Research Project A

Future of cars in Germany in 2035

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Abstract

Germany has a long history in the car sector. However, today’s car industry is drastically changing, triggered by the accelerated rise of new technologies, sustainability policies and changing consumer preferences. The purpose of this research project is to forecast, by using the scenario planning software INKA 4, the future of cars in Germany in 2035. The research project focused mainly on cars based on internal combustion engines (ICE), fuel cell vehicles (FCV), battery electric vehicles (BEV) and Hybrid electric vehicles (HEV) and their charging infrastructure in Germany. Also, the future of autonomous driving vehicles, public transportation and carsharing in Germany were taken into consideration. Considering these factors following four areas of influence were chosen: Technology, Economics, Politics and Social. Within these areas of influence thirteen input factors (descriptors) were defined by research on current literature. The results show three distinct scenarios that reflect a possible shift towards electric mobility, autonomous driving, and an increase in the use of car sharing.

Keywords: *scenario planning, future cars, Germany, hybrid cars, electric cars, fuel cell cars, car sharing, mobility, vision 2035*

Key findings

- The future of cars in Germany is affected by four areas of influence: Technology, Economics, Politics and Social. Among those four areas, a total of thirteen descriptors were selected as an input for the scenario building.
- With the software INKA 4 five different scenarios were generated. Three distinctive scenarios were chosen and described to outline the future of cars in Germany in 2035.
- It is highly probable that the future cars will be electrified and autonomous and that shared mobility will increase. The extent of the aforementioned change until 2035 depends highly on the German government and customer preferences.

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LIST OF ABBREVIATION

BEV	Battery electric vehicle
CO_2	Carbon dioxide
COVID 19	Coronavirus
FCV	Fuel cell vehicle
HEV	Hybrid electric vehicle
ICV	Internal Combustion Vehicle
ICE	Internal Combustion Engines
ICEV	Internal Combustion Electric Vehicle

1. INTRODUCTION

It is impossible to imagine our lives without mobility. Mobility means independence and without mobility it is very difficult to participate in the social and professional life of today (Zierer&Zierer, 2010). What remained the same during the last decades is that traveling by car in Germany is the most popular way to get from point A to point B. Seventy-seven percent of German households own a car, seventy percent use it on a regular basis (using it daily or multiple times a week) and further increases in traveling by car are expected over the next decade (Bobeth&Matthies, 2018; Bundesministerium für Verkehr und digitale Infrastruktur, 2020). The early days of cars fall into the last quarter of the nineteenth century. Since then, the cars, the possibilities of making cars and our relationship to cars have changed (Seiffert, 2009).

Today's car industry in Germany is drastically changing, triggered by the accelerated rise of new technologies, sustainability policies and changing consumer preferences. Even though there is a widespread agreement that there will be a game-changing disruption in the car industry, there is no common agreement on how the car industry will look like in the future. Also, in the literature there are disagreements about when these game-changing disruptions will take place.

Due to the great relevance of the future car market on Germany, this paper will discuss the following research question:

How does the future of cars in Germany look like in 2035?

After a detailed investigation on literature concerning the research question, the following areas were found to have the potential to shape the future of cars in Germany in 2035. These factors will be discussed and be part of the selected future scenarios of this paper.

The paper takes under consideration the alternatives to cars based on internal combustion engines (ICE) like fuel cell vehicles (FCV), battery electric vehicles (BEV) and Hybrid electric vehicles (HEV) and their charging infrastructure in Germany. These alternatives are relevant, because according to Ehsani et al. (Ehsani, Gao, Longo, & Ebrahimi, 2018) the oil resources will be used up by 2038 and another technological source for cars is needed (Ehsani, 2018, p. 8). Also, the European Commission is pursuing the goal of decarbonizing the European mobility system by 2050, making it greenhouse gas neutral (Umweltbundesamt, 2020).

Next to this the paper will be including a future perspective on autonomous driving vehicles in Germany. According to Research & Markets (Research & Markets, 2019) the market for fully autonomous vehicles in Germany will reach $28 billion by 2030 and since 2017 highly autonomous driving has been permitted in Germany (Deutsche Welle, 2020).

Another area that has the potential to shape the future of cars in Germany in 2035 is carsharing. Carsharing is currently expanding rapidly in Germany, reporting a strong increase in user numbers and is an important instrument for sustainable urban mobility (Best &Hasenheit, 2018). Urban mobility is also shaped by the sector of public transportation. The German government will contribute one billion euros in additional equity capital to the Deutsche Bahn each year between 2020 and 2030, accounting to 11 billion euros (Fockenbrock&Siebenhaar, 2019).

The paper addresses the before named areas influencing the future of cars in Germany by conducting research on the technological, economic, political, and social situations in Germany. It aims to predict upcoming future scenarios by using the scenario planning software INKA 4.

This paper is divided into five chapters. The first chapter outlines the importance of the research topic and presents the central research question. The second chapter provides a general introduction to cars in Germany. Within the third chapter, the methodology of the research team is introduced. Chapter four describes three selected future scenarios and the results drawn out of these scenarios. In Chapter five the main findings of this paper, the limitations and an outlook will be given.

2. INTRODUCTION TO THE CAR INDUSTRY IN GERMANY

This chapter provides an introduction to the car industry along with the current situation in Germany. Furthermore, it will focus on current problems such as the high CO2 pollution and on trends such as Electric mobility, Autonomous driving Cars and multi-mobility in Car sharing.

As far as the history goes, the first car was constructed by Karl Friedrich Benz (Hild and Tsuzuki, 1997) back in the year 1886 that made the German car industry a pioneer in Motor Vehicle Development. Thereafter, the German car industry has always been one of the leaders in the global automobile market with a total of 6.3 million vehicles produced in 2019. The German car companies are one of the most well-known and successful in the international market. Companies like the Volkswagen Group were in the top ranking of leading motor manufacturers based on global sales by selling almost 11 million units in 2019. Daimler AG and BMW Group were further behind with 3.36 million and 2.54 million cars respectively (Koptyug, Statista 2020).

Back in the year 2011, the German government had laid out an ambitious plan with the goal of achieving one million electric cars on the streets of Germany by the year 2020 (Bobeth and Matthies, 2018). This was the result of the global issue of ever-increasing focus on the mitigation of climatic conditions and reducing the levels of carbonization. The IPCC AR5 indicates that stabilization of carbon dioxide emissions in the transport sector by 2050 at roughly 2010 levels would be consistent with the 2°C global mean temperature increase target [i.e., 430 to 480 parts per million (ppm) CO2-equivalent (CO2-eq)] (Creutzig, Jochem, Edelenbosch, Mattauch, Vuuren, McCollum & Minx, 2015).

This decision hit the German automobile market immensely by compelling it to shift the industry's focus from cars with a combustion engine towards electric cars, renewable fuel sources and car sharing. Since then, the ongoing debate over reducing diesel fuel cars and boosting electric vehicles (EVs) has only intensified over the years (VDA, 2018). The road transport sector has been causing on an average 18% of the greenhouse gases for more than a decade (Letmathe and Suares, 2016), which has promoted the use of alternative technologies that could reduce such emissions.

The Electric Vehicles or more popularly known as EVs can enable a significant reduction in greenhouse gas emission of around 98% capacity (Smit, Whitehead and Washington, 2018). EVs can be further distinguished between Battery-Electric Vehicles or BEVs and Hybrid Electric Vehicles or HEVs. BEVs are powered solely by the electric motor that uses electricity and is plugged in to charge. They do not entail any kind of air pollutant exhaust emissions. HEV shave an internal combustion engine that generates additional electricity to extend its driving range once the existing battery is depleted. Generally, air pollutant emissions are generated when the combustion engine is used. On the other hand, Fuel Cell Vehicles or FCVs use hydrogen as its main source which is stored in on-board tanks in combustion with a fuel cell stack to generate electricity to run the battery that powers the electric motor.

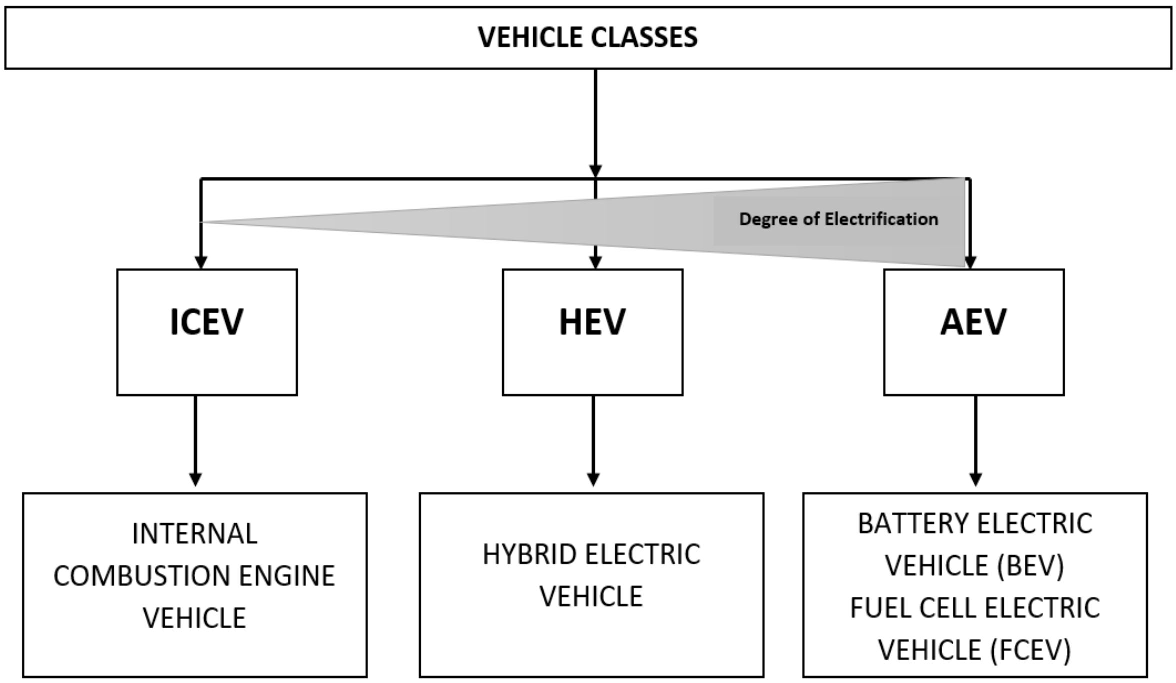

Figure 1: Is there a resource constraint (Pehlken, Albach, & Vogt, 2017, p. 42)

The automobile market in Germany is growing vigorously to be the lead in electric mobility making it the only country in the world to have a large selection of different types of electric vehicles on board. There are more than 57 electric models coming from the German manufacturers and the number rises to more than a 100 after including the foreign manufacturers (VDA 2018). There has been a 24% increase in new EV registrations in 2018 as compared to 2017. Currently, there are more than 60,000 new registration of BEVs and more than 44,000 new registration of HEVs, totaling to more than 100,000 new registration of EVs in Germany (Statista, 2020).

The ever-increasing reliance on technological advancement paired with Artificial Intelligence brought with it another challenge - the era of autonomous driving cars. Though, not fully operational for the common public yet, the development of autonomous driving cars is evidently snowballing. Campbell et al. stated the modern autonomous vehicles are capable of sensing their local environment, classifying the types of objects that they detect, reasoning about the evolution of the environment and planning complex motions that obey the relevant rules of the road (Campbell, Egerstedt, How and Murry, 2010). In 2016, the German government announced plans to develop autonomous driving infrastructure in Germany, and since 2017, the German Road Traffic Act enabled drivers to pass some car controls to an autonomous driving system (Research and Markets, 2019). However, autonomous driving cars still have a long way to go to become a common man's dream. These actions by the German government provided a huge thrust for the German manufacturers to work in the direction of autonomous driving cars.

Lastly, to lessen the burden of car availability and contributing to decarbonizing the environment, multimodal transport like car sharing is playing a significant role in creating a sustainable way of transportation. Ferrero et al. stated car sharing as to share the usage of a vehicle fleet by members for trip making on a per trip basis. Car sharing increases mobility for community members to reach destinations that are otherwise inaccessible by public transport, walking or biking. Also, it increases their awareness about the social and environmental impact and effectively reduces the urban emission and traffic congestion (Ferrero, Perboli, Rosano and Vesco, 2017). Car sharing companies like Share Now, Flinkster, MILES and Stadt Mobile are some of the popular names in the country. The numbers of registered car sharing users have risen from a mere 116,000 users in the year 2008 to a significant 2,290,000 users in 2020 along with 6,150 number of car sharing stations in Germany (Statista, 2020). It is expected that car sharing will skyrocket in the upcoming years.

