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Abstract:

The thesis addresses development of autonomous vehicles and their future implications in a sharing economy. Right now, autonomous vehicles are still in a research and development phase, but numerous of powerful stakeholders are already forming partnerships in order to strengthen their position on future transportation markets. Based on theories of innovation and dominant design, the thesis will analyze the development of autonomous vehicles with a focus on the interplay between technology developers, ride-hailing service providers, and automakers.

This research will examine essential pillars of autonomous technology that are the basic foundation of the autonomous driving intelligence. Once the connection between autonomous vehicles and sharing economy is explained, the research will analyze the market and governance formation. Study further emphasize on which ride-haling service providers have currently the highest chance to acquire a dominant design and become a market leader in providing autonomous on-demand transportation.

Acknowledgements

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Special credit belongs to my parents who mentally supported me to through my studies.

Also I would like to salute to all of the people who are involved in a development of Autonomous vehicles and related technology for those cars. They are working towards more sustainable and secure transportation for our future generations to come.

Key Words

Autonomy, Autonomous, Self-driving, Transportation, Ride-hailing, Sharing Economy,Dominant Design, Business Models

Table of Content

List of abbreviations

AT	Autonomous Taxi
AV	Autonomous vehicle
B2B	Business to Business
BM	Business Model
BMC	Business Model Canvas
C2C	Customer to Customer
CDV	Conventional Driven Vehicles
EV	Electric vehicle
FIFO	First in First out
GPS	Global Positioning System
HW	Hardware
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
IPR	Intellectual Property Rights
LiDAR	Light Detection and Ranging
NHTSA	National Highway Traffic Safety Administration
NLOS	Non-line-of-sight propagation
OEM	Original Equipment Manufacturer
R&D	Research and Development
SW	Software
TaSS	Transportation as a Service
V2I	Vehicle to infrastructure
V2p	Vehicle to Pedestrian
V2V	Vehicle to Vehicle
V2X	Vehicle to X

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1. Introduction

1.1 Opening

The invention of an automobile transportation shaped our society in a way how we commute, build our cities and infrastructure, where we live and how we created a new industry. Automobile mobility provide us with a set of advantages, such as considerable freedom of transportation for those who can afford to own the car and it helps to maintain a sustainable economic growth. Yet, there are many side effects, that make the current vehicles unsustainable, if we take into account their safety, energy-related environmental impacts, traffic congestions, time spent by their operation and land use.[1][2]

"Today's Cars Are Parked 95% of the Time." Paul Barter[3]

Considering that cars are used only 5 percent of the time, and they spent the rest of the time parked, makes personal vehicle ownership unsustainable. Over the decades since the first motor vehicle was introduced by Karl Benz, car manufacturers took a steady incremental approach in technology development of cars. Following the recent trends in an automotive research and development, there is a clear sign that many organizations are racing towards fully autonomous vehicles with technology that will get rid of drivers as the one who controls the cars. Autonomous vehicles have the potential to disrupt the automotive market as we know it nowadays and reestablish the power of involved stakeholders. As new stakeholders come into a play in a market, new partnerships will be formed to gain the competitive advantage against the other organizations. With an upcoming advanced technology of autonomous vehicles, the current model of personal vehicle ownership will be challenged by ride-hailing service providers.[4]

This report - based on a literature study, case studies, and extensive market research, will evaluate the relationship between several upcoming technologies and establishments related to a future of automotive industry. The paper is elaborating on how the autonomous cars can be used as a shared resource to make them a more sustainable product. It exploits the connection between autonomous vehicles and sharing economy, by observing the current trends in the industry.

Over the time, with a new radical innovation, the new dominant design will finally emerge. Before this will happen, the report will analyze the possible roles of the key stakeholders in a role as ride-hailing service providers, who will operate a fleet of autonomous vehicles. With all of the stakeholders involved in the research and development of the AVs, the report will observe the drivers in the innovation of the technology, and stakeholder's individual interests in the new emerging market.

Driving intelligence is such a huge complicated complex due to all of the processes that are happening in the background. The sensing of the environment around the vehicle is one of the key pillars of autonomy. Having the ability to sense all of the necessary objects and identify them correctly is a must. But the system can't rely only on sensing of the surroundings. Having the ability to define vehicle's localization with maximum accuracy and mapping the traffic structures along the way is important as well. In the same time can't put aside Driving Policy, that is responsible for decision-making that is transformed into controlling the actions of the vehicle.

Studies say that 95% of all traffic fatalities are caused by a human error. Saying that 41% of those traffic fatalities are caused by recognition errors of drivers, what stays for a driver's inattention, distraction either external or internal and inadequate surveillance. Autonomous vehicles don't encounter this kind of problems, so fort they could prevent this kind of fatalities. Just in the United States, this could prevent 300 000 fatalities per decade. This number could be globally up to 10 million lives per decade. Even though self-driving cars that are a factor of 100 safer than their predecessors without AI, fatal accidents will most likely occur, but in a smaller amount. There also arise a question, in a situation when a vehicle can't prevent the crash and knows that it's going to crash, how it will plan the crash itself? Plenty of moral questions can occur when the AI will have to deal with the crash.[5]

Preventing crashes will have an impact on the economy as well. Taking into consideration a quick research on incidental cost, in 2015 US spent over 400billion USD only on peripheral costs related to car accidents. Putting this into a context, 450billion USD is almost 19% of income tax revenue in 2015 that federal government earned. Government is fully aware of this and in 2016 President Barack Obama proposed 4billion USD for development of autonomous cars.[6]

Taking into consideration that AVs are safer we have to add that they are also more sustainable that conventional vehicles. Right now, the transportation sector is considered as a second largest source of CO2 in the US, where cars consume two billion barrels of oil annually. Taking into consideration that autonomous cars always drive optimally to save the fuel and enhance the traffic flow[7]. In case that AVs will be used a shared resource, it quite makes a sense to power them with electricity instead of gasoline, what could further on decrease the carbon footprint of driving such vehicles.

1.1.1 Potential Benefits of Autonomous vehicles

Autonomous vehicles bring plenty of potential benefits. While driving conventional vehicles causes a rise of a cortisol level, known as a stress hormone, riders in AVs won't experience the stress level related to driving and they could instead rest or work while traveling. Elimination of the taxi and truck drivers need will reduce the price for some of the services. Autonomous vehicles could be used by a non-drivers and will enable them to freely use cars without any dependence on other people. Increased safety will reduce many common accident risks and also related crash cost and insurance payments.

Increased road capacity and reduced cost by supporting platooning of vehicles that are able to drive in close distance, what further means saving a fuel due to a decreased resistance of vehicles.

Autonomous vehicle will offer more efficient parking when dropping off a passenger, the car can find it's parking spot by itself. What can reduce the waiting time for passenger and reduce the parking price, since the car can park itself in a cheaper area. AVs can reduce operational CO2 emissions of vehicles and increase fuel efficiency, due to a fact that they will drive more optimally than a human driver. If AVs will be used as a shared resource new car sharing services can provide several savings.

1.1.2 Potential problems of Autonomous vehicles

AVs can increase costs related to additional car equipment, services, and further maintenance, and further investments in roadway infrastructure will be also necessary. AVs may introduce new risks, in a sense of system failures that can occur. What can mean that AVs could be less safe in certain situations and conditions. Being connected to a cloud and operated by a central unit system, there will be security and privacy concerns related to cyber security threats, where vehicles can be controlled remotely. Further vulnerable abuse of information, tracking and data sharing could violate the passenger privacy and those cars could be used for some terrorist activities.

1.2 Motivation

If we take into a consideration that we are using cars only 5% of the time and that human error in driving is the causing too many fatalities, we will come into conclusion that cars itself are not the problem. Instead, we can redefine the problem by how we use cars, or by saying how we actually don't use them. If our cars will be capable to drive without us, why would we keep them idle in front of our homes and offices? It then seems logical that using autonomous vehicles as a shared resource will create more sustainable and safer ways of transportation.

The current development stage of AVs is in such a progress that we will soon put this concept into a reality. Building a affordable electronic AVs in a high volume is now even closer to a truth, with the price of a sensing technology and batteries going significantly down. Incoming 5G communication technology will even further enhance the true power of vehicles connected to a cloud. The trends in sharing economy that we observe in a recent decade could shift the personal ownership model of cars upside down.

There are many forces that drive the innovation and autonomous vehicles. Until nowadays, a car manufacturers were the leaders in the automotive industry, by holding most of the competitive power over the other stakeholders and suppliers. Now, with a new emerging technology; multiple new stakeholders are coming into a battle over the future automotive and transportation market.

Companies such as Google, Uber, and Tesla are not the typical car manufacturers, yet they are the top developers of the autonomous technology right now. The interplay between those tech developers, car manufactures and ride-hailing service providers will redistribute the power and roles in the automotive market as we know it nowadays.

2. Methodology

The following chapter describes how the study was conducted and presents the individual research methods used to answer the stated research objectives.

2.1 Research Design and Research Objectives

This sub-chapter will define the focus areas of the thesis research by formulating the research question. Considering the facts presented and discussed in the section above, the following research question has been formulated.

<u>Research Question:</u>

How is formed the Dominant design of autonomous vehicles regarding to a current development stage of the autonomous vehicles and what is the role of ride-hailing service providers in a future of transportation?

Due to a reason that the research question above is extensive and in order to make a bigger picture above the topic and the market, several sub-questions were formulated.

<u>Sub questions:</u>

- What is the connection between AVs and ride-hailing service?
- How do we classify the development stages of AVs?
- What is the role of Sensing, Mapping and Driving Policy in Autonomy?
- Who are the main stakeholders in the future of ride-hailing services, and how those stakeholders could possibly divide the responsibilities and the power?
- Who are the current leaders in the development of AVs, and what is the current State of the Art of AVs development?
- What are the possible business models for companies that will offer autonomous ride hailing services?
- Which organizations have the highest chance to dominate the autonomous ride-hailing market and capturing the dominant design?

2.2 Delimitation

Regarding the research question and its sub-questions, the study is exploring, how the dominant design of AVs is formed with the current research and development of AVs. More importantly, it's focusing towards the organizations that announced that they want to operate a fleet of AVs for a ride-hailing service, where the car is becoming a shared resource. There are multiple types of design, such as the physical design of the product, quality of the product/service or the design of the business model. Primarily, the research is exploring the dominant business models related to this topic and is further evaluating the potential success of dominating the market according to the selected criteria for evaluation.

Thesis isn't elaborating on specific topics related with autonomy such as moral dilemmas, rebound effect, liability, regulation and security threats to simply narrow down the research as much as possible. Even though those topics are highly relevant to future of autonomous transportation, they would cause a distraction of focus around the core of the thesis. Scope of the study is focusing only towards North American and European ride-hailing markets.

2.3 Literature review and the approach to theory development

The research consists of two parts and is divided into a literature an empirical evidence sections. While literature review gives us the context and the theoretical framework of the studies and publications that have been published, empirical study give us the issues from the case studies[8]. Both of the methods were conducted in a parallel, while the literature study was conducted before the empirical study in order to find the theoretical awareness. Later during the study, this theoretical knowledge helped to form and backed up the results in the analysis.

Figure 2.1: The connection between Lit. study and Emp. Study

This study is based on deductive theory development, that use the academic literature for the theory development. Based on the premises from the theory, the collected knowledge and premises are in the research: tested, applied and validated. Deductive reasoning is based on a logic, where in the process of reasoning from one or multiple premises we should come to a logically predictable conclusion [8]. In this paper, the knowledge from the theory will be validated with the collected data from case studies and reports. The individual findings in the analysis will reflect the patterns observed in a literature review.

As a methodological choice, the study is using qualitative research design that helps us to study the behavior and patterns that shape the future of the on-demand transportation nowadays.

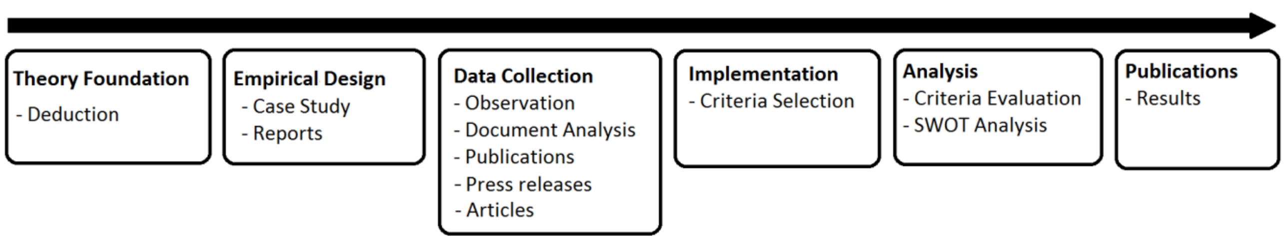


Figure 2.2: Overview of the Empirical Study

Figure 2.2. represents the overview of the study and it's continual flow. The study has also exploratory design because the paper is identifying the current situation in the market and is trying to connect the variables and relationships between the main stakeholders for the future of the autonomy and on-demand transportation.

"The emphasis in explanatory research is to study a situation or a problem in order to explain the relationship between variables."[9]

Analyzed data will be gathered from different literature sources, both primary and secondary literature sources. Academic papers, publications, reports, conference papers and case studies were sourced from a primary literature. Together with secondary literature sources such as articles, conference keynotes, journals, etc.

Theory

Collected theory in the study serves as a theoretical knowledge background for the analysis of the report. Selected theories reflect the research focus and help to explain the current trends in the automotive industry. Theory of Dominant Design explains the premises why some companies are able to dominate the market while other are getting behind. This theory foundation together with a Business models theory will be useful further to see which business models of ride-hailing companies have the highest potential to succeed once the technology for AVs is ready and approved by a regulator. Theory of Innovation is giving us an insights of certain drivers of innovation. This knowledge will be reflected upon a current stage of the AVs development and how are the key stakeholders involved in this phase. In a Sharing economy chapter, basic information about platforms, scaling and sharing resources will be introduced.

2.4 Reading guidelines

Purpose of this part of the paper is to get familiar with an outline of the study, and understand the context of individual chapters.

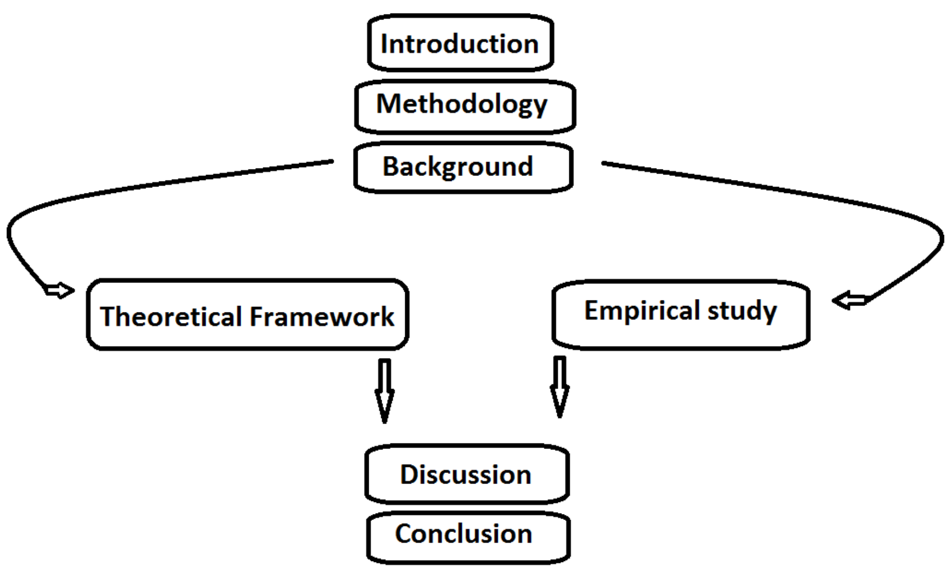


Figure 2.3: Structure of the study

Introduction chapter is mentioning a set of challenges in automotive transportation that autonomy could solve. Based on those challenges the research question and research objectives are formulated in a Methodology section. Methodology section further explains research methods and data collection. In a Background chapter the paper describe a couple of terms related to a problematic, there are mentioned the stages of autonomy and explained what the technological requirements for those stages. Theory chapter contains the theoretical framework of this paper, with collected knowledge from a literature. Based on the data collected from a research, in Analysis chapter, this knowledge and premises from the literature are questioned, tested, and validated. In the end of the Analysis, the paper elaborates on the main research question, and provide an answer to this question based on the criteria evaluation of the three competing ride-hailing companies. In a Discussion chapter, the paper comments on the foundings from the study. Conclusion serves as an assessment of the study.

2.5 Topics & Tools

The study consists of the following topics:

List of key developers of AVs that the thesis is going to elaborate on. The whole research will be then focused towards those stakeholders and comparing them with each other in a different sub-chapters.

Drivers that move the innovation process of autonomous cars and ride-sharing markets. Those results will be based on the theory of dominant design and theory of innovation.

Sharing economy that analyze the role of using car as a shared resource and how it can reshape the transportation system as we know it nowadays.

Techniques for a customer bonding. A market for autonomous transportation is enormous. After its penetration thesis will elaborate on how to get and keep a customer while crushing the competition.

Observed use cases bring value for a better understanding of how those companies work, what processes and strategies they are implementing and what are they trying to accomplish.

The study consists of the following Tools:

Business models as a tool to express how the company create value and capture the profit from its actions.

SWOT analysis points out the Strengths, Weaknesses, Opportunities and Threats of the organizations. In the study, the SWOT analysis will be applied to exploit the individual qualities and vulnerabilities of the organizations that have the interest to operate a fleet of ATs services.

3.Background

Intro

The background chapter will introduce to us some of the insights from the autonomous industry. First, it's explaining and defining few of the terms related to autonomy, autonomous vehicles and selected services related to using a car as a shared resource. Following a description of AVs development stages, where it is explaining how the advanced technology is taking over the vehicles control in different stages. The section later elaborates on pillars of the autonomy, as three essential elements of the driving intelligence. Also, several sensors that are sensing the surroundings of the vehicle are described and compared in a different light, weather and distance conditions. The chapter is also mentioning how 5G and V2X communication technology can further improve the technology of autonomous cars, where those cars exchange important data with the infrastructure, other cars and pedestrians. Most importantly, at the end of the chapter, the connection between autonomous vehicles and the sharing economy, where cars are used as a shared resource is explained and showed on an observation of related stakeholders.

3.1 Definitions

Autonomy

Autonomy, the ability or a state of being self-governing; acting separately from others. Applied this concept on cars, represents vehicles that are able to operate without any human interaction, by using artificial intelligence.

Self-driving vehicle

Any vehicle with sort of features that allow it to steer a course, accelerate and break with partial or no driver interaction.

Autonomous vehicle

Can drive itself from point A to point B, without the need of any interaction from the driver. The autonomous vehicle is able to move in space due ability to sense it’s close the surroundings, detects and identify the objects and environment around. Being capable of building the environment model and determining the exact location of location by using global positioning system enable an autonomous vehicle to move around. Along the Sensing and Mapping, Driving Policy determine how the vehicle is acting on a road. Autonomous vehicles have the potential to eliminate the driver’s errors, they aren’t operating intoxicated and they don’t get tired. Yet, there are plenty of challenges that needs to be acknowledged and fulfill in order to offer autonomous vehicles with maximum safety to the public.

Fully Autonomous

Fully autonomous are in fact divided into user-operated and driverless vehicles. It's mainly due to a regulator and insurance questions.

Ride-sharing

Defined as sharing of vehicles by other passengers, mainly to reduce the cost of a journey for the individuals, traffic congestion, and CO2 emissions. This requires a bit of planning to organize all of the passengers, time location wisely. Ride-sharing is often assigned to companies like Uber and Lyft but it's actually not true. The service is for example offered by a company named Bla-bla car.

Ride-hailing

A person who hails a vehicle is picked up immodestly from a starting point and transported to their destination. It's on-demand service since the passenger can immediately book a ride straight from his mobile device. They are charged according to a specific time and distance-based fee. Additionally, this price can be surged, in case that the demand for rides is too high and a number of drivers are too low. Those services are offered all around the world by big tech companies such as Uber, Lyft, Didi, and Ola.

Autonomous Taxi service

Is defined as a fully autonomous transportation on-demand for a public, where users can book a ride through the mobile based platform.

3.2 Stages of autonomous driving

This chapter is describing the evolution of autonomous driving and its individual stages, starting from no automation to full automation of vehicles. Those different stages are categorized based on their maturity stage and levels on functional aspects of technology related to autonomous driving.

3.2.1 Autonomous driving level classifications:

While talking about the automated driving market we first have to be sure about the type of automated type, system or level of automation we are talking about.

There are two main levels of automation classifications. US National Highway Traffic Safety Administration (NHTSA) ant SAE International standard. The main difference is that NHTSA was using

5 level scale for defining the stage of automated driving, while SAE is using 6 stages. Later SAE standard was accepted by NHTSA and is publicly accepted. For that reason, the thesis will use and further bellow describes SAE standard and it's six stages[10] of automated driving evaluation.[11]

Level 0 – No Automation

Degree of automation:

In this case, the driver has absolute control over the lateral and longitudinal dynamics of a vehicle. It means that human driver is responsible for the full-time performance of all aspects of driving task. And basically, the vast majority of cars nowadays have Level 0 of automation. Still, there can be some sort of warning systems used to give a signal to a driver in order to predict a collision. An example of such a system can be blind-spot detection or collision warnings.

Driver's responsibilities:

The driver is basically totally responsible for the safe operation of the vehicle, what means he also has to monitor and be aware of the traffic around the vehicle. There are no automatic functions to delegate the control of the vehicle yet.

Timeline:

Existing already, since all of the conventional cars since they were invented required a human interaction in order to control steering, throttle, and braking. Meanwhile, a driver was responsible for monitoring the surroundings, navigation of vehicle, proactive decision when to use turn signals, turn or change lanes.

Level 1 – Driver-assistance

Degree of automation:

This driver-assistance represents a level that most of the controlling is performed by a driver. Actions like acceleration and brakes can be automated. Can be referred as a traffic jam assistant, that keeps the vehicle in a flow. That means that the driver is not fully in control all the time for steering, throttle, and braking. Upon a certain moment, he can handover to control this functions to the driver assistance system and he has to be ready at all the time to take over the control.

Driver’s responsibilities:

The driver is fully responsible for the overall control of a vehicle and its safe operations. He can turn on the driver assistance and hand over the control of the vehicle to a system in a specific occasion. Yet, he has to be aware of the surroundings and be ready to step in either when the system can’t control the vehicle due to certain conditions or when he thinks that he could prevent an accident.

Timeline: Already existing. There are multiple vehicles with built-in traffic jam assistant, a driver-assistance system that is rated as a level 1 automation.

Level 2 – Partial Automation

Degree of automation:

In this case, there are a number of specific autonomous functions that are controlled individually by the system. Such an example could be lane keeping, automatic braking, cruise control and such. Level 2 is in a very beginning of the autonomy and can work only in specific conditions. Is mostly limited to a highway, where the system doesn't have to sense and identify red lights or to define the traffic signs. Its main features are that vehicle is able to keep in a lane on highways, while adjusting the steering, deaccelerate or accelerate accordingly to a vehicle in front and change the lane. Level 2 handover the control to the driver immediately when it detects object and events the system is not responding to. Even though it can help to a driver it's a bit dummy system, since it can operate only under a limited list of tasks and situations. Vehicles with level 2 of automation can be possibly used in certain suburban areas, ideally where the roads are narrow and easy to read for the detection units. But those situations will bring more risk and will require from driver pay attention to surroundings.

Driver’s responsibilities:

The driver is still responsible for the overall control of a vehicle and its safe operation. He can anyway delegate certain parts of the main steering system to auto-pilot that can maintain the same speed as the vehicle in front of him, following the road according to the traffic lines marked on a road and also adjust lateral dynamics of a vehicle. Yet those automatic functions don’t work simultaneously together. Driver has to be able to step into when the system is in a situation when it can’t read the situation around it or when it’s too complicated to navigate it by the automation unit.

Timeline:

Level 2 is already existing and publicly released to commercially used vehicles. Tesla is currently a leader in a market with the number of vehicles they sold with level 2 automation.

Level 3 – Conditional Automation

Degree of automation:

In this case, there are at least 2 main steering systems automated and simultaneously operated. Such as example could be a parallel function of a lane centering together with adaptive cruise. Vehicles with level 3 automation are capable of controlling a vehicle in some more complicated surroundings in a city area when we compare them with level two that was mostly restricted to a highway. Level three can sense and identify the traffic signs, red lights what means it can operate in urban areas, but not 100%. Also, a vehicle with level 3 automation have difficulties in sensing surroundings in different weather conditions.

Driver's responsibilities:

Driver car relies on some of the vehicle's controls functions and delegates some part of control to a vehicle, yet he still has to keep hands on the steering wheel as a safety protocol in case of danger. Currently, can see this mostly on a highway where some vehicles are able to operate with a little of driver assistance. But we drivers can use level 3 vehicles also in urban and sub-urban areas. They still have to take over the control when the system has some difficulties with finding the right path.

Timeline: Already existing

Level 4 – High Automation

Degree of automation:

In this case, a vehicle is designed in a such a matter that can operate safely while it's on automated driving mode. In any case of danger, a driver can still take over the control and all functions related to safety.

Driver's responsibilities:

The driver switches to automatic driving only in a case that it’s safe to do so. But then he is not required to monitor the traffic permanently in case the system is active. If there is a moment when a system is not able to maintain automatic driving, he can safely take over the vehicle’s control and turn it back when the system allows it again. The Google self-driving car is an example of such.

Timeline:

Tesla already rolled out their vehicles with a hardware level 5 automation ready and currently is at stage 4 of automation. Their vehicle can confidently navigate thought the urban areas and in a certain situation to operate without any driver on board as well. Regulations did not allow yet Tesla to release an on-air software update to their vehicles to enable the Tesla car owners to upgrade their vehicles to level 4 automation.

Level 5 – Full self-driving automation

Degree of automation:

In this case, the last stage of autonomy - all the driving functions of a vehicle are completely automated and performed safely without the need for human interaction. There are all of the conditions detected by the system. In most of the cases, steering wheel and all pedals are removed, so riders can’t control a vehicle at all. They are able to drive without a driver inside the vehicle on their own.

Overall, a vehicle has to be equipped with automatic transmissions, diverse and redundant sensors, based optical, radar, laser, ultrasonic or infrared technology. Those sensors have to be capable of operating in different weather conditions, such as rain, fog, snow, tunnels, unpaved roads, etc. Those cars have to be able to connect to a cloud with a long range system to access maps, road condition report, emergency and alert messages and software updates. Along to long range systems, short range systems for V2V communication will be fully functioned.

