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Master's Thesis

Self-Driving Cars:
Diffusion of Radical Innovations and Technology Acceptance

A new framework for measuring technology acceptance for SDCs

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Abstract

The self-driving car (SDC) is about to exit fantasy and enter reality. SDCs are expected to be available for purchase in just a few years, and the new technologies that enable autonomous driving hold much promise, regarding safety, environmental impact, increased mobility and higher comfortability.

However, there are worrying prospects, too. Some experts worry that the autonomous car might in practice lead to higher rates of pollution and more time and money spent on commuting. By making personal transport more enjoyable, as well as safer, there is a risk of drastically increased rates of urban sprawl, which is harmful to both the environment and the economy. Gains in fuel-efficiency may be off-set by increased levels of driving, in accordance with the so-called Jevon's Paradox of behavioral compensation.

This paper examines the status and the expected projection of these technologies. Although SDC technology has been thought to be just around the corner several times before, this time is believed to be different. The key difference is that the SDCs considered in this paper will work independently, meaning that they do not require any external additions to infrastructure to function properly.

The paper takes a customer-oriented perspective and provides insight to managers and decision-makers. It poses questions regarding technology acceptance: whether consumers will want to have cars that can drive themselves.

To answer the questions posed, expert interviews and an expert survey have been carried out. Additionally, a substantial literary review was undertaken, much of which related to expectations on SDC technology, traffic issues, innovation and technology acceptance. A comprehensive model for measuring and assessing acceptance of SDCs, called the Robotic Car Acceptance Model or ROCAM, is proposed.

Additionally, this paper lays out a detailed design of a possibly follow-up study. Two scenarios concerning the future of SDCs have been constructed, and these form the foundation of the proposed study.

Foreword

This paper is the de facto finale of my formal education in civil engineering. The work leading up to this report took place during spring and summer of 2014 at the office of Trivector Traffic in Lund, Sweden. It has been an interesting and enriching process.

I would like to thank those who helped me complete this project. First, my supervisor at Trivector Traffic, Emeli Adell, for her important insights on the topic and whose earlier works on technology acceptance have meant a lot for this project. Second, my supervisor at Lund University, Gösta Wijk, whose guidance have without a doubt raised the quality of this paper considerably.

I would also like to thank the City of Lund and its fine university. In a few days, I will return to Gothenburg to begin my career as Civil Engineer, but I will never forget the happy and important years I have spent here in Lund. I feel, now, that it was here that I truly became a man.

Finally, I would like to thank you, the reader, for showing an interest in this work. I hope you find it enlightening and interesting.

Lund, July 2014,
Hannes Enqvist

Due to a demanding new career in infrastructure construction, I didn't completely finish this paper until now. To the list of thanks above, I want to again thank both of my supervisors and my examiner for their great patience.
Emeli, Gösta and Ola – thank you!

Gothenburg, December 1, 2015
Hannes Enqvist

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Abbreviations

AV	-	Autonomous Vehicle
CTO	-	Chief Technology Officer
EEA	-	European Environment Agency
EU	-	European Union
GDP	-	Global Domestic Product
GPS	-	Global Positioning System
ITS	-	Intelligent Transport System
Lidar	-	Light Detection and Ranging
MWh	-	Mega Watt hour = 1 000 000 Watt hours
NGO	-	Non-Governmental Organization
NHTSA	-	National Highway Traffic Safety Administration
Radar	-	Radio Detection and Ranging
R&D	-	Research & Development
RAND	-	Research and Development (US Institute)
SDC	-	Self-Driving Car
SSNC	-	Swedish Society for Nature Conservation

Terminology

The 'Drive Me' project	*In collaboration with government bodies and the City of Gothenburg, Volvo Cars plans to let 100 members of the public use prototype autonomous vehicles for their daily commute.*
Self-driving car	*An automated vehicle, which can drive itself in most or all kinds of traffic situations. No human driver is needed. Also known as an autonomous car, robotic car, driverless car.*
Semi-autonomous car	*For the different levels in automation and their respective meaning, see chapter X*
V2X Communication	*Vehicle-to-External Environment: a collective term for V2V and V2I technologies, see below.*
V2V Communication	*Vehicle-to-Vehicle (V2V) communication is a concept where cars communicate with one another to share traffic information and exchange data about their respective current status and future planned action.*
V2I Communication	*Vehicle-to-Infrastructure (V2I) communication is the exchange of data between vehicles and, for instance, traffic authorities. Traffic authorities collect data from the vehicle regarding e.g. driving conditions and traffic situations, and distributes relevant information to the network of connected cars.*
First-mile-last-mile	*The first-mile-last-mile problem relates to public transportation's inability to get the traveler from exactly where they start to where they want to go. Instead, public transport only reaches certain predetermined points, i.e. bus stops.*

1. Introduction

In this chapter, the foundation of this project is presented. First, the project's background and purpose is explained. Second, it gives a brief presentation of the author's background and that of Trivector Traffic AB, initiator of this project.

1.1 Background

In March 2012, Google published a video showing a blind man "driving" a Toyota Prius, equipped with Google's self-driving technology, on public roads to run his errands. Today there are many major car producers that have built their own self-driving car (SDC) prototypes, including Volvo, Toyota, Audi, Bosch, Nissan, Mercedes-Benz, General Motors, Honda and Tesla Motors (EY, 2014; Shimizu, 2014). As of April, 2014, Google has traversed 1.1 million self-driven kilometers on public roads without ever causing an accident (Google, 2014). Volvo are currently testing their self-driven cars on public roads in Gothenburg, and the company plans to have made SDCs available for use by 2017 in a project dubbed *Drive Me* (Stevens, 2014). Volvo envisions all its new cars to be virtually uncrashable by the year 2020, much as a consequence of self-driving technologies.

> "If I didn't know better, I'd say a ghost was driving"
> - Joann Muller, reporting for Forbes from Google's self-driving car

The self-driving car, long a subject restricted to science-fiction, academic theory and contained laboratory experiments and exhibitions, is quickly becoming a reality. One of the technology's more prominent proponents is Catharina Emsäter-Svärd, Sweden's Minister for Transportation. She views the technology as key to increase traffic efficiency (Persson, 2014, p. 10).

> *"There is no doubt that cars will gain self-driving capabilities within a foreseeable future. Over several decades, billions of dollars of both private and public money has been invested in these technologies. They are now ready to be released on the market, and their backers expect to see a return on their investments."*
> *(Tingvall, 2014)*

> *"[…] autonomous Co-Pilot type vehicles will materialize in this decade. Fully autonomous, self-driving, robotic vehicles will appear 10 years from now"*
> *(ABI Research, 2012)*

> *"The industry consensus is that autonomous driving will be available by 2020. […] by 2035, sales of autonomous vehicles will reach 95.4 million annually, representing 75% of all light-vehicle sales. " (Navigant Research, 2013)*

> *"In North America, the first driverless vehicles will appear in the beginning of the next decade, evolving to more than 10 million robotic vehicles shipping in 2032."*
> *(Gallen, 2013).*

> *"Driverless cars will account for up to 75% of cars on the road by the year 2040"*
> *(IEEE, 2012).*

"I expect we will see complete market penetration for SDCs in 20-40 years"
(Survey, 2014)

"There is no technology barrier from going where we are now to the autonomous car. [...] The big barrier to overcome is customer acceptance. "
- Jim McBride, technical expert at Ford Research and Innovation (Fitchard, 2012)

The Self-Driving Car

The self-driving car (SDC) is a concept being developed by many major car corporations around the world. Cars that could drive themselves are expected to bring significant benefits in several areas, including safety, mobility, comfortability, reliability, accessibility, economy and fuel-efficiency (Survey, 2014; Tingvall, 2014; Hadi, 2014; ABI Research, 2012).

In contrast with another recent vehicle innovation, the electric car, which is dependent on major changes in infrastructure because of the need for electrical charging stations, the driverless technology currently being developed is meant to be working independently (Tingvall, 2014; McKinsey, 2011). This means that it will not require any additions to the existing transportation system However, authorities are discussing ideas and working on technologies that would aid the SDCs. Some think that SDCs would benefit greatly from dedicated driving lanes, but there are also simpler and less expensive measures being developed. The Swedish Transportation Administration is working with Volvo, Chalmers University of Technology and others to test the use of magnetic fields, which are expected to be able to increase the driving accuracy of SDCs, especially in poor weather conditions.

Levels of automation

As of writing, there is no standardized framework for measuring the level of automation in cars. This study will make use of the definitions put forth by the US National Highway Traffic Safety Agency (NHTSA, 2013), which divides self-driving into five levels, listed here:

- **Level 0: No Automation**, where the vehicle operation solely depends on the driver with no automated input. This includes situations where the driver is assisted by passive systems such as a GPS-transmitter or parking sensors. At this level, the driver is fully responsible for navigating the car.
- **Level 1: Function-Specific Automation (FSA),** when the vehicle automatically performs *one* specific control function. Examples include cruise control, where the vehicle maintains the speed set by the driver; and lane centering. These functions may allow the driver to let go of either the pedals or the steering wheel, but not both. At this level, the driver is fully responsible for navigating the car.
- **Level 2: Combined Function Automation (CFA).** At this level, the vehicle carries out two or more simultaneous functions automatically, for example both cruise control and lane centering. (This has been used in automatic congestion driving.) This differs significantly from Level 1, since it involves situations where the driver can let go of both steering and accelerating/braking. The driver is still fully responsible for navigating the car, and must be prepared to take over full control at all times.
- **Level 3: Limited Self-Driving Automation (LSDA).** This level entails situations where the car is able to fully drive itself, without the driver's assistance, under specific conditions. These conditions may relate to weather conditions or the traffic situation around the car.

Cars equipped with active security products, such as automatic emergency brake systems, typically fall into level 2 or level 3.

- **Level 4: Full Self-Driving Automation (FSDA).** This is when the car is able to make any journey all by itself, regardless of external conditions.

    Google's prototype, unveiled in May, 2014, is planned to have Level 4-automation. With a market release planned for some time between 2017 and 2020, the car will have no controls to enable manual driving such as a steering wheel or gas / brake pedals – just one single on/off switch (Urmson, 2014).

What might the future bring?

There are different visions of what the future of SDCs will look like. These depend largely on how competent one expects the technology to become, for instance whether one believes that Level 4 automation is feasible. As will be discussed in further detail later in this paper, many experts who believe in a future of SDCs still see Level 4 automation as unrealistic due to the difficulty in preparing a robotic car for all possible situations that may occur in complex real-life traffic. Here follows a short list of different schools of thought:

A. The glorifying view

Some (e.g., KPMG, 2013; Survey, 2014; Burns, et al., 2013) envision a future where cars can drive themselves 100% of the time. As a consequence, everyone may enjoy the personal mobility that a car brings, including children, handicapped people and intoxicated adults. And since these cars are expected to have other benefits, such as being 10 times safer, more fuel-efficient, faster and more reliable, practically everyone will choose SDCs over a traditional car. Relieving the would-be drivers from having to control the car, these kinds of SDCs would mean that travelers can work, play or even sleep during transport.

Some believe that this will develop into a society where much fewer people own a car and the total number of cars in use will decrease dramatically (Survey, 2014). Instead, people will use a kind of robotic car pool. If one needs to go somewhere, one summons an SDC with an app and tells it where to go. Upon arrival, one exits the car, which then drives off, either to pick up another passenger, or to park itself. Since cars today stand still more than 90% of the time, this sort of system is believed to reduce the amount of cars drastically, and the remaining car fleet can be optimized by, for instance, including smaller cars for use when only one or two people need the car, lessening "dead volume"[1]. And since they can park themselves, some conclude that parking lots may be placed outside of urban centers, leaving room for commerce or recreational space.

B. The moderate view

Others (e.g., Survey, 2014; Waters & Foy, 2013) believe that Level 3-SDC technology will eventually be commonplace and relieve drivers from having to control their car in many, but not all situations. Since the passenger must be ready to take over control if such a situation occurs, people will still have to have a driver's license to drive a car. In most cases, however, the car *will* be able to do the driving by itself, and it will then be safer, more reliable and less fuel consuming. At the same time, it will allow the driver to relax or concentrate on other things.

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[1] In Sweden today, the avarage number of people riding in one car is 1.2. (Swedish Transportation Agency, 2010)

C. The sceptic view

Still others (e.g., Lux Research, 2014; Survey, 2014) believe that Level 3-automation will be too expensive for most people, reaching only a share of 8% of the market. The remaining 92% will, however, be mandated to have Level 2-automation, which is expected to greatly benefit the traffic.

Automated driving technologies, available currently and in the near future:

SDCs navigate by utilizing a range of sensors, including cameras, GPS, radar[2], lidar[3] and ultrasound (Nath, 2013). A basic illustration of how an SDC operates is shown in Figure 1, below.

Sensors (input)	→	Computer (prosess)	→	Mechanical control (output)
- GPS - V2X		- Desision-making software - User interface		- Servo motors - Throttle / brakes - Steering wheel
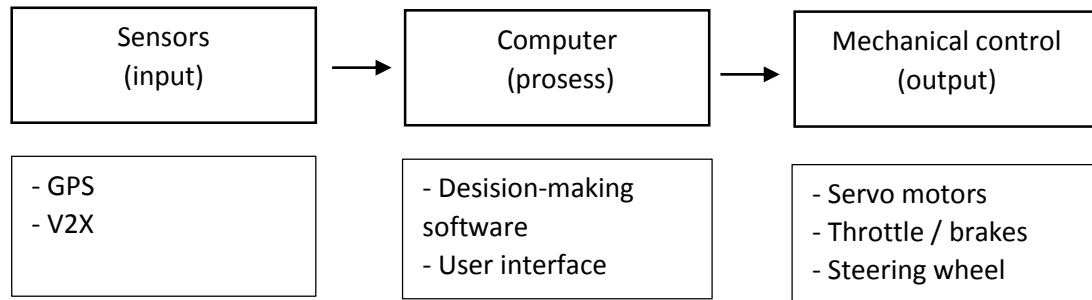
FIGURE 1 BASIC PRINCIPLES FOR CAR AUTOMATION. SOURCE: (FORREST & KONCA, 2007)

Table 1, below, depicts available and anticipated semi-automated driving systems and their respective expected time of introduction:

Manufacturer	Product name	Extent of automation	Expected market introduction
Mercedes-Benz	Stop-and-Go Pilot	Stop and go, up to 56 km/h[4]	Already available
BMW	Traffic Jam Assist	Stop and go, up to 40 km/h	2014
Volvo	Traffic Jam Assistance	Stop and go, up to 50 km/h	2014
Cadillac	Super Cruise	Full range hands-free	2016
Ford	Traffic Jam Assist	Stop and go, highway traffic	2017

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[2] Radio detection and ranging
[3] Light detection and ranging
[4] Due to current legal restrictions, the top speed is in practice limited to 10 km/h

Tesla Motors	Highway autopilot	Full automation on highways	2015
Tesla Motors	Full Autopilot	Full automation in 90% of the time	2017
Google	Driverless car	Level 4 automation	2017-2020

TABLE 1 SOME SEMI-AUTONOMOUS TECHNOLOGIES AND THEIR TIME OF MARKET INTRODUCTION. (GANNES, 2014; KPMG, 2013; WATERS & FOY, 2013; TESLA MOTORS, 2014)

1.2 Purpose

The main barrier to market success for SDCs does not have to do with technology – which is near its completion already – but with consumer acceptance (Fitchard, 2012; Tingvall, 2014; Waytz, et al., 2014). There are arguments to be made both for and against the likelihood of widespread adoption, and there are many experts who consider it likely that most people will shun the SDCs upon introduction. There will surely be enthusiasts, *innovators*, ready and willing to adopt the technology before everyone else. But how many are these individuals? And, more fundamentally, how can acceptance for SDCs be measured?

There is no universally accepted model for studying acceptance of new car technology by drivers. Attempts have been made, notably by Adell (2009), who used the IT-based UTAUT[5] model to examine driver acceptance, but without satisfying results. With its market entrance imminent and the potential disruption that may follow, a way to gauge the acceptance of SDCs is, as will be demonstrated in this paper, of particular importance. The need to find a way to model its expected acceptability by consumers has been has been highlighted by, for instance, Regan, et al. (2014, pp. 345-346). Such a model could be used, for instance, to help firms understand their customers, and act as a guide when considering which marketing strategy to follow.

At its conception, this project had just one purpose, which was to investigate car drivers' acceptance of the new technology that is the self-driving car. The resulting product to address this issue is a new framework for measuring technology acceptance of SDCs, called the Robotic Car Acceptance Model, or ROCAM.

During the work process, an alternative issue became apparent. This has to do with what the *future* impact of SDCs is likely to be, rather than the *current* levels of acceptance that would be investigated in accordance with the first stated purpose. Since it was concluded that addressing this issue would require more work than would fit the scope of this study, the second purpose of this study is to design the layout for a future study.

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[5] Unified Theory of Acceptance and Use of Technology (Adell, 2009; Chuttur, 2009). See chapter 2.2 for further information about UTAUT and other models of acceptance.

1.3 Research Questions

The two key questions that this paper aims to answer is presented here, as well as two sub-questions:

> **1. How can a framework for driver acceptance of SDCs be constructed?**
> *- Which factors are critical for driver acceptance?*
> *- Is the Swedish market likely to be a good proving ground for the new technologies?*
> **2. How should a study to examine the expected future impact of SDCs be designed?**

1.4 Delimitations

This study focuses on the Swedish market for SDCs. It examines the existing research from a marketing perspective. Although legal issues and liability concerns are important questions when discussing the market introduction of SDCs, these will not be taken into consideration for this paper. Furthermore, the technology behind SDCs is assumed to be very near completion, and is thus not considered a barrier for adoption. The barrier, which this work is most concerned with, is the technology readiness of car consumers.

1.5 Report Structure

Chapter 2 describes the theoretical tools and frameworks, which have been used to put the case study data into a comprehensible context.