3. METHODOLOGY

This chapter is divided into five parts. In the first part, scenario planning definitions are introduced. The second part briefly summarizes the history of scenario planning. Different scenario approaches will be discussed in the third part. The INKA 4 software and the most important steps in INKA are shown in the fourth part. The last part will illustrate the process outline of the project team.

The following quote is presented to open the first part.

"In today's increasingly dynamic, volatile and complex business world, companies in many industries face new challenges when it comes to strategic planning. Scenario planning is a popular approach used by companies to meet these challenges" (Schwenker & Wulf, 2013, p. 41).

3.1 SCENARIO PLANNING DEFINITIONS

There are many differing opinions regarding scenario planning due to its relatively young discipline. Many variations of scenario planning have been developed and its different interpretations have provided a good understanding of what scenario planning is (Chermack, 2011, p. 13).

According to Schoemaker (as cited in Schwenker & Wulf, 2013), scenario planning is a method for developing and analyzing possible future states and development paths. Wilson (2000) stated that scenarios are management tools used to improve the quality of executive decision making that helps executives make better, more resilient strategic decisions. Godet (2000) defined scenarios as a means to represent a future reality to shed light on possible future outcomes.

According to Porter (1985), the purpose of scenario planning is not to accurately predict the future, but rather to better understand the logical paths that lead to different scenarios and to help develop more comprehensive strategies. Scenario planning takes different perspectives of internal and external stakeholders into account and develops different possible views of the future. Uncertainty is also considered which allows strategists to deal more effectively with complexity, volatility and change when making strategic choices. In turn, this leads to increased responsiveness and alertness to changes in market conditions (Schwenker & Wulf, 2013). When used effectively, scenario planning functions as an organizational “radar,” scanning the environment for signals of potential discontinuities (Chermack, 2011).

Author	Date	Definition
Porter	1985	“An internally consistent view of what the future might turn out to be—not a forecast, but one possible future outcome” (p. 63)
Schwartz	1991	“A tool for ordering one’s perceptions about alternative future environments in which one’s decisions might be played out” (p. 45)
Simpson	1992	“The process of constructing alternate futures of a business’ external environment” (p. 10)
Bloom and Menefee	1994	“A description of a possible or probable future” (p. 223)
Collyns	1994	“An imaginative leap into the future” (p. 275)
Thomas	1994	“Scenario planning is inherently a learning process that challenges the comfortable conventional wisdoms of the organization by focusing attention on how the future may be different from the present” (p. 6)
Schoemaker	1995	“A disciplined methodology for imagining possible futures in which organizational decisions may be played out” (p. 25)
Van der Heijden	1997	(1) External scenarios are “internally consistent and challenging descriptions of possible futures”; (2) an internal scenario is “a causal line of argument, linking an action option with a goal,” or “one path through a person’s cognitive map” (p. 5)
De Geus	1997	“Tools for foresight-discussions and documents whose purpose is not a prediction or a plan, but a change in the mind-set of the people who use them” (p. 46)
Ringland	1998	“That part of strategic planning which relates to the tools and technologies for managing the uncertainties of the future” (p. 83)
Bawden	1998	“Scenario planning is one of a number of foresighting techniques used in the strategic development of organizations, which exploit the remarkable capacity of humans to both imagine and to learn from what is imagined”

Figure 2: Scenario planning definitions (Chermack, 2011, p. 14)

3.2 HISTORY OF SCENARIO PLANNING

Scenario techniques are firmly rooted in the military in the form of war game simulations and it was not until the 19th century, that the first documented scenario outlines were written by von Clausewitz and von Moltke (Bradfield, Wright, Burt, Cairns, & van der Heijden, 2005, p. 797).

In the business field, scenario planning first emerged in the RAND Corporation, which was set up for researching new weapon technology. Kahn, an employee of RAND, pioneered the techniques called the “future-now thinking”. The goal of this approach was to combine detailed analyses with imagination and produce futuristic reports.

In the mid-1960s, Kahn established the Hudson Institute, which specialized in writing stories about the future to help people consider the “unthinkable” (Chermack, 2011).

The Hudson Institute also began to seek corporate sponsors, which exposed companies such as Shell, Corning, IBM, and General Motors to this line of thinking. Ted Newland of Shell, one of the early corporate sponsors of scenario planning, encouraged Shell to start thinking about the future. In the 1970s, scenario planning was introduced by Shell to complement traditional forecasting tools. With the help of this approach, the company was able to react earlier and more effectively to the 1973 oil crisis than its competitors. The ability to act quickly has been credited as the primary reason behind the company’s lead in the oil industry over the years. Shell adopted scenario planning as a permanent strategy in 1972–1973 which successfully helped Shell through two more oil incidents in the 1980s (Bradfield et al., 2005, p. 799). Shell’s success with the scenario planning process encouraged numerous other organizations to begin thinking about the future in this different way. Corporations cautiously began to reintegrate the application of scenarios in planning situations. Scenario planning has been adopted at a national level in some cases, and its methods have been successful in bringing diverse groups of people together (Kahane, 1992; van der Merwe, 1994).

3.3 SCENARIO PLANNING APPROACHES

The last 40 years have seen several different approaches to scenario planning. Among the most influential have been those of Royal Dutch Shell and the consulting firm Global Business Network. These two approaches have seen as the "gold standard of corporate scenario generation". Two academic approaches are particularly important, those of van der Heijden and Schoemaker (Chermack et al., 2001).

Although they differ in terms of detail, the various approaches to scenario planning can be divided into three major categories: Intuitive Logics, the Probabilistic Modified Trends and the La Prospective methodologies (Bradfield et al., 2005, p. 805).

The figure below compares these three categories.

	Intuitive-Logics Models	*La Prospective* Models	Probabilistic Modified Trend Models
Purpose of the scenario work:	Multiple, from a once-off activity making sense of situations and developing strategy, to an ongoing activity associated with anticipation and adaptive organisational learning.	Usually a once-off activity associated with developing more effective policy and strategic decisions and tactical plans of action.	A once-off activity to enhance extrapolative prediction and policy evaluation.
Scenario perspective:	Descriptive or normative.	Usually descriptive, can be normative.	Descriptive.
Scope of the scenario exercise:	Can be either broad or narrow scope ranging from global, regional, country, industry to an issue specific focus.	Generally a narrow scope but examination of a broad range of factors within the scope.	Narrow scope focused on the probability and impact of specific events on historic trends.
Scenario horizon year:	Varies: 3–20 years.	Varies: 3–20 years.	Varies: 3–20 years.
Methodological orientation:	Process orientation - inductive or deductive, essentially subjective and qualitative in approach relying on disciplined intuition.	Outcome orientation - directed and objective, quantitative and anlytical approaches (with some subjectivity) relying on complex computer-based analysis and mathematical modeling.	Outcome orientation-directed and objective, quantitative and analytical approaches (with some subjectivity) using computer-based extrapolative forecasting and simulation models.
Nature of scenario team participants:	Internal - scenarios developed by a facilitated from within the organization.	Combination of some key individuals from within the organization led by an expert external consultant.	External - scenario exercise undertaken by expert external consultants.
Identification/selection of key driving forces:	Intuition - brainstorming techniques, analysis of STEEP factors, research, and discussion with remarkable people.	Interviews with actors involved in the phenomenon being studied and comprehensive structural analysis using sophisticated computer tools.	Fitting curves to historical time series data to identify trends and use of expert judgment to create database of potential high impact unprecedented future events.
Establishing the scenario set:	Defining the scenario logics as organizing themes or principles (often in the form of matrices).	Matrices of sets of probable assumptions based on key variables for the future.	Monte Carlo simulations to create an envelope of uncertainty around base forecasts of key indicators.
Scenario Exercise Output:	Qualitative - set of equally plausible scenarios in discursive narrative form supported by graphics, some limited quantification. Implications, strategic options and early warning signals increasingly a part of scenario output.	Quantitative and qualitative - multiple scenarios of alternative futures supported by comprehensive analysis incorporating possible actions and their consequences.	Quantitative - baseline case plus upper and lower quartiles of adjusted time series forecasts. may be embellished by short storylines.
Probabilities attached to scenarios:	No, all scenarios must be equally probable.	Yes, probability of the evolution of variables under assumption sets of actors' behaviour.	Yes, conditional probability of occurrence of unprecedented and disruptive future events.
Number of Scenarios generated:	Generally 2–4.	Multiple.	Usually 3–6 dependent on the number of simulations.

Figure 3: Comparison of the Salient Features of the Three Schools of Scenario Techniques (Bradfield et al., 2005, p. 807)

From the provided information, it is assumed that the methodology used by INKA 4 software aligns with the Probabilistic Modified Trend Models approach. The first reason for the alignment of INKA 4 software with the Probabilistic Modified Trend Models is the narrow scope of the scenario focusing on probability and the impact of specific events on historic trends. In general, INKA software is used to predict future scenarios based on past and current events together with their probability. Furthermore, there are key driving forces in the Probabilistic Modified Trend Models which are also included in INKA called areas of influences. They are selected based on historical data and the judgment of the researchers. The last two important reasons that support the alignment of INKA 4 software with the Probabilistic Modified Trend Models are the quantitative relationship between influencing factors (descriptors) and the probabilities attached to the scenarios in INKA.

3.4 SCENARIO SOFTWARE INKA 4

The scenario software INKA 4 was developed by Geschka& Partner. Based on the developed algorithm, the impact analysis is calculated, and the scenarios are evaluated. The procedure of INKA 4 is divided into 8 steps ("Szenariotechnik", 2020).

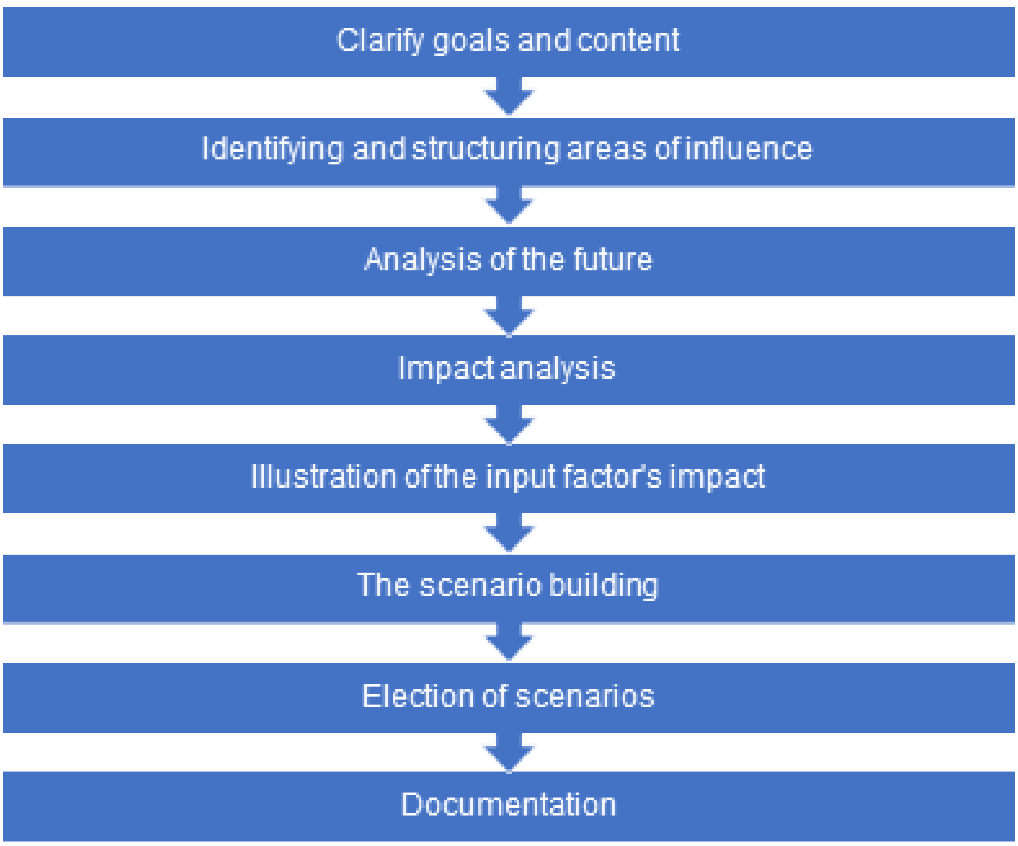

Figure 4: Eight steps in INKA 4 software ("Szenariotechnik", 2020)

1. Clarify goals and content: In the first step of a scenario planning project, the details of the topic should be defined. Some recommended questions are: **"**Which topic should be considered? What area of interest is to be looked at and at what point of time in the future? Should developments at certain points in time, so-called intermediate scenarios, be considered? Moreover, a list of strategic questions or problems should be developed.