Driver’s responsibilities:

The driver, in this case, acts as a passenger, he doesn’t have to observe and monitor the traffic. The driver needs to put the destination or other specification into the system. But its applied for both occupied and also unoccupied vehicles, by meaning the driver can request the car on demand by his phone to his desired location. Also in this case, a driver doesn’t have to be onboard at all, and a vehicle can drive to any legal destination by itself and make its own decision along the ride.

Timeline: Within next 2 years

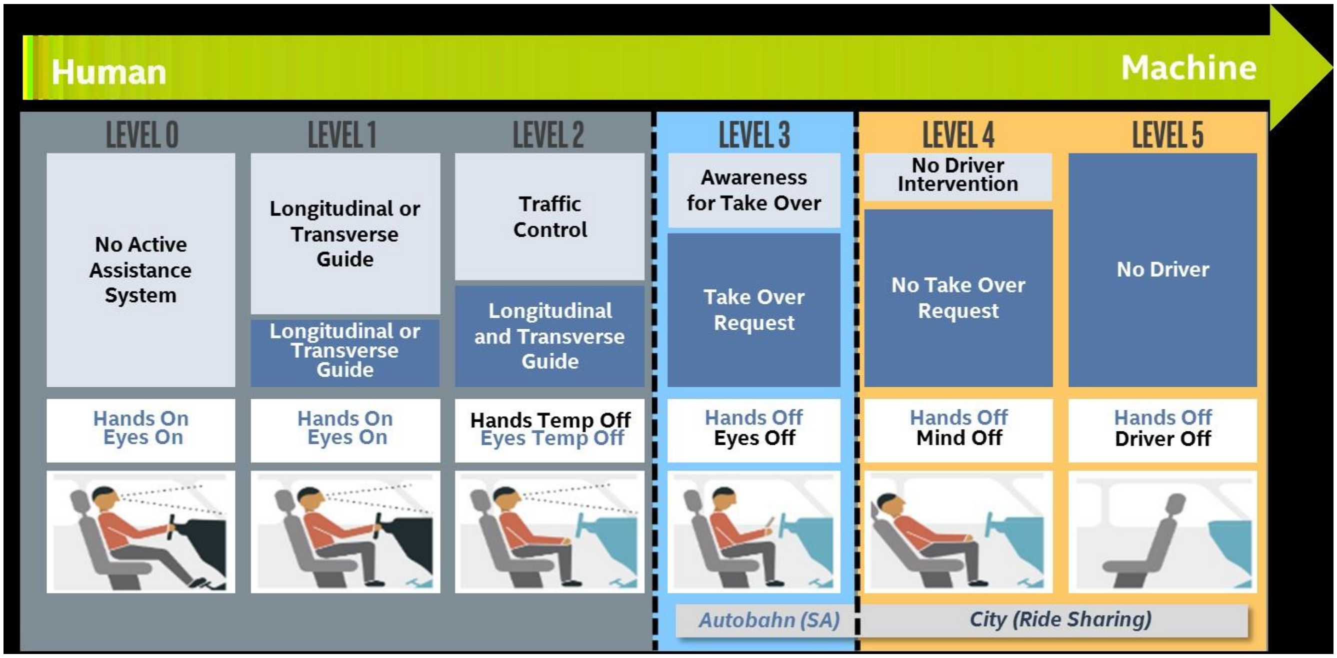


Figure 3.1: 5 levels of autonomy by SEA[12]

The elimination of human in driving activity requires necessary elements to operate with a various complex technology simultaneously. Decision-making capabilities of humans will be replaced by a deep machine learning algorithms where AI will be eventually able to take non-error actions based on a surroundings and conditions around the vehicle. Specially prepared, constantly updated maps with custom environmental models for determination of location and to help understand the surroundings and the meaning of objects assist AI in determining a drive-able path for the vehicle. Our vision will be replaced by a set of various sensors that have to detect the necessary objects and obstacles near the vehicle.

Autonomous vehicle implementation will consist of several phases. After reaching Level 5 regulatory approval for autonomous driving will be the next step in an automated driving world. Some states already started with the preparation of performance standards and requirements that manufacture will have to fulfill in order to get their vehicles for commercial purposes.

Stage	Notes
Level 2 – Limited automation (steering, braking and lane guidance)	This is the current state of art, available on some new vehicles.
Coordinated platooning	Currently technically feasible but requires vehicle-to-vehicle communications capability, and dedicated lanes to maximize safety and mobility benefits.
Level 3 – Restricted self-driving	Currently being tested. Google experimental cars have driven hundreds of thousands of miles in self-drive mode under restricted conditions.
Level 4 – Self-driving in all conditions	Requires more technological development.
Regulatory approval for automated driving on public roadways.	Some states have started developing performance standards and regulations that autonomous vehicles must meet to legally operate on public roads.
Fully-autonomous vehicles available for sale.	Several companies predict commercial sales of "driverless cars" between 2018 and 2020, although their capabilities and prices are not specified.
Autonomous vehicles become a major portion of total vehicle sales.	Will depend on performance, prices and consumer acceptance. New technologies usually require several years to build market acceptance.
Autonomous vehicles become a major portion of vehicle fleets.	As the portion of new vehicles with autonomous driving capability increases, their portion of the total vehicle fleet will increase over a few decades.
Autonomous vehicles become a major portion of vehicle travel.	Newer vehicles tend to be driven more than average, so new technologies tend to represent a larger portion of vehicle travel then the vehicle fleet.
Market saturation.	Everybody who wants an autonomous vehicle has one.
Universal	All vehicles operate autonomously.

Table 3.1. Autonomous Vehicle Implementation Stages[13]

After regulatory approval, autonomous cars will be ready for sale. Some companies say that autonomous cars for commercial purposes will be available on the market by 2018-2020. Their price is not yet stated. The point when autonomous vehicles will become a major share of a total number of vehicle sales depends on prices, performance, efficiency and consumer social acceptance. Disruptive technologies usually require a couple of years until they are widely accepted by a majority and dominate the market. When the sales of autonomous cars outgrowth the sales of classic vehicles, there will be a point when autonomous vehicles will become a major portion of all vehicle fleets. Estimates say that this situation will happen in a matter of decades. Then followed with a stage of market saturation when everyone who will want autonomous car will have one. Step after market saturation will be a point where all cars will be autonomous.

3.3 Pillars of autonomous driving

In this chapter, the three major elements that enable autonomous driving: Sensing, Mapping and Driving policy will be discussed. They are necessary components for Artificial Intelligence and Machine Learning and must be handled simultaneously – they are not three separate blocks made by different companies. In case they are made separately the unreasonable demands on each block will show up, what means they will never work properly. Sensing and Driving Policy are very complicated entities and if they are not being done by a single entity, then they have to be developed in a very close collaboration between the two companies.

3.3.1 Perception - Sensing

The purpose of Sensing is to build a 360-degree environmental model around the vehicle for detection of different kinds of objects. There are different tasks that sensing has to handle and the text bellow will discuss them one by one.

3.3.1.1 Sensors

There are talking about two kinds of sensors used in AV:

a) Proprioceptive sensors that are responsible for sensing cars state like, internal measurement unit, wheel encodes, etc.
b) Exteroceptive sensors that are responsible for sensing the surroundings of vehicle with radar, LiDAR, ultrasonic radar, etc.

In this section, exteroceptive sensors will be further described, because they are essential to AV application due to a fact that they perceive the ambient surrounding. [14]

3.3.1.2 Vision-based Cameras

Camera-based systems can be either monovision or stereo-vision concepts, depending on whether there is only one camera installed or a set of cameras. Cameras take an important role in a sensing of surroundings of a vehicle. They are equipped with image recognition that identifies the objects such as road and speed signs, traffic lights, road lines, other cars, etc. They can interoperate the text on the traffic signs and are able to classify them. They are the cheapest type of sensors out there for AV, but their processing is a bit costlier. They are processing tremendous amounts of data every second that needs to be processed real-time. This makes the processing a computational intense and algorithmically very complex task. Being able to recognize the color, cameras are perfect for scene interpretation.

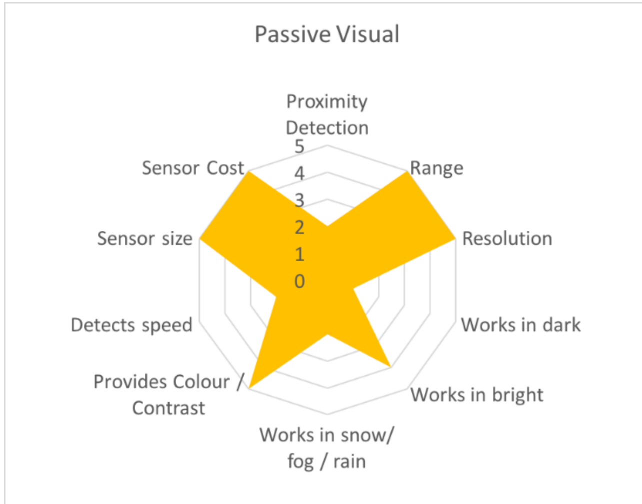


Figure 3.2: Vision based passive camera performance [15]

Depending on those cameras can be mounted all around the vehicle. Their position use to be either at front grilles, side mirrors a rear windshield, rear doors, etc. Most important cameras are usually in front of the vehicle and in the back. Short range camera and long range camera can be used to sense the objects in front of the vehicle from a close range distances up to a several hundred meters. Aside to their function of identifying objects, vision based cameras can predict their immediate trajectories when they use advanced scripts and algorithms.[16]

3.3.1.3 Radar

Generates electromagnetic waves and detect the reflection of those waves when it bounces back from close objects. Both short-range and long-range radars with a narrow-band 27-77 GHz are used for AV applications. Radars can determine the range, angle, and velocity of objects. Short-range radars sense the surroundings of a vehicle up to 30m, what is mostly applicable for low speeds. Their role is to detect objects around the vehicle with a close distance. Radar is good for detection and measurement of motion around the vehicle.

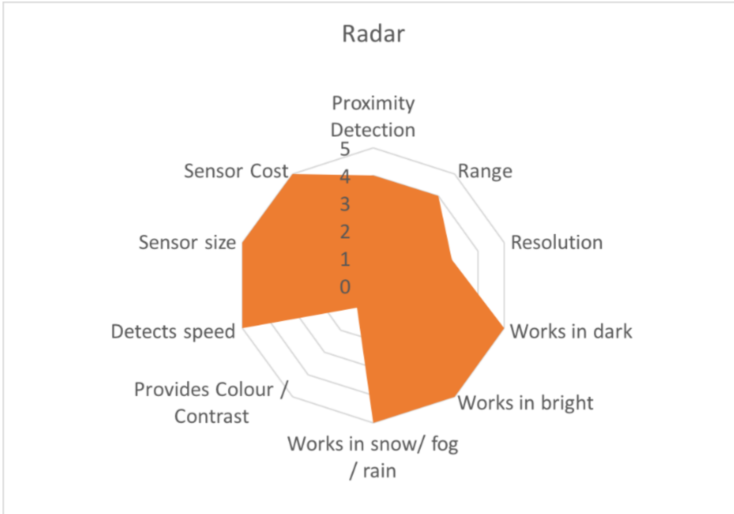


Figure 3.3: Radar Performance [17]

Can detect range, angle, and velocity of the objects. Radar is computationally lighter than a vision-based camera and is handling far less data than LiDAR. While radar is less angularly accurate than LiDAR, it can work in every weather or light condition. On the top of that can see behind the objects, what is specifically advantage when can sense the objects in front of the near cars. This is possible by reflecting the waves behind the objects near by.

Long-range radars are used for higher speeds and can detect objects over 200m. Those radars usually measure the speed of vehicles ahead and are mounted in front of the vehicle. [18] Currently, AV prototypes rely on the data from radar and LiDARs where they cross-validate the objects they are sensing.

3.3.1.4 Ultrasonic radar - Sonar

Generates sound waves with higher frequencies than the human ear can notice and detect the reflection of those waves when it bounces back from a close objects. They also use echo-times from sound waves that bounce off the objects nearby.

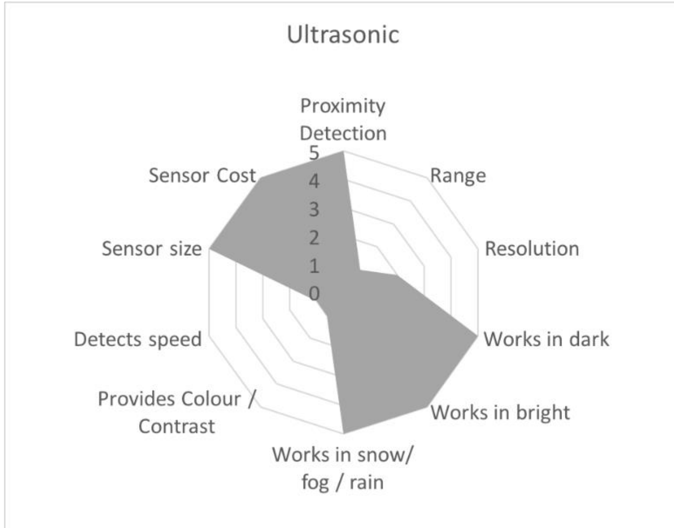


Figure 3.4:. Ultrasonic radar performance [19]

Ultrasonic radar can see a soft object like a dog, child and operate at all the speeds, but are suitable for short range distance. Usually, there are a couple of ultrasonic radars spreader all around the car, for creating a 360 degree object model around the vehicle. They enable to see a nearby car in a blind spot, highway barriers or on a side.

3.3.1.5 LiDAR

LiDAR stands for Light Detection and Raging, what can sounds similar to radar or sonar because they work on the same principle: echolocation. Being able to see with echoes mean to simply shoot something out and then track the time when it takes back. We can observe this principle in nature as well. Bats sends sound waves and are able to sense the waves that bounced back, determine the distance from the objects according to a how fast the wave came back to them. If you know how fast sound or light waves travel in a specific environment you know how long it took to reach the object and come back, then you know exactly how far is the object that the wave hit. We can bounce radio, sound or light waves. If we look into radio waves they are good to find a solid object over long distances but still have some cons. They can pass through some objects without bouncing, Sounds waves can disappear quickly and they travel relatively slowly. Overall it makes them insufficient for object detection over 4 meters. Lidar uses laser beam to send out short laser pulses of light and measuring the time it takes to receive the bounced array of light. It uses lasers arrays outside the visible spectrum. It's possible to build a big 3D map of object surrounding the sensor, from the measured the distance and direction data of those bounced pulses.[20]

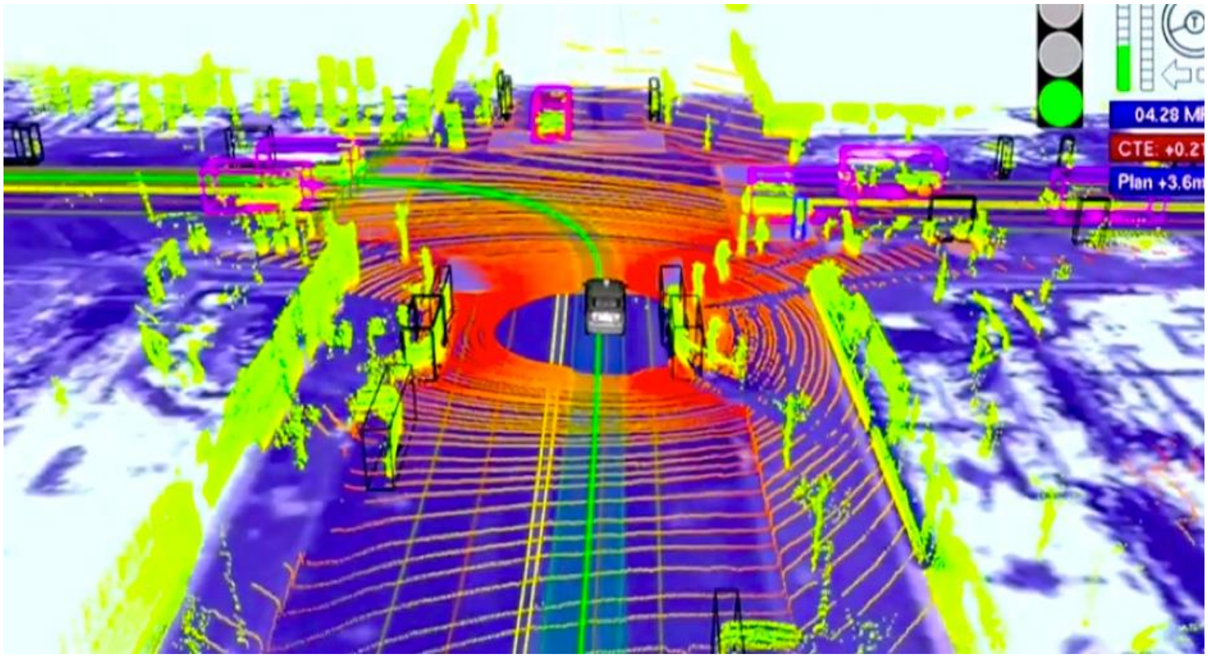


Figure 3.5: LiDAR sensing of surroundings [21]

LiDAR does not technically detect the close objects. Instead, they create a profile of the objects around and analyze the route of reflected beam. The 3D map or also called Point Cloud of the space around the sensors can be spectacularly detailed, consisting of millions of pulses per second and being able to complete hundreds of cycles per second. And because LiDAR produces a reasonably detailed 3D image, computer vision can spot a difference between types of objects, such as a car, pedestrian, bike etc. It's important because all of those objects act on a road differently and may require the car to slowdown, make more space on the side or such. Best sensors can currently detect objects up to 100 meters far away. This sensor is the most expensive now from all the other sensors that are used in autonomous cars. Their price can go up to 100 000 USD, but with further development, OEM was able to put this price significantly down already. With further development and later mass production of self-driving cars, the price will drop even further. LiDAR has it's limits as well. It can't read the signs, letters because they are flat. Heavy snow or fog can disturb the system relatively easily. Rather than using LiDAR as the only sensor that is needed is a good idea to use it in combination with other sensors simultaneously. Another problem with LiDAR is that they produce a large amount of data, that needs to be further processed.[22]

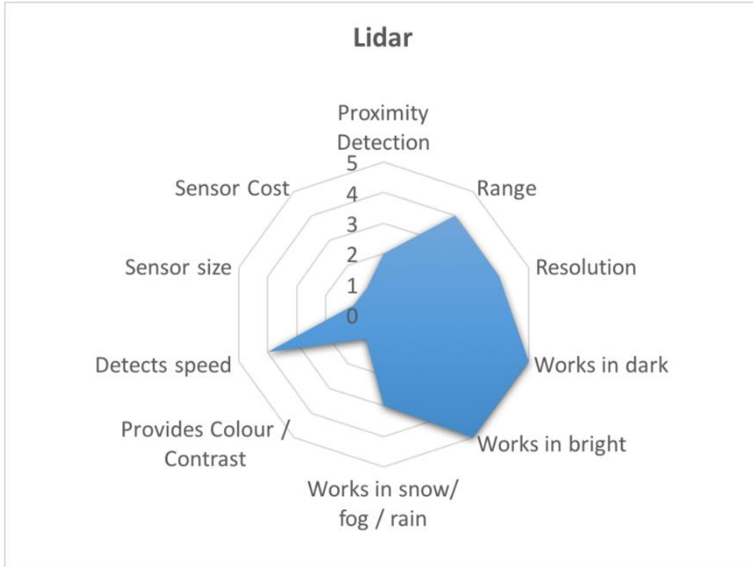


Figure 3.6: LiDAR performance [23]

Most of the current autonomous vehicle developers consider LiDAR as an essential technology for autonomous driving. On the other hand, Tesla claims that their autonomous vehicles don't need it and relay on the other set of sensors. This is questionable since the cameras don't perform well during the conditions of low light or glare and radar is not able to sense objects with such a details as LiDAR.

<u>Moving/Stationary Objects</u>

There are objects around that vehicle have to be aware of. The requirement for sensing is to detect all of the moving and static objects at a specific distance from the vehicle. Those objects are vehicles at any angle, enhanced pedestrians and cyclist detection, obstacles, pathway delimiters and general non-model-based objects.

Sensing has to go way beyond the detection task and use elements of AI. It has to understand what is the pedestrian actually doing, not only that if he is physically present. It has to identify whether he is looking at the vehicle and where is the pedestrian actually standing. Sensing has to determine whether he is in the center of the path for walking or on the edge and what direction he is moving.

Sensing works in very close collaboration with Driving intelligence to determine the driverable path in a semantic meaning for the system.

The goal, and for a now the biggest challenge in Sensing is to achieve zero false negative results. Giving any sort of false negative results could later represent fatal consequences. Yet it has to ignore the inanimate objects and pedestrian’s safe zones.

Path Delimiters:

Path delimiters task is to detection of the free space, where the car can actually move towards and drive in. Detection of any boundary such as curve guard drill or any road work signs. Its task is also to label those different types of boundaries.

Drivable Paths

Figuring out the drivable path is the hardest part of the sensing aspect. The system has to understand where all the drivable paths are, reads all the pavement markings, understand traffic signs etc.

There is a necessity to associate the semantic meaning to each drivable paths. The system has to determine whether is this path leading to the highway exit or whether is this path going straight or whether is there a split or a merge and etc. This are all the things that we are taking for granted when we are driving as a human, but they are a big challenge for AI and they are very complicated for autonomous driving. The absolute especial unit for figuring this out is a front facing camera, that can detect and recognize the color of traffic lights, read the traffic signs and scan road lines.

Front facing camera, front facing LiDAR, corner radars or front and rear laser scanners are sufficient for a highway operation. But once the vehicle is in city traffic where the things are becoming much more complicated, it’s not sufficient. In order to figure out the drivable paths, the need for surrounding cameras is a must as well.

Corner camera enables to detect pedestrians on a side of the vehicle what is handy especially when the vehicle is turning. This could be also possible to do with a LiDARs. More importantly, corner cameras help the vehicle to understand the drivable path, and only a camera can give that information.

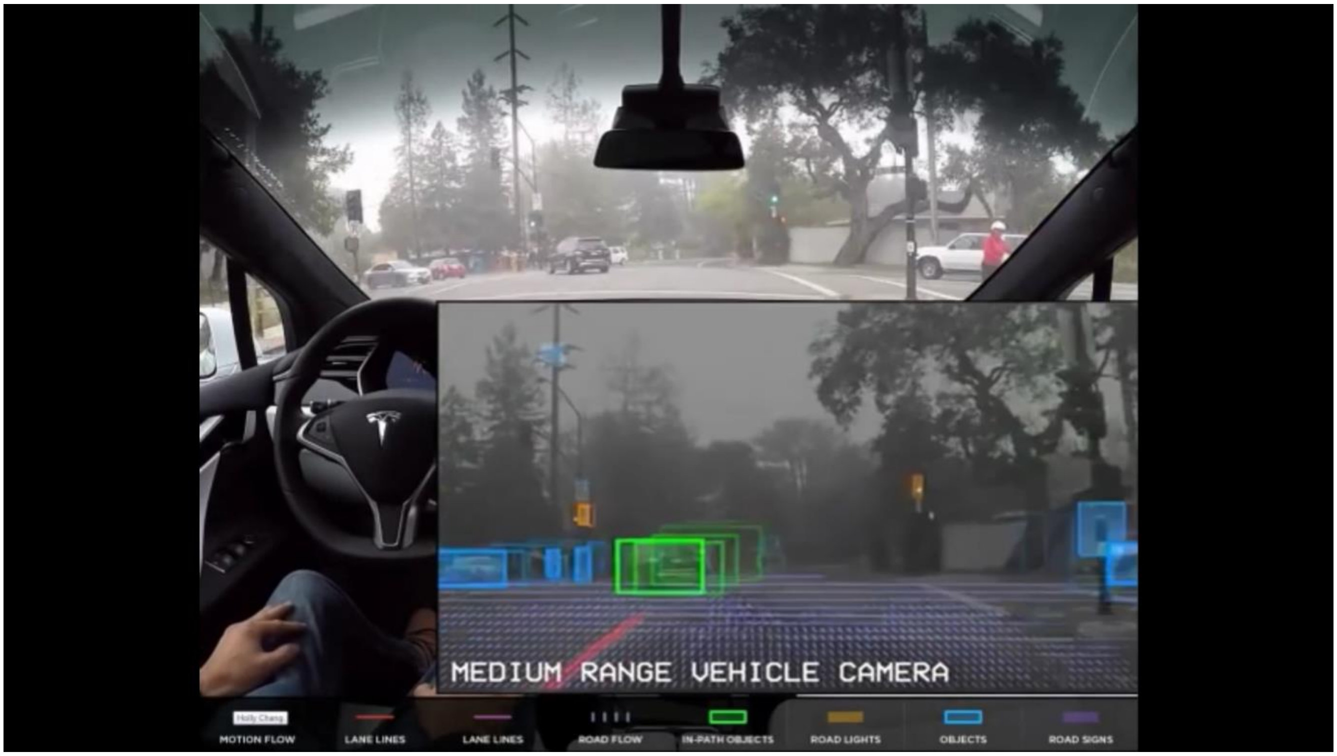


Figure 3.7 Tesla Self Driving Car Demo Video Analyzed [24]

3.3.2 Mapping

Mapping is another key element that helps to enable the autonomous cars to operate. Its task is to navigate vehicle on an existing infrastructure. By doing so it has to possess with the maps that are edited specially for a navigation of autonomous vehicles. Those maps have to be updated in a continuous process, as close as possible to a real-time. This means that any change in a road line design, any road work has to be updated straight into a map database. This continuous update could be done by a certain authority: city planning, road work companies that are responsible for maintenance of the roads etc. Another approach is to crowdsource this changes as a data from the other vehicles. In the following year, it will be a safety standard to have a front facing camera installed onboard. Those captured data could be sent into a cloud, processed and build upon maps we have nowadays.[25]

This would of course required a wireless connection between the vehicle and a cloud infrastructure V2I, what seems to come into a reality in the following decade. This could sound like a tremendous amount of data, but if they are processed internally in a vehicle already we could downsize this information into a very small data packages. Data per vehicle should be then very small, around 10 Kb/km what is definitely possible to transmit with the mobile network we have nowadays. Those maps have to be safety critical since the vehicle is depending on their reliability.