Chapter 3 explains the methods by which this project has been carried out.

Chapter 4 presents the case study on self-driving cars. Primary data gathered in interviews and the expert survey are presented here, as are the data collected from external sources.

Chapter 5 addresses the first stated purpose of this study, by analyzing the data from Chapter 4 based on the theoretical tools presented in Chapter 2. Here, research question 1 will be answered. A new framework for measuring technology acceptance for self-driving cars will be proposed here.

Chapter 6 addresses the second stated purpose of the study by presenting the layout of a proposed future study. Two possible future scenarios, describing plausible outcomes of the market introduction of Self-Driving Cars, are presented here. These act as the starting point in further research on the subject.

Chapter 7 presents the important conclusions from Chapters 5 and 6, the most important of which are the ROCAM and the design of a future study concerning the expected impact of SDCs.

1.6 Company and author presentations

Trivector Traffic is one of four companies in the Trivector Group, which was founded in 1987 in Lund, Sweden. Trivector Traffic is a consultancy and R&D company that aims to help achieve a more effective, sustainable and safe transport system. By "understanding the future first", Trivector uses the latest scientific methods and research to ensure the provision of knowledge-driven products and services.

At Trivector Traffic, it is believed that the future of personal and public transportation is likely to be greatly affected by self-driving cars (Ljungberg & Adell, 2014). To gain deeper insight into the status and future developments of the technology, Trivector instigated a project, of which this paper is a product.

The author of this paper, Hannes Enqvist, is a master's student in civil engineering, specializing in Industrial Business and Economics with a focus on innovation and management.

2. Theoretical Framework

In this chapter, the theoretical basis for the rest of the paper is presented. Topics discussed include innovation processes, radical innovations, diffusion of innovasion, customer innovativeness and technology acceptance.

2.1 Innovation

2.1.1 Incremental and radical innovation

Joseph Schumpeter (1947, p. 151) defined *innovation* as "the doing of new things or the doing of things that are already being done in a new way". According to Baron & Shane (2008), it is important to distinguish an *innovation* from an *invention*. An invention, according to them, becomes an innovation only when it is capitalized on. Innovations can be either *incremental* or *radical* (Dodgson, et al., 2008), (Christensen, 2011). Most innovations are incremental, meaning that they are of an evolutionary nature. Incremental innovation involves slightly upgrading to an already existing product. Examples include making a phone slightly thinner or a computer slightly faster.

Radical innovations, on the other hand, are revolutionary and imply major changes in the way a product or service works. Apple, Inc., is often noted for bringing radical innovations to the market (Verganti, 2008; Stefik & Stefik, 2004), for example when they introduced the first generation iPod along with iTunes and thus kicked off the business digital music downloads (Johnson, et al., 2008).

An alternative way to distinguish radical innovation from incremental has been suggested by Tidd, et al (2005) as follows: Incremental innovation means the doing of things in a new way, while radical means the doing of new things. Radical innovations are considered to be associated with high levels of uncertainty (Colarelli O'Connor & Rice, 2013).

Dodgson, et al., (2008) note that one way to distinguish incremental innovations from radical one is to assess its level of 'newness', which can be defined by the *newness matrix*, seen below in Figure 2:
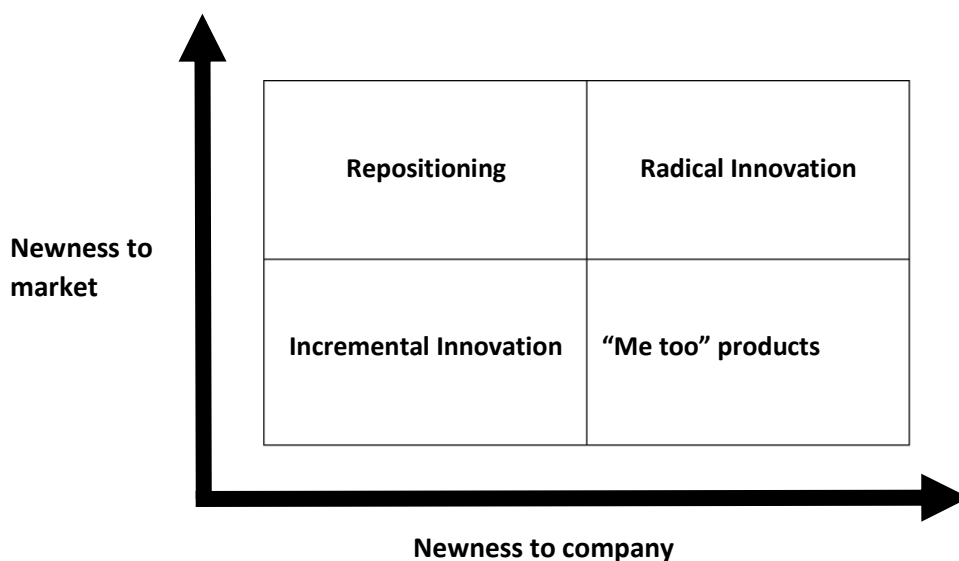

Newness to market

Repositioning	Radical Innovation
Incremental Innovation	"Me too" products

Newness to company

FIGURE 2. THE 'NEWNESS' MATRIX. SOURCE: (DODGSON, ET AL., 2008)

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Since neither car companies nor the car market have experience of selling, buying or using self-driving cars, SDCs are a clear example of a radical innovation.

Successful innovations have many great benefits. Clark & Wheelwright (1993, p. 84) have summarized these as follows:

- improved return on investment
- higher margins
- expanded sales volume
- increased value-added
- lower costs
- improved productivity

On the other hand, innovation is also both risky and costly. Risks include (Dodgson, et al., 2008, p. 202):

- Market risks – uncertainty about demand
- Competitive risks – what will competitors do?
- Technological risks – will the product work?
- Organizational risks – what organizational changes are needed
- Operational risks – can the product be delivered?
- Financial risks – large upfront investments, uncertain future pay-offs

These risks add up and leads to a high failure rate in new product development (NPD). Cooper (1990) states that less than 25% of new NPD projects are successful. More recent studies show that the average success rate for NPD projects have risen somewhat in later years, but it very much remains a highly risky business (Markham & Lee, 2013; McKinsey, 2012; Evanschitzky, et al., 2012).

So why do firms bother to innovate? Following their discussion about the potential risks and rewards of NPD, Dodgson, et al. (2008), conclude that it is more risky for a firm to choose *not* to innovate than to do so. Even though Kodak invented the first digital camera in 1975, it chose not to bring the technology to market for fear of cannibalization on its existing products (i.e. chose not to innovate). This decision effectively led to Kodak's downfall, when competitors such as Sony and Fujitsu eventually engineered digital cameras of their own to compete with Kodak's analog offerings (Christensen, 2011).

In the case of the car industry, it is important to keep up with new technology trends in order to be eligible for the premium market. This, in turn, is important since although premium cars make up only 12% of sales volume in the global car industry, they bring in 50% of the profits (The Economist, 2014). In other words, there are huge incentives for car firms to keep, and preferably increase, their market share in the premium car segment. To do this, they must keep up with emerging technologies.

Another important point to make is that NPD projects that turn out to be unsuccessful need not be seen as a waste of resources. There is much to learn from failed NPD projects, in areas such as marketing, technology, organizational weaknesses and market insight (Maidique & Zirger, 1985), (Dodgson, et al., 2008).

2.1.2 Research push, market pull the evolution of the innovation process

Innovations often start as a new idea within a company. An engineer might come up with a new idea, which makes a product better in some way, and subsequently this bettered product ends up on the market as a new innovation. If the innovation is successful, it will create new demand from the market. This process, when the innovation starts in the industry and then reaches the market, is known as *technology push* (Mohr, et al., 2010).

The reverse process is called *market pull*. This is when the market comes up with a new idea (i.e. a new demand arises) and the industry then creates a product to satisfy the new demand.

Even though customer *demand* is sometimes used interchangeably with customer *needs* and customer *wants*, the three terms actually differ in their respective meaning. Customer *need* relates to a basic human need, for example a person's **hunger**. To continue with this example, customer *want* describes what this person want to satisfy this hunger – his or her *want* is **food**. If that person also has enough money to purchase the food that it *wants* to satisfy his or her *need*, economists say that that person then has *demand* for the food. In other words, it is not enough to *want* something for it to be called *demand*, one also has to have the means of buying whatever is in question.

Technology push is considered to be the first generation of the innovation process, while market pull is usually referred to as the second one (Dodgson, et al., 2008). The innovation process has evolved further, through integration of innovation strategy into the core business strategy and collaboration between companies, suppliers and customers (Johnson, et al., 2008). Today, the process of innovation is considered to be in its fifth generation, which includes the concept known as *open innovation*.

Open innovation and collaboration with customers

Open innovation has been widely discussed and promoted in academic literature over the last couple of decades (Mohr, et al., 2010). Open innovation systems involve not just the innovating firm but emphasizes collaboration with external actors, for instance customers, suppliers, firms in other industries and even competitors. This concept was popularized by Henry Chesbrough in 2003, in response to a widespread not-invented-here mentality, which was considered to hinder technology advancement (Chesbrough, et al., 2006).

Gruner & Homburg (2000) have researched whether involvement of potential customers has an impact on the success of new product development (NPD). The study concluded that, overall, customer involvement has a positive impact on the new product's rate of adoption.

However, it warns that this is not the case for all types of customers. The authors divided customers into four segments: *lead users, financially attractive customers, close customers* and *technically attractive customers*. Whereas collaborating with three of the categories of customers proved beneficial, involvement of *the technically attractive* customers was shown to have a negative impact on the innovation's performance. The authors conclude that involving technically attractive customers, whose preferences often differ from those of the majority of customers, may mislead the innovating firm.

The same study also researched at which stage of NPD customers should be involved. The authors divided the NPD process into six stages:

1. Idea Generation
2. Product Concept Development
3. Project Definition
4. Engineering
5. Prototype Testing
6. Market Launch

Customer involvement in the early and late stages (stages 1, 2, 5 and 6) of NPD was found to be beneficial, whereas such collaboration during the middle stages (stages 3 and 4) had no notable positive impact on NPD performance.

2.1.3 First-movers and followers in innovation

With any new product or service, someone has to be first. If the innovation is successful (and imitable), the rest will follow. There are several benefits in being first-to-market with an innovation, such as knowledge procurement about both the innovation itself and its customers (Johnson, et al., 2014). The first-mover also has a unique opportunity to build a good reputation based on being the only player on a new market. Brand names such as Coca-Cola and Hoover became synonymous with their core products because of their being first on their respective markets, and to this day they reap enormous marketing rewards as a consequence.

Johnson, et al. (2014), also note that there are disadvantages to being first on the market with a new innovation, and that there are advantages to being second-to-market. To imitate another company's product costs about half as much as coming up with the innovation in the first place. Also, the followers have the opportunity to take lessons from the first-movers successes and failures. For these reasons, some writers argue that the most effective strategy when it comes to innovation is not to be first, but to be the "fast second" (Johnson, et al., 2014, pp. 308-309; Markides & Geroski, 2005). They suggest that whether it is better to lead or to follow depends on the situation's context. First-mover advantages are valued higher in slower-moving markets, since new innovations will more quickly be imitated in fast-moving markets, such as mobile phones, thereby making first-mover advantages short-lived.

2.1.4 The Diffusion of Innovation and the Rate of Adoption

The diffusion of innovation is defined as "the process by which innovations spread among users" (Johnson, et al., 2011, p. 303). The authors discuss the importance of the *pace* of innovation, by which they mean the speed and extent of market adoption of new products and services.

As innovation typically is an expensive process, the pace of diffusion is often crucial to commercial success, and this may vary widely. A commonly used example to highlight how the pace of diffusion can vary is the TV vs. the iPod. Whereas it took 37 years for the TV to sell 150M units, the iPod reached the same amount of units sold after just seven years on the market (Dodgson, et al., 2008). For an industry manager, the *speed* with which an innovation is adopted by customers, or *rate of adoption*, often makes the difference between failure and success. Because of this, it is vital to find out how to influence the rate of adoption in the best way possible. In the book *Diffusion of Innovations* (Rogers, 2003, p. 22), *rate of adoption* is defined as the "relative speed with which an innovation is adopted by members of a social system". In practice, it often entails the number of people who have adopted an innovation in one year.

The SDC is a future radical innovation, and it is of course very difficult to foresee the rate of adoption in such a case. Rogers (2003, p. 211) lists three methods to predict the rate of adoption for a forthcoming innovation. The first is to **draw conclusions from past innovations** which are similar in nature to the one in question. A second method is to **describe the innovation to potential adopters** and find out its *perceived* attributes, so as not to rely solely on the *actual* attributes. The third way is to actively **investigate the acceptability** of the innovation in pre-diffusion stages, such as test-marketing or other forms of trials.

Certainly, none of these methods are perfect, much depending on the fact that a customer's intention to buy something often differs from its eventual purchase decision (Arts, et al., 2011)

There are five important factors, which decide the pace of innovation adoption on the market, regarding both the supply and demand sides. On the supply side, the following five product features have been identified as being important for the pace of diffusion (Rogers, 2003, pp. 250-251; Dodgson, et al., 2008): relative advantage, compatibility, complexity, trialability and relationship management. These features are listed below, each with a related real-world example:

- *Relative advantage:* How the new innovation's performance compares to available alternatives. If the innovation is only slightly better than its predecessors, customers will not be willing to invest time and money to upgrade. The added utility must outweigh the cost of upgrading for the customer. Examples of products which have had problems with this are Microsoft's Windows 8 operating system and Nintendo's Wii U gaming console. In both of these cases, customers have not found these new products sufficiently superior to their respective predecessors; Windows 7 and the Wii. As a consequence, sales have been disappointing.
- *Compatibility.* Is the innovation compatible with currently used related services and products? In essence, to what degree will the user have to change their habits and routines when taking part of the innovation? A related example may be whether or not a customer's old smartphone apps will be available on a new phone. If they are not, the customer will be less likely to want to upgrade.
- *Complexity.* Are there many factors to take into account when deciding whether or not to pay for the innovation? One example is complex payment options and pricing structures. *ibid.* claims that simple pricing structures accelerate adoption.
- *Trialability:* The ability for customers to test a product or service before deciding on whether or not to purchase the innovation. This is traditionally a very important factor when purchasing a car, since it is the only way for a customer to try out important attributes such as driving comfort and vehicle handling. When it comes to self-driving cars, which will be an entirely new concept for everyone, experimentation is likely to be one of the most important issues.
- *Relationship management.* The way in which a company handles customer support. Important aspects include how easily obtained the information about the product or service is, how orders and enquiries are handled. Since driverless cars are a completely new kind of product, it will be important to keep customers informed and educated about the service, lest they just turn the feature off and do not use it.

Mohr, et al. (2010), add a sixth factor to better capture the real world circumstances:

- *Ability to communicate product benefits.* This factors in the communications channels through which information about a new product can be transmitted to the potential customers. Examples include internal channels; such as sales personnel and marketing campaigns; and external ones, for instance expert reviews, media coverage and discussions on social media.

On the **demand side**, the pace of diffusion is decided by the following three key factors:

- *Market awareness*. The customer must be aware of the product or service in order to make a purchasing decision.
- *Network effects.* This feature reflects on the fact that many products and services benefit from a broad existing user-base. For example, one of the main reasons that most people choose Facebook before other social networks is that Facebook already has the largest user-base on the market. Innovations often have to deal with a chicken-and-egg situation, which means that they are perceived as inferior due to their lack of customer base.
One such example is Microsoft's venture into the smartphone business with its Windows Phone (WP) operating system, which put the company in direct competition with the well-established iPhone and Android phones. Many people shun WP simply because they perceive that nobody else has it. Adding to the problem, developers ignore WP because of the low number of users, which leads to a lacking supply of apps, which discourages new user adoption and the negative spiral risks continuing.

- *Customer innovativeness*: The manner in which potential customers are spread between the enthusiasts which are highly likely to adopt new innovations (*"innovators")* and those who are indifferent or even hostile towards them (*"laggards"*). These categories are shown in Figure 3, as well as the relative portions of all customers that they make up, respectively. The most critical part of an innovation's diffusion is considered to be the 'crossing of the chasm', meaning how to reach the early and late majorities of customers (Mohr, et al., 2010).
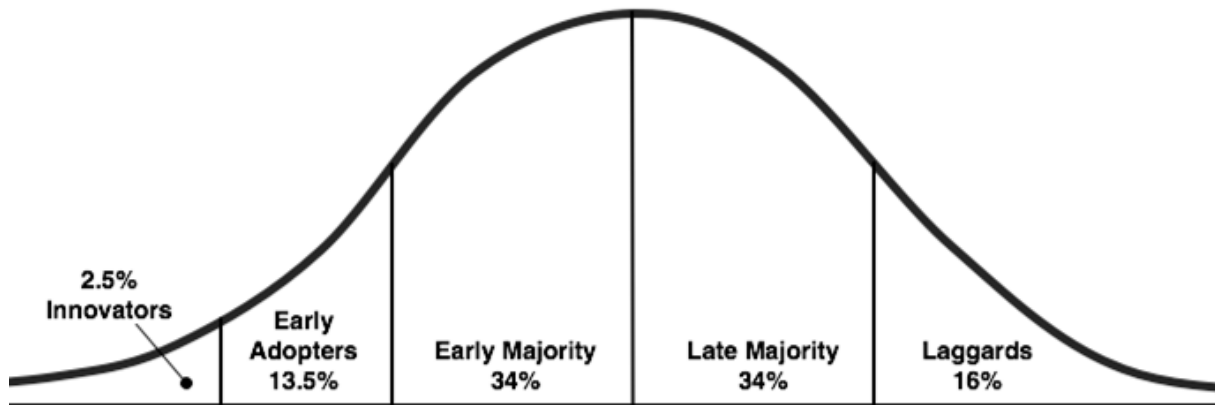

FIGURE 3 THE TECHNOLOGY ADOPTION LIFECYCLE MODEL, WHICH INCLUDES THE FIVE CATEGORIES OF CUSTOMER INNOVATIVENESS. BETWEEN EARLY ADOPTERS AND EARLY MAJORITY LIES 'THE CHASM'. SOURCE: ROGERS (2003, P. 262)

Rogers (2003, p. 111) observes that it is not a product's scientifically established attributes that count, but the ones that are *perceived* by the customer.