The project team discussed and listed all the strategic questions and details regarding the topic. Potential issues were also identified.

2. Identifying and structuring areas of influence: The important descriptors (influencing factors) of the scenario planning topic should be identified and structured in areas of influence. Defining areas of influences is useful for a project with more than 10 descriptors.

For this project, 13 descriptors were recorded in four areas of influence: Technology, Economics, Politics and Social.

Number	Influencing Area	Descriptor
1.1	Technology	The main energy source technology for electric car
1.2	Technology	The technology for fully autonomous driving car
2.1	Economics	Total cost comparison between e-cars and ICV
2.2	Economics	The new registration of conventional ICV car
2.3	Economics	Choice of customers between Hybrid and Battery car
3.1	Political	The use of public transportation in the future
3.2	Political	CO2 limitation
3.3	Political	Autonomous driving in Germany in 2035
3.4	Political	Charging infrastructure for e-cars
3.5	Political	Charging infrastructure for fuel cell cars
3.6	Political	The use of car sharing in Germany in 2035
4.1	Social and Demographic	Car sharing changing the private care ownership
4.2	Social and Demographic	Shared Mobility vehicles going electric

Figure 5: Chosen areas of influence and descriptors

3. Analysis of the future: For each descriptor, one to five future projections can be added. However, it is recommended to have a maximum of three projections to keep the complexity low.

The project team added two projections for each descriptor in this project.

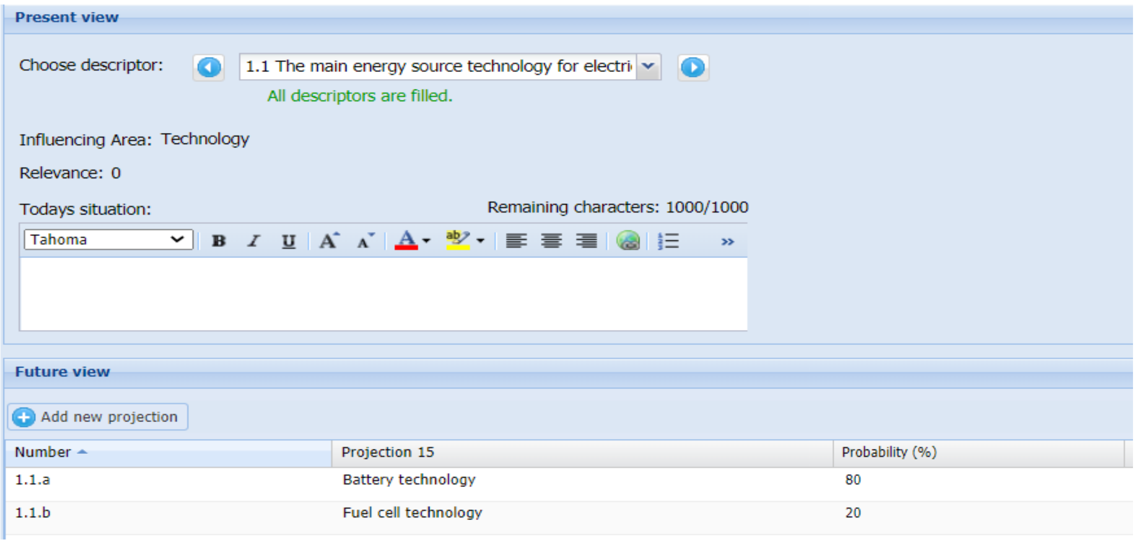

Figure 6: Example of one descriptor and its projection

4. Impact analysis: This is one of the parts of scenario technology in which the crosslinking of all descriptors is analyzed. The impact analysis is based on the impact matrix where the descriptors among each other are assessed.

In this step, the project team created the whole matrix in excel and discussed the relationship among the projections. The relationships are ranging from -3 to +3.

5. Illustration of the input factor's impact: The impact analysis results are shown in two tabular evaluations, in which the driving and driven factors are determined. INKA 4 also shows how strongly the descriptors are linked into the system and the degree of crosslinking is presented in a graphic.

After adding values for the relationship projections, the results of the project are shown in the Impact Matrix. In the Analysis tab of the Impact Matrix, the Impact Matrix table, the Impact Matrix Ranking drive, and the Impact Matrix graphic are shown.

6. The scenario building: After finishing the analysis of descriptors, the scenarios can be formed in the consistency matrix analysis. The alternative projections are compared and evaluated based on their consistency. The software algorithm identifies the most coherent scenario and further scenarios.

In this project, there are five different identified scenarios. INKA 4 software shows the most likely scenario and the most unlikely scenario.

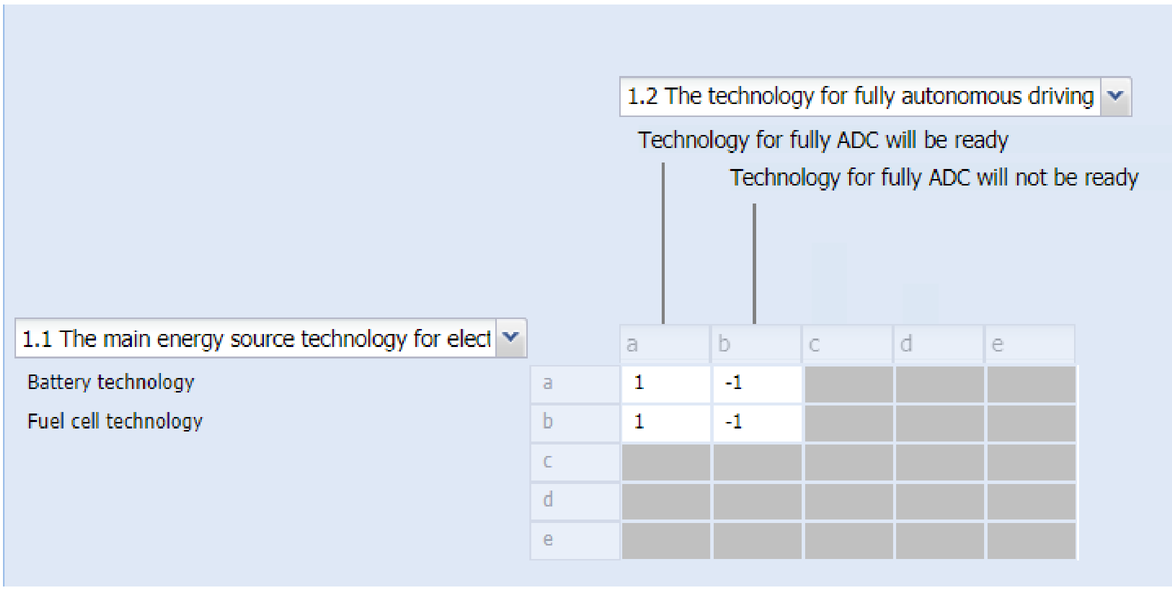

Figure 7: Example of consistency matrix input

7. Election of scenarios: A ranking proposed by INKA 4 shows the most likely scenarios. Key figures are calculated for different scenarios.

For choosing the scenarios, the rank and the consistency sum of the scenarios are illustrated in Differences I and II. The scenario portfolio is also presented to visualize the overall picture of the five scenarios.

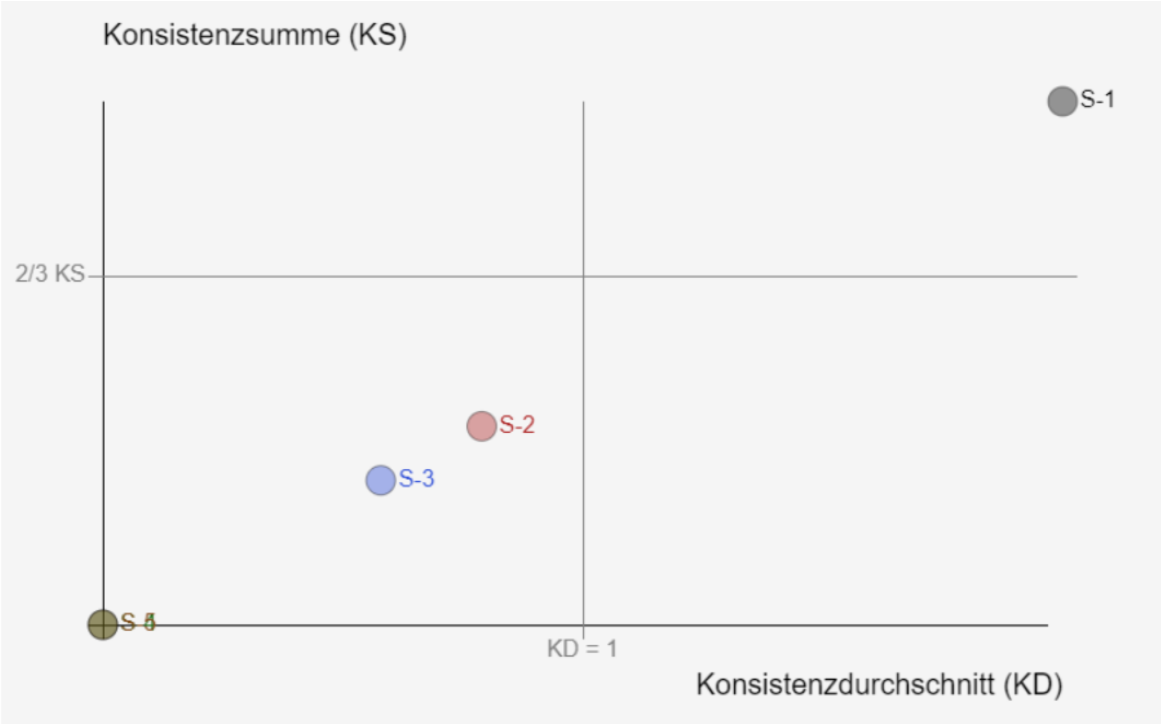

Figure 8: Scenario portfolio

8. Documentation: Documenting is the final step in which all entered information can be downloaded as a report in a PDF format.

The project team has downloaded the results of the scenario analysis. The team members decided to choose three scenarios based on three indicators (consistency sum, consistency average, and probability parameter) to write the report about.

3.5 Process outline

The scenario software INKA 4 is used to predict the future of cars in Germany in 2035. The project team performed a substantial literature review to identify areas of influence and related descriptors (Appendix 6.2). The following part will describe in detail the four areas of influence: Technology, Economics, Politics and Social.

Technology

The automotive business is undergoing significant change triggered by advanced technology. In this paper, two important areas are considered: The main technology source for cars and the technology for fully autonomous driving cars.

If the discovery and consumption of oil follow current trends, the world's oil resources will be used up by about 2038 (Ehsani, Gao, Longo, & Ebrahimi, 2018). Therefore, it is necessary to invest in another technological source for cars. By emphasizing on reducing carbon dioxide emissions, EU lawmakers push these energy technologies forward (Gobble, 2019, p. 4). In the last decade, substantial progress has been made in hybrid and electric vehicle technologies. That leads to the question: Which of these technologies will be the technology of the future? So far, the most promising technologies are Li-ion battery technology and Fuel cell technology.

Regarding autonomous driving cars, McKinsey estimates that autonomous cars will produce a substantial revenue reaching $450 to $750 billion by 2030 (Yaqoob et al., 2020, p. 174). Currently, increasing collaborations and partnerships among manufacturers and software providers are the trend in the German autonomous vehicle market. According to Yaqoob et al. (2020), there are five autonomous driving levels. The fully autonomous level for cars is level four and level five. While level four only covers a few driving scenarios, level five refers to fully autonomous driving in which the performance is equal to a human driver (Yaqoob et al., 2020, pp. 174–175). This paper predicts if the technology for fully autonomous driving cars will be ready in 2035.

Economics

Economics plays a significant role in the future of cars in Germany. According to Bobeth and Matthies (2018, p. 1765), financial aspects are not only important as a contextual factor but also the household's economic situation is important for the decision of purchasing a car. This paper takes into consideration three different descriptors: the total cost comparison between electric vehicles and ICEVs, the new registration of conventional ICEV cars and the choice of customers between hybrid and battery cars.