Maps suitable for navigation of autonomous cars can have multiple layers such as:

The Map layer where is a precise sub-line level representation of the road network, with precision between 10-20 cm. This layer includes curvature and slope, different lane marking types and roadside objects. This layer is designed for positioning and localization of AVs and to support automated maneuvering

The Activity layer is responsible for tracking dynamic events as they occur. This includes traffic conditions and hazard warning that can be accessible from different up to date API sources.

The Analytics layer keeps an eye on long-term location based driver behavior data for every road segment that is ahead in a plan of a journey. With those data, it can compute speed profiles.

3.3.3 Driving Intelligence Policy

Now some of the self-driving cars are too conservative and they create accidents by being and acting like non-human like behavior. Speaking of, if we actually want self-driving vehicles to existing on a road together with human-driven cars, we need to teach the self-driving cars to adopt human-like driving skills. Traffic is a Multi-agent game because we need to understand human-like behavior in order to merge it with traffic in a safe manner. What seems a bit amusing is that human drivers are bumping into self-driving cars and exposing a key flaw that AVs in an early stage of development can be overcautious.

Difference between Sensing and Planning

Sensing is the present image, the overall statement of where are the objects, where is the path. We are sensing the present situation where everything around vehicle is an obstacle and vehicle itself is a “center of the universe”.

Driving Policy is a planning for the future scenarios. It’s a multi-agent game, where the objects around are not just obstacles but they are behaviors which are moving. The system has to understand them, their logic and predict multiple possible future scenarios in a simulation. By virtually simulating them the vehicle can predict what could happen if it would react this or the other way and choose an optimal reaction.

<u>Reinforcement learning</u>

Is a virtual creation of different scenarios with the goal to learn a policy. During the learning process, there are states, actions and rewards or punishments. This means that the software is trained with machine learning algorithms to deliver a longer period or reliable autonomous driving capability.

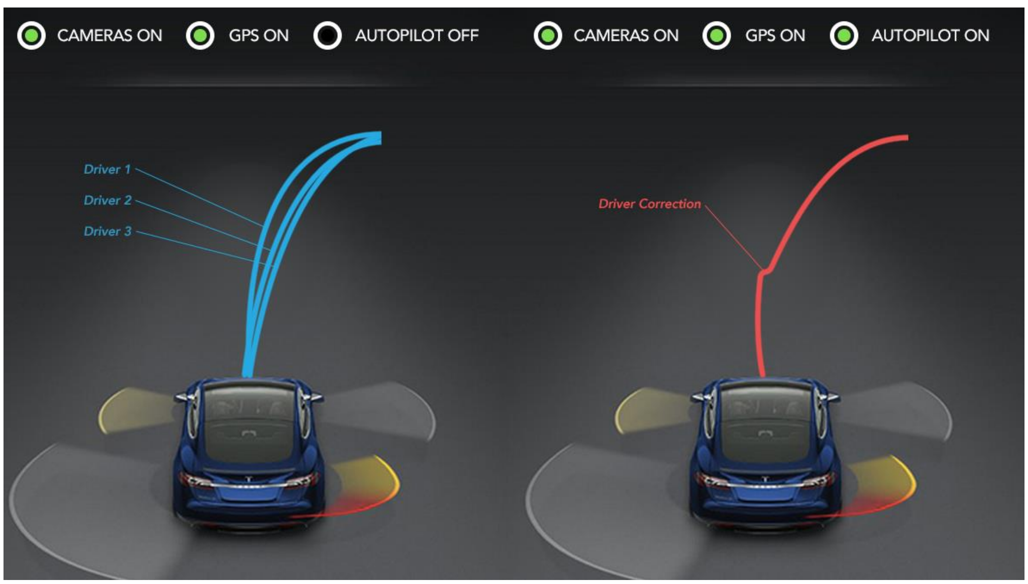


Figure 3.8: How cars learn [26]

An autonomous vehicle can learn through observation of human driving behavior. The car record how the drivers approach a stretch of road, steer the wheel, adjust the speed and such. Then process multiple of those same situations and compare the data points that system collected. In this situation, all the cameras and positioning system are turned on, but autopilot is disengaged and just observing the behavior. Those individual behaviors are compared to each other and as an outcome, the system can determine an optimal line where the vehicle should be heading. Vehicle can have preconceived notion of how to steering should be executed but it observes how human driver approaches the stations. See on a Figure 3.8 on the left side three blue lines that represent how human drivers kept the vehicle during the driving. The optimal route would be somewhere in the middle as an average of those three lines.

Learning through reinforcement is another way how machine learning stepping into a game of autonomy. In this case cameras, GPS and also autopilot function is engaged as well. That means that vehicle is driving by itself and decide where is the optimal line by itself. The vehicle attempt to drive the optimal line in real conditions and learn how to improve their behavior in the case that assistant driver steps in and provide a correction inputs. Until this point, there is no learning process involved. As soon as the human driver moves the wheel or anyhow control the vehicle, submits a control input. This provides the car with a negative reinforcement and also with an information that there is possibly a better optimal line to take. [27]

Learning process
For t = 1,2,….
Agent observes state St
Agent decides on action At
Environment provides reward Rt
Environment moves the agent to next state St+1

Every state and action pair is rewarded when the final result is a positive. Every state and action pair is punished when the final result is negative.

During the learning process the system move from state to state, by taking an action. Action could be slow down, change the lane or slow down. And state is a current and present situation the vehicles is in and the system is getting a reward. Reward is a feedback to the system to figure out whether he took a good action or not. The key optimization process during the simulation is to get accumulated reward and not just simultaneous reward. The simulation wants to optimize accumulated reward due to the fact that it goes into the future to fulfil the current goal. Current goal can be an entering the highway in a nearest entrance. System know that its 10 kilometers away and have to figure out the actions it have to take in order to take the entrance to the highway. The whole process until entering the highway will give zero reward to the system, until the vehicle will enter the highway. Than the system gets a positive reward and move to a state *t+1*.

Supervised Learning

In supervised learning the actions don’t affect the environment, so the system can easily collect training examples in advance and then search for a policy.

The effect of the action is local and we are not looking further into a future but instead onto a small action. In supervised learning, we already know the correct answer, but giving a chance to a system to sort those data. As a feedback, the test is always giving a right answer to the system, since we have the input and the output, while the output is always correct. That’s the way how the system is trained in the process of supervised learning.

3.4 The role of ICT in autonomy

Autonomous vehicles of the future will eventually rely on 5G network communication, but how will we get there? Qualcomm’s opinion is that vehicles will be connected to the cloud at all the time. By using a 5G network, cars will be able to position precisely where it is with a tolerance in a centimeter and will have access to 3D mapping cloud servers.[28]

3G and 4G are mostly focused on a delivering broadband to smartphones in higher data rates to connect them into a cloud. Transition to 5G will represent a slight shift where the network will support other specific use cases, including autonomy. 5G network will improve latency up to 1ms for mission-critical services that require an ultra-fast connection in order to operate real time. Moreover, the network will create a massive group of devices connected to cloud IoT. Requirements as low latency, enhanced security and very large number of connections will have to be provided.[29]

Vehicle to everything - V2X communication is an essential component for a safer autonomous driving.
We recognize and divide V2X into four types of communication, based on the elements that vehicle is communicating with. [30]

Vehicle to Vehicle (V2V) – where vehicle is exchanging the data with other vehicles directly, operating as a collision avoidance safety system.

Vehicle to Pedestrian (V2P) – where vehicle is exchanging the data with pedestrian’s smartphones devices, providing safety alerts to pedestrians and bicyclists.

Vehicle to Infrastructure (V2I) - where vehicle is exchanging the data with built network infrastructure.

Vehicle to Network (V2N) - where vehicle is exchanging the data with cloud services, related to real-time traffic and routing.

In general, more end to end points are involved, quality of information sharing increases.

Non line-of-sight sensing (NLOS) - V2X provides 360 degree NLOS awareness. NLOS situations are very normal part of a driving experience, generally occurs in intersections, on-ramps or during an weather conditions as rain, fog or snow.[31]

Conveying intent – Communicates intent of vehicles around, share sensor data and compare that transmitted information with a data from LiDAR and radars. Combining the data from sensors and transmitting the intent of vehicles around provide a higher level of predictability. For instance, when a vehicle in front suddenly changes the lane due to a road hazard in front of it, this vehicle could share this knowledge with vehicles behind it or close by.

Situation awareness – Sharing information from sensors about what is happening around the vehicle when there is a queue or crowd of cars.

This V2X communication technology require evolution towards 5G while maintaining a backwards compatibility.

Current stage of development

For a basic safety standard IEEE 802.11p or C-V2X R14 established a foundation for basic V2X services. IEEE 802.11p standard is licensed in ITS band of 5.9 GHz (5.85-5.925 GHz) and uses channels within the 75 MHz bandwidth.

For enhanced safety C-V2X R14 is based on LTE Advanced, that offers better terms for link budget perspective, what therefore improve the range and reliability.

Towards advanced safety new standard will be created C-V2X R15+ with higher throughput, reliability, wideband ranging and positioning and lower latency. In a certain stage car in a line could constantly see through the sensors of the car in front of you, by camera sensor sharing. Also, cooperative driving, an operation where vehicles drive in one lane with a short distance between each other, with a goal to make the traffic more fluent, safe the energy by lowering the resistance and improving the overall fleet agronomy will be possible. This could be especially useful for trucks, that could drive in a fleet together, would significantly lower the resources needed for operating the truck with a physical driver and saving a fuel. Aside to this R15+ standard will enable to create a real-time bird's eye map view.[32]

By combining city line communication under the cellular ecosystem it's possible to leverage one against the other eNBs, with unicast and broadcast services can be combined with Road side units (RSU) for V2V and V2I services.

Two complementary transmission modes that can work together to enable a broad range of automotive use cases.

Direct communications – Between vehicles, infrastructure, and pedestrians. Direct PC5 interfaces were designed for a broadcast and real-time information between vehicles traveling at high speeds and high-density traffic, even out of mobile network coverage. PC5 interface is symmetric, meaning Ui and infrastructure side are equivalent.

Network communications – Leveraging the existing LTE networks for wide area networking and cloud services. It utilizes Uu asymmetric interface – server that is normally used to access the server network. There is clear structure, based on an infrastructure side and client side. There are different Uplink and Downlink speeds.

3.5 Connection between Autonomous cars and Sharing economy

Some of the pro-autonomy people say that autonomous cars will results into using car as a shared resource, more specifically as autonomous taxis [33][34][35]. There has to be an obvious evidence that those two fields have a clear relationship evolved between each other. For such quest, the following chapter brings a closer look onto how autonomous vehicles and sharing economy are connected nowadays.

Our cars as a material possession cost vast amount of resources in order to purchase them. People often get loans just to afford to buy them, even though they use them only 5% of the time. It means that our cars are parked idle in front of our homes and offices for more than 95% of the time, without any usage. That's quite an expensive purchase for a product we don't use that much. Yet, we are so attached to cars because they offer plenty of advantages when compared to traditional mass public transportation.

Over the last decade, the boom of sharing economy platforms is now at their bests. We are slowly changing our mindset about personal ownership and are willing to share goods, offices, vehicles, apartments in a different amount that any before. It’s economically beneficial, creating new job positions and very flexible.

Autonomous cars allow people to buy time, meaning, they don’t have to take attention on a road and control the vehicle. They can focus on entirely different things when they are commuting to their destination. Whether it is working during the transportation or paying attention to their children, spouse or family member. We live in a very hectic world, where people are always busy and they often commute a lot to get to their final destination. Products and services that “sell time” to people can have tremendous value. Autonomous cars sell time to their users. Imagine getting extra hour in the morning while commuting to your workplace. There is so many things that people can do meanwhile.

Current ride hauling on demand services enables users to simply order a cab with a few clicks on their phone and without any extra walking towards a parking spot where they would have parked their vehicle another way.

“In just a few short decades, owning a car could be a lot like owning a horse — mostly for hobbyists and really unnecessary for transportation purposes.” Elon Musk Founder of Tesla Motors [36]

This is a bold statement, yet pretty much possible. Probably not in a next decade, but the ownership of cars could shift in a next few decades. The shift from personal ownership to sharing vehicles will start slowly since there is a whole cultural aspect that needs to be challenged and redefined. We have been used to own a car until nowadays, so it will take an enormous effort to go from this point. The speed of adoption will depend on many factors, but the quality of service and price will determine the speed of adoption and the shift form of ownership.

The trends that we can see nowadays with Car2Go, car sharing company where customers buy into a membership and can rent the car when they want to commute within a city. Those vehicles are spread across the city and customers can find their real-time location through their mobile application, book and access the vehicle. Price for such a services varies according to a mileage and time spent occupying the vehicle. Since some of the vehicles are electronic, customers can earn a bonus credit in case they return a vehicle to a charging unit or pick up the car from a distanced rural area into a city.

Spiri, Copenhagen-based On-demand ride-hailing startup is another great example of the upcoming trend in car sharing. Their service is unique in a sense that their drivers are actually their customers. They pick up the car and set their wished destination. If there is a demand in the same time for that route from other customers along the way, this driver has to adjust his route towards those customers, pick them up and transport to their destination. The more riders’ driver picks on the way, the cheaper the transport per person at the time is. Meaning, if the driver picks up passengers along the way, he can eventually drive for free. This means that company has no expenses with paying salary to any drivers and drivers can commute to their destination for free if they pick up passengers along the way.

But what is the connection of autonomous cars and sharing economy? Are those two necessarily connected, or those two entities can operate without each other? Let's look at a few trends in a car ride-hailing market and it's connections with companies that are currently developing autonomous vehicles.

There are few major players in ride hauling services around the world: Uber, Lyft, Didi, and Ola. They own a majority of a market share and operates in different geographical regions across the globe.

The biggest ride-hailing company Uber partnered with Volvo for testing autonomous vehicles for ride-hailing purposes. They started to operate Volvo's self-driving cars in Pittsburg where the service was offered to the public for testing purposes. For a now they are just in a testing phase, where riders can order a ride through their mobile application. A self-driving car with a driver will pick them up and transport to their destination. During those rides, a driver is still present and his duty is to observe the surroundings and take over control in a special situation. As a next step, Uber acquired OTTO [37] - driverless truck startup. Uber is already offering ride hauling services around the world on their platform. They already have a ride hauling customer base, and can add fleet of AVs as addition to their current services.

Another big player within an automotive and ride-sharing industry is General Motors that announced with Lyft a planned long-term strategic partnership to create and integrated network for on-demand self-driving cars in the US. General Motors will also invest 500mil USD in Lyft to maintain the rapid growth in a ridesharing market.

"*We see the future of personal mobility as connected, seamless and autonomous. With GM and Lyft working together, we believe we can successfully implement this vision more rapidly*."

President of General Motors Dan Ammann. [38]

Further John Zimmer, president and co-founder of Lyft, said: *"Working with GM, Lyft will continue to unlock new transportation experiences that bring positive change to our daily lives. Together we will build a better future by redefining traditional car ownership"* [38]

Huge ride-hailing Chinese market is dominated be a company called Didi. Uber tried to penetrate Chinese market in 2013 and were competing with Didi over the last couple of years to take over the market share. This was resulting into a lot of cash fueling into this race, eventually UBER backed off and agreed with Didi to leave the market and sell their activates to Didi. After all, Apple poured 1billion USD into Didi[39] and they will work on a self-driving cars together.

Current biggest ride-hailing operator in India Ola announced that they are very interested in self-driving cars and their development in the future. The situation in India is a bit more special. Drivers hardly obey any driving rules and operating a self-driving vehicle that is overly cautious can cause many problems.

In Singapore, nuTonomy operates a fleet of autonomous vehicles for testing purposes. People can now order a ride in a self-driving car on a specific route within the city. According to their company's vision, they aim to be the first company in the world to launch an autonomous on demand ride-haling system.[40]

Elon Musk, Founder of Tesla Motors revealed his master plan for beating Uber. Tesla is a leader in a development if we take into consideration that they have thousands of vehicles driving around the globe with self-driving technology. Their cars are already able to drive by themselves, yet they need a driver to be cautious for taking over the control of the vehicle. Tesla's owners will be able to share their vehicle during the day when they don't need it for ride-hauling services and make money out of it. This seems like a different vision for a business model that above-mentioned ride-hauling companies currently have. Personal ownership will probably dominate in their case. Elon wants to create a Tesla Network, what seems like a platform for on-demand autonomous ride-hailing services. Additionally, a fleet of autonomous cars will be added by Tesla in cities where demand is higher than a supply. Tesla owners should not expect to be able to lease out their Tesla vehicles for any competing self-driving services of companies like Uber, Lyft or any other self-driving ride-hailing service in a future.

From what we can observe now, visions of those companies are pretty similar. They intend is to have AVs used for ride-hailing on-demand transportation services, used by a public and make a profit out of it. This kind of service could work on a kind of "Airline model" where different companies are practically doing the same thing – transporting riders by AVs, but they will just try to play games with adjusting prices and fees, and levels of service.

Reasons for the imminent disruption

There are numerous reasons for the imminent disruption of automotive transportation by autonomous vehicles. Trends like electrification, connectivity, autonomous driving and diverse mobility have been observed for a year. But it’s only now when they are positioned to disrupt due to a fact that technology, consumers, and governance are finally ready. In order to drive the cost of transportation significantly down, autonomous cars will have to use an alternative source of fuel, such as electricity. Over the last years, electric cars became a desirable product by a consumer preference. Their usage in urban areas increased due to their fuel cost efficiency. Battery technology and cost significantly decreased what allows to build a cheaper electronic car. Tesla has been able to build an attractive electric vehicle, without compromising it’s looks or performance. Predictions say that there will be 1200% global increase of charging station during the period 2014-2020. Moreover, electric cars reduce the emissions and use the fuel more efficiently that combustion engines. If we are saying that electronic cars are causing less CO2 emissions, we have to take into consideration the way how they producing the energy, and if it’s eco-friendly or actually causing an environmental pollution. The government can play in this process their role as well when they can put electronic cars into an advantage to their peers with combustion engines. Tax allowance or deduction, free parking, allowing to drive in a city center can put electronic cars into an advantage.

Tech giants and startup scene recently started to discover the remaining part in the connected world, where IoT get a lot of attention due to it’s potential. Connected lifestyle is starting to take it's place in our vehicles as well. Our vehicles are starting to be connected to a cloud. V2V technology is expected to be ready by 2020 while communication network is simultaneously growing towards 5G.

The public is starting to realize benefits of autonomy after the technology is being demonstrated. There are over 16 states where after getting permission it’s legal to test autonomous vehicles. Both OEM and startups perceive autonomous cars as a big market with great opportunities. The price of sensors is getting down, especially the price of the most expensive LiDAR sensor significantly lowered.

Consumers start to prefer access to service over the ownership of products. Especially for car-sharing, there is a prediction of 600% revenue increase globally during the years 2013-2020. Smartphones makes the process of ordering a ride a simple process, while before ordering a taxi ride was complicated and time-consuming process.[41]

4. Theory

This section describes theories that will be used in a next phase of the thesis. They are being discussed due to a fact, that they will be as building blocks for the foundation of Business models. Those business models could be adapted by a key player that are offering ride-hailing services operated by autonomous cars commercially.

4.1 Theory of Dominant Design

The literature suggests that in a fight between multiple competing designs, eventually one design emerge as called dominant design over the others. There are several reasons and forces that are explaining this problematic. The role of the dominant design was first described more than 30 years ago by Abernathy (1978) and Abernathy and Utterback [42]. Over the time, this theory was interpreted by a range of other authors.

The concept of dominant design is describing a design as such, that perform so good and dominates its field, that everyone else wants to imitate it and built a better version of it [42].

Abernathy and Utterback describes dominant design as a situation when market accepts a specific product's design architecture, and then it defines the requirements of the whole product category[42. Utterback further defines the dominant design as a product in it own product category that wins the battle over the many competing designs and is then adhered by the innovators and competitors. They have to accept and adhere the design in case that they want to gain a market share[43]. Using the term product category, we can say that there can be more dominant designs that emerge in a different product categories or niches simultaneously without any specification towards geographical distinction. There can be differences in dominant designs over the several geographical regions.

The dominant design is most of the times a creative synthesis of innovations. It doesn't have to be the best technologically superior product on the market, but by far it's the best compromise between different functional characteristics. It doesn't have to fulfill the needs of a specific class to the same extent as some of the tailored designs do.[44] The emerging process of dominant design can be often called a black box process, that in a sort of way have to involve cooperation between technological and non-technological factors.[45] And still, there could be a situation when the emergence process won't escalates into creating a dominant design, where there are multiple designs competing on the market together. The emergence of the dominant design can also influence the future generations of the product category, where the company that acquire the dominant design can lock out their competitors and indicate the future development of the product category [46] (Schilling 1998). Anderson and Tushman describe the dominant business model as the one that acquire over a 50% of new product category installations[47].

Theory of dominant design doesn't stick only with a product or a service but can be applied to a system as well. In the 21st century, traditional ownership is shifting and popularity of sharing economy is rising. It changes the old stigma around owning things or have them physically. We can see this trend in a music industry where we were used to having music physically on a CD's, this later changed to downloading music into a personal computer. As mobile phones progressed in innovation people tended to download their music into their smartphones or mp3 players. Broadband internet access enabled to stream music right to our smartphones. Apple, Google then strived to emulate Spotify's streaming services. Alike change is happening in the movie industry where Netflix and Hulu are streaming movies straight to their customer's devices.

Electrification of cars seems more real than ever and a shift in car ownership is on a rise. Ride-sharing provided by companies like Uber, Lyft, Didi, Olu all around the world disrupted our transportation system in an urban area and forced to change the legislative in some of the countries.

"Once the cost of autonomous vehicles goes down to a friendly standard for the public and become legalized, it will become the dominant design for cars." J. Hanshen [48]

The Abernathy – Utterback Model [49]

"The dominant design product has features that competitors and innovators must adhere if they hope to command significant market share following" [50]

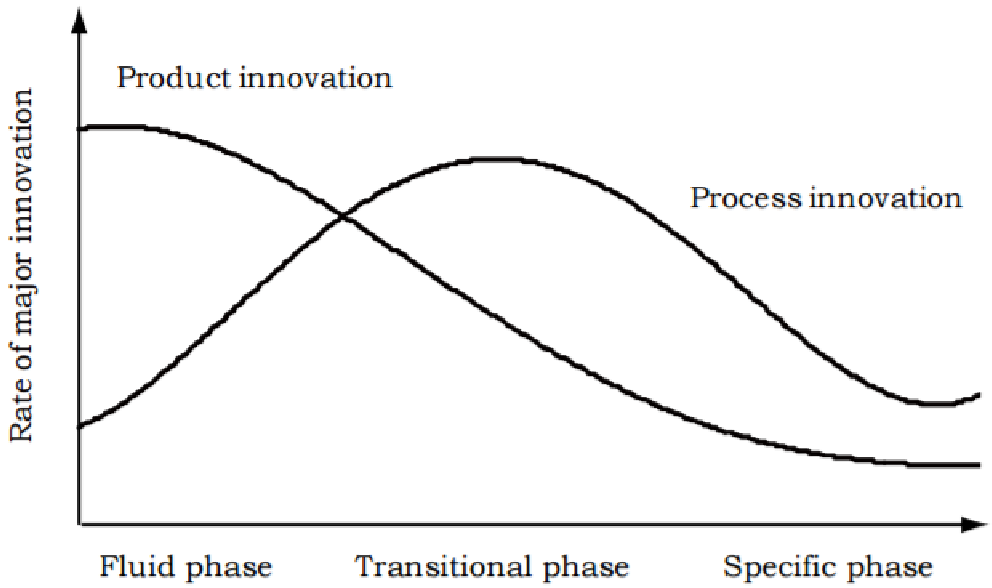


Figure 4.1: A-U model of product and process innovation[51]

Fluid Phase – The first phase is called fluid phase, where technological and market uncertainties dominate, there is a high number of changes that happen in a same time and outcomes can vary.

We can call it as an experimentation phase in the market. There are many product changes and radical innovations that are needed to shape the product. Highly skilled labor is a driver of a manufacturing process, in this phase is almost none process innovation. Competition between other companies is not yet at their highest, due to a fact that companies are not yet sure on a potential application for the specific innovation, or they are not sure about the future of the market.

There is a very low bargain power from a supplier, considering that there are no specialized materials used in the production yet. There is a danger in a sense from the old market and technology itself for the new entrance of new entrants, if this means that it could disrupt the current market.

At this point, a company can choose either of two strategies. The offensive move is to try to outmaneuver their competitors and make their product as the one with a dominant design. This move needs certain agreements with distributor and plenty of investments into a marketing in order to affect customers' perceptions.

Another move for a company can be to take over the complementary assets and wait until someone else will come up with a dominate design. In a point when this standard becomes clear, this company can use their competitive advantages all over the distribution channels, complementary technologies, additional services and supplier contracts to gain most of the profits. This whole process if very flexible but inefficient.

Transitional Phase

In transitional phase customer needs and it's technology application are more clear to producers so the process of standardization will finally emerge. Is common that in this phase the acceptance of the innovations tends to rise and the market starts growing as well.

In this phase, it can be very crucial to win the fight for the dominant design, since it enables the company to collect monopoly rents. Numerous Intellectual Property rights can be applied. In a case of Open source, the developers can build a complementary model or enhance some of the characteristics of the product.

The threat of new entrants in this phase is connected to the technology involved in the innovation. Companies will use tactics that could establish their product positioning on the market and eventually start upscaling the production and the process innovation.

Specific Phase

While in transitional phase companies focused on differentiation of their product, in next phase it's necessary to improve product performance and costs. There are clear sets of how the market segments look a like, so they will tend to focus on a certain customer.

Manufacture with highly specialized equipment will be on a rise, therefore certain pressure on a bargain between suppliers and companies will tend to increase. A competition will be more intense and after a certain time, the market moves towards oligopoly. Those companies who are conquering the market will secure their position thought improving supplier relations, distribution channels, adding extra services with a purpose to create entry barriers to new entrants.

According to Teece[53], there are two types of organizations; Product innovator and process imitators. Product innovators are the once who as a first commercialize the service or product on the market. Process imitators, on the other hand, are trying to imitate the dominant design of a service or product and label it as their own product. Surprisingly, imitators are usually the one who profit more than a first on market innovators. Later Teece showcases three areas that prevent imitators from stealing the developed product or service by Innovators.