One example is Microsoft's latest operating system for PCs, Windows 8. It did not matter that the company, as well as many important change agents, such as Tech bloggers, claimed that Windows 8 was faster, safer and more reliable (attributes deemed to have high importance in the PC market) than its predecessor (Bright, 2012; Warren, 2012; Visser, 2012). Many customers chose not to adopt because they preferred their old software over the new, 'modern', user interface that came with Windows 8. Even though experts claimed that Windows 8 had relatively low complexity and full compatibility with what customers were used to, its rate of adoption was significantly lower than that of Windows 7 because of a high **perceived complexity** and lacked in **perceived compatibility** by the end-users.

2.2 Technology Acceptability and Acceptance

Technology acceptance and acceptability measure to what extent a technology is used by its intended users.

Although acceptance and acceptability are recognized as highly important concepts in literature, there exists no universal definitions (Adell, 2009). Adell breaks down the different definitions found in literature into five categories:

1	2	3	4	5
Using the word '"accept"	Satisfying needs and requirements	Sum of attitudes	Willingness to use	Actual Use

TABLE 2. FIVE CATEGORIES OF ACCEPTANCE DEFINITIONS. SOURCE: ADELL (2009)

Adell (2009, p. 31) proposes the following definition of car driver acceptance, which will be used in this study:

> *Acceptance is the degree to which an individual intends to use a system and, when available, to incorporate the system in his/her driving.*

The field of car technology still lacks a widely accepted and used framework to assess new technology acceptance. In the field of IT, however, many models have been developed to foresee how acceptance of a new technology will turn out to be. This paper will take inspiration from these IT-related models to develop a new one, relating to new technology acceptance in the car industry.

The idea of applying the IT-related models to other industries have been discussed by, among others, Mekić & Özlen (2014) and Mardaneh, et al. (2012). Attempts to transfer the IT-related models to the field of car technology have been made, for instance in publications by Ghazizadeh & Lee(2014), Adell, et al. (2014a), Adell, et al. (2014b) and Adell(2009). Adell (2009, p. 44) lists important differences between IT and car technology, in order to discuss the transferability of IT-related models. The most crucial difference is that whereas a computer error might cause irritation for the user, an error in automation systems in a car could lead to serious or even fatal injury to both the driver and other people. Adell concludes that these differences must be taken into account, but that they should not stand in the way of new acceptance models for car technology taking inspiration from the IT sector.

The list of acceptance models below is adapted from Adell (2009, p. 40) and Chuttur (2009).

1. The Pleasure, Arousal and Dominance paradigm (Mehrabian & Russell, 1974)
2. Theory of Reasoned Action / TRA (Ajzen & Fishbein, 1980)
3. Expectation Disconfirmation theory (Oliver, 1980)
4. Social Exchange Theory (Kelley, 1979, Emersson, 1987)
5. Theory of Planned Behavior / TPB (Ajzen, 1985, Ajzen, 1991)
6. Technology Acceptance Model (TAM) (Davis, 1989)
7. the Model of PC Utilization (Thompson et al., 1991)
8. Social Influence Model (Fulk, et al., 1990 and Fulk, 1993)
9. Motivational Model (Davis, et al., 1992)
10. A combined model of TAM and TPB (Taylor & Todd, 1995)
11. Social Cognitive Theory (Compeau & Higgins, 1995)
12. Innovation Diffusion Theory (Rogers, 1995)
13. Task technology fit (Goodhue & Thompson, 1995)
14. System Implementation (Clegg, 2000)
15. Technology Readiness (Parasuraman, 2000)
16. Technology Acceptance Model 2 / TAM 2 (Venkatesh & Davis, 2000)
17. IS Continuance (Bhattachrjee, 2001)
18. Unified Theory of Acceptance and Use of Technology / UTAUT (Venkatesh, et al., 2003)
19. Three-Tier Use Model (Liaw et al., 2006)
20. Motivation variable of LGO (Saadé, 2007)
21. Social Identity Theory (e.g. Yang et al., 2007)
22. Technology Acceptance Model 3 / TAM 3 (Venkatesh & Bala, 2008)

Central to many of these models are the two concepts *perceived usefulness* and *perceived ease of use*, which are defined as follows:

> ***Perceived usefulness*** *is the extent to which a person believes that using a particular system will enhance his or her performance, while* ***perceived ease of use*** *is the extent to which a person believes that using a particular system will be free of effort.*
> - Davis (1989, p. 320)

Starting with Davis' Technology Acceptance Model – abbreviated as TAM and shown in Figure 4, below – which was developed as an extension of Theory of Reasoned Action (TRA) and Theory of Planned Behavior (TPB) and onwards, almost all of these models are primarily concerned with measuring the adoption of new IT systems (both software and hardware). However, they have sometimes been used in research concerning other areas, including the health sector (Chang, et al., 2007), environmental consumer products (Mardaneh, et al., 2012), tablet computers (Park & del Pobil, 2013) and smartphones (Mekić & Özlen, 2014). Eight of the models listed above (labeled numbers 2, 5, 6, 7, 9, 10, 11 and 12) were in 2003 combined into the Unified Theory of Acceptance and Use of Technology (UTAUT) model, which is highlighted in the list above.
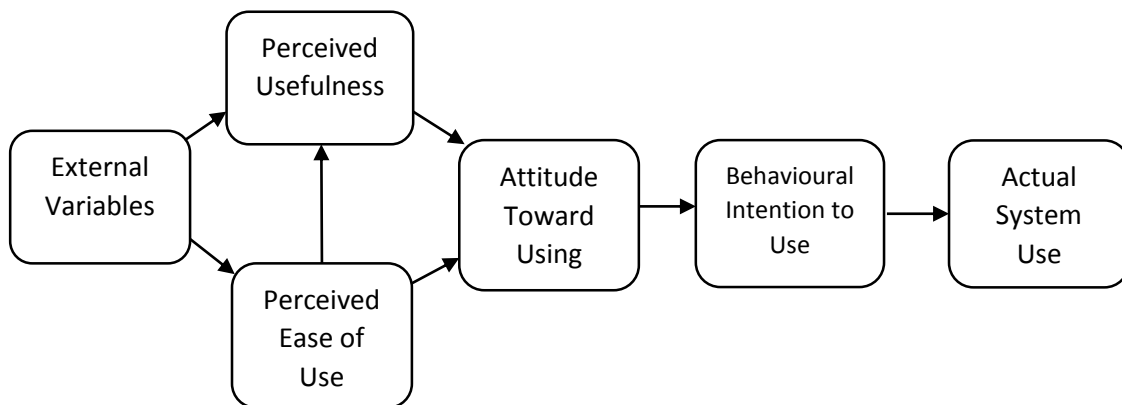

FIGURE 4. THE ORIGINAL TECHNOLOGY ACCEPTANCE MODEL (TAM). SOURCE: (DAVIS, 1989)

2.3 Jevon's Paradox and the Offset Hypothesis

Technological progress and innovation typically increase the utility of the related activity. In relation to the car industry, two areas which are constantly being bettered are *vehicle safety* and *fuel-efficiency.* Major innovations in these areas include the three-point safety belt and anti-lock brakes for vehicle safety; catalytic conversion and particulate filter systems to reduce environmental impact. However, there is a case to be made against these important technical improvements, and it has to do with human behavior.

Researchers have in several contexts observed a human tendency to compromise potential efficiency improvements by a change in driver behavior. This is known as *behavioral compensation*, or Jevon's paradox (Polimeni, 2006). It basically means that, for instance, if someone buys a new car which consumes half as much fuel as he or she is used to, the likelihood is that this person will drive twice as much, and thereby using up as much fuel as before.

Researchers have discovered a related behavior in the area of vehicle safety, known as the offset hypothesis. This states that when, for instance, the anti-lock brakes were popularized in the 1980's, the industry expected that great benefits in traffic safety would follow (Clifford, et al., 2006). Insurance

companies also saw much promise in the new technology, and offered customers incentives to buy a car with anti-lock brakes installed. However, empirical evidence eventually showed that the expected drop in traffic accidents failed to materialize.

Research conducted on the subject concludes that as drivers perceive their car as more safe, having anti-lock brakes installed, these drivers tend to change their driving behavior to a more aggressive style. This effectively cancels out the benefits of having anti-lock brakes installed. The safer the car is perceived, the less safe a driving style will typically be applied. The same pattern has been observed in other cases, for example concerning airbags.

3. Method

In this chapter, the methods by which the project has taken shape are presented and discussed. The first part gives insight to what research strategy has been followed. The rest of the chapter explains which techniques and frameworks have been used and how data collection has been carried out.

3.1 Research Strategy

3.1.1 Research approach

The results presented in chapters 5, 6 and 7 have been reached by a combination of different research methods. A large part of the collected data comes from two sessions of extensive literary reviews. Semi-structured interviews have been held with Claes Tingvall, head of safety at the Swedish Transportation Administration and professor in traffic safety at Chalmers University; and with Emeli Adell, doctor of engineering and consultant at Trivector Traffic.

The insights gained from the first set of interviews and literary review were condensed into the first version of the conceptual framework for robotic car acceptance, or ROCAM for short (see appendix C).

An expert survey was then carried out to gain deeper insights and find out what expectations experts have on SDC technology and the impacts it may have on traffic and society at large. Following the survey, a new round of literary studies was performed, and the collected results make up the final version of ROCAM, see Chapter 5.4.

In parallel with the ROCAM model, insights gathered in this study were used to construct two possible future scenarios regarding the diffusion of SDCs. These scenarios, presented in chapter 6, make up the foundation of a proposed layout for future studies on the subject of SDC diffusion and its implications for business and society.

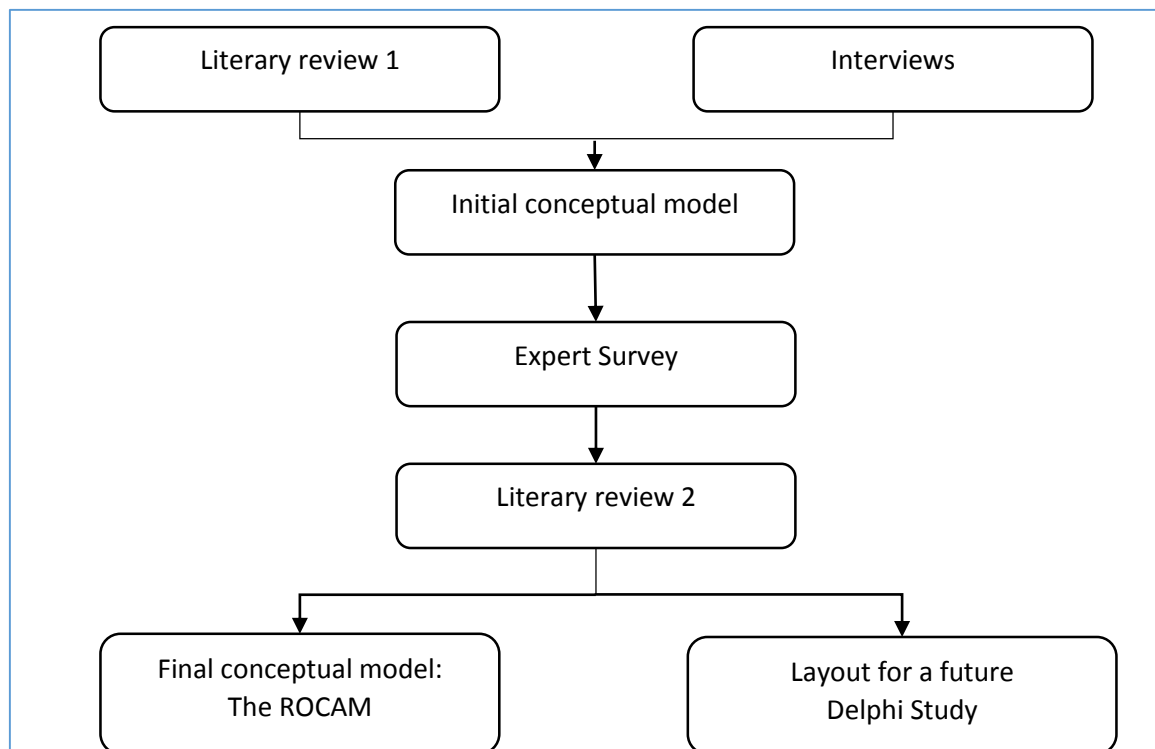Figure 5, below, demonstrates an overview of the research process.

FIGURE 3 OVERVIEW OF THE RESEARCH PROCESS

3.1.2 Qualitative and quantitative data

There are two types of data that can be collected as the foundation for an academic study (Höst, et al., 2006). These are quantitative, which involves data that can be counted or otherwise classified in fixed terms; and qualitative, which entails descriptive data, such as words and descriptions.

Quantitative data is relatively simple to draw relevant conclusions from, for instance by plotting collected data on a graph and look for patterns. Qualitative data, on the other hand, require some form of analytical process before it can be put into a context where it can, for instance, be compared.

Data can also be divided into primary and secondary data. Primary data is first-hand information that is collected specifically for a certain project, while secondary data means data that has been collected from external sources, such as articles or scientific reports. Primary and secondary data have their own strengths and weaknesses. Primary data is often more relevant to the research, in that it has been collected with the research question in mind. It is also often the most up-to-date information available. The drawback of primary data is secondary data's strength: scope. In most cases, the data already in existence is much more extensive than the researcher(s) can collect first-hand. A thorough literary review supplies the researcher(s) with an understanding of what research has been carried out on a subject already. This insight will minimize the risk of researching questions that already have been answered.

In this study, primary data has been collected mainly through interviews, as well as an expert survey, where six experts from different fields, all relevant to the topic of SDCs, have shared their views and predictions.

The project's results and insights have been achieved by combining theoretical frameworks, such as the Technology Acceptance Model, with a case study of SDCs. Most of the case study data is secondary in nature, and the first-hand data has acted as an up-to-date reality-check. This technique is often used to gain a better understanding of a complex situation (Robson, 2011).

The stated purpose of this project is to give insight into the current projection of the SDC, as well as to develop a new framework, to assess the technology acceptance for SDCs.

To discuss the uncertain future, this paper concludes with a set of *scenarios*. Scenarios are a way of attaining an overview of different possible futures. The study of scenarios has been defined as "a disciplined method for imagining possible futures" (Schoemaker, 1995, pp. 1-2). The aim with scenarios is not to make a single prediction of the future, but rather to explore which situations might arise depending on how relevant factors might change over time. Indeed, one of the main advantages with using scenarios is precisely that they avoid making a single prediction about what the future will bring (Johnson, et al., 2011). Such a narrow view would most likely turn out incorrect. Scenarios thus help people to open their minds for different opportunities and better prepare for unforeseen consequences.

3.2 Literature Study

Throughout this project, an extensive literary study has been carried out. Literary studies are essential in scientific writing (Höst, et al., 2006). One of the main purposes of literary studies is for the researcher(s) to obtain an understanding of how far research on the subject in question has come, i.e. which relevant conclusions have been drawn already and what questions remain unanswered (Höst, et al., 2006). The literary studies also enable the researcher to make an informed decision about which methods and frameworks should be used in the research (Bryman & Bell, 2007).

The secondary data that have been researched for this project have been collected from books, academic papers, reports from government and NGOs, business analyses and industry insights.

To collect secondary data, the EBSCOhost database and, to a lesser extent, Google Scholar and Google Search, have been used. Search terms used include:

Driverless cars, autonomous vehicles, technology adoption, technology acceptance, diffusion of innovation, Delphi study, innovation in Sweden

Books referenced have been provided by the author's personal collection, the libraries at Lund University and Trivector, and by both project supervisors, Emeli Adell and Gösta Wijk.