There are different predictions and estimations regarding the costs of different car types. Although the number of combust engine cars still account for a large percentage of cars in Germany, there is a shift towards e-cars. Both the purchase and use of e-cars have become significantly cheaper in recent years. The main reasons for this are falling battery costs, more efficient production, government purchase premiums and relatively cheap electricity compared to petrol or diesel (Volkswagen AG, 2020, p. 2).

Regarding the new ICV registration, there were 3,607,258 passenger cars newly registered in 2019. The number of new registrations of diesel-powered cars rose slightly by 3.7% after two years of decline. However, their share continued to decrease (2019: 32.0%; 2018: 32.3%). The number of new registrations of petrol-driven cars dropped by 0.3 percent to around 2.14 million to 59.2%. Therefore, the percentage of diesel and petrol-driven cars totaled to 91.2% in 2019.

Regarding the choice of the customers between hybrid and battery cars, MarketLine (Marketline, 2019) showed that the market grew by 51.5% to reach a volume of 166,474 units in 2018. It is predicted that the German hybrid & electric car market will rise to have a volume of 424,821 units in 2023, which equals an increase of 155.2% since 2018.

According to the Kraftfahrt-Bundesamt (Kraftfahrt-Bundesamt, 2020a), 3,607,258 passenger cars were newly registered in 2019. Electric vehicles achieved a growth rate of 75.5 % and cars with a hybrid drive of 83.7%.

Politics

The European and German governments have a significant impact on the future of cars in Germany. In the following paragraphs some of the most influencing decisions by the German and European government are named and their influence on the future cars in Germany is explained.

The European parliament and the European Council have decided to tighten the CO_2 limits further. The goal is to reduce the vehicle emission levels by 37.5 % between 2021 and 2030. If the car manufacturers fail to achieve this goal they are forced, starting in 2020, to pay a penalty of 95 Euro for each gram per kilometer of target exceedance (Daimler AG, 2019). Also, the European Commission is pursuing the target of decarbonizing the European mobility system by 2050 making it greenhouse gas neutral (Umweltbundesamt, 2020). Another incentive is given by the German government by the so known environmental bonus. Until the end of 2025, electric vehicle buyers will receive a purchase bonus of up to 6000 euros (Presse- und

Informationsamt der Bundesregierung, 2020). Next to this, the German government is supporting the distribution of public electric car charging stations by investing 3.5 billion euros into it. The aim is to have 50,000 publicly accessible charging stations nationwide by 2022 and one million electric car charging points across the country by 2030 (Statista, 2020a). These objectives are set out to reach the agreement of the Climate Change Conference in Paris and promotes the purchase of electric and hybrid vehicles.

Also, the German government is financially supporting the sector of public transportation by subsidizing the new construction and maintenance of the rail network. With the measure (Maßnahme) 21, the Federal Government will contribute one billion euros in additional equity capital to the Deutsche Bahn each year between 2020 and 2030, accounting to 11 billion Euros. This investment will help to modernize, extent and electrify the rail network and railway system. The goal is to increase the use of public transportation and to have less cars and pollution within the German cities (Fockenbrock&Siebenhaar, 2019). The number of rail passengers is expected to rise, and the goal of the German government is to double the number of passengers using public transportation (ChristlichDemokratische Union Deutschlands, 2019).

Another area heavily influenced by the German government and affecting the future of cars in Germany in 2035 is autonomous driving. Since 2017, highly automated driving has been permitted in Germany. This step corresponds to the third level of five levels on the way to a fully automated car as mentioned beforehand in the technology part. The German Federal Government is intensifying its work on the mobility of the future. In June 2019 there was a new action plan "Research for autonomous driving - an overarching research framework of the BMBF, BMWi and BMVI" implemented combining priorities and guidelines for the future of research funding for autonomous driving. The action plan is part of the Federal Government's High-Tech Strategy 2025 (Deutsche Welle, 2020). It includes six major projects focusing on autonomous driving with a project volume of around 200 million euros (BunesministeriumfürWirtschaft und Energie, 2019). Next to this the German government has established an infrastructure for test drives with driverless vehicles. The city of Hamburg is planning test drives with autonomous vehicles as early as

2021 (Statista, 2020b). The government believes that autonomous driving offers a wide range of opportunities by increasing safety and efficiency in road traffic and by helping with concepts of emission-free, intelligent, and innovative mobility (BunesministeriumfürWirtschaft und Energie, 2019).

All in all, the German government is heavily influencing the future of cars in Germany in 2035. It is doing this by supporting research and development, offering incentives to companies and German car customers that lead to lower CO_2emissions and penalizing car manufacturers that exceed the CO_2 limitations. Also, the future of cars in Germany in 2035 is influenced by decisions made by the European Union.

Social

Social shifts in society, whether mental or physical, can lead to a drastic variation in the way the industry and its players function. The notion of societal role is widely used by experts in every field to be a concept of considerable importance (Longfoot, 1972).

The cars play a crucial role for the German economy as one of fifteen vehicles sold in the world are produced in Germany (Kuhnimhof, 2017). The car being the dominant means of transport – 58% of all trips and 79% of passenger-kilometers are covered by car. Even in larger cities (cities with more than 100,000 inhabitants) with good public transport, cars are used for 50% of journeys and 71% of passenger kilometers (infas& DLR 2010). Urban car traffic causes many negative effects, including air pollution and CO2 emissions, congestion, parking pressure, and noise.

Carsharing is currently expanding rapidly in Germany and reporting a strong increase in user numbers. Also, car sharing is an important instrument for sustainable urban mobility (BCS 2016). The number of registered car sharing users in Germany rose to 2.46 million in 2019 and has been on the rise since (BCS, 2019). Car sharing essentially is classified into Station-based and Free-floating car sharing. In station-based car sharing, the car needs to be picked up and returned to the station. Whereas in free-floating car sharing there are no stations, the users can pick-up and drop-off the vehicles freely within a predefined service area (Ciari, Bock and Balmer, 2014). The growth of station-based carsharing and free-floating carsharing was

21.5% and 14.9% respectively in 2019 whilst integrating electric cars in process (BCS, 2019).

The societal shift plays a significant role in the transportation sector and the automobiles sector in Germany with changes in the mobility behaviors and patterns that will alter the face of cars and its usage in the upcoming times.

4. RESULTS

The 13 selected descriptors and their consistency values ranging from -3 to +3 were integrated into the INKA software and the following five scenarios were given out by Figure 9below. The scenarios ranked first, second and fifth were selected to be described in further detail.

Scenario one was chosen because it is the most probable scenario and has the highest consistency sum of 89.

The scenarios ranked second and third are relatively similar to each other. Due to the higher consistency sum (53), consistency average (0.9) and probability parameter (56) the second scenario was chosen instead of the third scenario.

The scenarios ranked fourth and fifth have an identical consistency sum (31) and consistency average (0.52). The slightly higher probability parameter of the fifth scenario made it preferable.

Rank:	1	2	3	4	5
Consistency Sum:	89	53	47	31	31
Consistency Average:	1,48	0,90	0,80	0,52	0,52
Probability parameter:	46	56	42	46	49
Descriptor:					
1.1 The main energy source technology for el…	a	a	a	a	b
1.2 The technology for fully autonomous driv…	a	a	a	a	b
2.1 Total cost comparison between e-cars and…	a	a	a	a	b
2.2 The new registration of conventional ICV…	a	b	a	b	b
2.3 Choice of customers between Hybrid and B…	b	b	a	b	a
3.1 The use of public transportation in the …	a	a	b	b	b
3.2 CO2 limitation	a	a	b	b	b
3.3 Autonomous driving in Germany in 2035	a	a	a	a	b
3.4 Charging infrastructure for e-cars	a	a	a	a	b
3.5 Charging infrastructure for fuel cell ca…	a	b	a	b	a
3.6 The use of car sharing in Germany in 2035	a	a	a	a	b
4.1 Car sharing changing the private care ow…	a	a	b	b	b
4.2 Shared Mobility vehicles going electric	a	a	a	a	a

Figure 9: Differences in the scenarios

Scenario S-1 (Rank 1) – “EASY”! The future cars in Germany will be electrified, autonomous, shared and will yield to changes.

The selected scenario S-1 has the highest consistency sum of 89 and a probability parameter of 46.

The most probable scenario to happen in the year 2035 shows that the future cars will be heavily influenced by the German government and consumers asking for cars that emit less CO_2.

The average emission levels of new registered cars in Germany will decrease by at least 37.5 % until 2035. This is not achievable with today's preferred cars based on an internal combustion engine (ICE). This is the reason why the new registration of ICV cars will decrease sharply until 2035. In 2019 diesel and petrol-driven cars still made up 91.2% of the new registered cars. In 2035 less than 80 % of the new registered cars will be based on an ICE. These changes allow a different engine technology to capture this part of the market. Possible options are hybrid and battery-based cars. According to this scenario, German customers will prefer battery-based cars in the future. A reason for German customers to prefer battery-based cars are the subventions given by the German government, which will make the total costs of electric vehicles lower compared to ICE based cars by 2035. The main reasons for this are falling battery costs, government purchase premiums and the relatively cheap electricity compared to petrol or diesel. Also, the German government is supporting the future of battery-based cars by expanding the publicly accessible electric charging stations. Until 2035 there will be around one million public charging points covering Germany nationwide and not only in big cities. Li-ion battery technology will be the dominant automotive battery technology in 2035, but there will also be a 1000 charging points for the fuel cell technology.

Since 2017 "highly automated driving has been permitted in Germany. This step corresponds to the third level on the way to a fully automated car. The third level means that the car is sufficiently intelligent to cope with everyday situations, but the system is designed so that the driver can override the system's wishes at any time and the responsibility remains with the driver. Fully autonomous driving begins with level four. Level four of autonomous driving means that in a few driving scenarios the passengers are regarded as passengers and are not liable for accidents in road traffic. According to Scenario 1 fully autonomous driving at level four will be legally and technically possible in 2035.

By investing into the modernization, extension, and electrification the number of rail passengers is expected to double. This will mean less cars and less pollution within German cities. Another factor influencing especially the German cities will be car sharing. Even though car sharing has grown rapidly in recent years only about 0.1% of passenger kilometers were provided by car sharing in Germany in 2017. Scenario

1 is expecting that car sharing will experience a disruptive growth with 2.5% of passenger kilometers being provided by car sharing in 2035. Next to this car sharing will lead among the users to not owning a private car and therefore as a catalyst for reducing private-vehicle ownership. Currently 10% of the car sharing vehicles are electrified. Until 2035 it is expected that this number will double and 20% of the car sharing vehicles will be electric.

Scenario S-2 (Rank 2) - Mainstream and "green" will go hand-in-hand!

INKA selected scenario 2 with a consistency sum of 53 and a probability parameter of 56.

Scenario 2 is similar to scenario 1 with two key differences: the registration of ICV cars and the charging infrastructure for fuel-cell cars. The first main difference that makes it a less 'green' alternative is the registration of ICV cars. Even though the cost for electric cars will be lower, the new registration of ICV cars is predicted to be higher than 80%. A reason for this could be the people's reluctance to change. This means that the use of diesel and benzin cars will remain about the same as today. It is highly likely that the shift to Electric cars in general will be rather sluggish and gradual as contrary to scenario 1. The second important difference is the stagnation of charging stations for FCVs in 2035. The stagnation in charging stations might impact the whole FCV car market in a negative way, hence, lowering the use of fuel-cell cars in the future. The researchers predict that the fuel-cell will become redundant due to the problems in storage, and transportation of hydrogen.

On the other hand, electric mobility will still persist in the market. The main source of technology for electric cars will still be the battery technology, with customers' preference towards battery cars. The two-fold use of public transportation like trains will as well aid in bringing down the pollution levels to 37.5%. The use of autonomous driving car will also be legal and in use. Next to that a social shift in carsharing is expected to effectively reduce the private car use.

This two-fold narrative is likely to slow-down the electrification and digitization in the field of the car industry in Germany in the upcoming years as two contrasting scenarios would co-exist together leading to an extremely unpredictable future.

Scenario S-5 (Rank 5) - There is still a long way to a "greener" future of cars!

This scenario has a consistency sum of 31 and a probability parameter of 49.