Appropriability Regime

Is an innovation stage where Innovators can protect their idea by applying for Intellectual Property Rights (IPR) protection, known as patents. By protecting your own ideas and inventions organizations are capable of maintaining their dominant position. It's necessary to protect the ideas as early as possible, while legally applying for their rights.

Dominant Design Paradigm

Is a stage where organizations are trying to find the dominant design for their service or product. Competitive cycles of improvement are results of launching the product on the market where the competition can disassemble the product and understand what is special about the product. Then the competition launches their own very similar or improved product and the role of the Innovator is to respond to it by additional innovation. This process continues until one designs emerge as dominant design and outperform the other ones, by being the best in fulfilling the customer's needs. Teece also says that winning a dominant design is a matter of a few aspects such as collateral assets that are including brand image and marketing channels; government and regulations that are related to the industry. Also from a technological aspect, systems and infrastructure that are service related are worth to invest in.

Complementary Assets

Coming up with the greatest revolutionary product doesn't necessarily means a dominance on the market. Part of a successful execution is the ability to scale aggressively simultaneously in multiple areas of an organization. Starting from sales and marketing, customer service, human resources and continuing to other parts of company's structure.[52] Complementary assets help organizations to quickly commercialize their products on the market.[53][54]

4.2 Theory of Innovation

We can say that innovation is a broader concept that technology itself. It includes technology perspective, knowledge capital and knows how are mainly based on the gathering of human also knowledge capital. Technology is primarily based on an accumulation of physical capital. As on the other we can divide human capital into many forms, e.g., organizational learning, human resources, R&D investment, creative forms of research applications and trial and error learnings. Innovation in general, involves a development of the new products, new processes or new structural improvements of a product category. We can describe it in plenty of forms, but every time, innovation tends to reduce unit costs or/and to expand a market demand. Schumpeter's definition of Innovation as a central role is focused on speeding up capitalist development is too broad. He defines it as a shift of the production frontier, develops new processes or products and finally changes the market structure as it was before the innovation process.

Schumpeter recognize 5 types of innovation[55]:

A) Introduction of a new product or new version of an old product
B) Executing a new method of production or sales of a product
C) Creating an entirely new market
D) Finding new sources of supply – can be related to a material or the way how the product is made
E) Recreation of an existing industry by creating or destroying of a monopoly organization

Schumpeter is speaking highly about the innovation, saying that it's a survival requirement for an organization. If they want to be profitable, they have to innovate. He sees innovation as historical process of development where the old structure is changed by new processes, products, and services.

Once the dominant design of the product or service is defined and the unit profits margins becomes usually low, since the economy of scale and competition is driving the overall price low. At this point, any radical change in development can be costly. Because of that, companies with a well-established production of the product decide to rather incrementally innovate the product instead of its radical change. On the other hand, most of the new products don't seems to fit into this kind of incremental approach. New products tend to require organizational change with an impact on corporate goals, production change, mostly originate from outside of the company. The competitive advantage of the new product over its ancestor's version of the product brings a exceptional functional performance. [56]

4.2.1 Diffusion of Innovation

The goal for many innovations is to get widely adapted by community, as quickly as possible**.** According to Rogers [57] there are five separate adaptor groups that play a role in a process of adaption to an innovation or new technology. Those groups can be categorized by a time of how long it takes them to adapt to an innovation or new behavior. In order to reach the potential of the market companies should target those groups with different value propositions, techniques and time dimensions.

Classified them as Innovator, Early Adopters, Early Majority, Late Majority and Laggards. Each group has to be approached differently. While Innovators are a tech enthusiast and want to try out technology right in the beginning when it's on a market, they are even willing to pay for a high price that is not yet reduced after implemented economy of scope or until are the expenses for offering the service or product lowered. Young people and technology enthusiasts are most likely to adopt sharing of autonomous vehicles in an early stage. As they opposite Laggards will switch to a new technology as the last group and are really hard to convince, due to that they don’t like changes and are feeling comfortable by using the older technology or services. Until the circumstances allow them to keep the old product and use it, they will stick to it. [58]

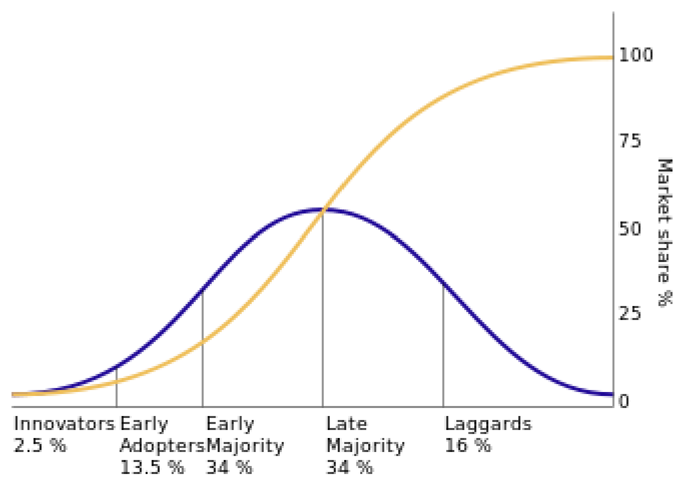


Figure 4.2: Roger’s diffusion of innovation curve [59]

Innovators will get the access to a new technology as a first once, they are risk takers and want to try the innovation almost immediately after they learn about it. Early adaptors also represent a small percentage of the community. They are trendsetters, who are really quick to adoption when its introduced by their innovative friends. Next adoption group is a Late Majority and Late Majority. Once those people see the innovation used by a people who they know and who they trust, they will begin to adapt the innovation by themselves. At this point the rate of adoption speeds up tremendously, steepening the slope of the curve. In order to reach to an entire community, innovation must hit the critical mass, this is the place on a curve where diffusion in a community begins to spread by its own. At this point, innovation is considered as a new and accepted social norm. Finally, once most of the people adopted an innovation, the S-curve flattens out and reaches the lagers, who are the most resistant to change, and in a certain case may never adapt the innovation.

Moore[60] argues that building a slightly better product will get the attention of innovators and early adopters, but the rest of the majority market will reject the better design unless it is marketed correctly. Moore call this process crossing the chasm, the point where the first two groups of Rogers theory graph are already on board with the product but the rest of the market [61]. This might give an advantage to a company that will be able to introduce the service as first and scale rapidly.

4.2.2 Drivers of Innovation - Market adoption

Market adoption of autonomous cars according to Roger's 5 characteristics of innovation. [62]

1.Relative advantage

Relative advantage applies to this technology due to its significant advantages and a huge difference when we compare autonomous cars with a normal car. With autonomous cars, people don't need to know how to drive vehicle, by reducing a risk of human error they are safer and more eco-friendly than usual cars.

2.Compatibility

Autonomous cars are able to operate and to adapt with our current existing infrastructure and roads. They are still consistent with actual experiences and values since people will use those vehicles as before, for transportation from one place to another.

But it carries a psychological barrier along the way. A certain sense of trust will have to be built if people have to allow sensors and AI to operate a vehicle on the road. It also brings juridical and ethical issues in case of accidents on the table.

3.Complexity

The ease of using this service is a must. In a case of autonomous cars and ride-hauling services, the whole process from ordering a ride until delivering a passenger to his destination have to be smooth and as much as easy for a customer as possible.

4.Trialability

In a sense of trialability, it doesn't exist yet for a majority of the population and will be probably very low when it released on the market. First, autonomous cars on the market are going to be rare and probably limited to a specific area of cities. Only a few people will have an access to try them out. Can mention nUtonomy that tested their autonomous cars around Singapore and people could test them.

5.Observability

As a matter of fact, it's quite hard to spot an autonomous car on streets due to a few cars out there. With all of the additional sensors, they can be quite well distinguished from the normal cars and they can spark the interest among the people, like Google street view cars.

4.3 Business Model

4.3.1 Definition

For an extended period of time, the business model concept had no clear definition. Over the time numerous of authors tried to defined the BM. Petrovic describes BM as a certain logic of a business system, behind the process that is resulting into a creating a value [63]. Rappa further elaborates that BM explains how the organization is making a profit and how is the company positioned in the value chain[64]. Osterwalder continues with the description, that BM is a conceptual tool, that describe the connection between a list of interconnected elements. This allow us to understand the logic of how the organization is operating in the background and what value it offers to a segment of customers [65].

"A business model describes the rationale of how an organization creates, delivers and captures value" [66]

4.3.2 Business model Canvas

The business model canvas is a strategic management tool, which helps companies to sketch or further develop new or existing business models. It contains nine blocks that are preformatted in a visual template. For our purposes individual block of BMC will be presented and explained to better understand the key elements related to BM. [67]

Nine Blocks of BMC:

<u>Key Activities</u>: Section describers the key activities that are necessary to execute at a company in order to make business model working. Key activities can be identified as Production, Platform/network, Problem-solving. In a production category, the company has to determine on design, production in a certain quantity and quality of product or service.

<u>Key Resources</u>: This block describes all the resources and assets that are needed in order to create value and business model work for the customer. For every business model its essential to exactly determine a key resource. From those resources organization, can create a value proposition, attack the markets, acquire and retain customers and profit. Key resources can represent Physical, financial, intellectual, financial or human.

<u>Partner Network</u>: This block describes the business alliances, a network of suppliers and partners which complement other aspects of the BM. There can be plenty of reasons why companies forge partnerships. Either because of reducing risk, raising their competitive advantage, acquire resources or to improve BM

performance. There can forge strategic partnerships with non-competitors. Or strategically alliance with competitors for mutual benefits. The economy of scale is one of the reasons why companies and organizations form strategical partnerships. They are performed in order to reduce the cost, while company outsources some of the product or service related processes to other company. Well formed partnerships can result in reduction of risk and uncertainty in a competitive environment. Taking over specific resources and activities can reduce cost and time for a company. By acquiring an intellectual property or buying a specific service, instead of building their own in-house solution.

Value Proposition: The value proposition represents a series of services and products that create a business offer and value for a customer segment. Value proposition has the power to change customers behavior by switching or favoring one company over another. In a core, it should solve customer problems, improve their struggles or satisfy their needs. It contains a package of services or products that are targeted towards a specific customer segment. Those values can be qualitative, such as price, performance or speed of service. Or qualitative, such as customer experience, customization or design. Value proposition can be similar to existing market, while they can bring some extra features that are differentiating the product or a service from existing one, or they can be innovative, with potential to disrupt the existing market or create a new specific segment of market.

Customer Segments: Defines different groups of organizations or people in order to determine the target audience that aims for a fit of products and services. Customer represents the key element of any business model. In order to bring a revenue into a company, he should be able to bring profit. But each customer can have a different expectation and is satisfied in a different way. In that case company, can segment them into individual groups and approach and target those groups individually. It's essential for a company to decide which segment to pick and serve them and which segment to ignore. Once this step is done, they can focus on a design the business model around this specific group of customers.

Channels: The means by which a company communicates and delivers products and services to customer segments and deliver a value proposition. include communication, distribution. They are fundamental for raising awareness among the customer segment about the services and products that the company offers. They can help a customer to evaluate the proposed value definition. After the purchase, it provides a customer support. Channels have five phases, where it starts by raising Awareness of company's services and product. Followed by Evaluation where a company is trying to determine whether they help customers to evaluate the value proposition. After that, phase Purchase is describing how organization allows customers to buy a service or product. The product has to be delivered and after sales organization have to offer a customer support.

Customer Relationship: The links an organization create between itself and its customer segments. The organization has to determine the type of relationship they want to establish between different customer segment. It can be varied from personal to automated contact. There is a certain driver for maintaining customer relationship such as customer acquisition, retention or boosting sales of the company. When there is a new market, companies can apply aggressive acquisition strategies, that can present huge free giveaways or some other actions by which they can attract the customer. When the market become saturated, they switch from customer acquisition to customer retention, with a strong focus to increase a revenue per customer.

Cost Structure: This block represents the most important costs related to a business model. Basically, the cost of the product or service should be minimized in every BM. There is many different cost structures: Cost-driven, Fixed Costs, Value Driven, variable costs, economies of scale or scope.

Revenue Streams: Revenue streams block represents the way an organization makes money through various revenue flow. Cost have to be subtracted in order to calculate the profit. The company can determine a value of a customer and how much are they willing to invest in order to acquire him. Each revenue stream and have specific pricing structures. There are a few ways of how to generate a revenue. Most used one is Asset sale where companies sell ownership rights to a specific product. Usage fee, a customer pays accordingly the tariff specific to service of the product. Subscription fee, selling of monthly or yearly subscriptions to customers, this generate a stable continues revenue stream. Lending/Renting/Leasing, Revenue stream is created by giving to a customer a right to use a specific product or service for a pre-determined time. A customer is paying for this opportunity back to a company. It brings a value to customers since they don't have to own and buy the product when they don't need to use it that often, or when it reduce their expenses, time or extra workload with maintenance. Licensing, the revenue stream is generated by giving a customer exclusive right and permission to use an intellectual property that is protected, in return for licensing fees. Pricing mechanisms can be divided into fixed pricing and dynamic pricing. In a transportation service, taxi drivers have fixed pricing that is calculated per km, while Uber is using surge pricing during the peak times when the demand for transportation is high and there are not enough drivers that can deliver the service.

4.3.3 Dominant Business model design and Customer Bonding

Execution of customer bonding is a driving force on a market today. Competing on a product-centric level such as price, quality, features, etc. are pretty basic techniques of how to attract a client but insufficient to lock-in customer relationship. If a competition grabs those forces and uses it to their market advantage, a customer can quickly adapt and change allegiance. Creating bonds that prevent their customers from switching between a competition or at least reduce this number can be a great driver for a business and greater margins. This can be done by customizing their offerings.

The bonding process is a continuum, as it tends to extend from the first loyalty that a customer feels towards a service or a product and leads to a full lock-in, from where customer have a tough time if he wants to switch to a competitor.

Through this section, four stages in the bonding continuum will be presented. In general, a successful best product strategy should result in a dominant design. Absolute complex customer solutions maintain a customer lock-in, strong relationships with a distribution or channels and intellectual properties in a sense of patents create a strong competitive lock-out that creates barriers for a new entrant into a market. Competitive lock-out and System lock-in go hand in hand.[68]

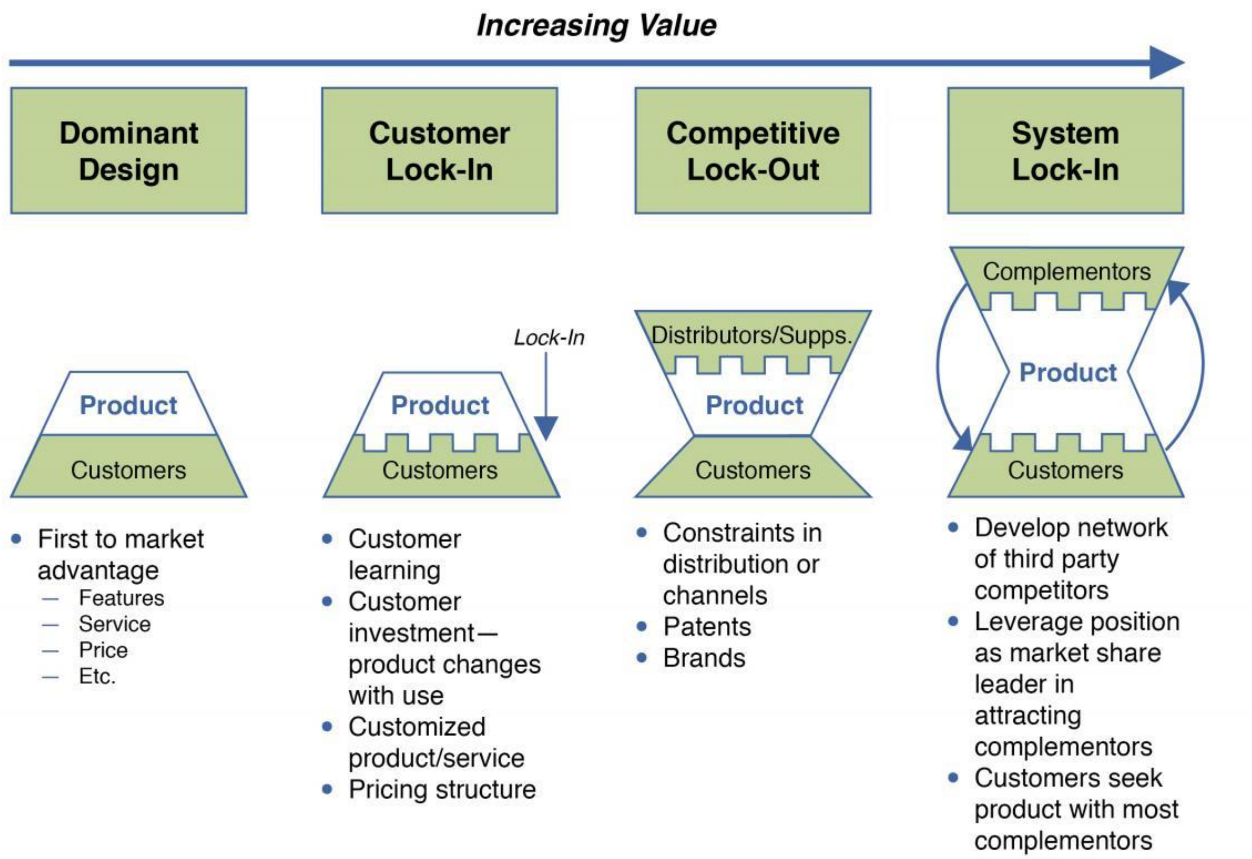


Figure 4.3: Four stages in the bonding continuum [69]

In a first stage, customers are highly attracted to a service or a product due to its intrinsic value. This can be lower price of the service or product, but can also represent a different set of features and extra services that are closely related to a product. Usually, there is a lot of experimentation and R&D made before presenting a dominant design. But building a product in a "basement" and then launching can be a risky strategy.

The competitor who is able to create such a design captures has a significant advantage to be a first mover and to gain an element of product loyalty. Even though this is a big advantage to take over the market, it can be costly to penetrate the market firstly. Then for the new entry movers market is already prepared for such a product and offering new or superior attributes can play a big role in attracting clients that were loyal to a competitor.

4.3.3.2 Customer Lock-In

Customer Lock-in is the next step in bonding. Process where customers are initially attracted to the service or product do to its competitive advantages and attributes, but even though they maintain to be loyal to a previous company due to a different externality that have been created while they were using their service or product.

The point is to create a switching barriers for a customer that make it harder for him to switch to a competitor due to a switching cost. Switching cost can represent money, time or other resources.

4.3.3.3 Competitive Lock-Out

Next step in bonding is to lock out the competitor on market. In this step, the company creates such a barrier for a new entry movers that will cost them significant effort and resources in order to penetrate the market and compete with them.

There can be a danger to create a monopoly in this essence since companies that rule the market can create such a strong force that destroy equal condition for a competition on market. There are numerous ways how to achieve this, this section will mention few of them.[70] The ability of brands to drive their own demand. Intellectual property – patents. Restricted access to physical distribution channels.

4.3.3.4 System Lock-in – Proprietary Standards

Proprietary standards reach to an extreme of the bonding continuum. This is the stage where every company would wish to find themselves. But there are significant rewards for achieving and maintain this point and this position. It doesn't have to be a rule that all industries offer such an opportunity to create standards like this. Even in case they do, it might not be possible to have them proprietary.

Creating a self-reinforcing feedback loop that is mentioned in Dominant design is a must since a company has to make complementary to adopt its standards.

4.4 Sharing economy

Sharing has always existed before, but an improvement of technology offered new a new platform.
After a diffusion of world wide web from the mid-90s, the rise of internet-based platforms was significant and some of them were enormously successful. Tech giants as eBay & Amazon – dominant marketplaces or service providers as Uber – transportation or Airbnb – accommodation. Term sharing include many forms of activities. We can divide them into non-commercial and commercial.
ownership has long been fundamental principal, essential creed of Western culture.

4.4.1 Capital

Erin Griffith claims that without a capital, many sharing economy platforms wouldn't grow in such a size as we know them nowadays. They can use money to offer more effective services than their competition that is non-profit and that's how they often outgrew them.[71] Uber raised over $11.56B thought 15 funding rounds in order to massively strengthen their position in a market. Over 77 investors contribute in those 15 rounds.

4.4.2 Timing

One of the triggers of sharing economy was economic crisis from 2008 when plenty of people lost their jobs and needed to find other ways to get an income. This helps to create positive conditions for acceptance of sharing of products and services and create a momentum. But there are other reasons why it's more appealing to customers nowadays, such as low cost, efficiency or new income opportunities. There are certain assumptions that collaborative consumption will continue to grow even after our economy will be fully recovered and stable [72].

4.4.3 Transaction cost theory

Is playing its role, due to a fact that the digital platforms enable to decrease transaction costs. Without the digital platforms, the transaction cost of contacting and searching would be much higher. Internet-based platforms are able to significantly reduce the transaction cost between the provides and customer.

Such an examples can be on-demand transportation company Uber. Platforms that provide lowering of transaction cost create either two-sided markets or create multi-sided platforms.

4.4.4 Collaborative consumption

A big shift that happened between 20th and 21st century when that period was called hyper-consumption we switched to an age of Collaborative Consumption. The fact is that it reinvents not just what we consume but also how we consume. Collaborative consumption is a showcase of wow using technology enable trust between strangers and helped to reinvent the public services. The inherent efficiency of the internet cost consciousness and importance of community has created an unbound marketplace, where are the producer, lender, borrower, and customer meeting up and create exchanges.

Collaborative consumption helps people to realize the great benefits of access to products and services over ownership, while they profit economically, save space, time, meet a new people and become active citizens. [73]

4.4.5 Internet-based platforms

With the rise of popularity of internet different types of new internet-based business models were created. E-commerce sites transform the rock based business into online stores and changes the way how consumers purchase goods.

5.Analysis

In this chapter, the study is combining the knowledge from the theory section with the data gathered from the empirical sources, and other materials in order to clarify the stated research objectives.

Further, the paper is analyzing the dominant design of autonomous ride-hailing services by observing the patterns in a current formation of partnerships between numerous key stakeholders. It explains how the redistribution of the power could be formed between OEMs, tech companies, and ride-hailing companies on a possible future scenario. It explains the role of a sharing economy in forming of a new transportation market. Berlin's case study brings plenty of insights that we need to when a fleet of ATs should replace the trips made by a conventional vehicle in a city. Then Navigant's research case study is ranking the current leaders in the development of autonomous vehicles according to a selected criteria related to the strategy and execution advancement. This helps us to identify from a long list of AVs developers once that are most relevant, and explore their future chances to dominate the market. In the end of the chapter, three main possible autonomous ride-hailing providers are compared on a set of selected criteria and evaluated their characteristics.

5.1 Dominant design

5.1.1 Dominat product design of a AVs

Will autonomous cars adjust to us, instead of us adjusting to them? Until nowadays carmakers used to design cars for individual drivers and families, but definitely not for a group of strangers. This could point towards a certain problem, and it actually already did. Just the tension that Uber caused when transformed personal rides into a public transport. Users that shared the rides with strangers experienced a lack of privacy and there have been plenty of driver mix-up for another. The presence of self-driving cars will have an influence on user interfaces and social norms that have to merge. Our society will need new kind of car after ride-sharing becomes more popular and self-driving cars more capable. This will influence a dominant design of our vehicles. [74]

A company called Ideo decided to develop a new project called Future of Automobility, where they are challenging a status quo and a current dominant design is put under an experiment. They created a vision for a future vehicle where ridesharing and autonomy will dominate. They decided to place the vehicle in a middle of a marketplace, where owners of self-driving cars can decide between private use, ride sharing and carpooling. The point is that owner car decides whether he want to ride solo alone or share the cost of the ride with other, simply by picking up riders along the way. The third option would be to actually rent their vehicle to others, during the time when they don't need or occupy it. Riders can also reduce the price of their trip by going errands for the owner.

Ideo tried to provoke car manufacturer to think about the notion of designed interiors of vehicles that will be used for sharing, when once a private vehicle becomes a public resource.

"We can imagine a world in a not-too-distant future where transportation becomes a utility." Daniela Rus [75]

Their model of the futuristic minivan with a glassy four seats designed a vehicle to shuttle riders that might or don't know each other. Riders can simply book a seat in advance and either choose a private mode where they have the vehicle just for themselves or for a social mode, where they share the vehicle with other riders. Plenty of features like noise cancellation when people that carpool doesn't want to be bothered by other riders. Or social mode can trigger acoustic enhancements that can help the riders to hear each other. They also played with an idea to enhance privacy for each individual rider by extra seat functions for a discrete environment.

Beyond privacy, Ideo worked on ways how to improve the riding experience further on. They designed the doors that would open and close automatically, in order to make it easier for passengers to get in and off the vehicle. Additional lighting beneath each seat, ensure that riders won't forget their belongings during the get off. Additional panel screen on the front and back side of vehicle display riders necessary information during pickup. This makes it easier for riders to find an unfamiliar car. This kind of ride-sharing or carpooling eclipse wont happened soon.

"*You may not see this happen overnight, but you'll definitely see gradual progression toward some of the things we're provoking*" Stillion [76]

Ideo tried to provoke the current state of dominant design of vehicles. They also played with an idea of driverless delivery services that can bring a host of riches to a customer's door. What if the workplace could come to riders instead of the other way around? It's an idealistic vision of the future. Car manufacturers should take into consideration a shift from a private ownership in a future and should think about possible future realities. Car manufacturers will have to take into consideration inside-vehicle experience, that will be part of autonomous ride sharing services.

5.1.2 Dominant Business model design

We tend to associate an industry's transformation tied with the adoption of a new technology. But even though that those new technologies play an important role, they never transformed an industry by itself. The key element that can link this new technology with an emerging market need is a business model. In any chosen industry, a dominant business model uses to emerge over the time flow. If we don't encounter market distortions, the model will mostly represent the most efficient way to allocate and position resources. Most of the times, companies and startups that are introducing a new model fail. There are only a few cases when they succeed, usually by perking the dominant business model or leveraging a new technology. [77]

Nowadays known unicorns were able to raise the number of their customers from a thousand to millions in a very short period of time. this allowed them to scale the company very fast.

"It took thirty-eight years before 50 million people gained access to radios. It took television thirteen years to earn an audience that size. It took Instagram a year and a half" Gary Vaynerchuk [78]

Another great example of a company that scaled their business rapidly is Airbnb that succeed to disrupt the hotel industry. Airbnb's platform provides more rooms than any international hotel chain around the globe, yet they don't own or manage a single property by themselves. They allow users to register and rent out their abundant rooms or apartments thought their online platform that matches their customers who are looking for accommodation. Airbnb manages the software platform and eventually charges for the service on a commission based pricing. Their operational cost is much lower since the internet dropped the cost of demand generation and the cost of supply exponentially. It allows them to scale up exponentially. If the company is able to drop the price of supply, their business explodes. They are not dependent on physical ownership or managing of the asset, this allows them to expand extremely fast.