Tables 4 and 5 present an overview of works referenced in this text:

Technology Acceptance	Method
(Adell, 2009)	(Bryman & Bell, 2007)
(Adell, et al., 2014a)	(Höst, et al., 2006)
(Adell, et al., 2014b)	(Keeney, et al., 2006)
(Mardaneh, et al., 2012)	(Martino, 1993)
(Chang, et al., 2007)	(Rescher, 1998)
(Chuttur, 2009)	(Robson, 2011)
(Dutta & Mira, 2011)	(Roman, 1970)
(Eisingerich & Bell, 2008)	(Rowe & Wright, 2001)
(Ghazizadeh & Lee, 2014)	(Rowe & Wright, 1999)
(Gottschalk, 2000)	(Sandford & Hsu, 2007)
(Lewan, 2012)	(Schoemaker, 1995)
(Mekić & Özlen, 2014)	(Skulmoski, et al., 2007)
(Park & del Pobil, 2013)	(Stevenson, 1995)
	(Watson, 2004)
	(Weaver, 1972)

TABLE 4. OVERVIEW OF REFERENCED WORKS REGARDING TECHNOLOGY ACCEPTANCE AND METHODOLOGY

SDC and V2X technology	Traffic	Innovation
(ABI Research, 2012)	(Bates & Leibling, 2012)	(Arts, et al., 2011)
(ABI Research, 2013)	(Bissmont, 2002)	(Baron & Shane, 2008)
(Burns, et al., 2013)	(Bloom & Khanna, 2007)	(Bright, 2012)
(Denso, 2013)	(Clifford, et al., 2006)	(Chesbrough, et al., 2006)
(EY, 2014)	(EEA, 2006)	(Christensen, 2011)
(European Commission, 2014)	(Hendricks, et al., 2001)	(Clark & Wheelwright, 1993)
(Fehrenbacher, 2011)	(Koppel, et al., 2005)	(Colarelli O'Connor & Rice, 2013)
(Fitchard, 2012)	(McKinsey, 2011)	(Dodgson, et al., 2008)
(Forrest & Konca, 2007)	(Nilsson, 2008)	(Evanschitzky, et al., 2012)
(Gallen, 2013)	(Pund, 2001)	(Gruner & Homburg, 2000)
(Gannes, 2014)	(SSNC, 2006)	(Henard & Szymanski, 2001)
(Google, 2014)	(Salmon, et al., 2005)	(Johnson, et al., 2008)
(Hadi, 2014)	(Swedish Transportation Agency, 2010)	(Johnson, et al., 2011)
(IEEE, 2012)	(Swedish Transportation Agency, 2012)	(Johnson, et al., 2014)
(KPMG, 2012)	(Swedish Transportation Agency, 2013)	(Johnson, et al., 2008)
(KPMG, 2013)	(Swedish Transportation Agency, 2014)	(Maidique & Zirger, 1985)
(Litman, 2014)	(The Economist, 2014)	(Markham & Lee, 2013)
(Ljungberg, 2014)	(Tingvall & Haworth, 1999)	(Markides & Geroski, 2005)
(Lux Research, 2014)	(Treat, et al., 1979)	(Mohr, et al., 2010)
(NHTSA, 2013)	(Vision Zero Initiative, 2013)	(Polimeni, 2006)
(Nath, 2013)	(Wedberg, 2010)	(Rogers, 2003)
(Navigant Research, 2013)	(The World Bank, 2008)	(Schumpeter, 1947)
(Persson, 2014)	(Business Recorder, 2014)	(Schwab, 2010)
(Regan, et al., 2014)		(Shanley, 2013)
(Shankland, 2014)		(Stefik & Stefik, 2004)
(Shimizu, 2014)		(Verganti, 2008)
(Stevens, 2014)		(Visser, 2012)
(Tschampa, 2013)		(Warren, 2012)
(Urmson, 2014)		
(Waters & Foy, 2013)		
(Waytz, et al., 2014)		

TABLE 5. OVERVIEW OF REFERENCED WORKS REGARDING SDCS, TRAFFIC AND INNOVATION

3.3 Empirical Study

3.3.1 Interviews

An interview is a systematic way of asking an interviewee questions regarding a certain subject (Höst, et al., 2006). Interviews may be divided into three types: unstructured, semi-structured and structured. The interviews that were conducted during this study, both formal and informal ones, were mostly semi-structured, so as to allow the interviewee more freedom to express their views. In a qualitative study, such as this one, it is important to carefully choose a few people to interview, rather than interview a large amount of people so as to make the interview results representative. Both the interviewees knowledge of and relevance to the subject in question has to be taken into account, as well as their reliability.

Interviews were held with Claes Tingvall, head of safety at the Swedish Transportation Administration and professor in traffic safety at Chalmers University; and with Emeli Adell, doctor of engineering and consultant at Trivector Traffic. Professor Tingvall was chosen because of his participation in the *Drive Me* project, and was deemed a highly relevant and reliable interview object because of his background in the industry.

The interview with professor Tingvall was carried out via a scheduled telephone interview. The questions posed can be found in Appendix A.

Doctor Adell has much experience from working first-hand with traffic-related issues, and her doctoral studies focused on technology acceptance. Over the course of this project, several semi-structured interviews were carried out in person with her, much of them relating to the same issues as the ones seen in Appendix A, but also relating to the subject of technology acceptance.

As is shown in Figure 4, above, the interviews mainly took place in the early parts of this project. The interview with professor Tingvall, who had much to say on the subject of SDCs and traffic innovations at large, gave much insight as to how the project should proceed. Shorter interviews were held sporadically with Doctor Adell, and open discussions were occasionally held with other traffic consultants at Trivector Traffic's Lund office, as well as the CEO and founder, Christer Ljungberg.

After an early interview on the management of innovation with project supervisor Gösta Wijk, it was decided that the *Delphi process* would be useful for gaining insight of the future of the SDC. This idea was also discussed with Doctor Adell, as well as with Professor Tingvall, and they both agreed that this approach would be suitable for the subject matter. The following section discusses the Delphi process in general, and the Delphi-inspired survey carried out in this project.

3.3.2 The Delphi Technique and an Expert Survey

The research of future events is an important but difficult topic (Stevenson, 1995). Over centuries people have done their best to understand the future, and in the past often superstitious methods, such as crystal gazing or analyzing the shape of smoke, were used to little proven effect. In the 1950's, professional institutes such as RAND started developing more scientific methods to predict the future. One of these methods is the *Delphi method*[6], and this was used to inspire the survey eventually carried out in this study.

The Delphi method, first developed in the 1950s at the Rand Institute to aid the US Army in decision-making during the Cold War, is a structured survey that collects insights and predictions from experts in a given field (Rescher, 1998). The method is based on the assumption that these experts, with their high involvement and understanding of the given area, should be able to make the "best guesses" of what the future will bring. The technique has been noted for being very useful when developing forecasts (Skulmoski, et al., 2007), which is important for the purpose of this paper.

The Delphi method is based on the belief that decisions formed by a constructed group are better that those formed in an unconstructed one (Rowe & Wright, 2001), and the notion that the knowledge of a group of experts will always be at least as great as that of any single member of the group (Martino, 1993). Another advantage is that individual bias tends to be cancelled out by using input from several experts. By choosing the participating expert panel with care, the risk of opinion bias will have been greatly reduced (Keeney, et al., 2006).

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[6] The Delphi Method takes its name from the Oracle of Delphi,

The Delphi method has been used extensively by decision makers, often with very good results (Sandford & Hsu, 2007). It has also been widely applied in academic research (Rowe & Wright, 1999). Several studies have researched the historical usage concluded that it is a valid research method (Sandford & Hsu, 2007; Keeney, et al., 2006).

The Delphi process involves one or more rounds of surveys to be answered by the chosen panel of experts (Gottschalk, 2000, p. 173). There are typically two or three rounds, and between the rounds the experts receive feedback on what the group has collectively stated. Although there are formal guidelines regarding how a Delphi process should be carried out, it is in practice often modified to suit the situation at hand (Weaver, 1972).

A key feature in Delphi is that the participants remain partially anonymous. During the process, no one but the researcher will know which experts are participating, and it will not be stated which individual is responsible for any particular answer in the survey results. This anonymity removes pier-pressure and allows the experts to give their opinions more openly. Rowe & Wright (2001) states that a rational method of verifying the Delphi results is to follow these up with a wider survey.

To complement the collected secondary data, a survey has been conducted for this project. In addition to act as a foundation in this study, this survey was used to construct the scenarios presented in chapter 7. These scenarios are in turn proposed to be the base of a future study. The idea of scenarios was discussed with both supervisors of the project, as well as in the interview with Claes Tingvall (Tingvall, 2014). Tingvall also provided some of the names of people who eventually participated in the survey carried out in this project.

Although ten experts were invited to answer the survey (and accepted to do so), only six of them actually did so. This answer frequency of 60% is quite typical of Delphi studies (Watson, 2004). For information on participants and questions used in the expert survey, see Appendix B.

4. Case study of Technology Acceptance of Self-Driving Cars

In this chapter, results from the case study of the radical innovation of Self-Driving Cars are presented.

4.1 Self-Driving Cars and V2X Technology

4.1.1 Self-driving or Driver aiding

The CEO of Tesla Motors, Elon Musk, envisions that 90% of all driving could be automated by 2017, but adds that truly full automation is not feasible due to the complexity involved in preparing automated responses for every possible situation (Waters & Foy, 2013). Musk is not alone in this way of thinking, which regards Level 4-automation as improbable, at least for the foreseeable future. Toyota's stated goal with automation is not a car that will drive itself, but rather an intelligent system that can step in and aid the driver in some situations, for instance when an accident is imminent. This same vision was voiced in the interview with Claes Tingvall during this project, as well as in the expert survey (Tingvall, 2014; Survey, 2014).

Industry analysts from KPMG believe that the automotive industry will go through the different levels of automation on the way to fully autonomous cars (KPMG, 2012; 2013). This is important, not only because it will allow the technology to be tried, tested and improved step-by-step, but also to expose drivers to the concept of self-driving cars. Drivers need to get used to the technology before they will accept a fully automated car as they get used to semi-autonomous functions (Tschampa, 2013; Fitchard, 2012).

4.1.2 Vehicle-to-Vehicle and Vehicle-to-Infrastructure technology

In Sweden, it is mandatory by law for a driver to notify other drivers when, for instance, he or she plans to take a turn (Wedberg, 2010). This is mandatory because the more coordinated drivers are, the safer the traffic will be. Also, better coordination between individual drivers makes the traffic more efficient overall, regarding both energy-usage and speed of transportation.

Vehicle to Vehicle (V2V) technology, which enables cars to send information to one another, is expected to greatly increase the amount and quality of the information, or data, which can be shared between cars (KPMG, 2013). If a V2V-connected car were to drive past an accident, for instance, it would transmit this information to other cars in the area, effectively warning these to take caution when proceeding (European Commission, 2014).

A related technology is V2I, which stands for *Vehicle to Infrastructure* (Regan, et al., 2014). This enables cars not only to exchange information with other cars, but also with, for instance, traffic authorities and the police department.

V2X (*Vehicle to External Environment*) is a collective term, involving both V2V and V2I. V2X technology is expected to bring significant benefits to traffic. As soon as something unexpected happens, like an accident or an animal approaching the road, all cars within a 300 meter radius (Denso, 2013) will be made aware of it and therefore able to take appropriate action. More importantly, by being able to "see" other vehicles where humans cannot (for instance when the view is blocked by a building), V2X technology will likely help car drivers to avoid accidents. By creating a collective 'hive mind', where all cars share information between themselves and with authorities, V2X technology is likely to make traffic more coordinated, making it safer and more efficient with regard to both time and energy usage (Fitchard, 2012). Of course, coordination requires that several cars make use of these technologies.

Indeed, the benefits of V2X technology will increase as the user base grows, a clear example of the network effects discussed in chapter 2.1.3.

Cars utilizing these technologies are expected to be available by 2015, and industry analysts from Gartner expect it will be an industry standard by 2016 (Fehrenbacher, 2011). Other analysts predict that 10.9% of new cars will have the technology installed in 2018, and that the figure will reach 69% by 2027 (ABI Research, 2013). In both the EU and the US, legislators are planning to make these technologies mandatory in new cars within a near future (Shankland, 2014).

4.2 Car Drivers' Technology Acceptance

4.2.1 Measuring Technology Acceptance for SDCs

> *There is no technology barrier from going where we are now to the autonomous car. […] The big barrier to overcome is customer acceptance.*
> - Jim McBride, technical expert at Ford Research and Innovation *(Fitchard, 2012)*

As was stated in the first chapter of this paper, as of writing, there exists no widely accepted comprehensive model to assess and measure technology acceptance for car drivers. Attempts have already been made to use the plethora of existing technology acceptance models in the IT sector and adapt these to the car industry. For instance, Adell (2009) investigated how well the UTAUT[7] model applies to measuring car drivers' acceptance of new technologies. Her research first finds that the original UTAUT can explain only 20% of acceptance behavior. She then tweaked the UTAUT to better fit the drivers' point of view, which resulted in an increased explanatory power (33%). She concludes that research should continue to find an appropriate model for investigating drivers' acceptance of technology, and makes the following suggestions for future modifications (Adell, 2009, p. 60):

- Include the driver's emotional reaction as a factor
- Give the included factors different weights to reflect their respective importance
- Include reliability issues in the model

As was discussed in Section 3.2, a key concept to the TAM[8] and its successors is user perception. It is not enough for a new car technology to be superior for it to influence acceptance, it is crucial that this is also *perceived* by the customer. If the customer is unaware of the technology in question, or misunderstands it, it will not influence their acceptance behavior as intended (Adell, et al., 2014). Indeed, a misunderstanding of technology might well influence acceptance negatively.

Since driver acceptance depends on the individual, Regan, et al. (2014, p. 338) except it to be influenced by factors such as age, gender, culture and personality.

In chapter 2, *radical innovation* and Roger's (2003) *adopter characterizations* were explained. When introducing a radical innovation on the market, it is important to find out who will be the early adopters. This issue was discussed in the expert survey (2014), and one expectation is that drivers who spend a lot of time commuting will have the strongest incentive to adopt SDCs, since they will have most to gain from not having to actively drive and can use their time commuting more productively, by, for instance, work, sleep or enjoy recreational activities. Another suggested group of early adopters

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[7] Unified Theory of Acceptance and Use of Technology, see Section
[8] Technology Acceptance Model

are be disabled or elderly people, who would have much to gain from the increased mobility provided by an SDC.

4.2.2 Psychology of Drivers' Acceptance of Technology

Technology is an increasingly common substitute for humanity. Sophisticated machines now perform tasks that once required a thoughtful human mind, from grading essays to diagnosing cancer patients to driving a car. As engineers overcome design barriers to creating such technology, important psychological barriers that users will face when using this technology emerge.

Perhaps most important, will people be willing to trust competent technology to replace a human mind, such as a teacher's mind when grading essays, or a doctor's mind when diagnosing cancer, or their own mind when driving a car?
– Waytz, et al. (2014, p. 113)

Waytz, et al. (2014) performed experiments to determine how consumer acceptance of autonomous cars is affected by *anthropomorphism*[9]. Their results suggest that attributing human characteristics to an SDC, such as name and gender, makes drivers more likely to trust the technology.

The issue of mistrust is important when it comes to robotic technologies, and it was raised by several of the experts who contributed to this study (Survey, 2014). They expect that many drivers might feel uneasy or even hostile when faced with self-driving technologies, at least at first. The experts suggest that a way to increase trust and make the driver feel more relaxed would be to show real-time information about what the car is doing (i.e., what it "sees", what it is "thinking" and what it "plans" to do next). The experts also stress that this information must be presented in an appropriate way, and that research is needed to determine what information should be conveyed and in what way. One of the experts also suggest that education of drivers will be needed, to prepare and inform about what an SDC will and won't do.

4.2.3 Current consumer awareness of vehicle automation

Theory states that consumer trust in new technology increases with the consumer's knowledge and understanding of that technology (Eisingerich & Bell, 2008). KPMG (2013, p. 23) confirms that this is true for the case of SDCs: the more drivers learn about SDCs, the more likely to adopt them they become. This was also confirmed by the Delphi (2014).

To gauge consumers' awareness of self-driving cars and their exposure to semi-autonomous technologies, sales data from Autoliv and research results from KPMG are presented in figures 5 and 6. Figure 5, below, shows a graph of annual sales figures for active security technologies from Autoliv, including automatic braking and steering. Cars with these technologies built-in count as semi-autonomous (Hadi, 2014).

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[9] Definition of *anthropomorphism*: Ascribing human characteristics to nonhuman things (Merriam-Webster, 2014).
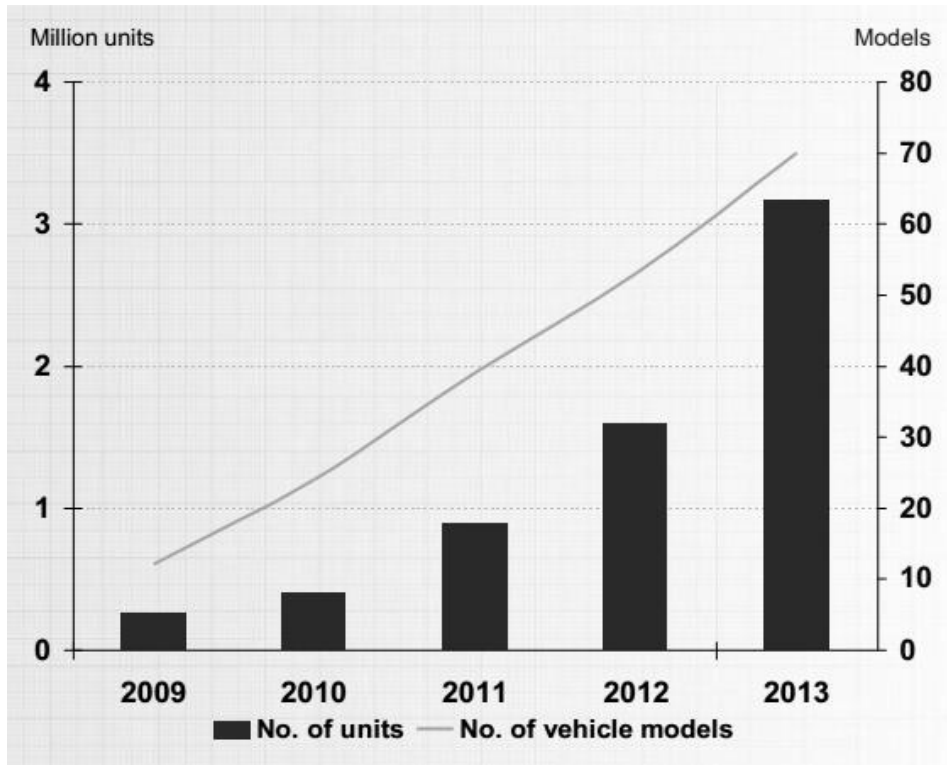
FIGURE 5 AUTOLIV'S SALES FIGURES FOR ACTIVE SECURITY PRODUCTS. SOURCE: HADI, 2014

Figure 6, below, comes from KPMG's 2013 report on SDCs (2013, p. 6). It shows the volume of internet discussions regarding SDCs. The upper line are all opinions registered, and the lower depicts how many of these have a positive view.
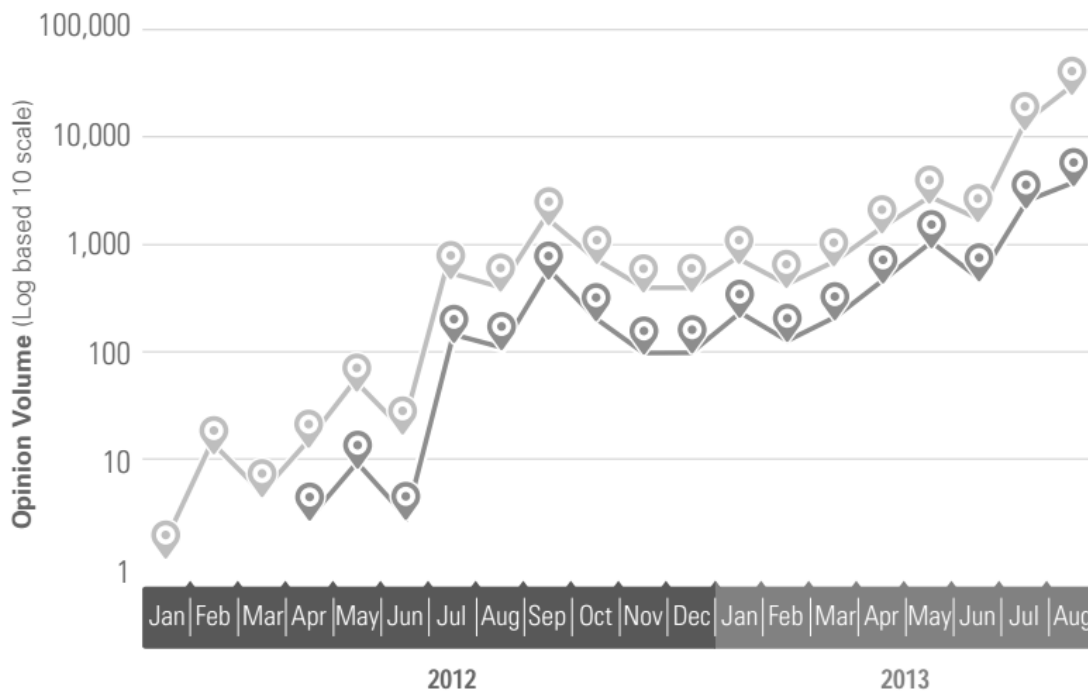

FIGURE 6. INTERNET DISCUSSIONS ABOUT SELF-DRIVING CARS ON INTERNET FORUMS. THE TOP LINE SHOWS ALL DISCUSSIONS, AND THE LOWER ONE HOW MANY OF THESE HAD A POSITIVE VIEW. SOURCE: KPMG, 2013

The trend of increasing interest in SDCs is still continuing to this day (Trends, 2014). Acceptance is also likely to rise if independent third parties were to endorse the technology (KPMG, 2013).