In this scenario, the cost of electric cars is high compared to ICVs. It is predicted that on average the cost for an electric car can be 20% higher than an ICV. The electric car charging infrastructure is not well-structured and convenient for drivers yet. In fact, the number of charging stations for electric cars will be less than 1 million. Regarding the energy for cars, fuel cell technology and their corresponding infrastructure will play a greater role in the cars in Germany in 2035. It is probable that if the German government set a higher priority on fuel cell technology, the number of charging points would rise to one thousand. If a customer has the willingness to change to a more sustainable vehicle, there is a greater chance that he will pay for a hybrid car than a battery car. The reason for this is that a hybrid car has a clear advantage in its driving range. ICVs will still account for more than 80% of newly registered cars in Germany and the main reason for this is the cost-effectiveness. The use of public transportation remains the same as today. A reason for this could be the higher convenience. Car sharing will not increase significantly as people still enjoy having and using their private cars. However, there could be a tendency towards electric mobility in the car-sharing sector. The technology for fully autonomous driving cars will not be advanced enough to reach level 4 and therefore will not be legally permitted. The combination of all these factors will lead to the fact that the CO_2 emissions will not decrease significantly in the next 15 years.

5. CONCLUSION, LIMITATIONS AND OUTLOOK

5.1 CONCLUSION

Mobility, especially individual physical mobility plays an essential role in nearly all societies. In Germany, the automotive sector is the backbone industry which contributes significantly to the economy. The accelerated rise of new technologies, sustainability policies and changing consumer preferences lead to remarkable changes in this industry. Still questionable is how those factors affect the future of cars in Germany. Therefore, this paper considers current information to recommend possible future scenarios.

To answer the question of how the future of cars in Germany will look like in 2035, three possible scenarios are presented:

“EASY”! The future cars in Germany will be electrified, autonomous, shared and will yield to changes. This first scenario shows a remarkable decrease in cars with combustion engines and a future in electrified, autonomous, and shared cars. This leads to a great reduction in greenhouse gas and contributes to a green future of cars in Germany. The average emission levels of new registered cars are predicted to decrease by at least 37.5 % until 2035. The shift toward the hybrid and battery-based cars will be supported by customers. Regarding the energy technology for electric vehicles, Li-ion battery technology will be the dominant one in 2035. According to scenario 1, fully autonomous driving at level four will be legally and technically possible in 2035. Besides that, car sharing will play a bigger role in the future of cars in Germany.

Mainstream and “green” will go hand-in-hand! This scenario illustrates that ICVs will still account for more than 80% of new registered cars. Although the cost of Electric cars will be lower than ICV cars, customers will prefer ICVs. One reason for this might be the customer's reluctance to change. Another difference is the decrease of charging stations for fuel-cell vehicles by 2035. The main source of technology for electric cars will still be battery technology, with customers' preference towards battery cars. Together with the increasing use of public transportation this will bring down the pollution levels to 37.5%.

There is still a long way to a "greener" future of cars! Although this is the least likely future scenario, it can be possible that the "greener" future of cars might not happen as early as we expect. The essential conditions why that might not be fulfilled due to (1) The total cost for electric cars being higher than the costs for an ICV, (2) The charging infrastructure not being well established yet, (3) Public transportation and car sharing will remain the same as today and (4) The fully autonomous driving cars will not be legally permitted yet. All these factors lead to the fact that the ICV will be the preferred type of vehicle from the customer point of view and therefore CO2 cannot be decreased tremendously during the next 15 years.

In conclusion, the findings of this paper suggest different possible future scenarios for cars in Germany. On the one hand, it is expected that cars will head toward electrified, autonomous and shared mobility. On the other hand, the extent to how "green" the future of cars in Germany depends significantly on the German government and customer preferences.

5.2 LIMITATIONS

Firstly, the paper does not consider any natural crises, extraordinary situations, any disruptive changes or the ongoing COVID-19 crisis that might or might not alter the car industry or related industries. Secondly, the predictions are made based on the extensive literature review conducted by the researchers to the best of their ability and current knowledge. Thirdly, the scenarios predicted by the INKA 4 software uses the information presented at this point in time, which might alter if new information is added to it.

5.3 OUTLOOK

The research paper expects that in the future the mobility options are going to be more environmentally friendly and ecologically safer than in today's time. ICEV cars will see a gradual decline due to the severe government restrictions. There will be a gradual increase in the use of electric mobility in cars with the advent of autonomous driving cars becoming mainstream. Car sharing services, public transportation and multi-mobility will be preferred by consumers. On the flip side, there is a chance that the ICEVs will still be the primary type of car. The sluggish infrastructure development of the charging infrastructure, expensive electric alternatives, and lack of legal authorization for fully autonomous driving cars would be the causes that might lead to a stagnant path to Germany's goal towards electric mobility.

6. APPENDIX

List of final descriptors

Technology

Descriptor name: The main technology of energy source for car in the future

Area of influence: Technology

Current situation: According to Ehsani et al. (2018) if oil discovery and consumption follow current trends, the world's oil resources will be used up by about 2038. Therefore, it is important to invest in another technological source for cars. So far, the most promising technologies in the future are Li-ion battery and fuel cell vehicles.

Specification A:

- **Name:** Battery technology (Li-ion battery) will the main source for energy

- **Description:** Li-ion battery technology is the dominant automotive battery technology today, thanks to its relatively high energy density and power density and a long lifetime (Bubeck, Tomaschek, &Fahl, 2016). The modern lithium-ion batteries (Li-Ion) have an energy capacity of approximately 100 to 250 Wh/kg (250 to 620 Wh/l).

- **Reason:** Li-ion technology is regarded as the most promising forerunner technology that will pave the way for a widespread implementation of EVs, in particular BEVs and PHEVs, in the short- and medium term. Already today, most new EVs make use of this battery type. It is predicted that, in 2020, Li-ion for e-mobility could make up 50-70%of all (Pehlken, Albach, and Vogt, 2017, p. 42). The German government now wants to take battery cell production into its own hands to reduce the risk of dependence elsewhere. Economics minister Peter Altmaier has proposed the construction of two large-scale factories, funded with €1 billion each, and has earmarked another €600 million for R&D (Gobble, 2019, p. 5)

- **Probability:** 80%

Specification B:

- **Name:** Fuel cell technology (Hydrogen) will be the main source for energy

- **Description:** In recent years, advanced vehicle technology research has turned to fuel cell vehicles (Ehsani et al., 2018, p.12). Until now, hydrogen (H2) is the only fuel that allows the operation of fuel cells for cars.

- **Reason:**

Compared with battery-powered EVs, a fuel-cell-powered vehicle has the advantages of a longer driving range without a long battery charging time. Compared with internal combustion engine vehicles, it has the advantages of high energy efficiency and much lower emissions due to the direct conversion of free energy in the fuel into electrical energy, without undergoing combustion (Ehsani et al., 2018, p.397). During its operation, there were proposals to replace the ICengine with a so-called fuel cell. Although the forecasts for fuel cells were very optimistic at the beginning of this century, this drive so far has not asserted itself on the world market. The only market vehicle with the fuel cell is Toyota-Mirai. Many believe that, with the development of the battery for the accumulation of electricity, the fuel cells become redundant. The biggest problems with hydrogen are with its storage, transport, or the absence of entire infrastructure. In the fuel cell, the hydrogen is then used as a source to produce electricity.

One of the leading companies in the field of fuel cells, the Daimler, has moved the focus of the research from the fuel cells to the development of batteries for the accumulation of electrical energy (Končalović et al., 2019, pp. 28–29). Therefore, fuel cell vehicles will still have a long way before commercialization.

- **Probability:** 20%

- **References:**

Ehsani, M., Gao, Y., Longo, S., & Ebrahimi, K. (2018). *Modern electric, hybrid electric, and fuel cell vehicles: Fundamentals, theory, and design* (Third edition /

Mehrdad Ehsani, Yimin Gao, Stefano Longo, Kambiz Ebrahimi). Boca Raton: CRC Press.

Bubeck, S., Tomaschek, J., &Fahl, U. (2016). Perspectives of electric mobility: Total cost of ownership of electric vehicles in Germany. *Transport Policy*, *50*, 63–77. https://doi.org/10.1016/j.tranpol.2016.05.012

Pehlken, A., Albach, S., & Vogt, T. (2017). Is there a resource constraint related to lithium ion batteries in cars? *The International Journal of Life Cycle Assessment*, *22*(1), 40–53. https://doi.org/10.1007/s11367-015-0925-4

Gobble, M. M. (2019). News and Analysis of the Global Innovation Scene. *Research-Technology Management*, *62*(1), 2–8. https://doi.org/10.1080/08956308.2019.1541709

Končalović, D., Živković, D., Gordić, D., Vukašinović, V., Josijević, M., &Stević, S. (2019). IMPROVEMENT OF ENERGY EFFICIENCY OF CITY VEHICLE FLEETS: CASE STUDY. *Mobility and Vehicle Mechanics*, *45*(4), 1–12. https://doi.org/10.24874/mvm.2019.45.04.01

Descriptor name: The technology for fully autonomous driving car

Area of influence: Technology

Current situation: In 2016, German government announced plans to develop autonomous driving infrastructure in the country. Further, the German Road Traffic Act enables the driver to pass the car controls to the autonomous driving system in June 2017 (Research & Markets, 2019). According to (Yaqoob et al., 2020) there are five autonomous driving levels. The fully autonomous level for cars are level four and level five. While level four only covers a few driving scenarios, level five refers to fully autonomous in which the performance is equal to human driver (Yaqoob et al., 2020, pp. 174–175).

Specification A:

- Name: The technology for fully autonomous driving car will be ready in 2035

- Description: According to (Research & Markets, 2019), it is predicted that the market for fully autonomous vehicles in Germany will reach $28.0 billion by 2030. Currently, the collaborations and partnerships among manufacturers and software providers is increasing in the German autonomous vehicles market. For instance, KPIT Technologies Limited, TTTechComputertechnik AG, and BMW AG collaborated in 2018 to develop autonomous driving software (Research & Markets, 2019).

- Reason: There was a joint project involving Mobileye, Intel, and BMW to produce the BMW VISION iNEXT. This is a concept of an autonomous car presented at CES 2016 to offer users fully connected, fully automatic, and highly autonomous driving services which is planned to debut on roads by 2021 (Yaqoob et al., 2020, p. 179). Besides, Gartner predicts that 250 million cars will be connected with each other by the end of 2020. Furthermore, the combination of 5G networks with network function virtualization (NFV) and software defined networking (SDN) makes it highly powerful for autonomous cars (Yaqoob et al., 2020, p. 175).

- Probability: 15%

Specification B:

- Name: The technology for fully autonomous driving car will not be ready in 2035

Description: Currently, the security factor still remains the biggest challenge for autonomous driving cars.

- Reason: Among the levels of car automation, level five is highly vulnerable to security threats because it is intended to enable driving without a driver. The security risk includes physical access attacks and man-in-the-middle attacks. A hacker may hack the car and use it to cause accidents and injuries. Besides, he can physically access the car and install malicious software in it. Regarding current application, the Mercedes-Benz F 015 was introduced but it is still in its infancy (Yaqoob et al., 2020, 178–179).

- Probability: 85%

- References:

Research, & Markets (2019, September 26). Germany Autonomous Vehicle Market Research Report 2019-2030. Retrieved from https://www.prnewswire.com/news-releases/germany-autonomous-vehicle-market-research-report-2019-2030-300926099.html

Yaqoob, I., Khan, L. U., Kazmi, S. M. A., Imran, M., Guizani, N., & Hong, C. S. (2020). Autonomous Driving Cars in Smart Cities: Recent Advances, Requirements, and Challenges. *IEEE Network*, *34*(1), 174–181. https://doi.org/10.1109/MNET.2019.1900120

Economics

Descriptor name: Total cost comparison between electric vehicles and ICEV

Area of influence: Economics

Current situation: According to Bobeth and Matthies (2018), costs play

a major role in the customers' cars purchasing decision. (Ajanovic& Haas, 2020, p.4) stated that, with respect to economic competitiveness, BEV will enter the market by about 2025. FCV will become competitive even later, by about 2040. HEV is already today a feasible technical option which combines the advantages of both electric drives and ICE vehicles at rather moderate additional costs. It is predicted that by 2050 the total overall driving costs of most fuels and powertrains will almost even out.

In January 2020, the car sales by fuel type in Germany using petrol, diesel, hybrid and electronic power systems are 126,806; 80,257; 30,805 and 7,492 respectively (Statista, 2020). Furthermore, from 2009 to 2019 more than 90% of car new registration are diesel-powered and petrol driven cars (Kraftfahrt-Bundesamt, 2020). Those figures show that people in Germany still tend to buy ICE because it is not only more comfortable to find a charging station, but also the purchase costs of electric vehicles are still much more expensive today.