Before the existence of Uber's platform that revolutionized on-demand transportation system, there was no need to change the taxi business. But straight after its introduction, the former dominant business model became highly vulnerable, for anyone who could use and leverage that technology in order to create a more interesting value proposition for customers. Now, Uber's new BM serves as the interface between what technology enables and what the market demands.

Right now, we are still before the knee of the curve, where the technology is being developed by a small steps. It seems deceptive because the technology is not yet ready to be released to public usage so the business models did not form yet. Deceptive growth is a period when the growth is slow, things change but we don’t feel the difference yet. Then a phase of disruptive exploding growth follows, technology become cheaper, faster and more precise.

Acquiring a dominant position on a market goes hand in a hand with a dominating the business model design. In this case, companies that are involved will fight for the whole dominant business model in order to have the biggest share of the market. The dominant business model doesn’t have to be the best on the market. Aggressive execution of BM can result into dominating the market even though the that the dominant design is not ideal. Competition nowadays is not between a products or services but often between business models. It’s normal that companies that are dominating the market are the ones who planed and execute better their BM. When we look at the different competitors, the one with more compelling, distinct and effective BM are usually the one on the top of it.

People don’t want to own things; they prefer to pay for solutions that have the potential to enrich their lives. The solution-based business models work because they offer a service or a product that people really want.

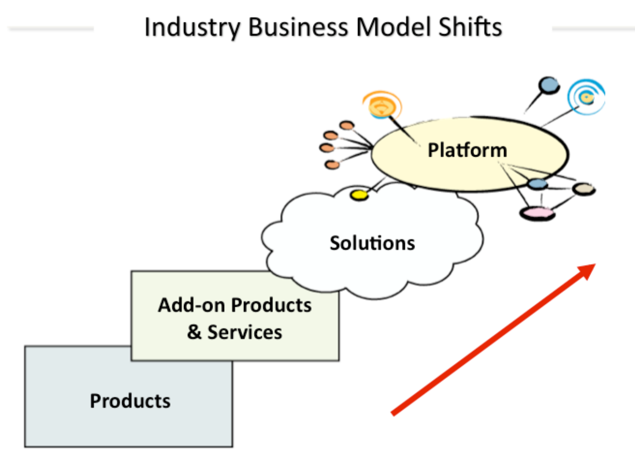


Figure 5.1: industry BM shifts [124]

On figure 5.1 is a journey of how industry evolution tends to evolve. Companies are not focusing that much on a product itself but on a whole solution based BM. And platforms are on top of it, with a potential to enhance it extremely. In the best scenario, it creates a virtuous cycle of exponential growth.

"In any given industry, a dominant business model tends to emerge over time. In the absence of market distortions, the model will reflect the most efficient way to allocate and organize resources. Most attempts to introduce a new model fail—but occasionally one succeeds in overturning the dominant model, usually by leveraging a new technology. If new entrants use the model to displace incumbents, or if competitors adopt it, then the industry has been transformed." [79]

5.2 Sharing Economy

In this subchapter, we will discuss what role is sharing economy playing in a world where autonomous vehicles are commercially accessible? Buying a car is probably largest or second largest investment in our lives, depending on whether we own an estate property or not. In the future, people will tend to rather buy mobility than cars. This is due to a fact that our cars are unused more than a 96% of the time during a day. But how do we get from personally owned mobility to a shared autonomy? This process will be explained bellow in a figure where are mentioned four phases

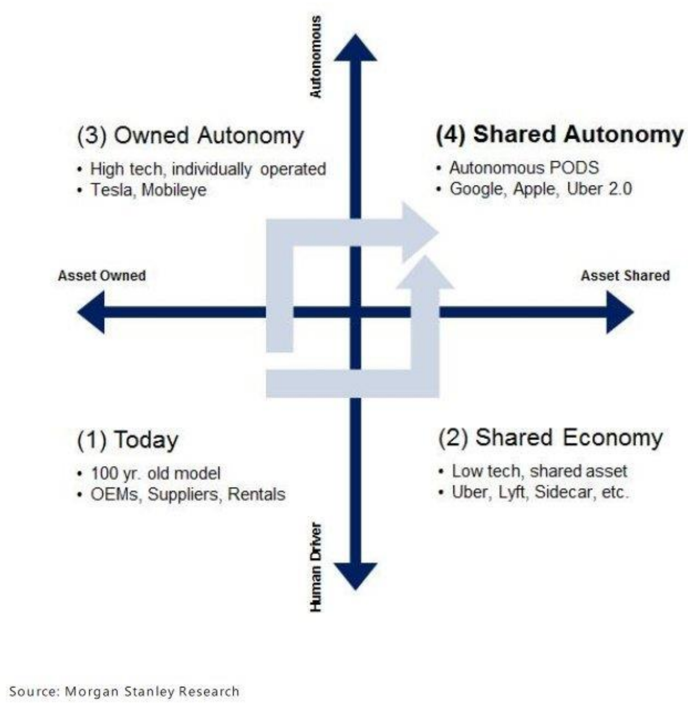


Figure 5.2: The Four Stages of Mobility [80]

1. Today we still have 100 years old model of ownership, where people physically own vehicles. For most of the people, cars are their second biggest investment in their whole life, after buying a real estate property. The problem is not that they own the car, it's that they are not using it 96% of the time during the day. The car is parked in front of their house, or in front of their office. Causing need for extra parking spot/ garage in their house or on the street. Sharing economy is addressing this problem, with a solution to compensate ownership with renting.

2. Shared Economy- Is a phase where a low-tech company shares the asset. TaSS-Transportation as a Service is introduced. One of a few examples can be Uber, Lyft, Car2Go, where car represent a shared resource where customers pay for its usage.

3. Owned Autonomy – Is a phase where a high-tech company introduces fully autonomous vehicles commercially on a market. People still tend to buy and own vehicle, they accepted the new technology but still prefer to have their own.

This can lower the number of vehicle per family, while some of the households own 2-3 cars, some of them will reduce this number due to a fact that more family members can share the car in between.

Yet, a new business model is introduced where owners of such a vehicle can set their car free and release it during the time when they are not using and make a profit. The car can meanwhile operate on streets and transport people or goods. This means, that owners can make a money while they are not using the car at all.

This services will be operated through online platforms individually. Such an example can be Tesla's master plan, where they want to allow the owners of Tesla cars to put their vehicles onto a platform during hours when they don't use the vehicle. Tesla wants to operate their own platform for that, purely only with Tesla cars. Tesla owner won't be able to release their car to a competitors platform. During the peak hours, Tesla could release their own fleet of autonomous cars in order to withstand demand.

Examples: Tesla, MobiEye, Dalmier

4. Shared Autonomy –This is a final stage where autonomous cars are not owned by an individual's but represent the world where the cars are owned by a company or institution and people can order a transportation on demand from the company. Probably whole design of the car will change and adjust to a service. Autonomous pods will be presented, some of the cars could have an extra storage for

transporting the goods and operate in a multitasking mode when they transport people, goods or combination.

Examples: Google car, Uber 2.0, Lutz Pathfinder

5.3 The role of OEM and Tech companies in stake

OEMs have currently very strong position in an automotive market, with a powerful negotiation position. But AV their influence will change. With greater complex and diversified mobility market, incumbent companies will have to in the same time compete on many playgrounds and eventually be forced to cooperate with their competitors. This paradigm shifts to mobility as a service, brings new kind of stakeholders to

the automotive market. OEMs will have to compete with them on a numerous case. Tech companies as Apple and Google with Mobility providers Lyft, Uber, Zipcar, Didi Kuaidi, and emerging OEMs Tesla and BYD, enormously increase the competitively on an automotive market.

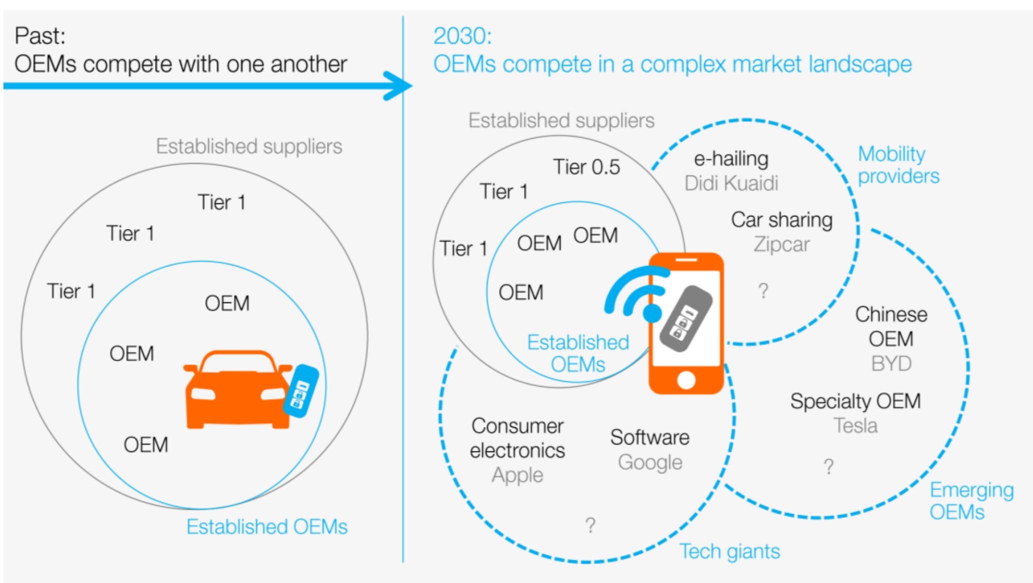


Figure 5.3. Old and new model of stakeholders in automotive industry [81]

Nowadays OEMs compete one with another, on their geographical marketplaces, in new markets current suppliers progressively catch a bigger part of the car's overall value. Emerging manufacturers will try to capture a share of new car sales. When Tier 0.5 will shift to offer other complete vehicle sub-systems, they will be able to create their own connections with the customer and additionally seize the mobility aftersales. OEMs are already under a big pressure to drive the cost of the vehicles lower while compromising the material and improving the efficiency of assembly lines. After this move, their position will be even tougher. Evolving new automotive and mobility industries will force to shift current market positions that could lead to a consolidation where incumbent players will form new forms of partnerships.

The fact is that software competence will become inherently important in a new automotive and mobility industries.

Tailored software will offer a wide spectrum of features and services ranging from special mobility services advanced safety to location-based services. Partnerships between technology and service providers will flourish and help to grow the customer base. With additional services and features, those partnerships will reduce the cost that is related to increased value for the end user. Emerging new mobility ecosystems will be outcomes of technological and consumer trends. Those ecosystems will push OEMs to continually integrate their vehicles into a cloud system. What put OEMs into a vulnerable position, since OEMs would prefer to profit from AVs connectivity as much as possible and prevent AVs from becoming commoditized content platform.

As markets are forming in this early stage it seems that new entrants are only focusing on economically efficient segments and activities across the whole value chain until they will have enough power to expand into another segment.

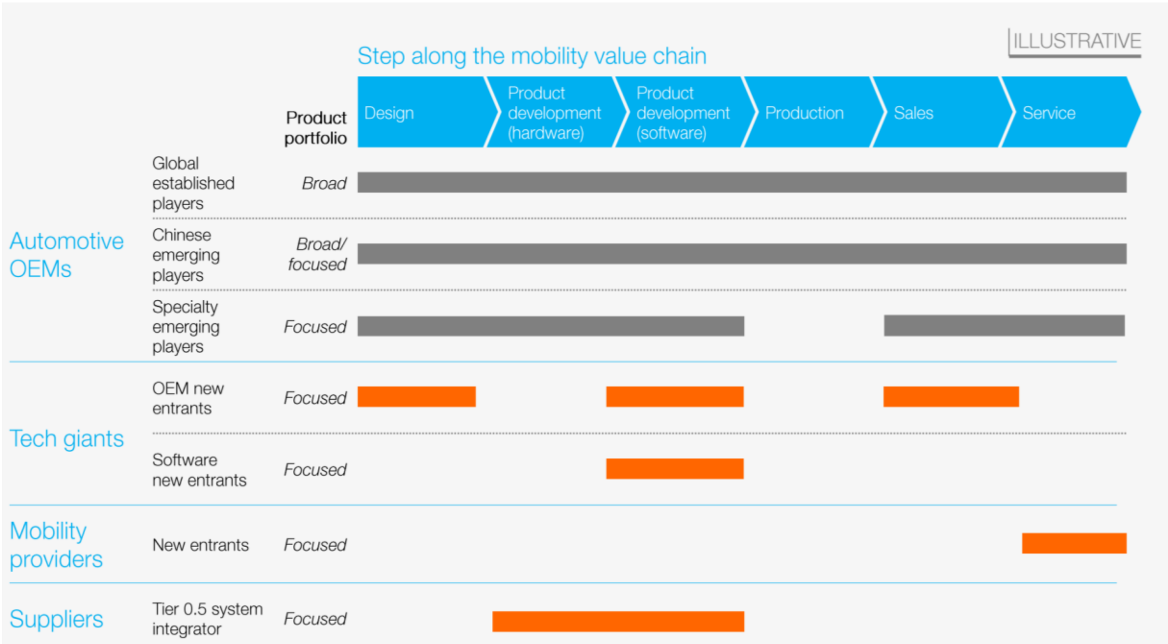


Figure 5.4: AV mobility value chain [81]

New players will in the begging focus only on certain segments of the mobility value chain, that are profitable attractive for them. Tech companies as Tesla, Lyft, Uber that are becoming more and more involved with AV mobility markets. This seems like just a begging, more startup companies that are creating enterprises under a tremendous amount of risk with possible enormous rewards will join as well. Companies with huge amount of capital would probably join this competitive war zone as well and will go for their own piece of a market share.

It seems that with an emergence of unusual revenue channels, mobility ownership value chain will be disrupted. Automotive incumbents are not able to predict the future of the automotive industry with precision. Yet, they can actively make strategic moves and be part of the automotive industry revolution. They have to put themselves out of the traditional mobility value chain before someone else will put them out of the business. This happened a couple of times before when the specific industry faced exponential innovations and top tech companies rather decided to stick with the old value chain model, instead of adjusting to a new emerging markets.

Total revenues generated by personal mobility will exponentially rise by 2030. Automotive OEMs will have to gain the profit from a multiple sources and not only by selling the vehicles. Automotive incumbents can do so by implementing an strategic approach towards new automotive value chain models, where they can profit from dense populated cities and recurring. Another profit stream could be capturing a post-sale revenue, by offering additional services or profitable partnerships. With a commercial spread of AVs in 2030, OEMs should prepare for uncertainty and proactively adjust to market trends sooner. [82]

5.3.1 Scenarios

Within a next decade with the upcoming rise of autonomy, numerous new stakeholders will compete with each other to take the piece of the automotive market. Rebalance of power will be necessary. Who and what kind of stakeholder will, in the end, serve the end user could further define the power dynamics in the change of roles.

In a very close sense of stakeholders, we will discuss three different players in the market.

Traditional OEMs, tech companies - 3rd party providers and Mobility on demand service providers. They will play their role in following future scenarios, yet undefined in a what extent.

First, there are two different ownership situations (A and B options), that are dividing the 6 different scenarios:

A) <u>Personal vehicle ownership</u> – In this case, self-driving capabilities and AI would become the only parameters that would define the power balance between Traditional OEM and tech giants that developed the self-driving AI. Cars will maintain their position as a personally owned possession and won't be shared. Within this first category, two scenarios can occur:

Scenario A1 – Business as usual

Traditional OEMs and suppliers will maintain their position through almost the whole value chain. They will be able to compete against the tech rivals, develop the AI unit by themselves, then produce the autonomous vehicles and sell it to their customers. They will hold their strong position as nowadays

Scenario A2 – Power to the tech rivals

3rd party technology rivals will develop the AI systems and will leverage their position against the OEMs and suppliers that will be forced to license the technology. This will keep OEMs closely dependent on tech rivals and won't be able to capture the majority of the profit. On the other hand 3rd party tech rivals will be highly profitable in this situation.

B) **<u>Mobility-on-demand</u>** – Car will become a shared resource, for either car-sharing, carpooling or ride-hailing transportation services

Scenario B1 - Business as usual

The ideal scenario for OEMs, when they develop AI technology by themselves, produce AVs in their factories and dominate autonomous mobility-on-demand services. It that sense, OEMs could continue to leverage their brand value and keep the retention of their customers by providing them an transportation services. OEMs would maintain their powerful position and current automotive BM wouldn't be changed that much significantly.

Scenario B2 - Power to the tech rivals

In this scenario, OEMs dominate the autonomous mobility-on-demand services but tech giants would strengthen their position by leveraging their AI systems and would license the technology to OEMs. OEMs profit margin would be under tremendous amount of pressure, because they will be highly dependent on a few AI technological suppliers.

Scenario B3 – Fleet business 2.0

Ride-hailing companies would dominate the market with mobility services, while OEMs would dominate the AI technology development and vehicle production. In this scenario, OEMs would sell their fleet of AVs directly to ride-hailing companies. In this sense, both sides would be highly dependable on each other and further power reconsideration will have to be negotiated. Due to a fact that most of the vehicles will be sold B2B, directly to ride-hailing companies, OEMs could safe sales and marketing expenses, related to a current BM of OEMs. This could leave OEMs in a good position with positive net outcomes, even if AVs prices are lower. Ride-hailing companies could, on the other hand, get a big discount for buying vehicles on contract in a huge amount.

Lower prices could eventually have a positive impact on an end-user and the mobility prices.

Scenario B4 – OEMs become tier 1S

Possibly the worst scenario for OEMs. Ride-hailing companies would dominate the autonomous on-demand transportation services, while tech giants would have the AI technology for AVs. It that case traditional OEMs would become contract manufacturers for mobility providers. In this case, the largest profit margin would go to tech giants, where they act as a mediator between the car manufacturers and mobility providers.

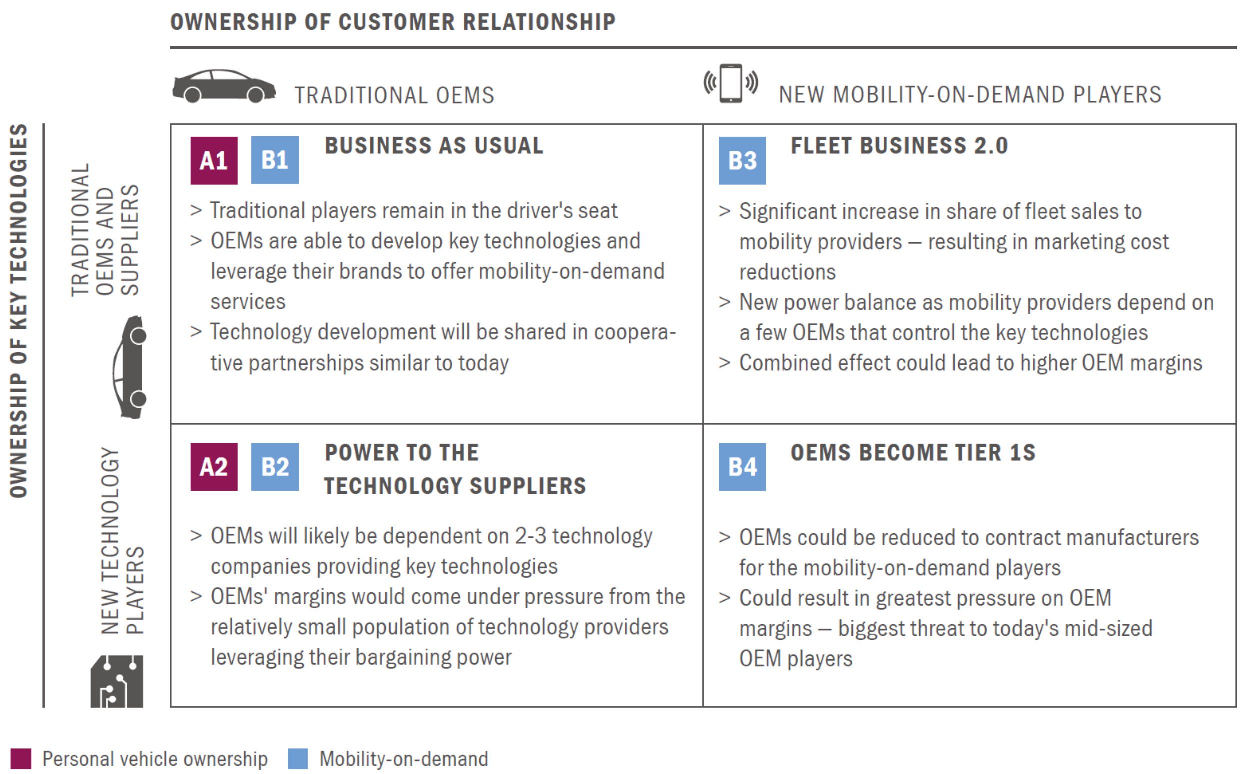


Figure 5.5: End game scenarios based on ownership [82]

Globally, OEMs will have to define their position in a autonomous world in a following years. McKinsey study identified following four strategic approaches that OEMs can choose to follow[83].

Premium incumbents – They already have significant experience in the automotive industry and have sufficient customer base that they could use as a target group. They have strong both, technical and commercial side at the same time. This group currently represents OEMs leaders in the development of AVs. They will probably gradually introduce the autonomous Levels in order and small incremental steps, instead of sudden introduction of Level 4 or Level 5 autonomy vehicles.

Attackers – Mostly consisted of big high-tech giants, as Google, Apple or Uber. Their primarily focus will be to use AVs for on-demand transportation. Their interest is to capture the dominant place in new business models and geographically scale the service quickly.

Fast followers – They don't want to put tremendous effort and resources right now into a development of AVs and will prefer to wait for their competition to develop the technology and drive the price of technology down.

Late entrants – This group has no current interest in developing their own technology right now. By doing so they are risking to put themselves out of the business. In the future, they will have the chance to buy the licenses and know-how from the companies who will be interested in making a profit by selling the technology to other players.

5.4 Case studies

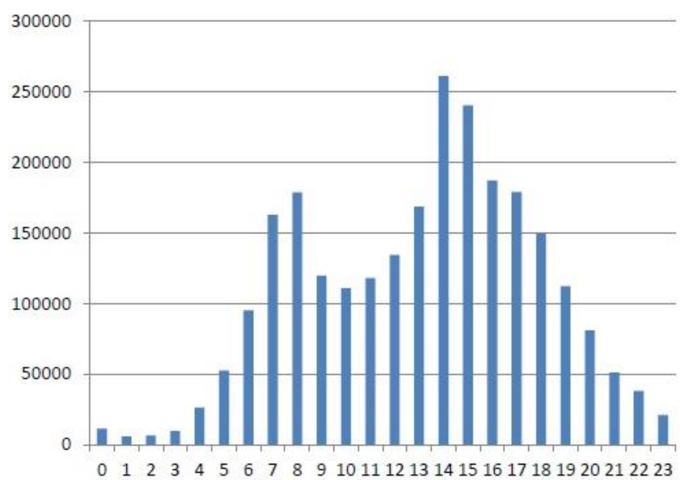
5.4.1 Simulation of city-wide replacement of private cars with autonomous taxis in Berlin

In this case study Department of Transport Systems Planning and Transport Telematics, TU Berlin simulates a city-wide replacement of privately owned cars with a fleet of autonomous cars of different sizes. This model simulates demand for private car trips in Berlin and serving all of the internal private car trips by autonomous cars.

Research is pointing out that due to a continuous development of AV it's just a matter of time when commercial autonomous taxi services will arise. After a successful adoption of this service, the state of driving and owning a car will eventually fade away. This will result in a complete replacement of conventional driven vehicles with autonomous taxis. One of the reasons why AT could replace CDV is their cost efficiency, where cost per driven km could be below 0.10$. In addition, the price could go much further lower in a case of using AT for carpooling. Due to a fact that those vehicles would have high annual mileages, it seems convenient that AT will be electric. This could eventually lead up the decline of greenhouse gas emissions per km by up to 94%. While the simulation study in Lisbon shows that one AT could replace ten CDV in a case of using them for AT carpooling services, it's only six vehicles in case of individual rides.[84]

The process of simulations carries out a precise simulation of a regular weekday in Berlin, without any special high traffic event such as can be huge music festival or sports match. Simulation is taken in MATSim open-source software, that allows a microscopic simulation of agent behavior operating at high processing speeds. This means that the software is properly equipped for simulation of large-scale scenarios. Simulation combines a traffic-flow scenario with a special scoring model for agents and algorithms that can plan the daily routes of agents. The system contains around 98 000 road links, 37 000 nodes, and public transit links. Thus, a system can use all main and minor roads, specifically to some city boundaries.

During this simulation only the car trips were included, all of the non-car trips from initial scenario haven't been used. Also, all of the external trips were excluded from the simulation. In total, 2.5 million trips have been used for a simulation of AT. Those rides were before covered with 1.1 million private cars and during the simulation, they have been replaced with a fleet of AT.



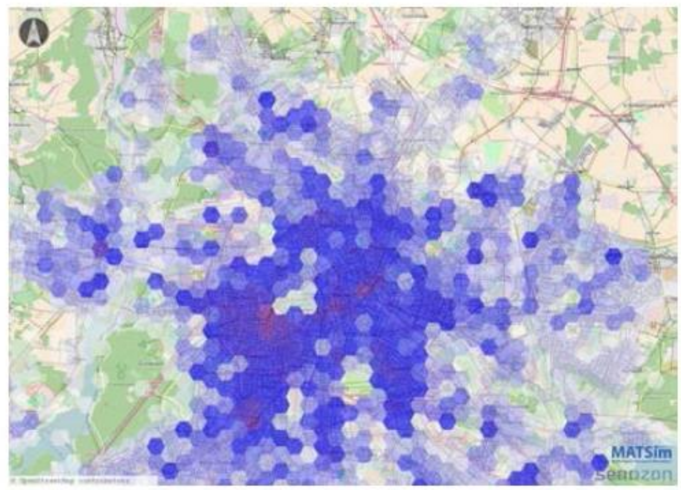


Fig. 5.6: Hourly demand for AT trips during the day

Fig. 5.7: Locations of AT trip origins [84]

Figure 5.6 represents hourly demand for AT trips along the typical workday at Berlin. Morning spike at 7 and 8 is mainly caused by work and school commuters. Followed by a small fall during a midday. Hours around afternoon 14 and 15 o'clock are critical to a fleet AT, where peak hour will fully test size and efficiency of the service.