Studies on the subject, may either directly or indirectly contribute to the public's awareness and level of knowledge. Consequently, this kind of research, testing and development of SDC-technology can increase the likelihood of acceptance from consumers (Survey, 2014).

Another important factor for acceptance is, of course, price. If research continues to imply that SDCs hold much promise in areas such as traffic safety, personal mobility and fuel-efficiency, governments will be likely to offer incentives for drivers to adopt the technology, as is often done with new, promising, vehicle technologies (Delphi, 2014; Swedish Transportation Agency, 2013).

4.2.4 Car buyers in Sweden and early adopters of SDCs

Sweden is considered to be one of the best countries in the world at new technology adoption (Schwab, 2010; Dutta & Mira, 2011), and its citizens are generally referred to as early adopters (Shanley, 2013; Lewan, 2012).

To Swedish car consumers, *safety* is regarded as the most important factor when deciding on which car to purchase (Koppel, et al., 2005). It should be noted that studies have consistently shown that 90-95% of traffic accidents are caused by human error, rather than machine error (Treat, et al., 1979; Hendricks, et al., 2001; Salmon, et al., 2005; EY, 2014). The matter of traffic safety has high priority in the Swedish government as well. In the 1990's, the government adopted *Vision Zero* as national policy (Tingvall, 2014; Vision Zero Initiative, 2013). Vision Zero envisions a goal where no person should die or suffer permanent injury in Swedish traffic. In the interview for this paper, Tingvall claims to expect SDCs to be key in reaching that goal.

Another highly important factor is *environmental sustainability* (Nilsson, 2008).

The previous section (c.f. chapter 4.2.2) stated that third-party approval will have a positive effect on drivers' technology acceptance. This is already happening around the world. In Sweden, for instance, Volvo has teamed up with the government, municipalities, the academia and private research institutes to bring SDCs closer to reality. All these parties are vying for self-driving technology, and Sweden's ex-minister for infrastructure, Catharina Elmsäter-Svärd, believes that this cooperation will benefit the technology (Persson, 2014, p. 10). More recently, the current Swedish government is actively examining how to introduce SCDs on public roads (Tibell, 2015). Indirectly, by an accumulation of trust that comes with the different institutions involved, and directly, by actively cooperating to find and address opportunities and threats. For instance, the Swedish Transport Administration is currently conducting trials where they are using magnetic fields as guidance for SDCs (Tingvall, 2014). The magnetic fields will, according to Tingvall, enable SDCs to "see" even further and with more details, and more importantly they will provide vision when visibility is low, for instance during fog or when a physical object (e.g., a bus) obscures the view.

Thus, third party-involvement will be likely to not only increase acceptance, it is expected to be essential in bringing the technology into maturity (Survey, 2014; Persson, 2014; Tingvall, 2014). The experts expect that, as with most (if not all) new technologies, SDCs will be likely to experience unforeseen problems in its early stages of market introduction. These problems risk seriously diminishing trust and acceptance of SDCs, and it might well become necessary for the technology's stakeholders to put resources into drive the technology forwards by offering incentives.

4.3 Cars, urbanization and urban sprawl

> *"For energy efficiency, choose urban density over urban sprawl."*
> *-Wim Thomas, chief energy advisor at Shell Global (Business Recorder, 2014)*

While some of the experts surveyed (Survey, 2014) expect that SDCs will have only benefits if one looks objectively on the subject, others raise some concerns. The main and most often cited one has to do with increased levels of *urban sprawl*. The same issue has been discussed in the reviewed secondary data (e.g., Litman, 2014; Ljungberg, 2014). Urban sprawl will be elaborated upon in the following section.

There is a positive relationship between urbanization and household income (The World Bank, 2008). By realizing economies of scale, urbanization brings other significant advantages in essential areas, such as healthcare, education, transportation and communication (Bloom & Khanna, 2007). Additionally, work opportunities are generally better in cities than in rural areas.

In many parts of the world, a long period of increasing urbanization followed the industrial revolution as more and more people moved into the cities where industries thrived (SSNC, 2006). During the first part of the 20th century, this trend was broken in the US. The impact of private car ownership meant substantially better means of transportation. This led many cities to expand widely as people increasingly moved to the suburbs as they could comfortably commute larger distances (EEA, 2006). This phenomenon, known as *urban sprawl*, meant that population density of many cities radically decreased. Although the same trend has been seen is Europe, it has been much less apparent due to historical and cultural factors.

The European Environmental Agency (EEA) defines urban sprawl as "low-density expansion of large urban areas". The EEA notes that urban sprawl often leap-frogs over whole areas, leaving large unused space between cities and suburbs. In its 2006 report, the EEA states that urban sprawl leads to inefficiency regarding use of energy, land and soil, which have negative effects on the environment. Furthermore, urban sprawl goes hand-in-hand with increased car dependence and more miles driven (SSNC, 2006). Thus, urban sprawl leads both directly and indirectly to greater CO_2 emissions per capita, thereby hindering climate policy. A 2002 Scania-based study has compared the CO_2-emissions from urban households with that of suburban ones (Bissmont, 2002). The study found that the average daily emissions of CO_2 was 7 560 grams for outlying households, and 3 420 grams for centrally located ones. In other words, central homes consumes less than half as much as outlying ones per person on average.

Population density ($\frac{residents + workers}{hectare}$)	Travel-related yearly energy consumption, MWh/capita	Cost of transport (% of GDP)
< 25	15.3	12.4
25 to 50	5.6	11.1
50 to 100	3.8	8.6
> 100	3.4	5.7

TABLE 5. ENERGY USED IN TRANSPORTATION BY DIFFERENT RATES OF POPULATION DENSITY. SOURCE: (EEA, 2006)
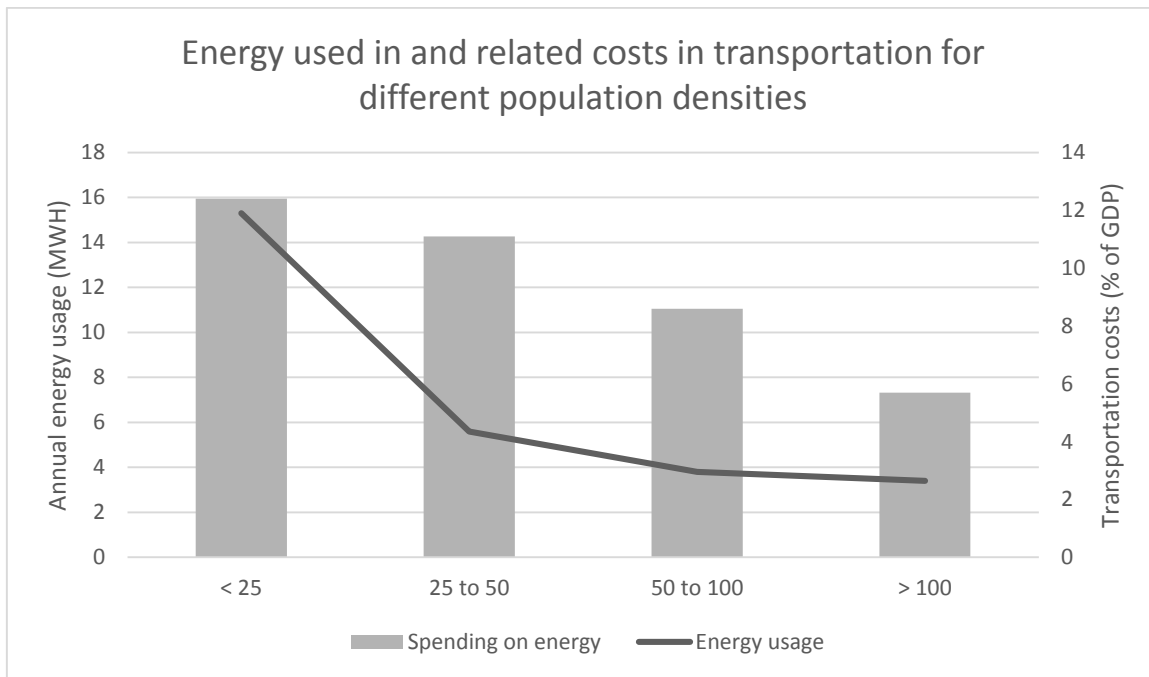
Figure 7. Graphical representation of Table 5.

Similar relationships have been observed in other studies, for example by Shell (Business Recorder, 2014).

From an economic perspective, urban sprawl has a negative impact on society, since it leads to more time and money spent on commuting. Furthermore, the transportation system needs to extend to accommodate new housing sites. As the road network gets more extensive in tandem with an increasingly dispersed city, it loses economic efficiency (Pund, 2001).

4.4 Car pools, on-demand car sharing and car ownership

As was depicted in the introduction of this paper, there are many, including some of the experts surveyed in this paper's expert survey (2014), who believe that the wide-spread introduction of SDCs will eventually lead to dramatically decreased levels of car ownership. These experts expect that, instead of owning their own car, many people will opt to join a driverless car sharing program. Much personal transportation that have in the past been made by manual driving will instead be made by use of "robot taxis", summoned at will by, for instance, an app on your smartphone (KPMG, 2013). This system of shared driverless cars will by some estimates lead to a drop of 80% of the total number of cars (Han, 2014).

In today's society, a typical car is used only 3.5% of the time (Bates & Leibling, 2012). For the remaining 96.5%, it is parked. This insight has led many to discuss the concept of car-sharing programs (Swedish Transportation Agency, 2014), where drivers co-own cars and use them only when they need to, in order to raise the level of usage. Currently in Sweden, one of these shared cars typically replaces 5-7 personally owned ones (Swedish Transportation Agency, 2012, p. 58), and the shared car phenomenon is on the rise. The Swedish startup FlexiDrive, which allows users to create a flexible and easy-to-set-up car pool by renting and renting out their own private, has in May 2014 noted a record 200 000 unique visitors on its website (Engervall, 2014).

By decreasing the total amount of cars, environmental strain is expected to be lessened, and quality of urban life ('livability') will rise (Tingvall, 2014; Survey, 2014).

5. Discussion and Analysis

To address the first stated purpose of this study, this chapter discusses and analyzes the data aquired in the case study presented in Chapter 4 by using the the theoretical framework presented in Chapter 3.

Self-driving cars (SDCs) are heading towards the market quickly. As was shown in Chapter 1.1, SDC technologies of all levels (c.f. chapter 1.1) are expected to be available for purchase in the near-future, and V2X technologies will likely be made mandatory for new cars within a few years(c.f. chapter 4.1.2). Together, these technologies are expected to transform the transportation situation by reducing traffic accidents and pollution, providing a whole new level of comfort to car drivers and speeding up the traffic. But is the SDC feasible? By using Roger's (2003) attributes of innovations, this question will be answered in the following section.

5.1 The Attributes of Innovations for Self-Driving Cars

In chapter 3.1.4 of this paper, factors important for reaching high levels of diffusion of new technologies were listed as *relative advantage, compatibility, complexity, trialability, observability* and *ability to communicate product benefits.* In this section, of these factors will be discussed in relation to the self-driving car.

5.1.1 Attributes on the supply side

Relative advantage

One of the main advantages to SDCs is concerned with safety. Since over 90% of traffic accidents are caused by *human error*, such as fatigue, distracted driving or DUI[10] (Hadi, 2014), SDCs are expected to be radically safer than traditional cars. They are also expected to increase fuel-efficiency, and reduce travel times. Since both safety and environmental friendliness are considered top priorities for Swedish car buyers, these factors are working strongly in the SDC's favor. The fact that the SDC also allows the would-be driver to relax, work or play is as added bonus.

Compatibility

Even though ideas to improve SDC utility are being investigated, for instance by placing magnets in the road to great a vast magnetic field which would act as guidance for SDCs, the cars under development by Volvo and others will not require any additions to current infrastructure(c.f. chapter 1.1). As such, drivers will not be required to change their travel habits or patterns at all. Compatibility is thus expected to be high.

In comparison, the electric car lacks in compatibility, since the supply of electric charging stations is still lacking. This means that drivers cannot plan and act as freely as they are used to with petrol-driven cars.

Complexity

The SDC is intended to ease the car driver's workload, without any considerable trade-offs (c.f. Chapter 1.1). Google's prototype car has no pedals no steering wheel, just one button: Start / Stop. Complexity in SDCs is expected to be very low, probably lower than traditional cars.

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[10] Driving Under the Influence

Trialability

Although there is currently no way for customers to try SDCs, they will likely be available to test-drive just like traditional cars – especially since automakers are well aware of the fact that no one has driven an SDC before. Trialability is, in other words, expected to be high.

Observability

Consumers will most probably be highly aware of SDCs and their (expected) advantages. Media buzz on the subject is already abound, and increasing in volume as new SDC-related announcements are made and more research on the subject is published. If the technology lives up to its promises of safer traffic, reduced levels of fuel-usage and increased travel comfortability, potential users are sure to be informed about this. These advantages are also immediately recognizable and highly relatable to people who see, hear or read about SDCs. Observability, in other words, is expected to be high.

Ability to communicate product benefits

If SDCs continue to look as promising as they do today, and eventually prove it by empirical experience, the car industry will have no problem in communicating their benefits to consumers. For one, they will, just as today, have their partner network consisting of, for instance, car dealerships to spread information and allow customers to try out the technology. Again, as stated under *Observability*, it will be easy for people to relate and understand these communicated benefits and how they could relate to their life. Furthermore, governments and NGOs are expected to be campaigning as well, in order to speed up the rate of adoption. This might be especially in Sweden, where the government is actively pursuing Vision Zero. The ability to communicate product benefits is therefor expected to be high.

5.1.2 Attributes on the demand side

Market awareness

Potential customers are already being informed about self-driving cars by coverage on news sources and internet chatter (c.f. chapter 4.2.3). More importantly for acceptance, many cars sold today already have automation of Levels 1 and 2, which will give customers first-hand experience of SDC technology. As is shown in chapter 1.1, these technologies are advancing as well as spreading fast. With this in mind, the market awareness is expected to be high once SDCs go on sale.

As Sweden will be host of Volvo's *Drive Me* project, its people will likely become highly aware of SDCs, relative to other nations.

Network effects

SDC and, even more so, V2X technologies will gain in value as the technologies spread, as was discussed in Chapter 4.1.2. Only when a critical mass of road traffic is connected, will the V2V technology be able to fulfill its promise regarding traffic coordination and collaboration. This means that SDC attraction will increase with a growth in user-base. Since the network-related benefits won't apply to the early adopters, they should not be widely advertised in SDCs market introduction.

Customer innovativeness

The adopter characterization concept, discussed in Chapter 2.1.4, is important when considering radical innovations such as the SDC. Marketers must identify likely early-adopters and communicate the benefits of SDCs to these appropriately. Because of its innovative and relatively technology-ready population (c.f. chapter 4.2.2), Sweden is thought to be a good starting point for SDCs.

As time goes on, and the market sees and experiences more and more semi-autonomous cars, technology readiness will rise further (c.f. chapter 4.1.2).

5.1.3 Summary of the Attributes of Innovations for Self-Driving Cars

Roger's attributes has been shown to explain a lot regarding an innovation's diffusion ability, or its likelihood of successfully spreading among users. After considering these attributes one-by-one, it is concluded that SDCs have a high chance of success, since the relating expected benefits outweigh the expected drawbacks.