The updated environmental bonus, offered in Germany since February 2020, ensures further savings for electric cars. Pure electric basic models up to a list price of €47,600 (gross) are now subsidized with €6,570 (gross). The Volkswagen ID.3 pure electric model will be available in Germany from summer 2020 from 23,430 €, which is below the price level of comparable combustion engines (Volkswagen AG, 2020).

Specification A:

- Name: The total cost for electric vehicles will be lower compared to ICEV

- Description: The total cost of for electric cars will be in general cheaper

than the total of ICEV in 2035.

- Reason:

Both the purchase and use of e-cars have become significantly cheaper in recent years. The main reasons for this are falling battery costs, more efficient production, government purchase premiums and relatively cheap electricity compared to petrol or diesel (Volkswagen AG, 2020, p. 2). For the future cost estimations, full electric vehicles can reach economic viability from 2030 onwards for many of the investigated vehicles and users (Bubeck et al., 2016, p.63).According to the forecast of the studies it is predicted that e-vehicles will be cheaper than ICE vehicles by 2035 with a very high probability.

- Probability: 80%

Specification B:

- Name: The total cost for electric vehicles is 20% more expensive than ICEV in 2035

- Description: The cost for electric cars also depends on the energy cost, which is a major uncertainty remaining regarding BEV and FCV is how fast technological learning will take place especially for the battery and the fuel cells (Ajanovic& Haas, 2020).

- Reason:

If a breakthrough in the BEV technology as expected is not possible, due to learning curves, as well as governmental regulations and governmental promotions, a cost reduction of at least 10% can be still expected.

- Probability: 20%

- References:

Ajanovic, A., & Haas, R. (2020, June 29). An economic, ecological and energetic assessment of battery electric, hybrid and fuel cell cars - IEEE Conference Publication. Retrieved from https://ieeexplore.ieee.org/document/6837311

Bobeth, S., &Matthies, E. (2018). New opportunities for electric car adoption: the case of range myths, new forms of subsidies, and social norms. *Energy Efficiency*, *11*(7), 1763–1782. https://doi.org/10.1007/s12053-017-9586-4

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Statista (2020). Monthly car sales by fuel type Germany 2018-2020 | Statista. Retrieved from https://www.statista.com/statistics/417021/monthly-car-registrations-in-germany-by-fuel-type/

Volkswagen AG (2020, April 14). The big cost comparison: e-car vs. combustion engine. Retrieved from https://www.volkswagen-newsroom.com/en/stories/the-big-cost-comparison-e-car-vs-combustion-engine-5869

Descriptor name: The new registration of conventional ICV car

Area of influence: Economics

Current situation: According to ("Kraftfahrt-Bundesamt - Neuzulassungen - Jahresbilanz der Neuzulassungen 2019," 2020), 3,607,258 passenger cars were newly registered in 2019. The number of new registrations of diesel- powered cars rose slightly around 3.7% after two years of decline. However, their share continued to decrease (2019: 32.0%; 2018: 32.3%). The number of new registrations of petrol-driven cars dropped by 0.3 percent to around 2.14 million to 59.2%. Therefore, the percentage of diesel and petrol driven cars totaled 91.2% in 2019.

Specification A:

- Name: The new registration of ICV (benzin and diesel) will reduce to under 80% (98,2 2018, 91: 2019).

- Description:

- Reason: In October 2009, EU lawmakers drafted a law seeking an even greater reduction in carbon dioxide emissions for Europe's new cars than had previously been required (Gobble, 2019, p. 4). Furthermore, in May 2016, the German government introduced a buyer's premium of 6000 EUR for battery electric vehicles and a premium of 3,000 EUR for plug-in hybrid electric vehicles which encourage the people buy more e cars instead of ICV car in the future (Bubeck et al., 2016, p. 64). In recent decades, the research and development activities related to transportation have emphasized the development of high-efficiency, clean, and safe transportation. Electric vehicles (EVs), hybrid electric vehicles (HEVs), and fuel cell vehicles have been typically proposed to replace conventional vehicles in the near future (Ehsani, 2018, p. 1).

- Probability: 20%

Specification B:

- Name: The new registration of ICEV car will be more than 80%

- Description: Although the new registration for benzin and diesel reduced from 2008 to 2018, 99% to 98,2% respectively (Kraftfahrt-Bundesamt, 2020), this reduction is relatively small year by year.

- Reason: So far, the high cost of e cars and the lacking of well charging infrastructure are the main disadvantages that discourage customers to buy electrical cars. Therefore, it is expected that ICV will still account for the large market share in the future.

- Probability: 80%

- References:

Bubeck, S., Tomaschek, J., &Fahl, U. (2016). Perspectives of electric mobility: Total cost of ownership of electric vehicles in Germany. *Transport Policy*, *50*, 63–77. https://doi.org/10.1016/j.tranpol.2016.05.012

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Descriptor name: The choice of customers between Hybrid and Battery cars

Area of influence: Economics

Current situation: In 2018, German hybrid & electric cars market grew by 51.5% in 2018 to reach a volume of 166,474 units. It is predicted that the German hybrid & electric cars market is forecast to have a volume of 424,821 units in 2023, an increase of 155.2% since 2018 (MarketLine, 2019).

According to ("Kraftfahrt-Bundesamt- Jahresbilanz der Neuzulassungen 2019," 2020), 3,607,258 passenger cars were newly registered in 2019. Electric vehicles achieved a growth rate of 75.5 % and cars with hybrid drive 83.7%.

Specification A:

- Name: Customer will prefer buying Hybrid cars

- Description: In terms of category segmentation in Germany, Hybrid is the largest segment of the hybrid & electric cars market, accounting for 78.2% of the market's total volume (MarketLine, 2019).

- Reason: According to Statista (2019), the new registration in 2018 for HEV is 52,648 units. Research shows that PHEVs are cost optimal for many drivers because of the low variable costs, unlimited total range and not too high additional initial investment compared to ICEs (Plötz, Gnann, &Wietschel, 2012).

- Probability: 85%

Specification B:

- Name: Customers will prefer buying Battery cars

- Description: In 2019, BEV new registration is 36,541 units (Statista, 2019).

- Reason: According to Markel and Simpson (2007), BEV has low operating cost. However, their limitations which are driving range and long charging time will not allow realizing large mileages in most use cases. Therefore, it is expected that over the next decade BEVs will be interesting either for niche markets such as car sharing within cities or for customers who are willing to pay for environmentally friendly driving.

- Probability: 15%

- References:

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Plötz, P., Gnann, T., &Wietschel, M. (2012). Total Ownership Cost Projection for the German Electric Vehicle Market with Implications for its Future Power and Electricity Demand

Social&Demographics

Descriptor name: Car sharing is changing the private car ownership

Area of influence: Social, Car sharing in political framework

Current situation: In Germany, the car is the dominant means of transport – 58% of all trips and 79% of passenger-kilometers are covered by car. Even in larger cities (cities with more than 100,000 inhabitants) with good public transport, cars are used for 50% of journeys and 71% of passenger kilometers (infas& DLR 2010). Urban car traffic causes many negative effects, including air pollution and CO2 emissions, congestion, parking pressure, and noise. Carsharing is currently expanding rapidly in Germany and reporting a strong increase in user numbers, is an important instrument for sustainable urban mobility (BCS 2016). The present boom is mainly due to so-called "free-floating carsharing" offering one-way rentals with per-minute billing. Station-based car sharing is also continuously growing, both in terms of cities offering car sharing services and number of customers.

Carsharing should not be considered as a single measure but should be established as a permanent component of municipal mobility strategy. The appropriate political framework – like a comprehensive management of carparking and the expansion of low emission zones – can enhance the positive effects of carsharing even more.

Around 20.200 car sharing vehicles are available at the beginning of 2019 in Germany, 2.250 more than the year before, that is 11.13% increase just within a year.

Specification A:

- Name: Car sharing will replace up to 20 private cars by 2030

- Description: As of the beginning of 2016, station-based car sharing providers collectively count 430,000 registered customers in 537 cities and communities in Germany (BCS 2016). To date there have been many studies dealing with the environmental effects of station-based car sharing providers. One of the first analyses can be found in Wiederseiner (1993), who showed, using the example of STATTAUTO in Nuremberg, that a large number of respondents, 54%, were car owners prior to their car sharing membership. In another study, Baum &Pesch (1994) proved that 23% shed their private cars because of carsharing. In his study on STATTAUTO Berlin, Petersen (1995) calculated that, with each purchased car sharing car, 3.89 private cars will be shed. Similar studies in the mid-2000s also confirmed the high impact of station-based car sharing on private car ownership. Maertins (2006), for example, proved that 33% of users do not purchase a private car and 16% got rid of a car due to carsharing. Therefore, free-floating fleets could reduce car ownership in cities.

- Reason: According to a study from the German car sharing association (BundesverbandCarSharing) with infas Institute from 2016, a station-based car sharing vehicle replaces between 8 and 20 private cars. At the beginning of 2019 there were 2,46 million registered carsharing users, 350.000 more than the year before. With a growing rate of 21,5 percent, the increase in station-based carsharing was above average. The growing rate of free-floating customers was 14,9 percent, so it is reduced compared to the year before. Overall, carsharing is growing in Germany.

In the times of car sharing, with an increasing number of station-based car sharing providers as well as the free-floating car sharing providers, owning a car is no longer necessary due to the constant mobility services as it leads to higher costs, whereas car sharing deems as sufficient. Another reason is due to the environmental factors, people are opting more towards car sharing. The limited parking space availability, and interconnected transport modes and the uniform pricing system of car sharing are also some of the reasons to not owning a private car. The customers of both carsharing systems are satisfied with their everyday mobility, even without the use of a private car.

- Probability: 70%

- References:

FlemmingGiesel and Claudia Nobis, The Impact of Carsharing on Car Ownership in German Cities, Transportation Research Procedia 19 (2016) 215 – 224 doi: 10.1016/j.trpro.2016.12.082

Rüdiger Hahn, Felix Ostertag, Adrian Lehr, Marion Büttgen, Sabine Benoit (2019), “I like it, but I don't use it”: Impact of carsharing business models on usage intentions in the sharing economy, DOI: 10.1002/bse.2441

Carsharing statistic 2019: Carsharing in Germany is still on a growing path, BundesverbandCarSharing e. V. (bcs) 20.02.2019 https://carsharing.de/sites/default/files/uploads/pm_carsharing-statistik_2019_englisch.pdf

Immer mehr Städte mit CarSharing-Angebot, Bundesverband CarSharing e. V. (bcs) 18.02.2020

JörgFirnkorn& Martin Müller, What will be the environmental effects of new free-floating car-sharing systems? The case of car2go in Ulm, Ecological Economics 70 (2011) 1519–1528, doi:10.1016/j.ecolecon.2011.03.014

Specification B:

- Name: People will still purchase a private car in spite of car sharing

- Description: In the case of DriveNow, 18% of the non-car owners stated that they are planning a car purchase. Again, there are significant differences compared to

Flinkster. Only 6% of the same group wants to buy a car soon. So, it can be seen that a significant proportion of the non-car owners are thinking about a car purchase. There is also a significant proportion of people planning a car purchase. This is true especially for car-savvy persons for whom car ownership is very important and can also lead to car purchase.

- Reason: The larger the household size, the more important a private car is deemed to be, and when a person assesses that carsharing is more comfortable than public transport, the probability of purchasing a car increase. Especially the people with a higher affinity to private cars. Additionally, with a start of a family, the purchase of a car is more likely.

- Probability: 30%

- References:

FlemmingGiesel and Claudia Nobis, The Impact of Carsharing on Car Ownership in German Cities, Transportation Research Procedia 19 (2016) 215 – 224 doi: 10.1016/j.trpro.2016.12.082

Descriptor name: Shared Mobility vehicles going electric

Area of influence: Social, technology

Current situation: Currently, ten percent of car-sharing vehicles in Germany are electric or hybrid vehicles (BCS, 2018b), a percentage share that is around 100 times higher than the national passenger car fleet (Kraftfahrt-Bundesamt, 2017).

Specification A:

Name: 20% of car sharing vehicles will be electric by 2030 increasing its usage and benefits.

Description: McKinsey estimated that car sharing would lead to opportunities beyond selling mobility services or building purpose-built vehicles, including gaining customer data, testing new technologies and ensuring the fleet emission compliance (via electric vehicles) (McKinsey, 2017).

