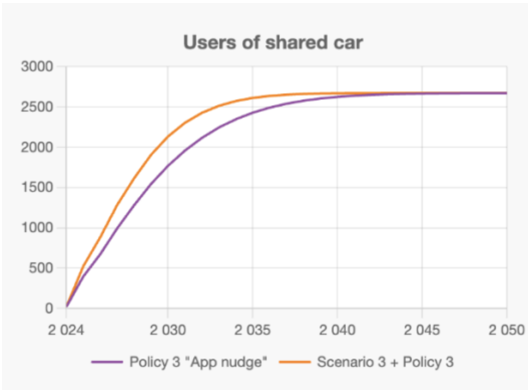
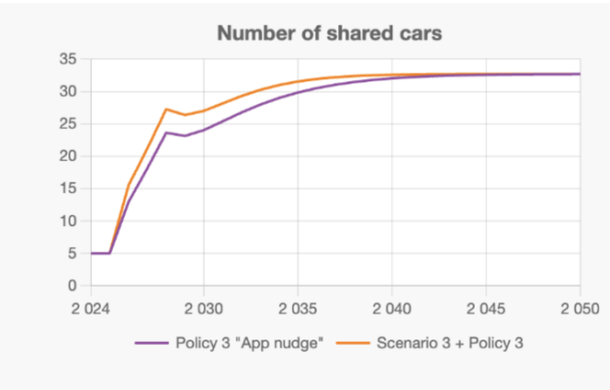




Scenario 3 + policy 3:





Scenario 3 + policy 1 and policy 3