Sweden is expected to be a good early market for the new technology. Besides high levels of technology-readiness as a nation, Sweden will also be the home of Volvo's *Drive Me* project, which will likely lead to a relatively high awareness among the people.

5.2 Management of radical Innovation

As was concluded in chapter 2.1.1, SDCs are an example of radical innovation and, as such, there is great uncertainty regarding them. Two alternative drivers of innovation are *technology push* and *demand pull* (c.f. chapter 2.1.2). One of these drivers will typically follow the other: if a new customer demand arises, the industry will try to provide to that demand, and if the industry creates new technology for which there is no demand, it must work to create that demand. In the case of SDCs, it can be argued that there no demand yet exists, and that it is a clear case of technology push. However, if you look at the more basic level of *customer want* there is an alternative argument to be made about a latent demand, i.e. one which customers are not yet aware of. Even though practically nobody is *demanding* an SDC in particular yet, customers always *want* higher comfortability, mobility and fuel-efficiency. If the industry succeeds in presenting a good enough offering with SDCs, this customer *want* will likely turn into customer *needs.* Whichever company makes this happen is likely to experience major benefits (c.f. chapter 2.1.1).

The first-mover, i.e., the firm which succeeds in offering an SDC to customers first of all, may enjoy great benefits from being the only available supplier until someone else enters the fray (c.f. 2.1.3). On the other hand, the firms who are followers will have an opportunity to learn from successes and mistakes made by the first-mover, without enduring the same risk. The case can be made differently, but for such a radical innovation, it is likely better to be a so-called fast second than to be first.

People already trust machines and computers for many important things. People today query their phone about directions or product recommendations, and they have for a long time trusted calculators to aid them in decision-making. However, as the importance of the task to be done gets higher, trust in machines declines. One example is money and finance. Many people are still hostile toward online banking and even the use of credit cards, preferring cash in spite of the greater risks posed. For SDCs to become a success, people will need to start trusting machines with their own and others' lives.

In chapter 4.2.2, it was shown that annual sales of active security systems are rising fast. Since these systems are in fact a form of (semi-)autonomous driving technology, their spread and increased use on the market will make drivers more aware of and used to the idea of SDCs. Since increased awareness and knowledge leads to higher acceptance (c.f. chapter 4.2.2), this trend will likely be beneficial for the market introduction of SDCs.

There are many who doubt that Level 4-automation will become a reality in the future (see section 4.) Since there will, however unlikely, occur situations which the automatic system is unfit to handle, this means that the would-be driver has to be ready to take over control of the car. By extension, this makes the idea of driverless taxi fleets improbable, as well as using SDCs to transport people without a driver's license, including the blind and children. The scenario of completely driverless on-demand car pools which you summon with your smartphone is thus not likely, at least not for the foreseeable future.

As a way of both promoting the SDC technology and increasing its attractiveness, car firms should consider involving key types of customers in the coming late stages of development, and the early stages of marketing (c.f. chapter 2.1.2). It seems that Volvo is already planning on doing precisely this, by providing 100 regular commuters in Gothenburg with SDCs to drive them to and from work. This may well give provide Volvo with important insights in customer preferences as well as how well the technology performs in the real world. As was noted in chapter 2.1.4, this sort of customer involvement has been identified as a good way to gauge the future movements of a radical innovation and might thus be of high importance to the marketing strategy of SDCs.

The early marketing of SDCs should be aimed at customers likely to be *innovators* and *early adopters*. However, as these categories of customers typically only make up about 15% of the market (c.f. chapter 2.1.4), the most important phase of a product's diffusion is considered to be the 'crossing of the chasm', meaning how to reach the majority of customers. Increased real-world use of SDC technology will increase market awareness overall and the observability is expected to be high. Since acceptability increases with customer awareness (c.f. chapter 4.2.3), the crossing of the chasm is not expected to be very difficult in this case (given that the early adopters accept and use SDCs).

Psychological aspects of technology usage must be taken into consideration when forming a marketing strategy for SDCs. In chapter 4.2.2, it was stated that giving SDCs human characteristics might increase levels of acceptability. This concept, called anthropomorphism, should also be taken into account when designing the final product and marketing campaign.

5.3 Societal implications, risks and rewards

Society at large may see great rewards from the successful diffusion of SDCs. Most importantly, SDCs may increase road safety dramatically (c.f. 1.1) by reducing the presence of human error and increasing the coordination between cars (V2V) and the external infrastructure (V2I). Fuel efficiency and land-use will also benefit from a fleet of connected SDCs.

The *offset hypothesis* (c.f. chapter 2.3), which in the past have led to disappointing benefits from upgrades in vehicle safety, may not apply to SDCs – at least not at automation levels 3 and 4. This might be the case because of the fact that the offset hypothesis is a wholly human behavior, and would thus be eliminated if computers controlled the car. However, for cars with automation levels 1 and 2, the offset hypothesis might come into play, reducing the technology's potential safety benefits.

Jevons paradox, on the other hand, (c.f. chapter 2.3) will be likely to apply to SDCs. By increasing the comfortability and, at the same time, decreasing driving costs, SDCs might lead people to greatly increase their use of cars. This may lead to an even worse traffic situation than we have today (if the coordination V2X technologies provide cannot compensate sufficiently), which in turn might lead to a higher number of traffic accidents in absolute terms. An indirect effect from higher levels of driving is more obesity and higher levels of diabetes. SDCs also risk bringing a new wave of urban sprawl, which is considered to be harmful to society as a whole (c.f. chapter 4.3).

Some experts believe that SDCs will lead to a dramatic increase in the use of shared cars (c.f. chapter 4.4), which would greatly benefit society by decreasing the amount of cars in traffic by 80%, thereby increasing urban livability and lessening traffic-related environmental impact. These issues are discussed further in Chapter 7.

5.4 ROCAM: The Robotic Car Acceptance Model

The aim of this paper is to answer one key question, as well as two sub-questions:

> **1. How can a framework for driver acceptance of SDCs be constructed?**
> A. *Which factors are critical for consumer acceptance?*
> B. *Is the Swedish market likely to be a good proving ground for the new technologies?*

In this section, the two sub-questions will first be answered with the previous discussions in mind, and finally a conceptual model for a framework to measure driver acceptance of SDCs – the Robotic Car Acceptance Model, abbreviated as ROCAM – will be proposed. Sub-question B will be answered first.

> B. *Is the Swedish market likely to be a good proving ground for the new technologies?*

The answer to is, simply put, 'Yes'. Sweden is among the world's best countries at new technology adoption, and the expected benefits SDCs are expected to bring, related to safety and the environment, will be viewed as important relative advantages by Swedish car consumers. The fact that Volvo – a national champion in Swedish commerce and subject of cultural pride – is at the forefront of this new field will likely push Swedes further towards adoption.

As have been discussed throughout this paper and summarized in this chapter, the experts surveyed in this project are in agreement over the expected success of SDC technology. The technology, which promises improvements regarding personal mobility, public safety and environmental sustainability, is in its very late, near-mature, stages. Market introduction is just around the corner, and there are many powerful backers and stakeholders. Not just the car industry, but governments and NGOs are expected to drive this technology towards its diffusion, in order to reach the expected network effects.

> **How can a framework for driver acceptance of SDCs be constructed?**
> *- Which factors are critical for consumer acceptance?*

Because the main question requires an answer to sub-question A, this will be answered first. The discussion will then lead to the proposed framework, ROCAM, to answer the main question.

Throughout this text, several factors which are expected to be crucial for consumers' choice of whether or not to accept SDC technology have been identified. They have to do with:

1. *Trust in SDC technology*
2. *Understanding of SDC technology*
3. *Perceived anthropomorphism*
4. *Perceived risk relating to SDC technology*
5. *Perceived safety of SDC technology*
6. *Perceived environmental benefits of SDC technology*
7. *Perceived comfortability of SDC technology*
8. *Perceived costs and savings arisen from SDC technology*
9. *Perceived reliability of SDC technology*
10. *Perceived complexity of SDC technology*

As was noted in earlier parts of this paper (c.f. chapter 1.2, chapter 2.2), there is need for a new model to measure drivers' technology acceptance. To construct a comprehensive conceptual model of acceptance of SDC technology, factors 1-3 will be packaged into one: **Technology Readiness**. The level of trust is to an extent in formed by his or her awareness and understanding of that system and the fact that the level of anthropomorphism has been shown to affect trust in driverless cars (c.f. chapter

4.2.2). Factor 4, regarding **Risk**, will be left as-is, but factors 5-8 will form the factor **Perceived Usefulness**. Factors 9-10 will together make up **Perceived Ease of Use**.

The conceptual model will take the original TAM[11] as a starting point, and then extend the model by implementing **Technology Readiness** and **Perceived Risk** as additional drivers of acceptance. Nine hypotheses regarding the relationship between the included factors, i.e. what impact they have on each other, will be formed. These nine hypotheses will be denoted as *H1-H9.*
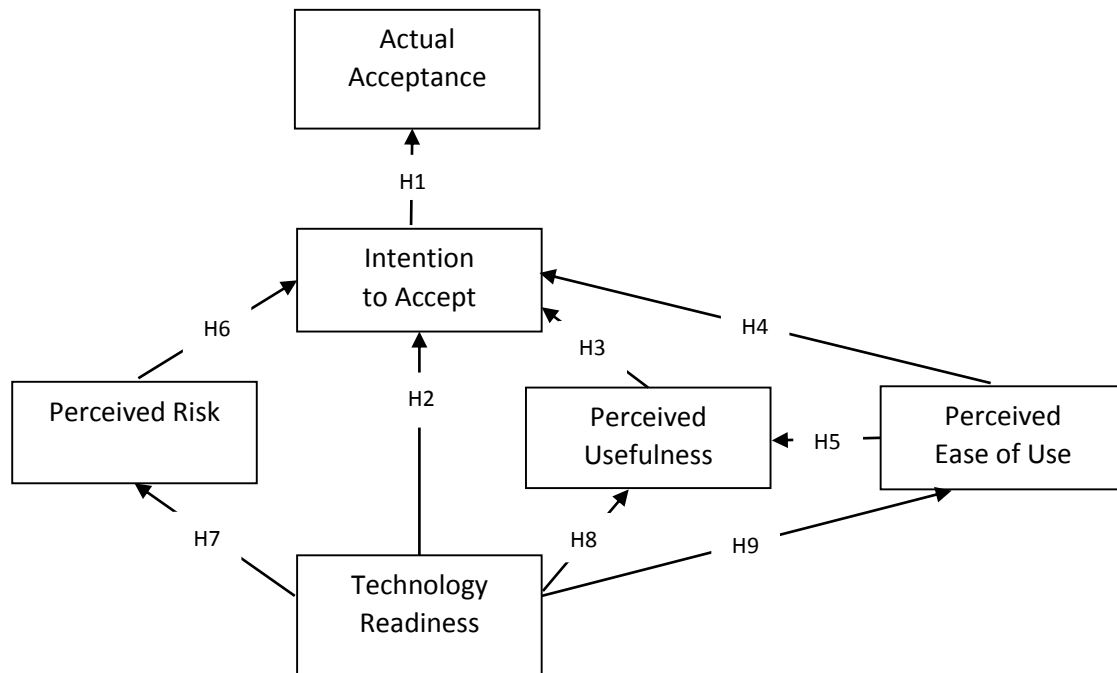
FIGURE 8. A CONCEPTUAL MODEL FOR ROCAM, THE ROBOTIC CAR ACCEPTANCE MODEL

H1: Driver intention to accept SDC technology positively influences actual driver acceptance of SDCs.
H2: Driver intention to accept SDCs is positively influenced by technology readiness.
H3: Driver intention to accept SDC technology is positively influenced by its perceived usefulness.
H4: Driver intention to accept SDC technology is positively related to its perceived ease of use.
H5: The perceived ease of use of SDCs has a positive effect on their perceived usefulness.
H6: Driver intention to adopt SDC technology is negatively affected by the related perceived risk.
H7: Technology readiness has a negative impact on the related risk.
H8: The perceived usefulness of SDCs is positively affected by the level of technology readiness.
H9: The perceived ease of use of SDC technology is positively affected by the level of technology readiness.

It is clear that the intention to accept any technology positively influences the chances of eventual actual acceptation. This positive relationship will be denoted as *H1*.

The fact that consumer trust is crucial and essential for driver acceptance has been noted several times in this text, and makes sense intuitively. Therefore, **Technology Readiness** in relation with SDC technology will be regarded as the base foundation for the decision to adopt or reject SDC technology. Considering the stakes involved with car purchasing (considerable amounts of money and, more importantly, the potential impact on one's health), the likelihood to accept the technology without

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[11] The Technology Acceptance Model, discussed in Chapter 3.2

trust in it is slim to none. The intention to accept SDC technology is thus likely to rise as trust in the technology increases. This positive relationship will be denoted as *H2*.

Next, we consider **Perceived Usefulness.** It has already been stated (c.f., Chapter 3.1.4) that a product's relative advantage has high explanatory power over the intention to accept that product. Therefore, **Perceived Usefulness** is hypothesized to have a positive impact on **Intention to Accept**, and this relationship is denoted as *H3.*

Another factor discussed in Chapter 3.1.4 with regards to the impact on a customer's adoption/rejection-decision was *complexity*, and it was concluded that complexity has a negative impact on the likelihood to adopt. The responding factor in the TAM is **Perceived Ease of Use**, and in the extended model **Perceived Ease of Use** will be hypothesized to have a positive impact on **Intention to accept**. This relationship will be denoted as *H4*.

As can be seen in Chapter 3.2, the relationships hypothesized by *H1*, *H3* and *H4* are all part of the original TAM framework. In the original model, it is also hypothesized that a product's **Perceived Ease of Use** has a direct positive impact on that product's **Perceived Usefulness**. This positive relationship is expected to be as true in this case, and it will be denoted as *H5.*

A new factor in the extended model is **Perceived Risk**. Clearly, this has a negative impact on the **Intention to Accept**, and this relationship will be denoted as *H6.*

Trust is a foundation of **Technology Readiness**. The more trust that a customer has for the SDC technology, the less risk they will perceive. This negative impact of **Technology Readiness** on **Perceived Risk** will be denoted as *H7.*

Technology Readiness also influences both the **Perceived Usefulness** and the **Perceived Ease of Use**. These positive relationships will be denoted as *H8* and *H9*, respectively.

The ROCAM can be used by decision-makers to investigate consumers' level of acceptance of SDCs. This insight may increase the accuracy of strategies concerning marketing, city planning and the development of SDC-related technologies. It would be interesting to perform these investigations continually with for instance, six month-intervals. This would allow the researcher to see how the acceptance changes over time, and this insight might be used to predict future acceptance as well.

6. Layout for a Delphi Study: A Proposal for Further Research

To address the second stated purpose of this study, this chapter presents the foundation for a proposed next step in the research of the diffusion of Self-Driving Cars.

This chapter will answer the second research question posed in this study:

2. How should a study to examine the expected future impact of SDCs be designed?

By drawing upon the insights generated during this project, two possible scenarios of the future of SDCs have been constructed. These scenarios are proposed to make up the foundation of a future Delphi study, which may provide a nuanced view of *how* the SDC's market deployment will turn out, *when* this is expected to happen and *at what pace*.

6.1. Purpose of the proposed study

It is difficult, if not impossible, to gather enough primary data to make an accurate prediction of the future of SDCs. To continue the work done in this project, it is proposed a full-scale Delphi process is proposed here. In this section, the layout of such a study will be formed. The study is proposed with two purposes in mind:

1. To gain an understanding of the industry's expectations on SDCs and their views on how best to proceed.
2. To increase the objective knowledge of the subject of SDCs.

These proposed purposes should allow the study should to do the following:

- Identify key opportunities and threats raised by SDCs for different stakeholders.
- Form a nuanced view of the strengths and weaknesses with the SDC and related issues.

Figure 9 shows an overview of the proposed stuty, and its relationship to the study presented in this paper.
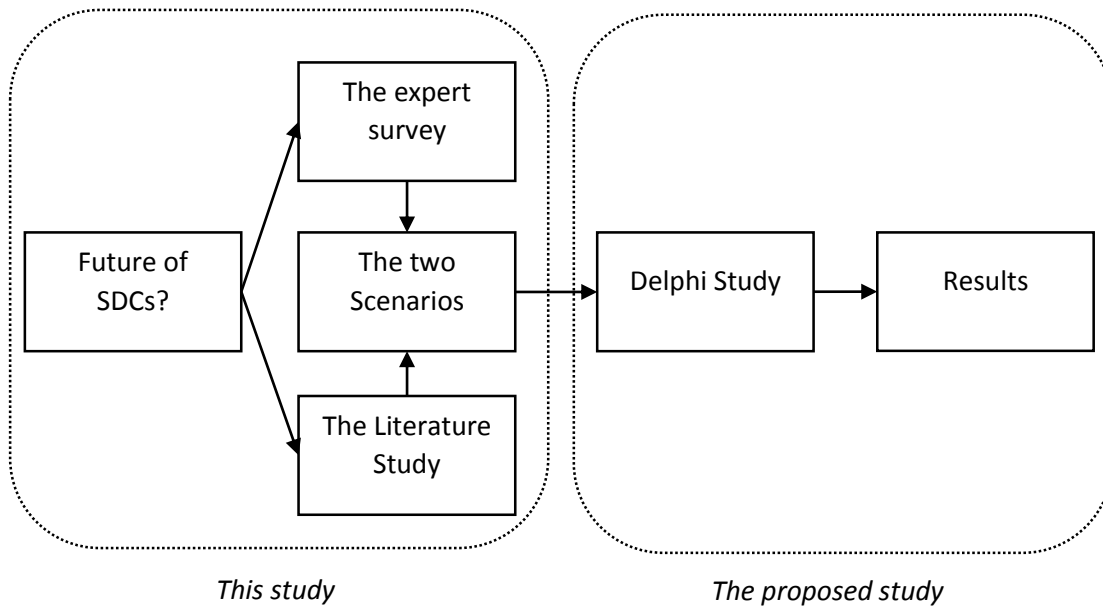
FIGURE 9. AN OVERVIEW OF THE PROPOSED STUDY IN RELATION TO THE ONE PRESENTED IN THIS PAPER.