Reason: a higher share of car-sharing cars are electric or hybrid vehicles when compared to private cars (BCS, 2018b; Kraftfahrt-Bundesamt, 2017). This is because car-sharing cars are used in cities, where the shorter reach of such cars is not very relevant. At the same time, the providers of car-sharing services, which are often car-manufacturers, can present themselves as environmentally friendly. While many car-sharing users for the first time try electric vehicles, also a positive effect on sales of these cars could be expected.

Probability: 55%

References: Aaron Best and Marius Hasenheit, Car Sharing in Germany: A Case Study on the Circular Economy (2018), European Union's Horizon 2020

Specification B:

Name: Public transport will be electric by 2030 and preferred by people

Description: By far, the most widely used form of shared mobility is public transport. In Germany, urban transit and rail services accounted for 17.2% of passenger trips in 2016 (BMVI, 2017, p. 217).

Reason: Similar growth has been seen for public transport (transit and rail combined) at 10.9%. Public transport in many cases is a crucial mode of transport for disabled and elderly people or individuals without a driver's license. Several studies highlight a distinction between station-based and free-floating car sharing schemes. Station-based car sharing users are more likely to use public transport (Lichtenberg and27 :: Car Sharing in Germany: A Case Study on the Circular Economy Hanel, 2007) and less likely to have a private car, compared to the general population (Sioui et al., 2013) However, other studies indicate that free-floating car sharing users are also more likely to possess public-transport passes, signifying they are likely to use public transport intensely (Kopp &Axhausen, 2015). These users also walk and cycle more than average consumers (Katzev, 2003). Public transport is a good alternative for car sharing, because it is circular by definition, since few transport vehicles are used by a large number of people. Additionally, public transport often is cost-effective and accessible for most people. Public transport fares are frequently subsidised throughout the world. Generally, such steady support is necessary to pay for transport infrastructures, such as a metro network, thereby achieving economies of scale (Santos et al., 2010)

Probability: 45%

References:

Dr. Tatjana Streit and Dr.-Ing. Martin Kagerbauer, Public Transport and Mobility in Germany – Trends and Drivers (2014), Institute for Transport Studies, Karlsruhe Institute of Technology (KIT)

Political

Descriptor name: The use of public transportation in the future

Area of influence: Political

Current situation: There has been a sharp increase in the volume of local and long-distance public transport. This can be observed above all in the metropolitan areas, where it corresponds to the perception of the population. In Germany public transport passengers used buses and trains for almost 11.6 billion trips in 2018. This equals to more than 30 million people using buses and trains every day (StatistischesBundesamt [Destatis], 2019).

At the same time, however, there has been an increase in overall traffic and, above all, in motorized private transport. In 2017, private transport will account for three quarters of all passenger kilometers. In the transport mix, local public transport is gaining a slight share, while the share of passengers on private transport is declining. The bottom line is that the choice of transport mode in Germany has hardly changed over the last years (BundesministeriumfürVerkehr und digitaleInfrastruktur, 2020). Without more rail transportation in Germany it will hardly be able to achieve the targets it has set during the Paris Climate Agreement in December 2015 (Balser, 2019).

Specification A:

- Name: The use of trains will double in Germany by 2035

- Description: Governmental support for the Deutsche Bahn

- Reason: Up to now, the German government has financially supported the new construction and maintenance of the rail network. There have been subsidies for local transport, but not for long-distance transport. With the measure (Maßnahme) 21, the Federal Government will contribute one billion euros in additional equity capital to the Deutsche Bahn each year between 2020 and 2030, accounting to 11 billion euros. The goal of this investment is to modernize, extent and electrify the rail network and railway system. The aim is to increase the use of public transportation and to have less pollution within German cities (Fockenbrock&Siebenhaar, 2019).

The number of rail passengers is expected to rise, and the aim of the German government is to double the number of passengers using public transportation by 2030 (ChristlichDemokratische Union Deutschlands, 2019).

- Probability: 65%

Specification B:

- Name: The use of trains will remain the same or increase just insignificantly in Germany

- Description: The use of public transportation in Germany has hardly changed over the last five years even though there have been investments by the government before (VuMA, 2018).

- Reason: The poor infrastructure is considered the reason for massive quality problems and delays. In the beginning of 2020, every fifth long-distance train operated by Deutsche Bahn arrived unpunctual. The expansion will take time, and the improvements for customers will hardly be felt in the coming years. The ministry of transport is questioning if even with the high investments by the government there will be such a turnaround until 2030 (Balser, 2019).

Next to that seventy-seven percent of the German households still own a car and seventy percent of the population use a car on regular basis (using it daily or multiple times a week) (Bobeth&Matthies, 2018).

- **Probability:** 35 %

References:

Balser, M. (2019). Wohin nur mit den Milliarden für die Schiene? Retrieved from https://www.sueddeutsche.de/wirtschaft/deutsche-bahn-investitionen-schienennetz-1.4616897

Bobeth, S., &Matthies, E. (2018). New opportunities for electric car adoption: the case of range myths, new forms of subsidies, and social norms. *Energy Efficiency*, *11*(7), 1763–1782. https://doi.org/10.1007/s12053-017-9586-4

Bundesministerium für Verkehr und digitale Infrastruktur (2020). Mobilität in Deutschland (MiD). Retrievedfrom https://www.bmvi.de/SharedDocs/DE/Artikel/G/mobilitaet-in-deutschland.html

Christlich Demokratische Union Deutschlands (2019). Mobilität der Zukunft: Beschluss des Bundesvorstandes der CDU Deutschland. Retrievedfrom https://www.cdu.de/artikel/mobilitaet-der-zukunft

Fockenbrock, D., & Siebenhaar, H.-P. (2019). Milliardensegen durch das Klimapaket: So will der Staat die Bahn sanieren: Deutschland und Österreich päppeln mit dem Vorwand Klimaschutz ihre Bahngesellschaften auf. Die Konkurrenz fürchtet Wettbewerbsverzerrungen und schlägt Alarm. Retrievedfromhttps://www.handelsblatt.com/unternehmen/handel-konsumgueter/schienenverkehr-milliardensegen-durch-das-klimapaket-so-will-der-staat-die-bahn-sanieren/25055306.html?ticket=ST-992428-CaOB3Eqozfr5L6aeLYSq-ap3

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VuMA (2018). Bevölkerung in Deutschland nach Häufigkeit des Reisens mit der Deutschen Bahn in den letzten 2 Jahren, von 2015 bis 2018 (Personen in Millionen). Retrieved from https://de.statista.com/statistik/daten/studie/180948/umfrage/haeufigkeit-von-reisen-deutsche-bahn/

Descriptor name: Limit of the European parliament for the emission of CO_2 per kilometer of new passenger cars

Area of influence: Political

Current situation: The European Parliament and the European Council decided to tighten the CO2 limits between 2015 and 2019 to a target of 130 grams of CO_2 per kilometer applied for the EU fleet-wide average emission of new passenger cars. The emissions of 130 g CO_2/km correspond to a fuel consumption of around 5.6 litres per 100 km (l/100 km) of petrol or 4.9 l/100 km of diesel. According to EEA data (Monitoring of CO2 emissions from passenger cars – Regulation (EC) No 443/2009, 2019) the average emissions level of the new cars registered in 2018 in the EU and Iceland were 120.4 g CO_2/km (Daimler AG, 2019).

Specification A:

- Name: The average emission levels of new registered cars in Germany will decrease by at least 37.5 % until 2035

- Description: The European Parliament and the European Council decided to tighten the CO2 limits further. Between 2021 and 2030 the vehicle emissions are to be reduced by 37.5 percent. If a manufacturer fails to achieve his specific target penalty payments are threatened starting in 2020. Each manufacturer must pay a penalty of 95 Euro for each gram per kilometer of target exceedance. There are exceptions for manufacturers selling less than 300,000 vehicles per year (Daimler AG, 2019).

The European Commission is also pursuing the goal of decarbonizing the European mobility system by 2050 making it greenhouse gas neutral (Umweltbundesamt, 2020).

- Reason: At the Climate Change Conference in Paris, 195 countries including the European countries reached a global climate change agreement. The agreement includes a global action plan, which is to limit global warming to below 2 °C in order to combat climate change (Daimler AG, 2019).

The importance of environmental awareness is also notable within the program of the German parties. Die Grünen (The Green Party) made climate protection the focus of their campaigns (tagesschau.de, 2017) and since then have had an increasing number of members and steadily rising survey results (Statista, 2019).

Next to this the Umweltbundesamt (Federal Environment Agency) did a representative survey on environmental awareness in Germany in 2016. The survey clearly showed that measures by the Government for climate protection are very important. Also, 68 percent of the respondents agreed that the promotion of electric vehicles is important (Benthin&Gellrich, 2017).

To promote the purchase of electric vehicles the German government has given a so known environmental bonus. Until the end of 2025, electric vehicles buyers can receive a purchase bonus of up to 6000 euros (Presse- und Informationsamt der Bundesregierung, 2020).

- Probability: 75%

Specification B:

- Name: The average emission levels of new registered cars in Germany will not decrease by at least 37.5 % until 2035

- Description: Parts of the car industry deplore that the targets by the European parliament are driven purely by political motives and without taking technological and socio-economic realities into account.

- Reason: Parts of the car industry are criticizing that there are still several obstacles for a widespread consumer acceptance such as affordability and the lack of sufficiently dense network of recharging and refueling infrastructure. They also criticize that these ambitious CO2 targets will have an huge impact on jobs across the automotive value chain and will not have concrete plans to manage this employment and skill transition in a socially-acceptable way and in time (European Automobile Manufacturers Association, 2018).

- Probability: 25%

References:

Benthin, R., &Gellrich, A. (2017). Umweltbewusstsein in Deutschland 2016: Ergebnisse einer repräsentativen Bevölkerungsumfrage. Retrieved from https://www.umweltbundesamt.de/sites/default/files/medien/376/publikationen/umweltbewusstsein_deutschland_2016_bf.pdf

Daimler AG (2019). CO2 targets are becoming ever more demanding worldwide. Retrieved from https://www.daimler.com/sustainability/climate/wltp/wltp-part-5.html

European Automobile Manufacturers Association (2018). Auto industry reacts to deal on CO2 targets for cars and vans. Retrieved from https://www.acea.be/press-releases/article/auto-industry-reacts-to-deal-on-co2-targets-for-cars-and-vans

Monitoring of CO2 emissions from passenger cars – Regulation (EC) No 443/2009 (2019).

Presse- und Informationsamt der Bundesregierung (2020). Kaufprämie für Elektroautos erhöht. Retrievedfrom https://www.bundesregierung.de/breg-de/themen/energiewende/kaufpraemie-fuer-elektroautos-erhoeht-369482

Statista (2019). Bündnis 90/Die Grünen. Retrievedfrom https://de.statista.com/statistik/studie/id/58730/dokument/buendnis-90-die-gruenen/

Tagesschau.de (2017). Wie die Parteien das Klima schützen wollen: Programmvergleich. Retrieved from https://www.tagesschau.de/inland/btw17/programmvergleich/programmvergleich-klimaschutz-101.html

Umweltbundesamt (2020). Nachhaltige Mobilität. Retrievedfrom https://www.umweltbundesamt.de/themen/verkehr-laerm/nachhaltige-mobilitaet

Descriptor name: Autonomous driving in Germany in 2035

Area of influence: Political, Technical

Current situation: Since 2017 "highly automated driving has been permitted in Germany. This step corresponds to the third level on the way to a fully automated car. The third level means that the car is sufficiently intelligent to cope with everyday situations on its own including steering, braking and warnings in critical situations. Nevertheless, the system is designed so that the driver can override the system's wishes at any time and the responsibility remains with the driver (Deutsche Welle, 2020).

In fully autonomous driving, there is no longer a driver. All passengers are regarded as passengers and are therefore not liable for violations of the rules or accidents in road traffic.

Specification A:

- Name: Until 2035 every tenth car will drive autonomously

- Description: The German Federal Government is intensifying its work on the mobility of the future. In June 2019 there was a new action plan "Research for autonomous driving - an overarching research framework of the BMBF, BMWi and BMVI" implemented combining priorities and guidelines for the future orientation of research funding for autonomous driving. The action plan is part of the Federal Government's High-Tech Strategy 2025 (Deutsche Welle, 2020).Six major projects focusing on autonomous driving with a project volume of around 200 million euros are currently underway (BUNDESMINISTERIUM FÜR WIRTSCHAFT UND ENERGIE, 2019).

Germany has established an infrastructure for test drives with driverless vehicles. The city of Hamburg is planning test drives with autonomous vehicles as early as 2021. After billions of test kilometers in simulations or on public roads, the self-propelled cars are beginning to leave the test tracks (Statista, 2020).