Figure 5.7 show overall origins of the simulated trips, during the day in most of the areas there was an almost identical share of incoming and outgoing trips. With a bit less dense within suburban areas.

Simulation of AT dispatching was enabled with MATSims Dynamic Vehicle Routing Problem extension, that supports simulation of on-demand transport services used for an AT fleet. The whole process is held by a dispatcher who reacts towards a sent status. This can be a new ride request, AT arrival or departure. A dispatcher then dynamically re-optimize ATs' routes and schedules in a most efficient way.

Conventional taxis serve on a FIFO – First in First out basis rule, what sounds fine since the demand for conventional taxis is quite low compared with a size of the fleet. This rule is truly inefficient during a high demand peak times when all the taxis are busy. In case that one the taxis turn to idle, it will be automatically assigned to a rider who was waiting the longest time, no matter the distance between them. Having the same rule for AT during the peak time would result into high unoccupied vehicle times, higher cost per km and mileage.

Therefore, two categories were presented. Oversupply at least one open idle AT without any open requests and undersupply period without any idle AT and at least one open request. Those scenarios are handled differently when oversupply occurs the closes idle AT will handle the request and pick up the passenger. This is a classic low demand scenario when dispatcher handle the request immediately as they arrive.

During undersupply when a AT becomes idle it is being assigned to the closest request. This balancing strategy is focusing on maximizing AT utilization, resulting in higher throughput and reduce the waiting time for AT. To simulate 24 hours simulation took eventually over 3 hours on a regular computer.

Results

For a simulation, multiple fleet size was picked, ranging from 50 000 to 250 000 vehicles, in order to find a suitable fleet size that could use the vehicles in the most efficient way.

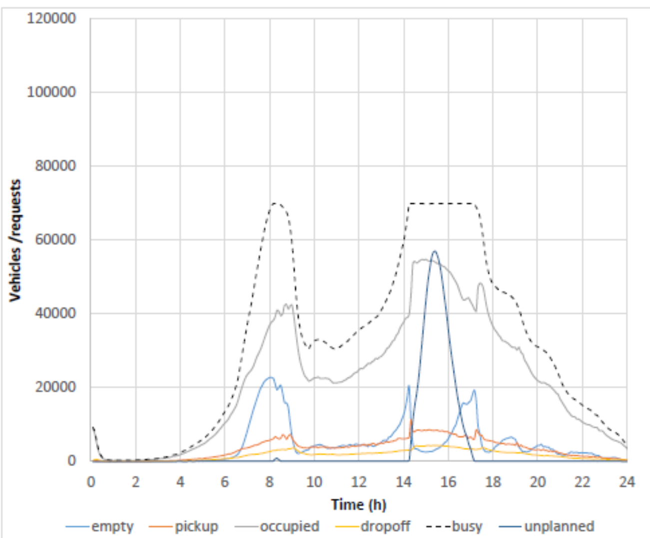
From a customer's point of view, waiting times for the AT service are crucial during the simulation. In an ideal scenario, waiting times shouldn't be longer than actual searching for a parked vehicle. Pricing and operating scheme were not yet presented, and it will probably reshape demand for AT service a lot. One of the use cases can be reducing peak times by lowering the price during the off-peak times and introduce surge pricing during the peak times.

Operators interests are to minimize the expanses of introducing and operating ATs. This can be achieved by reducing the fleet size into a size that can serve most efficiently, while reducing the empty drive time of ATs when there are no passengers in vehicle, thus those times are non-revenue for operators.

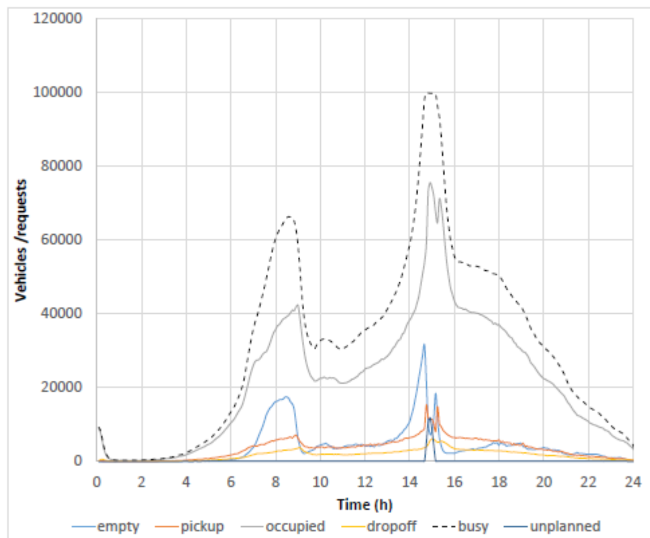
<u>Fleet size determination</u>

The simulation took into consideration scale of fleet size between 50 000 and 250 000. In order to observe the impact of fleet size towards the quality of service (waiting times, managing the peaks, idle and empty drive times) the fleet was incremented by 10 000 vehicles during each test between the sample scale.

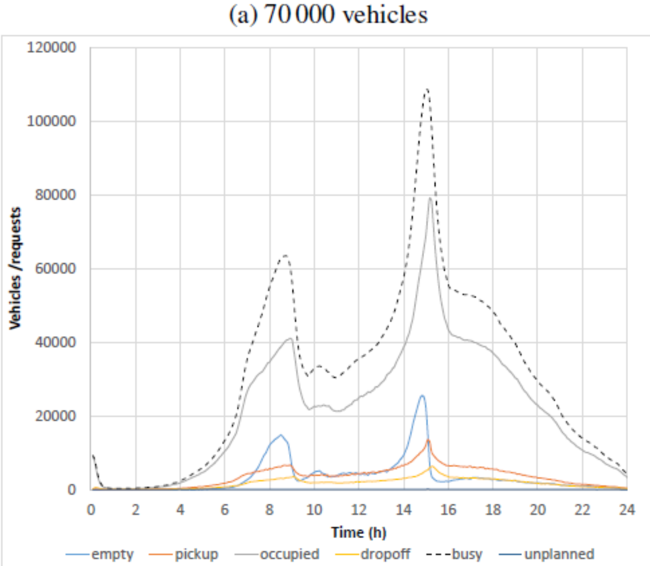
Figure 5.8 represents the dynamics of AT dispatching for a size of fleet ranging from 70 000 to 160 000. A graph shows the number of ATs in different tasks during the whole day. Light blue color when a vehicle is driving empty towards the rider. Orange color represents picking up rider, gray color means that AT is carrying a rider and yellow line shows the number of ATs that are dropping off riders. All of the busy vehicles represent dashed back line and the amount of currently unplanned or unserved request is marked with a dark blue line.



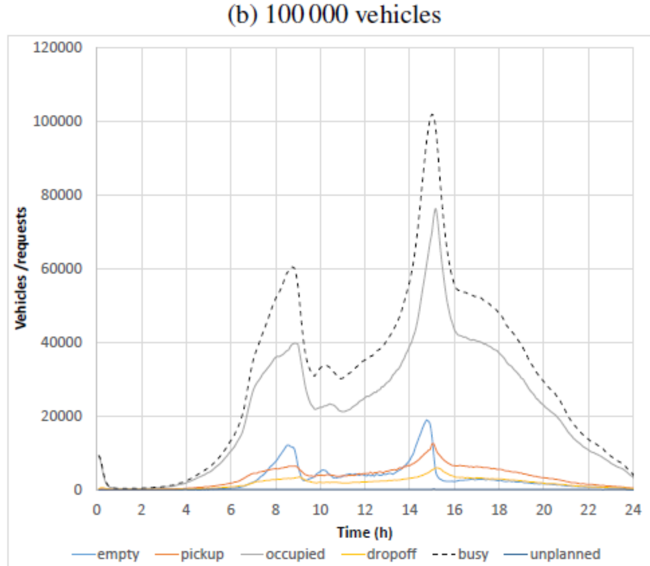
(a) 70 000 vehicles



(b) 100 000 vehicles



(c) 130 000 vehicles



(d) 160 000 vehicles

Figure 5.8: Vehicle operations and open request over the whole day for different AT fleet sizes [84]

Simulation with 100k ATs shows a temporary shortage of idle vehicles around 3 pm, due to that all vehicles are busy at that moment and there are a few rides that can't be cover at the time, but it's not dramatic. Fluctuation of empty drives is caused by a dispatching mode that change the ordering system from First Come First Served mode to advanced mode where the efficiency is a priority. As a conclusion, 100k size fleet seems as a perfect compromise between the size of the fleet and QoS. Even though there have been a temporal undersupply, 100k size fleet average time was around 2.5 minutes and during the 95th percentile a bit higher.

Simulation with 130 000 ATs manages to cover the afternoon peak time by serving all of the riders immediately with an idle vehicle.

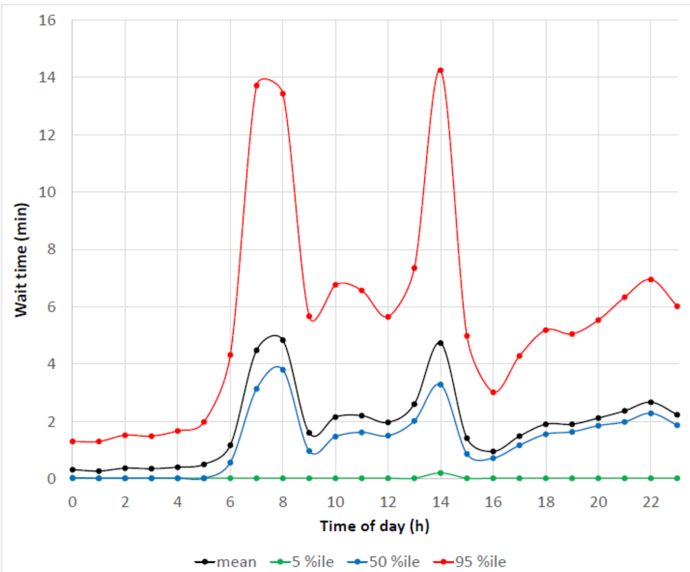
Bigger AT fleet sizes in a range from 140k to 250k show a big number of idle ATs during the day. Most of the time there is more idle ATs that serving ATs at most of the times. Founding shows that bigger the flee is fewer vehicles are used across the afternoon peak time. It's mainly caused due to a fact that empty rides get shorter because there is too many idle vehicles available and spread more efficiently.

Another case are fleet sizes from 50k to 80k that suffer during the morning peaks that got bigger. That is mainly directly affecting the performance of the fleet, vehicles spent more time driving empty and that results into an obvious increase of average waiting times. There are less idle vehicles and they have to commute longer distances towards the riders. Thus fleets of those sizes are insufficient to handle the service demand.100 000 ATs case

After examine all of the size fleet samples, 90k-100k size fleet result into a most efficient for the operator and will be elaborated further on in this case study. It's equal to a vehicle to AT replacement ratio between 1:10 to 1:12 according to assumptions of this study case.

Passenger wait times

Figure 5.9 provide a detail hourly statistics about the wait times of passengers and ATs performance. Average waiting times for a ride were 2:28 min, those times differ according to each hour, depend on a demand and number of spread idle vehicles. This time is psychologically acceptable, riders don't even have to wait outside for the vehicle, but they can order it few minutes in advance and when the time comes they can go out of the building and take a ride. Waiting times around 2 minutes are not achievable during the peak times in the morning and afternoon, where average waiting times rise to almost 5 minutes.



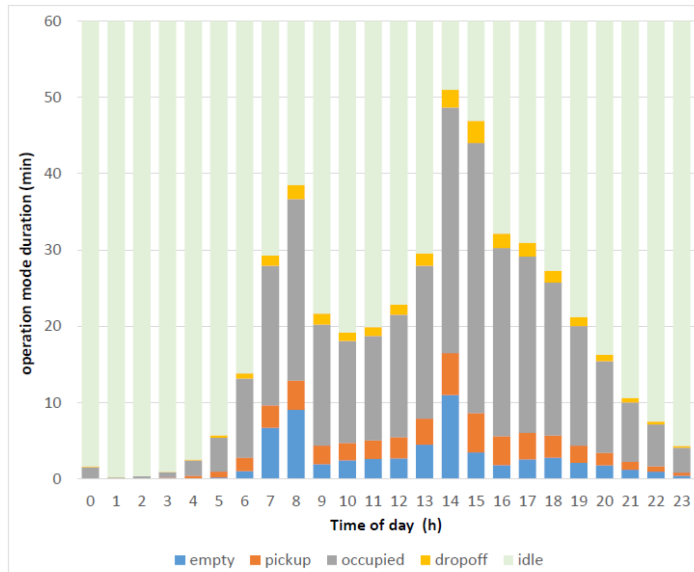


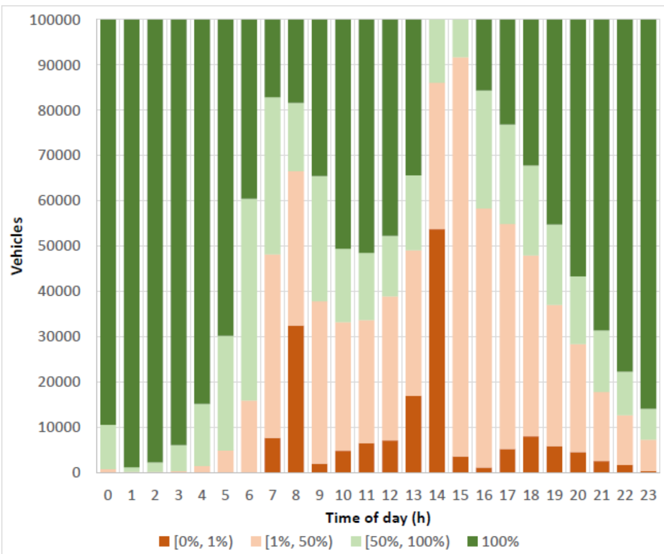
Fig. 5.9: Passenger wait times for each hour Fig. 5.10: Average operation mode split for each hour the [84]

Vehicle utilization

Figure 5.11 represents the average hourly performance of ATs, showing the AT's at different operation modes such as idle times, empty rides, an occupation of a vehicle and drop offs. In average, AT is used just 7.5 hours a day what represents slightly more than 30% of the time spent in operation mode. But we have to take into account that average CDVs in Berlin are used 40 minutes a day. Most of the time during the day ATs are in idle mode, left unused. That's because the fleet is built to sustain the morning and afternoon peaks with a sufficient number of idle vehicles.

Apart from that, the ATs workload is not spread in a pattern over the hours. Figure 5.12 shows this lack of balance where it categorizes vehicles into different categories. The dark green line represents vehicles that are always idle, Light green line mostly idle vehicles, Light red line belongs to vehicles that are always busy.

No AT is idle all the time when there is the afternoon peak, but each hour there is 10% of vehicles busy for no more than 30 minutes. Nights time is specific for a low demand and no ATs is busy for the entire hour, there is a small percentage of ATs that are still busy for over 30 minutes during specific nighttime hours.



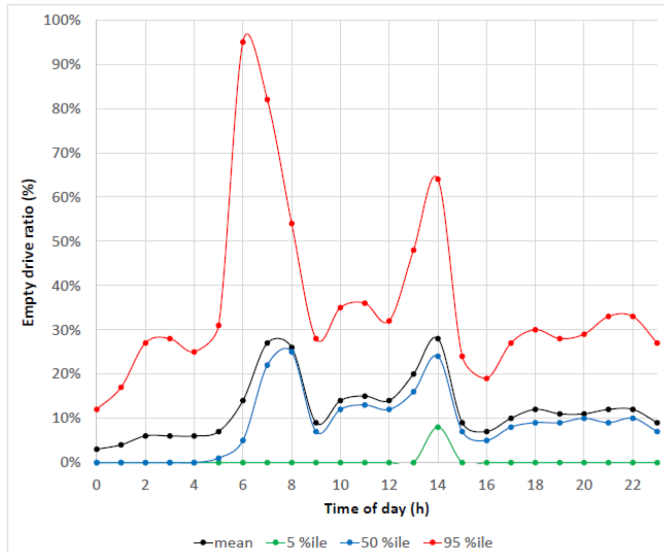


Figure 5.11: Vehicles categorized by the hourly share of idle time [84] Fig. 5.12: Empty drive ratios for each hour [84]

Ratio optimization of empty drive times to total driving time is also a performance criterion for a well-organized fleet operation. Figure 5.12 shows that during the day this ratio is below 15%, but during high demand times in the morning and afternoon, this number rise to almost 30%.

Outcomes

Results of this simulation suggest that the most efficient AT fleet size for Berlin would be the one with 100 000 ATs. This number of vehicles would be enough to replace privately owned cars within a city while maintaining an optimal transportation performance. The study shows that in this case, one AT vehicle could replace up to 10 conventionally driven vehicles.

The result of this study case shows that fleet size of 90k to 100k ATs is the most suitable option for the operator if the ATs would replace CDV trips in Berlin. During the simulation, 1.1 million CDV were replaced with a 100k fleet of autonomous taxis. This amount is sufficient to cover the peak times that are specific to Berlin.

A simulation shows a 17% increase of total drive time caused by empty trips, yet the higher congestion doesn't seem to occur, due to a lower number of vehicles operating in the city. This additional driving time can be compensated by a reduction of parking search and improved traffic flow that could reduce traffic congestions.

Fleet size should be chosen according to its ability to cover the peak times. Performance during this high demand times can be adjusted in a number of different ways. Applying surge pricing during the peak times according to demand can help to spread the demand over the hours. Carpooling during the peak times can result in better coverage during the peak hours. Lowering the fare prices during low demand times could distribute the demand during the day.

Additionally, using fleet of ATs for multiple services such as goods delivery and distribution during the night time and low demand hours in a day may help to improve fleet utilization of idle vehicles during off-peak times. Trip durations and distances vary according to the city. Augmentable could be to have a conclusion about how mobility patterns would change or stay the same way as they are right now after introducing ATs fleet commercially.

Simulation is taking into a consideration that if the same simulation was re-running in different cities, there would be different results. There are certain facts that should be taken into consideration, specific and individual for each city. An operator has to identify those accordingly to optimize the AT fleet size if they want to maximize the efficiency of service.

5.5 Current Leaders in the development of Autonomous vehicles

This subchapter investigates the current leaders in research and development of AVs. As a main source for the founding has been used Navigant Research study from April 2017 [85] that compared individual developers of AVs on a 2D scale. Navigant Research published their leaderboard that is comparing 18 developers based on selected criteria. In this chapter, the results of the Navigant research will be introduced and commented. Some of the data will be used in a Key player chapter as an information foundation for individual stakeholders that are involved. In addition development of a three AVs stakeholders: Ford, GM, and Google will be shortly presented because those three stakeholders will later play important role in a forming of strategic partnerships with ride-hailing companies.

Navigant research based their evaluation on this 10 criteria:

- Vision
- Go-to-Market Strategy
- Partners
- Production Strategy
- Technology
- Sales, Marketing, and Distribution
- Product Capability
- Product Quality and Reliability
- Product Portfolio
- Staying Power

Those companies are profiled, rated and ranked with a purpose to give an objective assessment of their strengths and weaknesses in the global market for autonomous driving vehicles.

Companies are given a score according to their current state of the development on a rating scale from 1-100. Scoring is based on an evaluation of each developer in terms of how well is the current stage established and comprehensive based on an advanced driver assistance systems building blocks; what public announcements regarding fully autonomous cars company have made and how committed the company is towards its long-term goals.

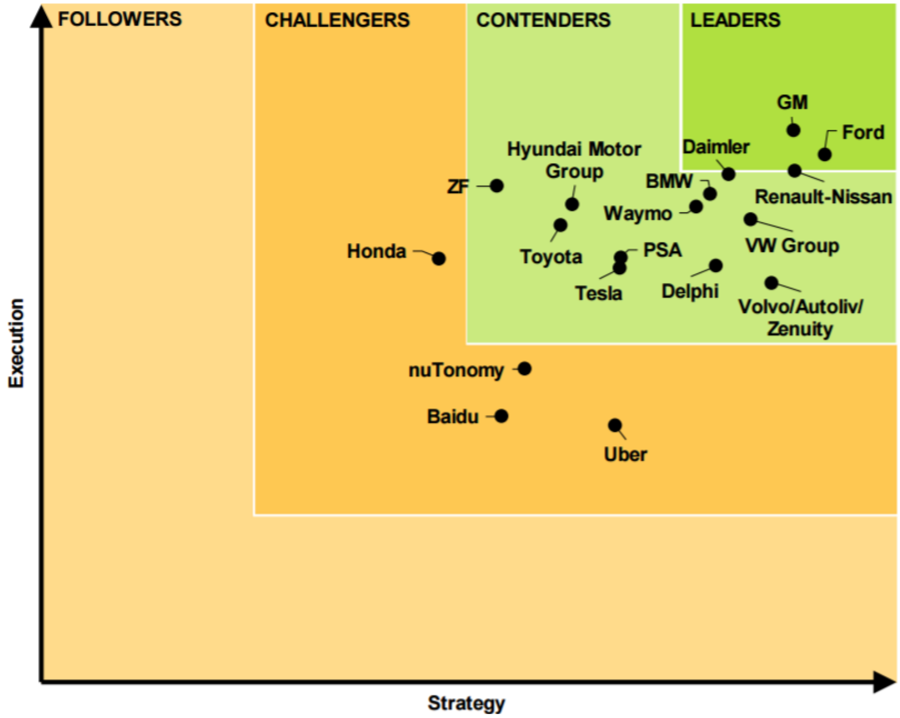


Figure 5.13. The Navigant Research Leaderboard Grid [85]

The scores of all 18 developers of autonomy are shown on a Figure 5.13. Based on results, four companies are leaders on the graph, since they scored higher than 75 points on Strategy and also Execution scale.

Based on the evaluation, Ford is currently a leading the development, closely followed by General Motors (GM), Renault-Nissan Alliance and Daimler.

The majority of the remaining developers are marked as Contenders, that are slacking behind Leaders with either weaker strategy or execution. This group is followed by numerous challengers, who are lacking in both, execution and strategy.

Following OEMs were selected for a reason that they created partnerships with companies that are interested in offering an On-demand ride-hailing service with ATs. Those companies are mentioned later in the report and will take into consideration some of the data from this section.

5.5.1 Ford

In the begging of 2017, Ford invested 700mil USD into a Flat Rock Assembly Plant in Michigan, a plant that is supporting a production of autonomous vehicles Level 4. On the top of that Ford announced 1 billion USD investment into a startup Argo AI, with a plan to have over 200 software engineers working on a challenge that autonomy offers. Ford would own in that case majority of the shares in the company.

By a Navigant report, Ford has been ranked as an overall leader in autonomy, considering the overall scores from listed criteria's. Ford dominated in a Strategy part of the evaluation and dominated with strong partnerships with a following companies.

Velodyne: Ford invested into Velodyne[86] – the company that is producing Light Detection and Ranging sensors called LiDAR. LiDARs are an essential sensor for autonomous cars for 3d mapping of surroundings. The reason behind this investment was to drive the price lower for LiDARs by mass production. Ford have now long-lasting relationship with the company and was one of the first who used those sensors for high-resolution mapping and also autonomous driving a decade ago. Ford acquired or invested into multiple other companies with a purpose to speed up and improve a full vertical integration for automated mobility. Including consumer services and also sensing systems.

SAIPS: Israel-based computer vision and machine learning company who Ford acquired for a strategical purpose. SAIPS have a strong position in AI and enhanced computer vision – what are pillars of autonomy. Ford was especially interested in their algorithmic solutions that can handle image and video processing, an ability of deep learning, signal processing and classification. SAIPS's technology has potential to help vehicles to learn and adapt to their surroundings.

Nirenberg Neuroscience LLC: In this case, Ford has partner agreement with Nirenberg Neuroscience. They have a very specific machine vision technology, by getting into the neural code that the eye uses to transfer the signals into the brain, their technology is able to track drivers attention, object recognition, read facial expressions. This sort of partnership means for Ford to bring humanlike intelligence to the processes where machine learning is taking it's role.

Civil Maps: Civil Maps provides cognition for autonomous vehicles, while the software crowdsource a dynamic, continental scale, 3D map for safe navigation of those vehicles[87].

Chariot: A company that is a network of a crowdsourced and crowdfunded commuter routes, that are faster, more reliable than a mass transit and much more affordable than ride-sharing alternatives in driving.

Argo AI is an artificial intelligence company that will play its role in creating a software for autonomous vehicles. This software will power the AV with AI, those AV will be initially operated in cities and then across a wider theory. The company was founded by a former Google and Uber leaders and brings the top talents into the company that will contribute in developing the AI software. Ford acquired the company for 1bil USD. [88]

Ford joined in the early stage Defense Advanced Research Projects Agency (DARPA) Grand Challenge program, where the company was developing their own autonomous pickup truck. Later in 2013, Ford started to test and develop their own fleet of autonomous cars on their Ford Fusion model. Straight towards Level 4[89] by 2021. In the begging of 2017, Ford introduced their second-generation Ford Fusion model with autonomous elements and Level 2 autonomy.

Ford's primarily vision is to sell AVs to ride-hailing companies, but they can also surprise their competitors by launching their own transportation on-demand platform and mass produce Level 4 capable autonomous by late 2021. Ford expects to profit by selling their fleet of AVs to ride-hailing companies, but also by licensing the technology to other firms. This could include their automotive manufacture competitors as well. [90]

5.5.2 GM

General Motors Company, based in Detroit is home for Cadillac, Chevrolet, and Buick vehicles. GM developed Chevrolet Bolt EV specially optimized for ride-hailing services. According to Navigant report, GM scored with a great Strategy and Execution right behind the Ford.

The massive effort that GM is pursing can be seen in an act where GM is hiring 1100 new people that would work on AV project, on the top of the employees that are already working on that project. GM plans to launch the AT's for on-demand ride-hailing services as a first company on the market, their current stage of development is strictly under cover.

GM acquired USA based company Cruise Automation [91] that integrates its image recognition devices into vehicles. Cruise Automation is working on self-driving kits for cars, that can be installed additionally into a normal car and transform them into AV. GM with Cruise Automation is testing their self-driving vehicle Bolt EV on public roads in Phoenix, San Francisco, and Detroit. In 2018 Lyft wants to deploy for testing on public roads over 1000 vehicles with Lyft collaboration.