6.2.   Using the Scenarios in the Study

The Delphi study was described in detail in chapter 3.3.2. The proposed study would identify stakeholders relating to future traffic and the automotive industry. It is recommended to interview between 5 and 20 people, in accordance with the guidelines found in Appendix B. Care should be taken to form a heterogeneous group, containing different views and priorities.

The researcher(s) should then ask the interviewees to regard two separate future scenarios where SDCs are already a part of traffic. The two scenarios differ regarding the impact of SDCs. Scenario A considers a future where SDCs have radically changed personal mobility and traffic as a whole. Scenario B regards a future where SDCs are not universally adopted, which makes them less effective because of lacking network effects. These scenarios are presented in full in the next section.

The two scenarios are extreme outcomes, and the future will likely be a mixture of both. They are made this way intentionally, to make the interviewees consider a middle-ground, and to ascertain what the future will be most likely to bring. The interviewees should be encouraged to speak openly and honestly, so as to increase the likelihood of identifying new aspects of a future of SDCs.

It is unclear *when* these scenarios would be likely to take place. Indeed, one of the questions that will be asked seeks to answer this issue. However, it is recommended to put them quite far into the future, at least ten years. This is recommended because the interviewee is expected to be less bias, for instance regarding the stakes of his or her firm, when considering a distant future than a near one.

6.3.   The Two Scenarios – Radical or incremental Impact

Many consequences expected to be brought by the advent of SDCs have been identified throughout the text. Two of the most important ones for society as a whole are:

- The effect SDCs may have on the amount of cars in use
- The effect SDCs may have concerning urbanization and urban sprawl

Two different scenarios, depending on different outcomes of these two consequences, have been constructed and are presented in the following section. The first scenario, **Scenario A**, expects SDCs to bring about radical change in personal mobility, traffic and society at large, and the second one, **Scenario B**, assumes that SDCs will bring only incremental change. Figure 9 presents the scenarios in a 2x2 matrix.
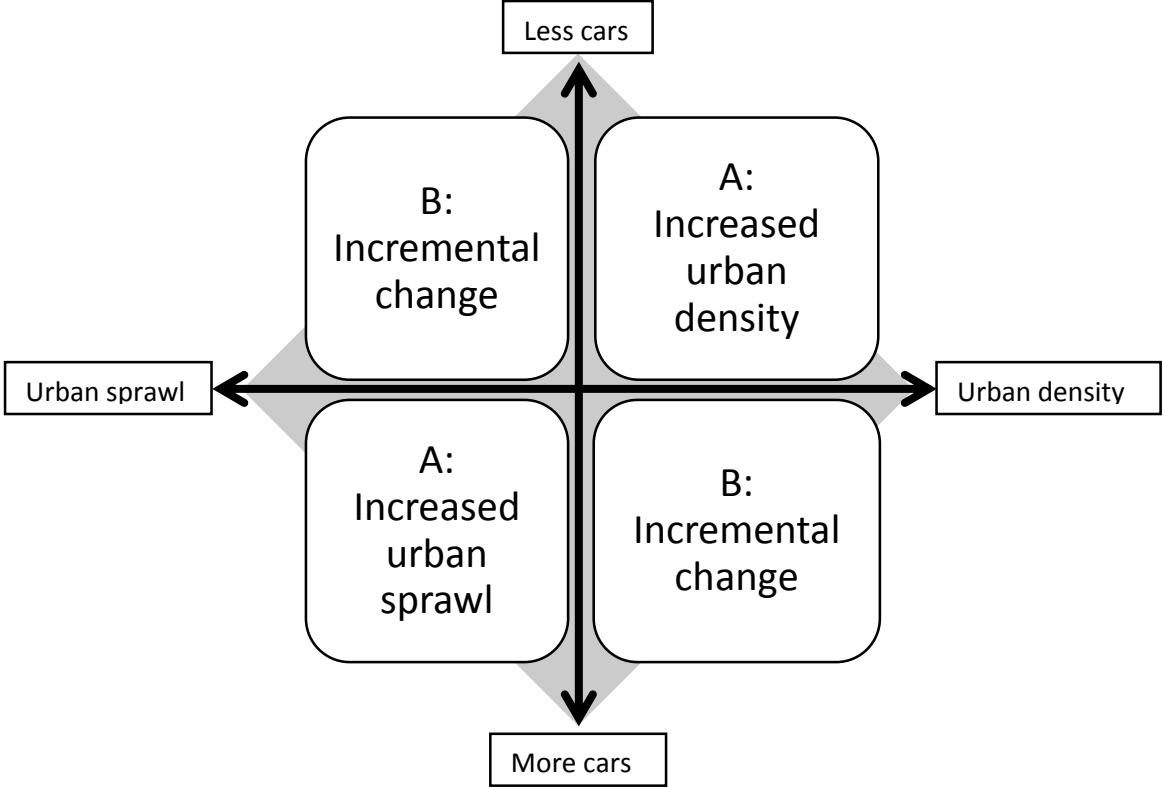

FIGURE 10. THE TWO SCENARIOS A AND B DEPEND ON THE LEVELS OF URBANIZATION AND AMOUNT OF CARS IN USE.

A. *Radical change*

In this scenario, the self-driving car has become a proven success that has changed traffic beyond all recognition. Since its entry on the market, not a single accident has been caused by a self-driving vehicle, a fact that has generated a continuously increased trust in the concept. Research made on the subject invariably finds driverless cars to be superior to human drivers in matters of traffic safety, fuel-efficiency, vehicle lifetime and driving skill (meaning that transport is quicker and travel times are less variable).

So-called 'robot taxis' have largely replaced human taxi drivers by offering customers quicker and safer transport at a lower price. Self-driving cars can drive pick people up when needed, take them to their destination and then drive off to pick up another passenger. Personal transportation has never before been so cheap, so efficient, so care-free or so easy.

Many people who used to own a car choose not to, choosing instead to join autonomous car pools or to make use of 'robot taxis'. People who previously didn't have access to a car can now subscribe to a drive-on-demand program. By offering a solution to the first-mile, last-mile problem, self-driving cars have made public transportation more attractive. Increased use of on-demand vehicles and public transportation lessens the amount of cars in use. Subsequently, urban livability increases and this is likely to lead to increased urban density.

But there are also many households who have simply replaced their traditional car or cars with self-driving ones. By increasing the travel comfortability, the self-driving cars have made long commutes much less of a deterrent and as a response, many have chosen moved further away than ever from city centers. This outlook will likely lead to increased levels of urban sprawl and higher rates of car-use by those who own their own SDC.

Public transportation may prosper from the surge in new customers caused by the solution of the first-mile, last-mile problem. Increased profits would allow public transportation to make new investments to increase the level of service, further raising demand. This would lead to a more efficient system of personal transportation and a decreased *number of cars in use.*

On the other hand, many people who used to travel by public transportation now make use of SDCs instead. This drop in customers may force public transportation to make budget cuts, further reducing its appeal. As the quality of service drops in public transportation, the demand for SDCs rises further. This may lead to an increased *number of cars in use.*

In this scenario, it is clear that the SDC has radically changed personal mobility. However, the scenario contains opposing forces with regards to urban density versus urban sprawl. The question is to what extent these processes will respectively take form.

B. Incremental change

This scenario regards a future where SDCs fail to impact society as much as many of today's experts believe. The SDC turn out to be more of an incremental innovation than a radical one: a natural, undramatic generational upgrade of the personal vehicle, comparable to the implementation of GPS-powered maps or the automatic gearbox. People on average drive much as they always have, the difference being that those who want to can now focus on other things instead of having to concentrate on the road while in transport.

But history has shown that many drivers are not prepared to let go of manual control of the car, for different reasons. This is true, regardless of SDCs having been empirically proven over and over to be less likely to crash than traditional cars, and that the consequences of an accident are mostly less dire for SDCs than traditional cars. Many people are still hostile towards the idea of letting a machine drive for them. Some worry about privacy issues, for instance that information about their driving will be recorded and the ways this personal data might be used. Others fear cyber-attacks, for instance that terrorists will take over control of the car fleet and crash them into crowds of people. Many are unwilling to accept the risk, however small it may be, of being in an accident caused by computer error, and some simply aren't willing to give up the joy of manual driving.

In a future where many humans still decide to drive manually, SDCs must take more precaution to prevent accidents caused by the human factor. They will have to be much more careful than if most cars were driverless and could communicate their travel data with one another to increase coordination on the road. For a computer, traditional cars will have to be handled with the utmost care. Since human driving styles is often illogical – and even illegal – SDCs will be required to drive extremely slowly in many situations to eliminate the possibility of a crash caused, in full or in part, by a human-driven car. This occasional snail-paced driving has led 'robot taxi' firms go out of business, and overall reduces the appeal of SDCs considerably, further adding to the technology's problem.

Since SDCs cannot drive effectively in many situations (for instance when surrounded by human drivers), the people who do use SDCs are in practice doing a lot of the driving themselves, preferring to rely on their own driving to reach their destination sooner. This makes riding in an SDC less of a comfortable experience, since those who do are always on 'stand-by', ready to take over the wheel when needed.

6.4. Designing the Study Interviews

In accordance with the principles of the Delphi Study (c.f. chapter 3.3.2), the researchers should prepare a set of questions relating to the different scenarios. The questions should seek to gain insight regarding several issues, including the following:

- *When would you expect a future such as the one described here to take place?*
- *Where do you think the most important opportunities will arise in this scenario? Who do you think will be able to exploit these?*
- *What impact do you expect this scenario to have on your enterprise?*
- *How do you think levels of urban sprawl / urban density will be affected?*

And then, when both scenarios have been considered, a final question should be:

- *Which of the two scenarios do you see as most plausible?*

This last question can, for instance, be answered by considering Figure 10, below. The interviewee can either simply fill in where on the X-axis they think the future will be, or engage in an open discussion on the matter.
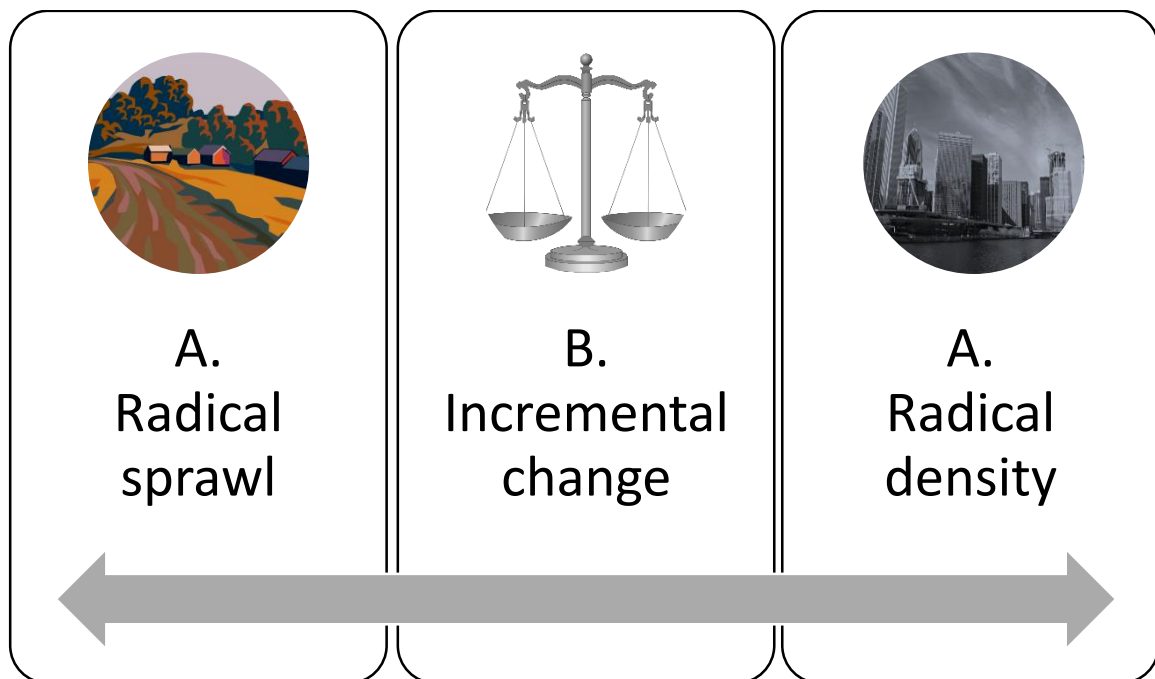

FIGURE 11. A GRAPHICAL REPRESENTATION OF THE DIFFERENT SCENARIOS.

The answers are then to be collected and processed and aggregated to a form, perhaps as updated versions of the scenarios, which would be more detailed and where more factors are taken into consideration. Once a comprehensive summary of the first round of interviews has been made, it will be distributed back as feedback to the interviewees. They will be asked to consider this updated scenario and comment on it.

There will, in all probability, be some disagreement among the group surveyed. The researcher(s) will register these in another update of the scenarios, which the interviewees will again be asked to consider.

This interview-feedback-loop, illustrated in Figure 11, continues until a satisfactory level of consensus is reached.
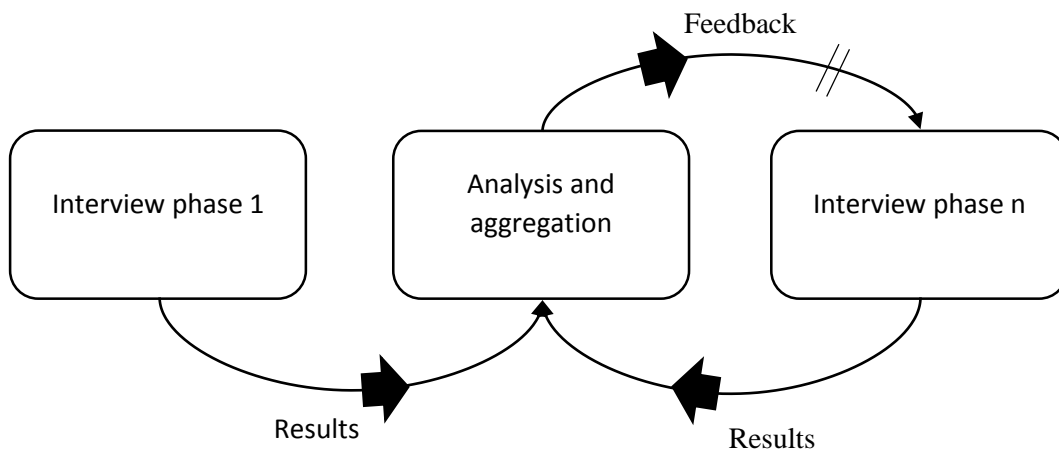
6.5   Expected results and their implications

The project proposed in this chapter is expected to add significantly to the study of the diffusion of self-driving cars. Not only will it add to the knowledge base on the subject, it will also investigate how key stakeholders view the prospect of SDCs. By asking the interviewees to consider two alternative extreme outcomes of the future of SDCs, the study is expected to find a detailed and plausible middle-ground, as depicted in Figure 12.
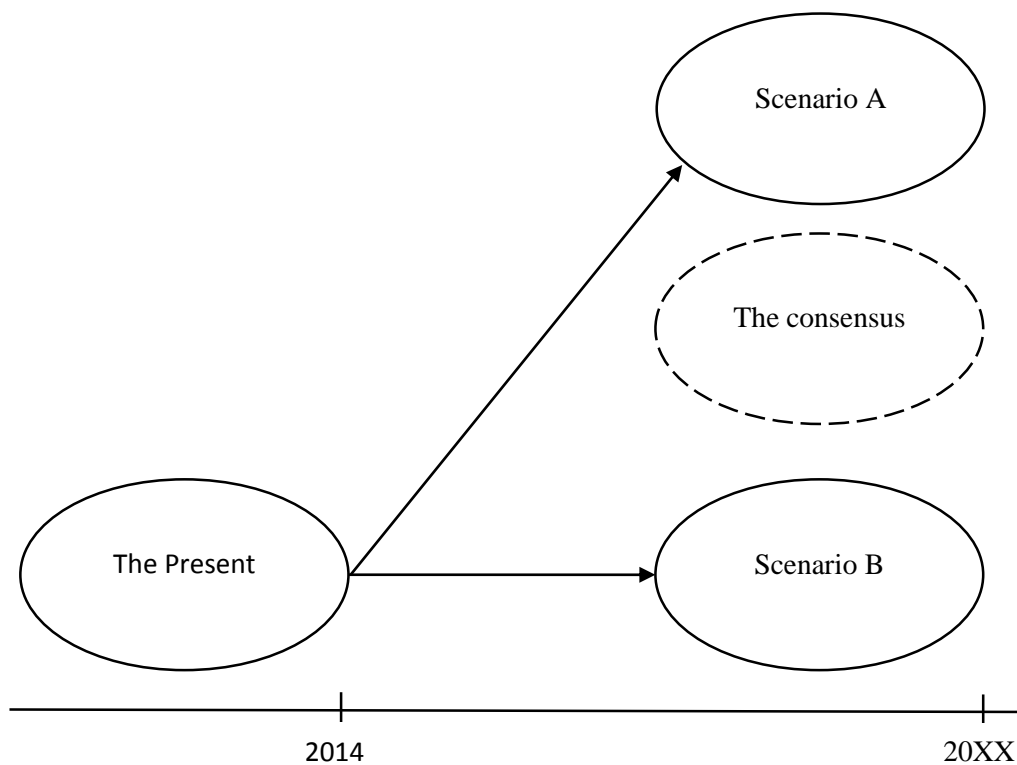
It is quite possible that entirely new approaches to the subject will be discovered during the interview-feedback-loop process, which may in turn lead to a more effective deployment of the technology, or perhaps to the rise of new business models that aim to exploit newly discovered opportunities. Should significant threats be identified in the study, it will be easier to counter these than if they had never been foreseen. City planning would benefit greatly from any insights into how future traffic is likely to develop.