- Reason: The German Federal Government believes that autonomous driving offers a wide range of opportunities: from increased safety and efficiency in road traffic to concepts for emission-free, intelligent and innovative mobility (BUNDESMINISTERIUM FÜR WIRTSCHAFT UND ENERGIE, 2019).

- Probability: 20 %

Specification B:

- Name: Autonomous driving in Germany will not yet be possible in 2035

- Description: Legal aspects need to be clarified

- Reason: So far there is no legal regulation for autonomous driving in Germany where the driver is only a passenger. The difficulty to be clarified is who is liable in the event of an accident. However, debates among car insurers and ethicists who analyze decisions made in accidents have only just begun (Deutsche Welle, 2020).Next to that the ethics committee has also rightly set high standards in the area of data protection (Daimler AG, 2020).

- Probability: 80 %

References

BUNDESMINISTERIUM FÜR WIRTSCHAFT UND ENERGIE (2019). Bundesregierung bringt Mobilität der Zukunft voran. Retrieved from https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2019/20190628-bundesregierung-bringt-mobilitaet-der-zukunft-voran.html

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Statista (2020). Jedes zehnte Fahrzeug fährt bis 2030 autonom. Retrieved from https://de.statista.com/presse/p/autonomes_fahren_2020/

Descriptor name: Charging infrastructure for cars including electrical motors

Area of influence: Political

Current situation: There are various vehicles that can be driven electrically: battery-powered e-cars, hybrids and plug-in hybrids. Hybrid vehicles have two drive systems. A combustion engine is supported by an electric motor. In some cases, hybrid cars can also cover longer distances purely electrically. While in a normal hybrid vehicle the battery is only charged by the combustion engine or during braking, the larger battery of a plug-in hybrid can also be charged externally and the “plug-in hybrid” can travel a distance of up to 50km with just using electric power (Končalović et al., 2019).

As of October 2019, there were 34,639 publicly available charging stations for electric vehicles in Germany Statista (2020).

Specification A:

- Name: The number of public charging points will rise to one million across Germany until 2035

- Description: Chancellor Angela Merkel's office said the government would invest €3.5 billion to expand electric car charging stations. The target is for 50,000 publicly accessible charging stations nationwide by 2022. Merkel has said that she wants one million electric car charging points across the country by 2030 Statista (2020).

- Reason: The government wants to further reduce CO2 emissions from cars (Die Bundesregierung, 2020)

- Probability: 20 %

Specification B:

- Name: The number of public charging points will be less than one million across Germany until 2035

- Description: In the first quarter of 2020, the number of charging stations in Germany was around 19,000 (Statista, 2020).

- Reason: The German government wants to get an overview in the first place before investing billions into the charging infrastructure (tagesschau.de, 2019).

- Probability: 80 %

- References:

Die Bundesregierung (2020). Verkehr. Retrieved from https://www.bundesregierung.de/breg-de/themen/energiewende/fragen-und-antworten/verkehr

Končalović, D., Živković, D., Gordić, D., Vukašinović, V., Josijević, M., &Stević, S. (2019). IMPROVEMENT OF ENERGY EFFICIENCY OF CITY VEHICLE FLEETS: CASE STUDY. *Mobility and Vehicle Mechanics*, *45*(4), 1–12. https://doi.org/10.24874/mvm.2019.45.04.01

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Tagesschau.de (2019). Viel Frust beim Stromtanken. Retrieved from https://www.tagesschau.de/inland/emobilitaet-ladestationen-101.html

Descriptor name: Charging infrastructure for fuel cell cars

Area of influence: Political

Current situation: Fuel cells are running by mixing hydrogen with oxygen to generate electricity. The German government is promoting hydrogen/fuel cell drives. As part of the National Innovation Programme Hydrogen and Fuel Cell Technology (NIP 2), the German government launched a new funding programme in March 2017 to bring more fuel cell vehicles onto the road (Die Bundesregierung, 2020).

Specification A:

- Name: The number of public charging points for fuel cells will rise to one thousand across Germany until 2035

- Description: Germany is one of the key leaders in hydrogen and fuel cell development in Europe. To promote the fuel cell and hydrogen energy strategy, the German federal government set up the National Organization for Hydrogen and Fuel Cell Technology ("NOW"), responsible for the coordination and management of the National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP). ("deloitte-cn-fueling-the-future-of-mobility-en-200101pdf"). Currently there are 83 H2 filling stations available (H2 MOBILITY Deutschland GmbH & Co. KG).

In 2023 the number of publicly accessible hydrogen filling stations is supposed to be 400 nationwide (Die Bundesregierung, 2020).

- Reason: The government wants to further reduce CO2 emissions from cars (Die Bundesregierung, 2020)

- Probability: 15 %

Specification B:

- Name: Electric cars will out rule the fuel cell-based cars and the number of public charging points will not increase in Germany until 2035

- Description: Until now, hydrogen (H2) is the only fuel that allows the operation of fuel cells for cars. Although the forecasts for fuel cells were very optimistic at the beginning of this century, this drive so far has not asserted itself on the world market. The only market vehicle with the fuel cell is the Toyota-Mirai. Many experts believe that, with the development of the battery for the accumulation of electricity, the fuel cells become redundant. The biggest problems with hydrogen are with its storage, transport and the absence of the entire infrastructure.

- Reason: Volkswagen and other German car producers are currently in favor of the electric cars (Volkswagen AG). Even Daimler one of the leading companies in the field of fuel cells has moved its focus away from the research of fuel cells to the development of batteries for the accumulation of electrical energy (Končalović et al., 2019).

- Probability: 85 %

- References:

Deloitte-cn-fueling-the-future-of-mobility-en-200101pdf. Retrieved from https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/finance/deloitte-cn-fueling-the-future-of-mobility-en-200101.pdf

Die Bundesregierung (2020). Verkehr. Retrievedfrom https://www.bundesregierung.de/breg-de/themen/energiewende/fragen-und-antworten/verkehr

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Volkswagen AG. Wasserstoff oder Batterie? Bis auf Weiteres ein klarer Fall. Retrieved from https://www.volkswagenag.com/de/news/stories/2019/08/hydrogen-or-battery--that-is-the-question.html

Descriptor name: The use of car sharing in Germany in 2035

Area of influence: Political

Current situation: The number of people using car sharing has grown rapidly in recent years. As of January 2018, there were 2,110,000 customers registered with 165 car-sharing providers in 677 different German cities and communities. Even though the car-sharing sector has grown rapidly in recent years only about one billion passenger kilometers were provided by car sharing which equals to 0.1% of total motor-vehicle passenger kilometer in Germany in 2017 (Best &Hasenheit, 2018).

Specification A:

- Name: 2.5% of the total motor-vehicle passenger kilometers in Germany will be driven by car sharing in 2035.

- Description: Car sharing will experience disruptive growth while acting as a catalyst for reducing private-vehicle ownership and use. While this percentage might seem small, it would mean that car-sharing passenger-kilometers would rise to a level equivalent to 28% of public transport's current passenger-kilometres (Best &Hasenheit, 2018).

- Probability: 60 %

Specification B:

- Name: 0.5% of the total motor-vehicle passenger kilometers in Germany will be driven by car sharing in 2035

- Reason: In this scenario, the usage of car sharing would increase by 0.5%, in line with the expected increase in passenger-km (Best &Hasenheit, 2018).

- Probability: 40 %

- References:

Aaron Best and Marius Hasenheit, Car Sharing in Germany: A Case Study on the Circular Economy (2018), European Union's Horizon 2020

Consistency Matrix

		1.1		1.2		2.1		2.2		2.3		3.1		3.2		3.3		3.4		3.5		3.6		4.1		4.2	
		a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
1.1 The main energy source techı	a Battery technology			1	-1	3	-3	3	-3	2	3	-1	1	3	-3	1	-1	3	-3	-2	2	2	-2	-1	1	3	0
	b Fuel cell technology			1	-1	2	-2	2	-2	1	2	-1	1	2	-2	1	-1	-1	1	3	-3	1	-1	-1	1	2	1
1.2 The technology for fully aut	a Technology for fully ADC wi	1	1			1	-1	1	-1	-1	1	0	0	1	-1	3	-3	1	-1	1	-1	1	-1	0	0	0	0
	b Technology for fully ADC wi	-1	-1			-1	1	-1	1	1	-1	0	0	-1	1	-3	3	-1	1	-1	1	-1	1	0	0	0	0
2.1 Total cost comparison betwe	a Total cost for e-cars will	3	2	1	-1			3	-3	3	3	1	-1	3	-2	0	0	2	-2	1	-1	1	-1	0	0	2	0
	b Total cost for e-cars is 20	-3	-2	-1	1			-3	3	-2	-3	-1	1	-3	2	0	0	-2	2	-1	1	-1	1	0	0	-2	0
2.2 The new registration of conv	a The new registration of ICV	3	2	1	-1	3	-3			3	2	1	0	3	-3	1	-1	3	-3	2	-2	1	-1	1	-1	0	0
	b New registration of ICV car	-3	-2	-1	1	-3	3			-2	-2	0	1	-3	3	-1	1	-2	2	-2	2	-1	1	-1	1	0	0
2.3 Choice of customers between	a Customer will prefer buying	2	1	-1	1	3	-2	3	-2			0	0	2	-2	0	0	3	-3	2	-2	0	0	-1	1	2	0
	b Customers will prefer buyin	3	2	1	-1	3	-3	2	-2			0	0	3	-3	1	-1	3	-3	-2	2	0	0	-1	1	3	0
3.1 The use of public transporta	a The use of trains will doub	-1	-1	0	0	1	-1	1	0	0	0			3	-3	0	0	0	0	0	0	1	-1	1	-1	0	0
	b The use of trains will rema	1	1	0	0	-1	1	0	1	0	0			-3	3	0	0	0	0	0	0	-1	1	-1	1	0	0
3.2 CO2 limitation	a Average emission levels dec	3	2	1	-1	3	-3	3	-3	2	3	3	-3			1	-1	1	-1	1	-1	1	-1	2	-2	2	2
	b Average emission levels wil	-3	-2	-1	1	-2	2	-3	3	-2	-3	-3	3			-1	1	-1	1	-1	1	-1	1	-2	2	-2	-2
3.3 Autonomous driving in Germai	a Every tenth car will drive	1	1	3	-3	0	0	1	-1	0	1	0	0	1	-1			1	-1	1	-1	1	-1	0	0	0	0
	b Autonomous driving level 4	-1	-1	-3	3	0	0	-1	1	0	-1	0	0	-1	1			-1	1	-1	1	-1	1	0	0	0	0
3.4 Charging infrastructure for	a Charging points will rise t	3	-1	1	-1	2	-2	3	-2	3	3	0	0	1	-1	1	-1			-2	2	1	-1	1	-1	3	0
	b Charging points will be les	-3	1	-1	1	-2	2	-3	2	-3	-3	0	0	-1	1	-1	1			2	-2	-1	1	-1	1	-2	0
3.5 Charging infrastructure for	a Charging points for Hydroge	-2	3	1	-1	1	-1	2	-2	2	-2	0	0	1	-1	1	-1	-2	2			0	0	0	1	2	0
	b Charging points for Hydroge	2	-3	-1	1	-1	1	-2	2	-2	2	0	0	-1	1	-1	1	2	-2			0	0	0	0	-2	0
3.6 The use of car sharing in Ge	a 2.5% of the km will be driv	2	1	1	-1	1	-1	1	-1	0	0	1	-1	1	-1	1	-1	1	-1	0	0			3	-1	0	0
	b 0.5% of the km will be driv	-2	-1	-1	1	-1	1	-1	1	0	0	-1	1	-1	1	-1	1	-1	1	0	0			-1	1	0	0
4.1 Car sharing changing the pr:	a People using car sharing wi	-1	-1	0	0	0	0	1	-1	-1	-1	1	-1	2	-2	0	0	1	-1	0	0	3	-1			0	0
	b People use car sharing will	1	1	0	0	0	0	-1	1	1	1	-1	1	-2	2	0	0	-1	1	1	0	-1	1			0	0
4.2 Shared Mobility vehicles go:	a 20% of car sharing vehicles	3	2	0	0	2	-2	0	0	2	3	0	0	2	-2	0	0	3	-2	2	-2	0	0	0	0		
	b Public transport will be el	0	1	0	0	0	0	0	0	0	0	0	0	2	-2	0	0	0	0	0	0	0	0	0	0		

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