5.5.3 Google – Waymo

Google self-driving car is currently under a Google-backed company called Waymo. Google ran the project in their X labs since 2009. X Lab is an innovation hub, where Google works on a moonshot projects. Later in 2016 Waymo took over the project, and is under a Alphabet Inc holding company that owns Google as well.

Google – Waymo tested their self-driving car on a couple of different vehicles. They probably posses with probably the most advanced autonomous technology out there. And Waymo is also considered by a wide public to be a leader in a technology development. This is mostly caused by a transparency that Google offered to a public with their project.

Waymo shifted their strategy to use their supplier's technology to backed their project and focused on developing and producing their own sensors. Waymo succeeds to reduce the price of sensors by 90%, what is a significant advantage against their rivals.

By far, Waymo's vehicles drove over 4 million km for testing purposes and during this time, the company was able to improve their disengagements factor significantly. Currently leading in this factor against their rivals as well with only 0.13[92] disengagements per 1000km of their self-driving mode.

At this point, Waymo has no interest in producing the cars or running their own ride-sharing services by themselves. Instead, they prefer to partner up with companies that have an on-demand ride-hailing platform and provide their ATs to the company. Waymo's interests are also later in collecting the big data, with which Google could later operate.

5.6 Criteria Definition

This subchapter is dealing with a specific criteria that estimate the likelihood of success of different business models described in this thesis. They can predict the success of individual companies that are developing autonomous cars right now with a vision to deploy their ride-hauling services in the future. Numerous criteria's in relation to Theory of dominant design will be described, compared and evaluated.

"Who wins in the end may come down to which plan comes to market first or which vision offers the best value proposition and utility to customers. If you can combine a well-established ride-sharing service with driverless tech, that's the holy grail right there. That's where Uber has Tesla beat — not only is it developing driverless tech that's getting better at tackling difficult Pittsburgh terrain everyday, but it already has an established customer base."[93]

Below are listed proposed criteria for evaluation of the possibility to successfully dominate the market of ATs. By those criteria will be later evaluated small list of key stakeholders in an autonomous transportation industry. Criteria are divided into two sections; Strategy and Execution. Evaluation scale contains values from 0 to 10, where 0 is the lowest score and 10 is the highest score the company can get, per one criteria. Then after evaluation, all of those points are counted together and compared with competitors.

5.6.1 Strategy

Vision – Measures the company's publicly announced goals in relation to autonomous transportation of today and a future. Visions that are clearly and effectively introduced to a public have higher scores.

Partner network – Measures the company's strategical partnership formations with an OEMs, suppliers and tech giants. Those partners will further provide them with either technology, fleet of AVs or another kind of resources. Establishing partnerships that strengthen company's position results into a higher score.

Go to Market Strategy – Measures the company's ability to reach out to the customers, through a variety of sales and marketing channels.

Market Advantages – Measures the company's product, service, technology and other advantages on the market. The more relevant are those advantages, higher the score is.

Business Model – Measures the company's ability to make the service profitable and capture the vast amount of the market share. The more likelihood that the company will be able to come up with a dominant business model, higher the score is.

5.6.1 Execution

Technology & Timing_– Measures the company's ability to develop or implement the autonomous technology elements that currently put the company into a competitive advantage and is in the same time able to maintain the progress. The more advanced autonomous technology is company using, higher the score is.

Resources – Based on three elements: Human Resources, Capital and IPR

Human Resources – Elaborates on the people who are working in the company towards the autonomous on-demand transportation. Capital – Evaluates whether the company has enough financial resources to finance the R&D, Market penetration and later on to provide a mobility on demand transportation. Intellectual properties – Evaluates the Intellectual properties, if there are some that can be later on leveraged against the competitors.

5.7 Key players – development

This section is focusing on the key players in a future autonomous ride-sharing market. Paper analyze three cases where different companies work together towards AT services. Those four cases have a different approach in development, business model, value proposition. There are two cases where a current top ride-hailing tech startup companies collaborating with OEM, followed by a case where tech giant company with a long history of developing AV wants to be in the market as well, and in the end there is a new OEM entrant Tesla who seems like a current leader in the AV market In those cases, their state of the art and development approach will be analyzed. Their vision for a business model introduced further on. All of those collected data will be analyzed in a SWOT analysis and then in Comparisons evaluated and compared to each other.

5.7.1 Uber - Daimler and Volvo collaboration

Uber managed to form an interesting partnership with a car manufacturer Daimler, Ford, and Volvo. Those two automakers belong to one of the most progressive developers of AVs. Further on, the role of Uber as a ride-hailing operator will be analyzed, assessed, evaluated and commented. The outcome should be a comment on Uber's business model as a future provider of autonomous ride-hailing services. In a Discussion chapter, those outcomes will be followed with a Uber's likelihood of capturing the dominant business model design and the power distribution over its stakeholders.

About Uber

Uber is a current global leader in ride-hailing transportation services, where it serves as a multisided platform for an ordering a ride in specific cities across the globe. Uber is matching drivers that are usually owners of their vehicles with riders that are searching for a ride. Therefore, Uber is called the biggest taxi service company, yet they don't own any vehicles by themselves. Their drivers have to either own a vehicle, rent it through the private company, friend or Ubers partners. With an excellent strategy, execution, and couple of investment rounds, Uber was able to seize the opportunity and scale this rapidly. Currently Uber spread across 77 countries and 527 cities across the globe. They had a problem with regulations in a certain city, due to unfair advantages compared to traditional taxis and poor tax legislation.

Uber have 8 million users that are using Uber as mobility on demand. They simply request a ride thought Ubers mobile app where they allocate their position and their desired destination. Choose a class of vehicle and request a ride. Ide riders around will get a notification that they can pick up that rider and have to confirm it or decline.

The company is currently at 60 billion USD valuation and raised multiple big rounds of investments. [94] .So far more than a 2 billion rides were made by Uber drivers and this number is rising exponentially.

Partner Network

Uber has bet to cooperate with three car manufacturers, Daimler, Ford, and Volvo. Daimler is one of the biggest vehicle manufactures around the globe, owning sub-branches such as Mercedes-Benz, Smart Automobile, Mitsubishi Fuso, Western Start, etc. Daimler agreed to collaborate with Bosch to develop a fully AVs by 2020. Bosch one of the largest automotive tech and HW suppliers worldwide. They are working together to bring AV Level 4 fully automated driving and Level 5 that can operate without anyone onboard[95].

<u>Daimler</u>

According to a press release[96] of Daimler and Bosch, they have a common vision to create shared AT that can drive autonomous cars in urban areas. Customer can order a ride via a mobile platform, while the AT transport the rider without the need of having a driver on board. After the rider is transported from the point A to point B, AT can pick up another customer. And that's where Uber comes to play its role with providing ride-hailing services with AT[97]. Uber has no interest to manufacture their own cars because it's really difficult and complex tasks, that require tremendous amount of R&D, human resources, and funding[98]. Car2Go on demand car rental company is a subsidiary of Daimler. It's spread across the European and American cities where offering car sharing services.

Volvo

Simultaneously Uber partnering with Volvo Group, the Swedish car manufacturing company. They announced their partnership in August 2016, where Volvo provided Uber with 100 Volo XC90s vehicles, for a ride-hailing program in Pittsburgh[99]. Since that time Uber and Volvo were working together on the HW part of the autonomous systems. Uber's plan was to rather collaborate with a development of AVs and ATs than working on that projects alone like for instance Google. They signed a joint project where they both want to contribute to a development of Level 5 AVs. Those two companies are contributing combined 300 Mil USD to the project. The project is, therefore, combining a Silicon Valley tech startup giant and car manufacture. Volvo is a world leader in a technology of active safety and their vehicles correspond to a great safety credibility. Both of the companies will use the same vehicle for the next step of their own self-driving vehicle strategies. [100]

Research & Development

Saying that Uber is interested into developing software AI part of AV rather than manufacture the cars by themselves. An additional step in a development for Uber will be leveraging their large network of Uber drivers. In an R&D phase, it's important to collect a huge amount of data to improve the intelligence and reliability of autonomous cars. This can be achieved by either driving simulations or performing in a real environment, by testing the car on the road, collect the data from the sensors and followed by analysis of the results. If we take for instance Google self-driving project, for resting they need a full-time employee who will operate the vehicle. Uber, in this case, can equip a vehicle with sufficient technology and keep the drivers who are working for them doing those two things simultaneously. This can be easily scaled if Uber will want to test with a larger sample of vehicles. This crowdsourcing method seems much cheaper than Google's. If Uber will scale this largely, they will have a tremendous advantage over their competitors, with a opportunity to edge cutting software and algorithm performance.

Uber is already applying this approach to testing in a few American cities and in Gothenburg, with Volvo's vehicles.

Testing for purely data collection is not geographically restricted, but if the car will have to act as semi-autonomous or autonomous on the road, those tests can be done now only in a specific city in US, Asia and Europe.

While road testing seems like a logical approach to teach and test self-driving cars, Uber is developing the AI of its cars also in simulations. They are using hugely popular game GTA, which features fast cars and different nefarious activities to train intelligence and algorithms, that can help the self-driving car to operate in a real environment. The environment in this game is so realistic that it can be used to generate data, type of data that we can compare with a real-world imagery.

The idea behind this simulation is to gather the data about the surroundings and observe car's behavior. In this process, engineers created a software layer that is in-between the game and the computer's HW. Its task is to automatically classify different objects placed in the road scenes, that we can find in the game. It's a part of segmentation network, where different labels are tagged and move to machine learning algorithms. Labeling enables to recognize different objects on the road, such as cars, pedestrians, traffic signs, road, road lines, lamps and other objects, either in the simulation or in the real world. Labeling can be done manually, where it takes almost one hour to label a single frame with the objects. Doing this in the simulation is a matter of a few seconds where the system can label thousands of images. The purpose of that is to reduce the time spent on labeling and creating segmentation network. Systems itself is learning how to label those objects from simulation and then the algorithms can be used in real world conditions. In general, it takes thousands of hours to even collect those images in a real world.
Uber can with artificial environment effortlessly collect really well annotated date at a large scale, with different weather and lighting conditions. [101] [102]

Vision for BM

As Ubers CEO Travis Kalanick said at the Code Conference, that Uber will eventually replace the drivers of their cars with a robo-taxis – ATs[103]. R&D and manufacture of vehicles is an enormously tough quest and Uber is fully aware of this. They are good at scaling the technology and services across the globe and have no interest in producing the vehicles on their own. Rather, they want to build upon their existing platform and user base an autonomous AT services. Uber is opening up their ride-hailing platform, where their partners will be able to sign their fleet of AT independently. As a first Uber's step was that they partnered with Daimler. Daimler will own and operate its vehicles by themselves, Uber will, on the other hand, offer their ridesharing network services and Uber's technology.

Currently Uber works as a multi-sided platform, that is connecting riders with drivers. Uber doesn't own the vehicles; they attract drivers that have their own cars on their platform. In that case, drivers work as contractors, by this Uber leveraged the low cost of expenses to massively scale around the globe. Being light on assets, Uber managed to build a powerful network effect and quickly adapted their service into new markets.

Yet self-driving cars have the potential to eliminate private car ownership, what plays against current Uber's business model. The privately held car has only 5% utilization and is passive during the rest of the time, either parked in the garage or parking lot. Almost 20% of commercial land in USA metropolitans is solely used for parking, what represents a huge waste of resources. Self-driving cars could reduce the price of the fare significantly, ranging from 60% to 80% of current level, if we take into consideration also the driver salary and super-efficient utilization. This will lead people into a using the service and abandon the private car ownership, what means that Uber's business model as a multisided platform will be outdated. Successful businesses constantly reinvent themselves, they put themselves out of the business before their competitors will do the same. Uber will have to seriously adjust their current business model, to stay in the market. [104]

As Uber already have a customer base on their platform, they should build autonomous transportation on top of it. Uber needs to build and their own fleet of autonomous cars if they want to keep the cost low and still keep their position on a market with a large car network. Uber partnered up with car manufacturers Volvo, Ford and Daimler to supply them with a fleet of AVs in a future. Research, development, and manufacture of autonomous cars is a costly project, that requires plenty of resources. Uber have no interests in developing their own self-driving car as for instance Tesla, Uber give this responsibility to its partners who will eventually produce the cars as well. For a now Uber distance themselves of owning those vehicles, they expect that automakers will deliver a fleet of autonomous vehicles to their platform, while those cars will be own by the same automakers or institutions. Uber is currently in 581 [105] cities all around the globe, it would be costly in case they would have to finance the project by buying those fleets. Cover even 1/5th of the cities they are operating in with a fleet of autonomous cars will require a huge amount of capital. Especially when Uber is not making any profit overall. It's part of their strategy, pouring a vast amount of cash in order to massively grow, fight against the competition and scale the market share. Even though the company is evaluated insanely high between $40 billion and $50 billion by various estimates, they are still depending on large capital investments. Luckily for Uber, they have a large user base and can leverage this position to demand favorite deals with automakers for the ownership of user and big data, but also revenue sharing. Right now the price of the technology is high, but the expectations are that it will go exponentially down. Additionally, the cost of operations will go down for Uber significantly down as well, if we take into consideration that an average Uber driver earn $50 000 [106] annually. Those savings could help Uber to take over the autonomous car fleet ownerships in some of the cities and maximize the revenue.

Market Advantages

Uber have intentions to disrupt truck and delivery industry as well. Only in the US, there is over 1.6 million employed truck and delivery drivers. This market represents $90 billion, capturing just 5 or 10% of the delivery market with autonomous driving technology represents $9 billion in earnings for Uber.

In addition, Uber merged with Otto, company that is developing self-driving trucks. Autonomous trucks could represent a huge saving in the transportation of goods. A fleet of autonomous trucks could drive closely in one line, with a small distance between each other. This enhances the ergonomic of trucks and significantly reduce the fuel consumption. Trucks could operate almost 24/7, without breaks that are mandatory for drivers to take a rest. In addition, the costs would further go down, due to unnecessary to pay two full-time drivers for doing their job.

Resources

Previous years Uber haven't been profitable, even though it's valuation is 70bilion USD. Uber have to raise capital regularly in order to don't burn out all of the capital they have available. The reason why they are not profitable yet is because they are massively expanding across the globe, and all of those expenses are related mostly with this fast scaling process. In case that Uber will have to buy the fleets of autonomous cars, they will have to raise another big investment rounds.

Uber is not primarily focusing on developing the AVs and will be directly dependable on an OEMs autonomous vehicles developers. But on the other hand, is strengthening its position by being involved in developing the on-demand transportation system for ATs. Human resources are extremely important and Uber is doing well in attracting world-class software engineers.

Regarding Uber's intellectual properties, they are mostly related to design of their ride-hailing mobile app interface. Uber is currently facing a lawsuit from Google-Wayamo do to abuse of their patents regarding self-driving technology[107]. Google is claiming that they ex-employee that migrate from their company and was working on Google self-driving car project to Uber, stolen valuable confidential documents about their self-driving technology in favor of Uber.

Criteria Evaluation

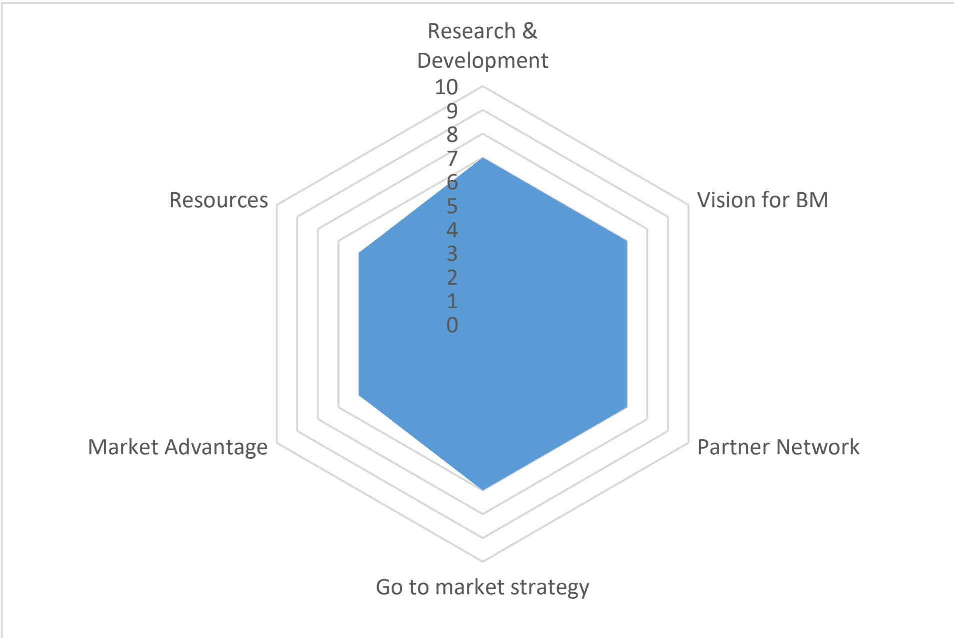


Figure 5.14: Criteria performance Uber

Uber ended up with a lowest score in the Criteria evaluation scheme, just a two points behind the Tesla. Uber successfully formed a powerful partnership with a couple of OEMs such as Volvo, Daimler & Ford. All three of those stakeholders have the vision to be able to sell Level 5 vehicles in a few years and have currently very advanced technology. OEMs are in this case responsible for the development of AVs and their production, Uber will then buy their fleets of AVs in high volumes. But it seems that Uber will become in this position less dominant and OEMs will strengthen their position in a market. Still, this might won't be that bad for Uber, who's vision is to scale the service massively on its market. Uber can leverage their current ride-hailing end-user network and build on the top of it. If Uber will be able to massively scale the service, they will still earn a tremendous amount of the profit by earning a percentage from the cost of the trip, especially if they will have millions of rides per day.

SWOT Analysis

Strengths
- Platform with over 40 Million monthly riders[108]

Weakness
- Uber is not developing their own AVs vehicle and is dependent on automakers
- Is expanding so massively right not that they don't have any profit and need Venture Capital investments

Opportunities
- Is excellent in scaling the ride-hailing service across the globe
- Electric ATs will drive the price per trip down what will result in even higher demand for ride-hailing transportation
- Uber's Carpooling service with new ATs will even further reduce the prices
- Uber is already offering extra services

Threats
- Recent problems with a culture and poor management inside the company. String of PR disasters
- High profile accident[109]
- Lawsuit from Google for copyrights[110]

5.7.2 Lyft – GM and Google-Waymo Collaboration

Ride-hailing operator called Lyft managed to create a truly unique partnership with General Motors and Google Waymo tech company. Further on, the role of Lyft as a ride-hailing operator will be analyzed, assessed, evaluated and commented. The outcome should be a comment on Lyft's business model as a future provider of autonomous ride-hailing services. In a Discussion chapter, those outcomes will be followed with a Lyft's likelihood of capturing the dominant business model design and the power distribution over its stakeholders.

About Lyft

San Francisco-based ride-hailing company founded in 2012 is a direct competitor to Uber and work on a very similar basis. Lyft raised total 11 funding rounds, at the value of 2.6 Billion USD and the company's valuation is around 5,5 Billion USD[111].

Partners

General Motors - GM

GM in 2016 invested 500Mil USD into Lyft and exchange for a 10 stake in the Lyft. GM plans are to make their Chevrolet Bolt EV vehicle primary platform for developing autonomous vehicles. Bolt was a specially optimized electronic vehicle with a low footprint for ride-hailing services. Gm's CEO Mary Barra said that GM will put on an assembly line in Michigan first AV prototypes by the mid-2017. Meanwhile, GM rolled out their Cadillac CT6 vehicles with Level 2 automation Super Cruise system.

"With GM and Lyft working together, we believe we can successfully implement this vision more rapidly." GM President Dan Ammann [112].

Didi Kaudi

Lyft partnered up with Chinese top ride-hailing service provider in a sense that when Chinese users of Didi Kaudi arrive in the USA they can open their Didi Kaudi's app and hail a ride by Lyft riders and vice-versa[113]. Saying so, Lyft is considerably less afraid of partnerships with their close competitors than Uber.

Google-Waymo

Google American based international technology company that is specializing mostly in Internet-related services and products, with valuation over 600billion USD[114] have more than 10 years of experience with developing AVs. Currently, the google self-driving car project is running under a Google's sister company Waymo. Their primary focus is towards developing the technology and AI software for AVs. They partnered up with Fiat-Chrysler automaker, who could later produce the cars for them. Research and technology wise, Waymo is currently with their progress the leader in the development of AVs out there.

Lyft and Google Waymo partnership is a bold move towards Lyft's current biggest rival Uber that is also providing ride-hailing services. Google has filed a patent that is able to efficiently determine the pickup and drop off locations for ATs [115]. Autonomous vehicles probably wont be able to drive everywhere where currently human drivers can. For that reason, some of the pick up and drop off locations won't be accessible for AVs. In addition, some other factors as speed limits, construction sites and so on are not a suitable for those purposes neither.

The purpose of the partnership is that Google will be Lyft's AT's fleet supplier, meaning that Lyft is taking their hands off from AVs research and development and is interested in partnering up with a companies that can supply them with a fleets of AVs.

Vision

Lyft's president and co-founder, John Zimmer announced that Lyft could bring ATs into streets within 5 years. Company's vision is that in a next 5 years, the majority of Lyft riders will be operated by ATs. And 100 coverage of ATs rides will happen within 10 years. They also see car ownership in a next 20 years as irrelevant. Further on, Zimmer sees Lyft more as a network of traditional and autonomous cars. He says that Lyft is planning to implement subscription-based pricing model for ATs.

"*You'll subscribe to Lyft just like you subscribe to Spotify," [116] Zimmer said.*

Lyft is already testing subscription models for their carpooled rides with other riders along the way. They introduced two kinds of subscriptions, where riders can either buy a pass with 10 carpooled rides. In that case, Lyft users will pay 20 USD for the pass, where the price for a trip is fixed to 2 USD. The second model is a monthly unlimited subscription for 29 USD. The purpose of the partnership with GM is to launch an on-demand network of ATs.

There are rumors behind Lyft that the company could be acquired by automakers or a tech company with the intention to strengthen their position on the on demand market and scale their business faster.

Research & Development

Lyft is not developing the AVs or AI processing software. Rather chose a strong partner that are current leaders in the research and development of AVs and driving intelligence. Both of their crucial partners will be able to produce the AV's when the technology will be ready and approved by regulations.

Market Advantages

Experiences in ride-hailing and carpooling services can Lyft leverage and build up their current service an option where their users can order a ride with ATs. They can also use their current network of users for a testing ATs, getting their customers familiar with the technology for a later transition from human-driven vehicles to self-driving taxis. Lyft's biggest assets are their partners with that will either put their fleet of AVs onto their platform or they will sell it directly to a Lyft.

Resources

Lyft is lacking in resources due to a fact that they are dependent on external investors. They are on a right track to being profitable from their current ride-hailing services, but in order to massively expand when the technology and regulations for AVs are ready they will need a tremendous amount of capital. This can put Lyft into a vulnerable position, where their partners could leverage their position against the Lyft and take the profit share or instead acquire them.

Criteria Evaluation

Figure 5.15: Criteria performance Lyft

Lyft performed the best in the criteria evaluation scheme, both in strategy and execution parts. Lyft was able to for possibly the most powerful strategic partnerships with important OEM and Tech giant stakeholders. GM and Google-Waymo have currently possibly the most advanced autonomous technology and they formed really powerful partnerships with other companies, to supercharge their R&D process and strengthen their position in the future autonomy market. All of those three stakeholder players will be more or less equal to each other, what is a good news for Lyft a company that is not developing their own AVs and is sort of dependent on its partners. Another weakness of Lyft if their lack of resources, mostly of the capital. Lyft will be highly dependent on the capital from their investors.

There is also a really high chance that Google will acquire Lyft. What is probably the best scenario for both of them. Google would therefore, enabled the capital for massive scaling across the regions.

SWOT Analysis

Strengths

- Partnerships

- Experiences with ride-hailing services and currently in a great position to take over the market

Weaknesses

- Small company, also significantly smaller than Uber
- Not enough capital for expansion

Opportunities

- Leverage their current network of users for ride-hailing
- Can potentially outstand Uber - their biggest rival in on-demand transportation services
- Being acquired by OEM or tech giant Google

Threats

- Is dependent on OEMs because is not taking any effort to develop their own vehicles
- If won't position itself as a equal partner to OEM and Tech giants

5.7.3 Tesla

Tesla is relatively new carmaker on a market, yet with relatively most mature technology for AVs. Tesla's vision and business model will be further analyzed and evaluated, based on a selected criteria.

About Tesla

Tesla Inc. is a major American automaker, energy storage company, and producer of solar panels, based in California. Tesla is quite a new player on an automotive market, with producing nearly 100k vehicles a year. Tesla is one of the most aggressive electric and autonomous vehicles, currently focusing on a production of upper-class electronic vehicles. Relatively new player on the automotive market, but the company is progressing quite quickly and with their car and battery factory is trying to be as self-sufficient as possible.

Research & Development

Tesla is currently executing their 10 years old Master plan, where in the begging their plan was to develop and create low volume expensive car. From the profit develop a medium volume car with a bit more affordable price (Tesla Model S). And again used the money made on sold Model S cars to create a high volume car for the affordable price, that masses would buy (Tesla Model 3).

Current stage of development – Tesla is commercially selling their vehicles with working adaptive cruise control technology, that is equivalent to Level 3 autonomy. Tesla Model X, Model S Model 3, are already equipped with the necessary hardware that enables a car to become fully autonomous. However, Tesla is actually depending on regulatory approval, until that time even though the vehicle is capable of full autonomy, users can't use it yet. Once the regulations are approved, Tesla will roll out a software update to their vehicles and their owners will be ready to use it. Until that time, owners can enjoy the autopilot features. Tesla updates their vehicles Over-The-Air Software, which means they are wirelessly updating the software in their cars. Most of the updates enhance the performance and fix security bugs. This allows to roll out the new updates to all of the cars in a very short period of time, without the necessity of doing this manually.

For a commercial use, Tesla vehicles are now allowed only with an adaptive cruise control, what means that the vehicle can match speed to traffic conditions, automatically switch lanes without any required action by a driver, get on and off highways and park itself.

Tesla's vehicles using twelve ultrasonic sensors, spread all around the vehicle, can detect hard and soft objects. In addition to ultrasonic sensors, their vehicles have installed 8 cameras, allowing a vehicle to find the optimal route, navigate through the urban area even without any lane marking. The previous edition of their vehicles had only one camera in front, but now new Tesla cars provide 360-degree visibility and front cameras over a 250m range.