In conclusion, the study proposed in this chapter is expected to be of great value for business and society at large.

7. Conclusions

In this chapter, conclusions from chapter 5 and chapter 6 are presented. Second, the implications for managers and policy-makers are discussed. Finally, further suggestions will be made as to where research should go next.

When this study was initiated, its stated purpose was to examine how to measure current levels of technology acceptance with regards to self-driving cars (SDCs). The research led to a proposed new framework to measure and assess the technology acceptance for SDCs. This framework is called the Robotic Car Acceptance Model, or ROCAM. It is shown in Figure 14, and presented in full in chapter 5.4.
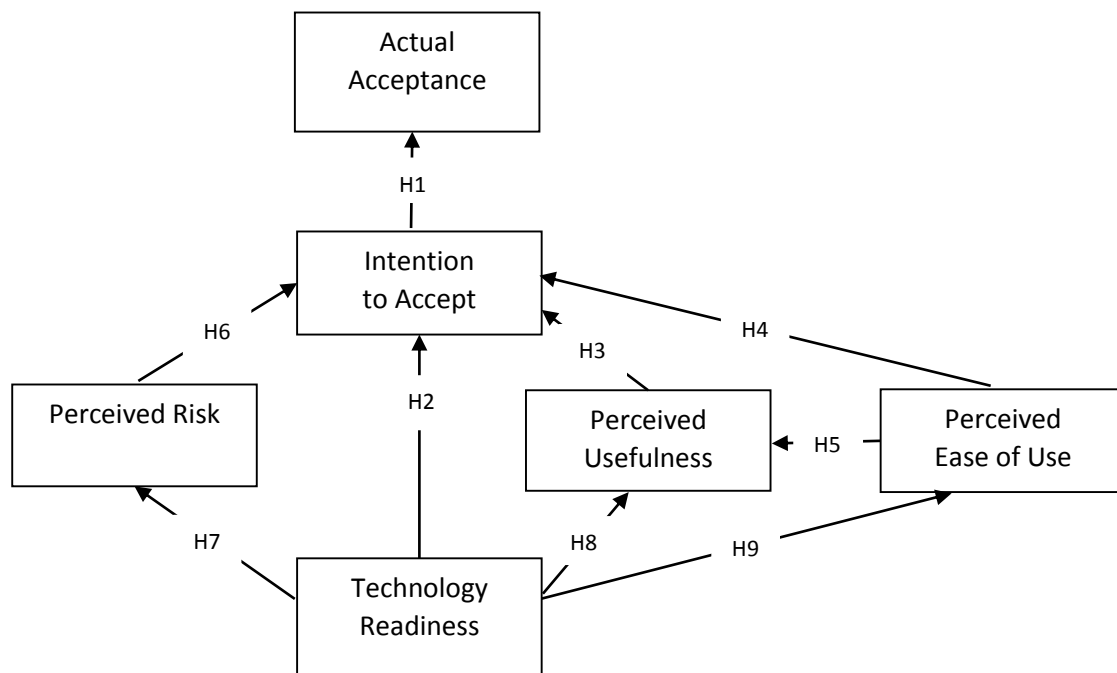

FIGURE 15. THE ROCAM (ROBOTIC CAR ACCEPTANCE MODEL).

During the study process, it became apparent that it would also be highly interesting to perform a thorough examination of what impact SDCs are expected to have on our future society and the business sector. Since it was concluded that to answer this issue would require more work than the scope of this study permitted, the layout for a future study was designed instead. The proposed study would set off by using the two scenarios constructed in this paper, which are presented in chapter 6.3. Figure 16 shows the conceptual layout of the proposed study, including how it relates to the work presented in this paper. See chapter 6 for full details on the proposed follow-up study.
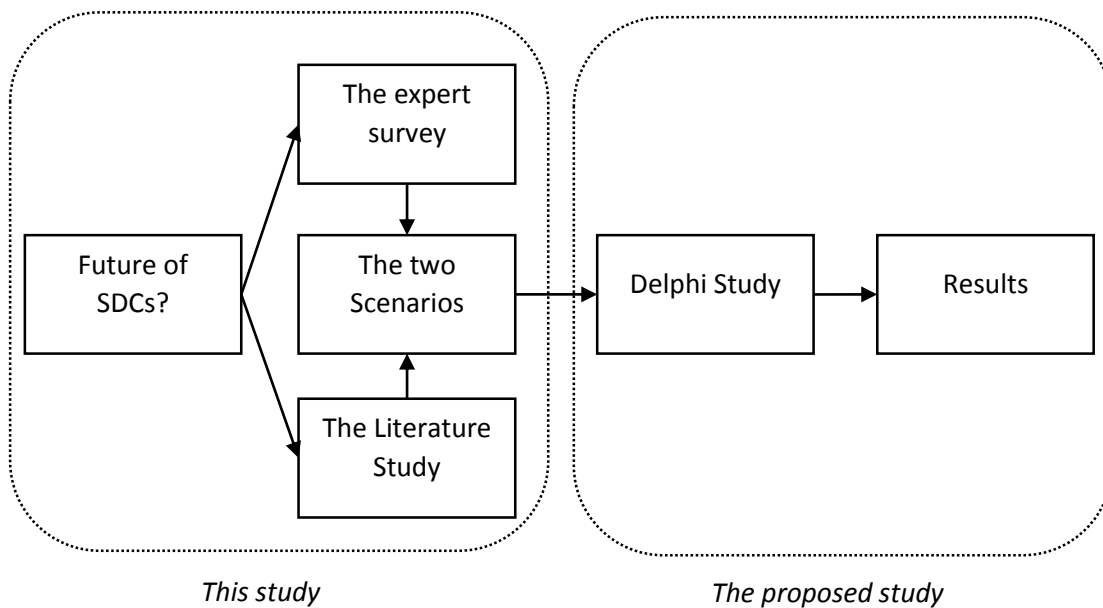
Driverless cars are no longer a thing of science fiction, but a real concept which is widely expected to available to consumers at the very latest in the 2020's, but perhaps even before then. Experts expect them to lead to a dramatic decrease in traffic accidents, enable better traffic flow and increase fuel efficiency.

Complete autonomy will not arrive overnight: its diffusion will come stepwise, from automation levels 1 to 4. Function-specific automation, also known as automation level 1[12], is already widely available in cars today, and Level 2-systems (combined function automation) are increasingly common. Although many experts see Level 4-automation as unfeasible within a foreseeable future, the path to full deployment of cars with Level 3-automation is expected to take somewhere between 20 and 40 years, and the direct benefits for traffic are expected by many to be enormous.

Implications for managers
In the proposed new framework, ROCAM, it is suggested that the individual Technology Readiness is the foundation for acceptance of SDCs. Managers seeking to be among the first to sell SDCs must keep this in mind, and take care to market the SDCs correctly. The early adopters will be those with high levels of Technology Readiness. Sweden, full of technology enthusiasts, is therefore likely to be a good place to start. As more and more of these innovators try and test SDC technology, the technology readiness of others will rise. The "crossing of the chasm" might not be so perilous, if the right customers are targeted at the right time.

A good way to build trust (which is an important aspect of Technology Readiness), is to get approval from third-parties. With that in mind, managers should tend to relationships with, for instance, governments and NGOs, and lobby for the promotion of SDC technology as safe, efficient and comfortable.

The ROCAM is ready to be used as an instrument to find out current levels of technology acceptance for SDCs. It is hypothesized that important insights could be generated by performing ROCAM-assisted

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[12] See chapter 1.1 for the definitions of different levels of automation

market research continually, since the results would show how acceptance changes over time and could be used to predict future acceptance with greater accuracy.

Implications for society / decision makers

An automotive revolution is upon us. SDC and V2X technologies are expected to change the traffic landscape dramatically. Many see only benefits, such as increased levels of personal mobility, traffic safety and fuel-efficiency. Some expect this revolution to lead to much less cars on the road and make city parking lots obsolete, since the cars can park themselves somewhere out-of-sight. One hypothesis is that these technologies will lead people to choose robotic car pools over owning their own car. Since shared cars already, with today's modest use of car pools, replace 5-7 personally owned ones, the total number of cars is expected to drop by 80% if this came true. This development might also provide solution to the first-mile and last-mile problems, thereby increasing the attractiveness of public transportation.

However, another hypothesis is that people will still want to own their own car, and that the SDCs will simply replace existing ones. As SDCs lead to higher levels of comfortability, mobility and fuel-efficiency, people will likely use their car much more. This will decrease the usage of public transport which will suffer from loss of revenue. Resulting savings will further diminish the attractiveness of public transportation, and a negative spiral ensues. These developments will also likely lead to urban sprawl, which is harmful both to the economy and the environment. Other indirect negative consequences are increased levels of obesity and diabetes, resulting from increased use of transport by car.

Since these scenarios are likely to lead to much fewer traffic accidents, as well as a more efficient traffic with regards to both travel times and fuel-efficiency, it can be argued that policy makers should keep supporting SDC development and deployment. Because it is in the nature of radical innovations to have uncertain beginnings, incentives to purchase SDCs, such as tax reliefs and parking subsidies, might well be needed.

Regarding Scenario A and Scenario B, society would be much better off in in Scenario A. Decision-makers should therefore work actively to bring society into a future of shared vehicles and increased quality of urban living ('livability'). Car pools and services such as Flexidrive, should be promoted as a way of pushing people's mindsets toward Scenario A. Public finances should propel the emergence of shared SDC networks, such as robot-taxi companies.

Future research

One of the purposes of this project is to provide a starting point for future research of the self-driving car. A proposed future study has been designed and presented in chapter 6. In this section, some other suggestions of where research should go next are made.

The ROCAM is a product of theoretical reasoning in that it has not been tested in an actual case. This would be a natural place to follow up the conclusions drawn in this paper.

To increase understanding of driver acceptance of SDCs, research is needed regarding the related sociologic and psychological aspects (c.f. chapter 4.1.2). An interesting conundrum to research would be the following: imagine that it eventually gets empirically proven and trusted that V2V-connected SDCs reduces the risk of traffic accidents by 90%. Would people then be willing to accept that the accidents that do occur (i.e., the remaining 10%) are caused by computer error? Questions like these are of vital importance to understand the market for SDCs, but they are difficult to answer and would require a survey of greater scope than this one.

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Appendixes

Appendix A – Interview questions

The set of questions below were posed in an interview held on February 20 with Claes Tingvall, professor in traffic safety at Chalmers University of Technology and head of safety at the Swedish Transport Administration. Tingvall is currently working on the Drive Me project together with Volvo Cars and others, and is arguably best known for being one of the main drivers behind Sweden's *Vision Zero* (Tingvall & Haworth, 1999).

- Do you believe that self-driving cars will become commonplace in the coming 25 years?
- How far has the development of SDCs come and what remains to be done?
- To what extent will self-driving be possible? (i.e. what level of automation[13] is feasible)
- What are SDCs most important advantages? Are there any disadvantages?
- How will V2V and V2I-technology be utilized?
- Will drivers accept this new technology? Who are likely to be the early adopters?
- What levels of safety do you think will be acceptable for SDCs?
- What is the Drive Me project and your department's role in it?
- What people would you recommend to involve in an expert survey on the subject of SDCs?

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[13] See chapter 1.1

Appendix B – Participants and questions in the Expert Survey

According to Rowe & Wright (2001), one should observe the following principles when conducting a Delphi process:

- Use experts with appropriate domain knowledge.
- Use heterogeneous experts.
- Use between 5 and 20 experts.
- Obtain the final forecast by weighing all the experts' estimates equally and aggregating them.
- Frame questions in a balanced manner
- Avoid incorporating irrelevant information into questions
- When possible, give estimates of uncertainties as frequencies rather than probabilities or odds.

These principles were observed when choosing who to include in the expert survey, and how to phrase the questions. The process included the people from the following organizations:

Position	Organization
Project Coordinator	Services department at the City of Lund
Professor, road traffic safety and ITS	Faculty of Engineering, Lund University
Press secretary, involved with *Drive Me*	City council, Gothenburg
Founder and CEO	Trivector Traffic AB
Technical Specialist, project coordinator for *Drive Me*	Volvo Car Group
Senior Transport Specialist	The Swedish Transport Administration (Trafikverket)
Unit Manager	Streets and Parks Department, Malmö
Administrative officer, involved in *Drive Me*	Swedish Transport Agency
Chief Technical Officer	AstaZero Proving Ground
Researcher in traffic safety, society and road-use	The Swedish National Road and Transport Research Institute

TABLE 2. PARTICIPANTS IN THE EXPERT SURVEY

Questions posed

1. What are your thoughts on the subject of self-driving cars, and the fact that public road trials are being carried out already?
2. What do you expect to be SDCs greatest advantages and disadvantages?
3. Regarding driver acceptance, what do you expect to be the biggest hurdles and how could these be overcome?
4. Which category of people will have most to gain from SDCs? Will some be worse off?
5. What percentage of new cars will have self-driving capabilities by the year 2038?
6. Given a successful market introduction and diffusion of SDCs in the future, what will the implications be for…
   a) …car ownership and number of cars in everyday traffic?
   b) …city planning and the urban environment?
   c) …public transportation?
   d) …traffic safety?
   e) …environmental issues, for instance carbon emissions?

Conclusions and reflections

There did exist individual bias within the expert group, both for and against the prospect of SDCs. As is to be expected from a well-chosen group, however, these individual biases seemed to cancel each other out when all answers were taken into account.

Appendix C – First concept model of ROCAM

As is shown in chapter 3.1, the Robotic Car Acceptance Model presented in chapter 5.4 is the successor of en earlier version. For readers interested in the work process of this project, or technology acceptance models in general, the first version of ROCAM is presented here. The updated version in chapter 5.4 was reworked to make it more comprehensive and thus more useful.
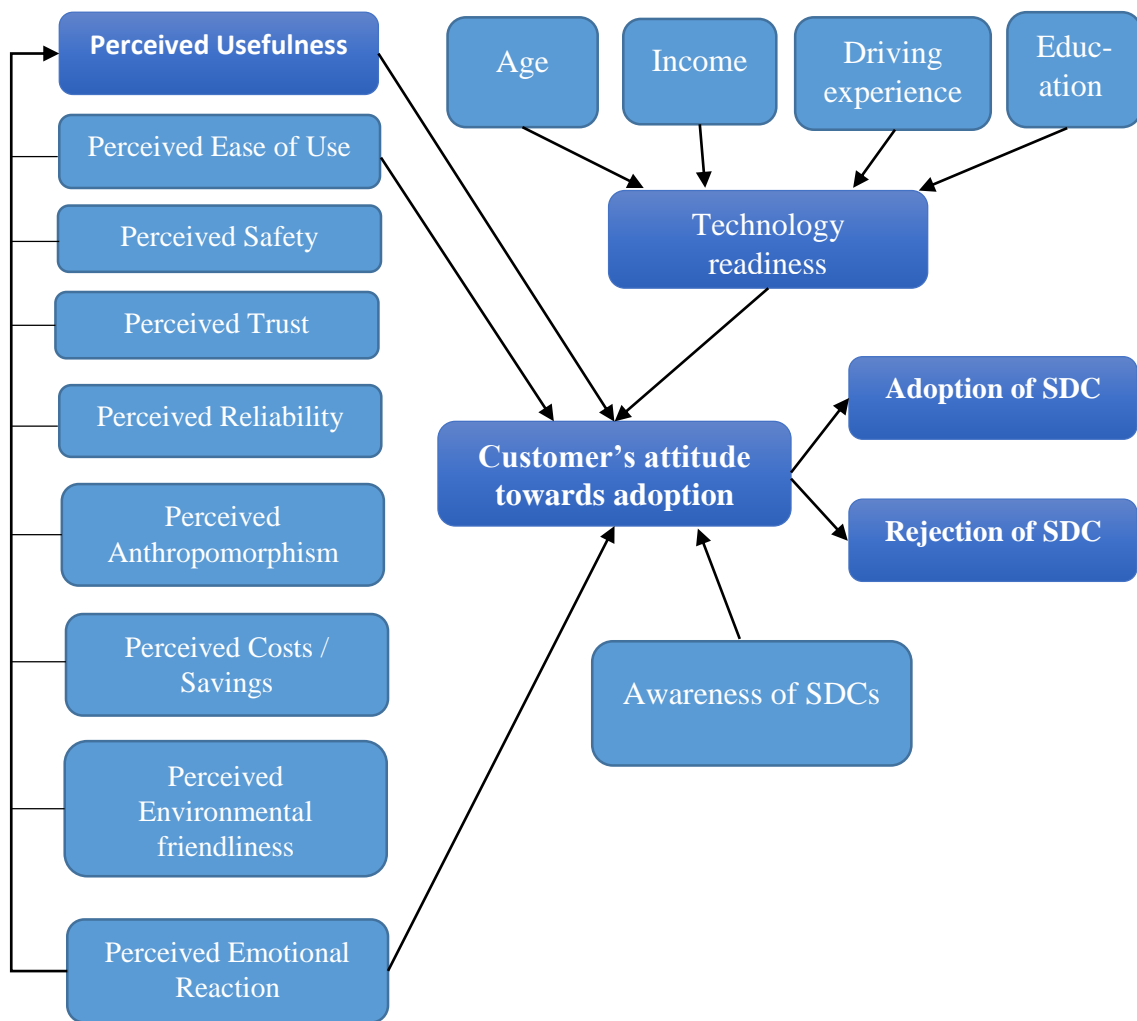

FIGURE C. THE FIRST VERSION OF THE ROBOTIC CAR ACCEPTANCE MODEL, ROCAM.