Enhanced processing that allows to vehicle sees through heavy rain, mist, dust and even a vehicle in front of it.

Powered with Nvidia's Titan GPU, it's new onboard computing system have computing power 40 times more powerful than in their previous Tesla's system.

In addition to the price of Tesla's vehicle, purchase of self-driving system now cost 8000 USD extra, what seems as the cheapest variant on the market, still this price will probably go down, after a while.

[117]

Tesla's new autonomous hardware 2.0 doesn’t include Lidar, which it’s widely used by Tesla’s competitors Ford, Google, and Volvo. Tesla developed their own vision processing tools, giving them the ability to be less dependent on the OEM. Leaving Lidar sensor behind was the main reason why Tesla is able to provide much cheaper technology for autonomous driving. This will keep the price lower for a short term, but with the evolution of technology and investments from car manufactures the price of Lidar will drop significantly.

Extra features, if you get into your Tesla vehicle, and don’t enter any destination, a car will look into owners calendar, and take the owner to an assumed destination, or home if there is nothing marked in the calendar.

Tesla already stated on it’s website that car sharing and ride-hailing for friends and family is allowed, but doing this kind of service for getting profit will be strictly allowed only on the Tesla Network. This also means that any Tesla car won’t be permitted to transport any person who is using Uber ride application unless they book vehicle directly from their own Tesla’s platform.

There are more than 100 000 Tesla vehicles driving daily on the roads. Tesla is leveraging this because those cars have installed fully autonomous HW on board and are connected to a cloud. All of those vehicles are currently running in a Shadow mode. In a Shadow mode, operating a vehicle is harvesting piles of data that company could later use. The cars log instances when the onboard autopilot system would take the actions and compare them with the real life actions made by the driver. This will significantly help to improve the driving logic of the system and will help Tesla to get the regulatory approval for Level 5 autonomy easier with all of the collected data and tested on millions of kilometers.

Vision for BM

Tesla wants to be true as less dependent on the partnerships as possible. They are planning to be involved in a whole value chain, from research and development of their own fully AVs, producing them in their own factories to creating a Tesla network platform for sharing their customers autonomous Tesla vehicles. Tesla plans to first sell those cars to customers, where the personal ownership will remain, yet they can decide to sublet their car for the period of time when they don’t use the car onto Tesla’s ride-hailing platform. This means extra earnings for the owners of Tesla vehicles, while they don’t have to work by themselves at all. In a case of traffic peaks, and an insufficient number of idle vehicles around the city, Tesla would supplement this by putting their own fleet of autonomous cars onto a platform.

Partners

Nvidia- American based tech company that is developing and producing graphics processing unit. Nvidia supply Tesla's vehicles with a onboard processing units. [118]

Market Advantages

According to a Navigant Research, Tesla sits in the middle, between all of the other competitors. The company is really strong on vision part, mostly due to their mastermind CEO Elon Musk and it's already selling semi-autonomous cars with autopilot and fully autonomous ready HW. But the Navigant report put their scoring lower, because Tesla is relatively new automaker between extremely competitive environment. Another reason why Tesla surprisingly didn't score high in technology was the lack of LiDAR sensor, that might be truly important for Level 5 autonomy.

Resources

Tesla is involved in a numerous of tech businesses and has multiple streams of income. Their driving force of Research and Development is executed by one of the best world class engineers. But it also means that the company is burning the capital at an extreme speed and can run out of it quickly. Their business model will already generate the source of profit from the selling of their vehicles, additionally, they will charge a commission based fee when a vehicle will be shared on their ride-hailing platform.

Criteria evaluation

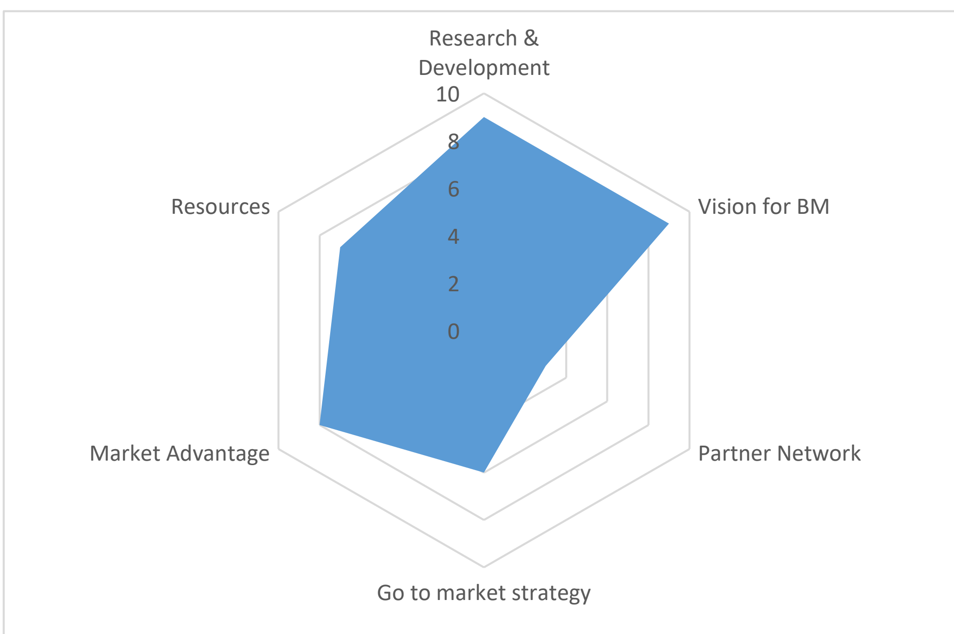


Figure 5.16: Criteria performance Tesla

Tesla in criteria evaluation scored a 2nd place, few points behind the Lyft. Tesla excels in most of the areas while it performs poorly in a Partner Network. Tesla is trying to be as less dependent on the key partners as possible. Their vision is to have a development of AVs, their production and autonomous ride-hailing platform all in-house, without being significantly dependent on anyone. By doing so, they can capture the profit through the whole value chain process, but it can be also a risky and significantly harder strategy if it's executed poorly. Tesla is also currently not able to manufacture vehicles in a high volume; this can change soon with their new Giga factory. The vision for a business plan is to sell their vehicles to their customers what represents owned autonomy model. While those customers can release their AVs to Tesla Network ride-hailing platform when they are not using the vehicle. In addition, Tesla will provide their own fleet of ATs to cover the high demand peak times. This is basically a model where Tesla can capture the revenue in a three different stages. They could scale really quickly with this strategy if we take into consideration that their own customers will help them to scale, and at the same time, they will profit out of it by selling the vehicles. Some sources say that Tesla's technology is the most mature out there. With HW autonomy Level 5 ready, and SW that is improving exponentially. Tesla is also using shadow mode when they are harvesting the data from their current vehicles. Tesla is part of many moonshot projects and is burning the cash quickly. The company will have to find multiple sources of capital to fund their projects.

SWOT Analysis

Strengths

- Leader in the development of AVs by some sources
- Tesla's cars already have the sufficient HW for autonomy Level 5 and are waiting for regulation approval to make the feature commercial
- Produce electric vehicles and owns the network of el. Charger stations across the globe
- Shadow mode for harvesting the data over the cloud from their cars

Weaknesses

- Tesla can't currently run in every state with their sales, marketing and distribution
- Not implementing LiDAR as their sensor and thinks it's not needed [119]
- Trying to be independent and leave partners aside
- Tesla network – peak times

Opportunities

- Tesla's masterplan with a multiple moonshot
- Scaling – owned autonomy and their own fleet of ATs peak hours
- Revenue stream is not dependent purely on margin from the rides
- Sales made by selling cars mainly

Threats

- Thinks that owned autonomy rather than shared autonomy is the way to go
- Very young player in a brutal auto-making industry
- Quickly burning the cash (Tesla, mega factory, self-reliant, SpaceX, Hyperloop, tunnels for cars)
- What are doing their fleet of ATs during off the peak hours when there is lower demand?
- Their competitor Audi with electric vehicle and autonomy sings [120]
- Lyft's CEO have a different point of view about Tesla's vision [121]

6. Discussion

In the beginning we found a two problem definitions, first one was that due to a human error there is over 80% of the accidents on the roads and thousands of deadly fatalities. Second problem was that our cars are parked over 95% of the time and remain unused during the day. Solution to the human error in driving could be replacing human driver with an autonomous technology that can't get tired, distracted, drunk and is in general less aware of the situation on a road than human driver. Nowadays, vast amount of automakers are working towards fully autonomous vehicles that will replace those us as a drivers. The fact that we are using cars inefficiently could solve if we decided to use cars as a shared resource. Using car a shared resource can take many forms, from carpooling, ride-hailing to ride-pooling. The idea behind this study is that ride-hailing companies will offer a fleet of autonomous cars on their platform. During the research this study observed and found few companies that formed partnership, in order to make this idea real. Probably the biggest influence in this have a big tech companies and current ride-hailing services such as Google-Waymo, Tesla, Uber and Lyft. They see the future of transportation as where people no longer own vehicle but rather share car as a resource. As a main drivers in innovation is the technology that is now available and soon developed. The price of sensors is going rapidly down, computing technology is getting cheaper as well, we are now able to more than ever apply AI and use big data that we can collect. Soon ready 5G technology will even further improve the safety and efficiency of autonomous vehicles. Electric vehicle battery cost dropped 80% by the last 6 years and will more likely continue to drop even further [122].Removing the cost for a "taxi" driver and operate a fleet of electric autonomous cars will drive the price per kilometer further down. This will be one of the selling points to an end-users, that will convince them to switch from a owned mobility to share on-demand autonomy. Diffusion of innovation and getting new customer segments on board will be a tough challenge. Good thing is that an early majority of people that are living in an urban area is very opened to use regularly ride-hailing services. But shifting from personal ownership of cars to shared autonomy will probably take a longer time, depending on a culture, demographical location, efficiency and service performance. Tesla is making an important move where they let their customers to use some elements of autonomy in their own vehicles and can get used to the technology. This idea is followed by Uber, Lyft, and Google where they allocated a small fleet of autonomous cars, where people can request a ride with an autonomous car and experience the technology in a real life. This enables to build a trust for the end-users to technology and promote transparency with the performance ability that the technology poses.

But, are we there yet technology wise? Nation Highway Traffic Safety Administration classify 6 levels of autonomy, from Level 0 to Level 5, based on a maturity of the technology. At the moment couple of automakers are allowed to and are selling vehicles with autonomy Level 2 stage. Car manufacturers as GM and Ford showcased that they vehicles are almost Level 3 ready. Tesla's, Google's car showed that their vehicles and technology are capable of operating as Level 4 autonomy, just a few steps before the fully autonomous stage. The hardest part will be then to ensure Level 5 capability of the vehicles and fulfill the requirements for getting an approval by a regulator to operate a fleet of autonomous cars without any human on board.

From a literature, we can identify that we are currently in a fluid phase where a lot of uncertainties dominate the research and development phase. No dominant design is established yet and companies are competing to develop a more mature technology. This can be observable when we see a radical change in development, also with a high demand for a high skilled labor, mostly software engineers that will progressively help to develop the driving intelligence. There are very low barging with suppliers since there is not any economy of scale yet. Companies will have two possible moves, either to choose an offensive move and try to acquire the dominant design and by doing so outmaneuver the competitors. Or to take over a complementary asset that will help them to scale the business later quickly and more effective. Teece divides the two groups of main stakeholders as technology innovators and process imitators. We can see that innovators such as Google, Tesla and Ford are registering Intellectual Property Rights to protect their progress in development against the process imitators. Recently Google started a lawsuit against their rival Uber, stating that their ex-employee stole valuable information when moved to Uber. Facing a lawsuit against such a tech giant is significantly slowing down Uber's progress in R&D. Another pattern we can observe is that Uber and Lyft are taking over the complementary assets, for successful scaling of the business and that Lyft is also attacking a dominant business model design by partnering with possibly most powerful stakeholders.

Autonomous vehicles are often referred as a vehicles that have potential to reduce a carbon emission that is produced by a conventional vehicles. Very few studies are actually pointing out on a rebound effect, that in case that autonomous on-demand transportation became too cheap, people could use it instead of normal transportation and by doing so dramatically increase the number of individual trips. On top of this, there will be a additional travel distance to a trip origins related to a ride-hailing services, what doesn't seems like a such a big issue in a high density populated areas, but it's possible that it will add 10-20% additional traveled distance in a lower density areas. Another disadvantage of ATs could be a problem with a frequently need for a cleaning after the passages leave there trash and a risk of vandalism. Due to those two things there will probably be a need to constantly record and monitor the behavior of passengers, and they would lost the privacy.

Berlin case study helped to get an idea of what things needs to be taken into consideration when choosing a size of a fleet that will replace the trips made by conventional cars. Those data will vary from city to city, but it was and valuable insight, that in this particular case 2,5 million daily rides that are operated by a 1 million vehicles could be for an optimal performance replaced by a 100 000 ATs, what represents reduction 1:10, and is capable of covering the daily traffic peaks that occur in the morning and afternoons. This size was selected by a simulation as a most efficient, where cars are driving idle less time, the passenger waiting time is most of the time quite low. It turned out that still we would use those cars in average 9 hours a day, but the rest of the time those cars could be used for a transportation and delivery purposes instead to maximize the efficiency.

Navigant case study revealed which developers of the AVs are exceling in execution of development and future vision, by ranking them according to a criteria score they earned. We used those information foundations later in the analysis to evaluate the partnerships that individual stakeholders created.

"To make that business of autonomous, on-demand networks in cities successful, it requires the ability to engineer autonomous systems, to build self-driving vehicles in volume and to deploy them in a ride sharing fleet."[123]

Identified three main stakeholders: Automakers – OEMs, Tech Companies, and Ride-hailing providers. There will be a set of other stakeholders, but in this case, the study reveals that the form of partnerships between those three is essential. To provide an ATs service, these three things play a significant role: Production of vehicles, technology, and ride-hailing platform. Our study reveals three kinds of stakeholders that possess the ability to supply at least one of this requirements. Forming a partnership between those three entities enables companies to focus only on the entity that they excel and work together with their partners on the solutions of the other entities. By doing so they can save resources, get ahead of their competition, but it also brings a risk where they lose a certain amount of power due to redistributing the power with their partners.

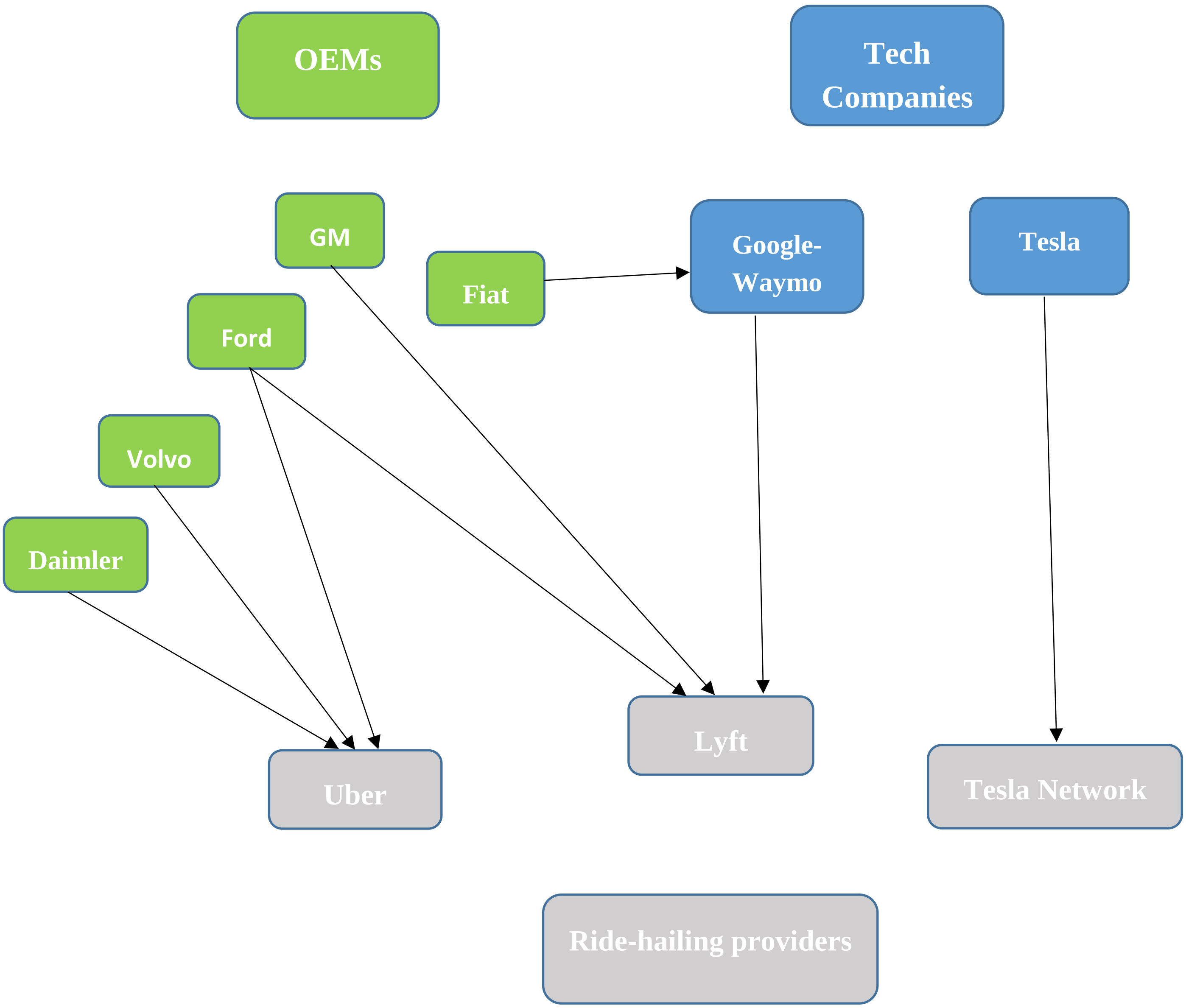


Figure 6.1: Main Stakeholder relationships

Looking at figure 6.1 we can see five automakers: GM, Fiat, Ford, Volvo, and Daimler. From the analysis, we observed that none of them decided to go on their own and provide autonomous ride-hailing services. Right now they are working incrementally on an autonomous technology for cars and install this technology to their vehicles gradually to ensure the safety on board and comfort for their customers. Nothing will probably change for them in their business model until they develop autonomy Level 4 and 5 vehicles. At this point, they will have to rebuild their business model, according to partnerships they announced until now. Three automakers Daimler, Volvo, and Ford announced that they will supply ride-hailing company Uber with a fleet of AVs. In this case, Ford decided to partner up with two ride-hailing rivals Uber and Lyft at the same time and will also sell the license to their patents to other competitors. General Motors announced the partnership with a ride-hailing company called Lyft, where the company will supply Lyft with a fleet of AVs. Carmaker Fiat partnered up with a Tech company Google-Waymo and will play its role as a car supplier, where Google-Waymo will develop and sell AVs to Lyft. On this scheme, Tesla is a Tech company but operates as a carmaker, technology company and also ATs provider. Tesla is developing and manufacturing their own AVs, eventually, their vehicles will operate as ATs on their own Tesla Network ride-hailing platform.

By criteria assessment, the paper found a likelihood of the three main autonomous ride-hailing competitors that are fighting for the dominant business model. Grading was based on a gathered material in the study.

	Uber	**Lyft**	**Tesla**
Research & Development	7	9	9
Vision for BM	7	8	9
Partner Network	7	9	3
Go to market strategy	7	8	6
Market Advantage	6	9	8
Resources	6	4	7
Total	40	47	42

Table: 6.1 Criteria evaluation

Table 6.1 represents the evaluation of three ride-hailing competitors in individual criteria. At the bottom, there is an total sum of the score of each of them. The scale of the evaluation per criteria is from 0 to 10, where 0 value represents the lowest score and 10 is the maximum on a scale. All together there was a chance to score maximally 60 points, if we take into account that there were 6 criteria, by which companies were evaluated. We can see that score-wisely Lyft earned the most of the points, followed by a Tesla an Uber. The difference is not tremendous but it represents Lyft's current slight advantage in company's vision and execution towards fully autonomous ride-hailing transportation.

Business models:

Uber formed a kind of partnership where he as a new entrant dominates mobility services. OEMs will develop, produce and sell or lend a fleet of AVs to them, what means that there will have to be negotiated a new balance of power between the main stakeholders. OEMs Ford, Daimler, and Volvo partnered with Uber to supply the company with a fleet of AVs. Yet, if we take into consideration the price of a car unit costs, a volume of cars that will be needed in each city to scale, Uber won't be able to fund this project without very significant investments from outside. Most likely they will rely on their OEM partners to lend the fleet of cars to them where Uber will charge a small service fee for each ride completed on their platform. Right now Uber operate their multisided platform as a C2C business, where they gather drivers with their own vehicles with riders that seek for transportation services. Uber can leverage their network of end-users known as riders and build upon their service by adding gradually a fleet of ATs on their platform. Riders could then select what kind of transportation they would like to choose, with or without the driver, where the price will probably differentiate. Uber's tactic will be probably to form as much as valuable partnerships with OEM's that will be able to develop and produce AVs in volume and to scale the service quickly across the geographical regions where they want to operate. Their valuable knowledge and experiences with scaling the business across the globe will be a significant competitive advantage. Uber successfully acquired a dominant design of ride-hailing service where they crushed their competition over the regions globally. They managed to lock their customers on their platform, so customers don't switch to their competitors. Therefore, Uber have a great position to rule the market of autonomous on-demand transportation in case that they will find a way how to scale their service quickly.

Lyft is already right now competing against Uber as a ride-hailing service provider. Lyft managed to form quite a unique partnership with one of the most powerful stakeholders in the AVs market, Google, and General Motors. Both of this stakeholders are truly powerful allies, while GM is developing their own autonomous technology, possess with capacity and resources to produce mass volume AVs. Google is developing purely only technology and is without any compromise fighting against their competitor's registration intellectual property rights that are key for an AVs, and there will be ensured a plenty of slowdowns and legal complications for their competition. Google is currently striking also a huge lawsuit against Uber, who could become the biggest rival and competitor in autonomous on-demand transportation services. This is truly an excellent strategy that Lyft went for, creating a very powerful partnership with OEM General Motors and Technological giant Google-Waymo. This will of course put

Lyft into a vulnerable position, where GM and Google will be probably in a position of the power. But as rumors are spreading and as Lyft announced before, they could be acquired by a bigger organization, that could ensure a continual stream of resources that is required for scaling the service in the future. The possible situation could be that Google and GM would acquire Lyft together, and divide the ownership and profit adequately.

Tesla decided to develop autonomous technology, produce and operate an autonomous on-demand transportation services by itself. What puts them into an interesting position, because they won't share the profits with other companies, due to an in-house solutions. Yet It also puts them into a danger where they have to focus on too many things in areas where they could lack the skills and knowledge. Tesla is already selling their vehicles with hardware that is autonomy Level 5 ready and according to their CEO Elon Musk it's just a matter of time until regulations will allow their cars to operate in a fully autonomous mode. Due to their transparency, it could seem that Tesla is currently company with most mature autonomous technology, but this could be misleading due to the fact that Tesla decided to don't use LiDAR sensor technology, that significantly helps to the driving intelligence to recognize the distances from the objects with a superior resolution. It is the most expensive sensing tool of the autonomous vehicle and it seems that Tesla decided to go without it to ensure affordable prices of their vehicles. Tesla believes that LiDAR is not the necessary sensor and their cars will operate well even without them. A tremendous advantage over Tesla's competitors is that all of the cars that they sold so far are running in a shadow mode, that crowd mining the infrastructure data and helps the driving intelligence to learn and improve their action. Tesla's plan is to sell their fully autonomous vehicles to a public, where their customers can lend the idle vehicle to Tesla network platform and make an profit when they don't use their car. What means that Tesla is supporting owned autonomy and in the same time with their ride-hailing platform will support shared autonomy. Meaning that Tesla will make a profit when they will sell their vehicles and also when their customers will share their vehicles on Tesla network platform. It seems like a steady plan to organically grow and scale their business, where Tesla without any other external stakeholders will cover the whole value chain, without a necessity to buy cars by themselves. In addition, Tesla will deliver their own fleet of ATs on their platform to cover the peaks, when the demand will be bigger than the supply. This can bring a question what are those vehicles doing during off-peak hours and how Tesla will redistribute the demand so they are not waiting idle for most of the day. Tesla has an interesting business model when compared with their rivals, yet if they want to be their equal competitor they will have to find a way how to produce their cars in a high volume amounts in order to cover high demand.

The study was based mostly on qualitative data, where information about the industry was collected from case studies, reports, journals and articles. Validation of information from articles can be questioned, but in some cases, it was the only accessible source of the up-to-day information from the industry. During the research, the attempts to get interviews with relevant people from Volvo Sweden, Tesla, Uber, and Spiri failed, due to no interest of companies to share any kind of data from their R&D since that information were classified. Attempt to interview two employees from ride-hailing company Spiri failed due to a lack of their available time. Still, the data collected from other sources seems like a great foundation to come up with answers to research questions. Our study revealed a connection between autonomous vehicles and ride-hailing services. The study further found a connection between three main stakeholders and their possible power distribution.

As a suggestion for a further possible follow-up to this research could be to observe how can ride-hailing companies compete with one another once the dominant design is

7. Conclusion

This study explains an importance of using a variation of sensors for detecting the surroundings around the vehicle, where they complete they each other in areas of lower performance. Paper successfully confirmed the hypothesis about a connection between an autonomous vehicles and sharing economy. Based on an observation of formed partnerships between and key stakeholders, it seems that autonomous vehicles could be used for a "Uber-like" on-demand ride-hailing services when the technology will be mature enough and approved by a regulator. There will be a few competitors trying to acquire the dominant design of the service, where they will operate in the similar way as airline companies – offering the same service, but with different prices schemes, features and extra services. This research has also examined how the dominant design of autonomous vehicles is being formed by a three main stakeholders: Automakers, Tech companies and Ride-hailing companies. Those main stakeholders will have different roles and are currently forming a redistribution of power in a automotive industry. Based on gathered data about the autonomous ride-hailing competitors and proposed criteria assessment it seems like Lyft have currently the best chance to dominate the future of autonomous on-demand transportation markets. Lyft limited the number of partners and choose only the strategic once. Together they formed a very powerful group with a high chance to win the battle over a dominant business model.

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