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Customer perceptions of the added value of a new technology
a study in the automotive industry

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Award date:
2019

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EINDHOVEN UNIVERSITY OF TECHNOLOGY

Customer perceptions of the added value of a new technology:

A study in the automotive industry

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In partial fulfillment of the requirements for the degree of

Master Thesis Innovation Management

Innovation, Technology Entrepreneurship & Marketing (ITEM) group

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March 29, 2019

TUE. School of Industrial Engineering and Innovation Sciences
Series Master Theses Innovation Management

Subject headings: customer perceived added value, customer perceptions, benefits and sacrifices, new technology, technology innovations, new product development, steering technology, Steer-by-Wire, Autonomous Driving, automotive industry

Preface

This report describes the master thesis project executed to accomplish my last part of the master Innovation Management at Eindhoven University of Technology. During the master program, I had the opportunity to live and study in Singapore for one semester, but also to live in Gothenburg (Sweden), to conduct this graduation project from August 2018 to February 2019, marking the end of an unforgettable time of being a student.

There are several people I would like to thank for helping me during the project. First of all, I would like to thank my first supervisor and mentor during my whole master program, prof. dr. Sjoerd Romme, for supporting me the past years, especially during my master thesis project, but also prior to that when I was searching for the right company to conduct my master thesis. With his expertise and experience he always gave me useful advises, and helped me structuring my thesis process and report. During every meeting we had, whether it was via Skype or e-mail when I was in Sweden, or face-to-face when I was in The Netherlands, he always gave me new insights and provided me with critical feedback.

Besides my first supervisor, I would also like to thank my second supervisor, dr. ir. Boukje Huijben. Her different point of view on my thesis report gave me new insights, and made me realize I needed to elaborate more on certain parts of the report, so that everyone would be able to understand it.

Moreover, I would like to thank my supervisors at Volvo Cars, Matthijs Klomp and Joakim Norrby, for giving me the opportunity to conduct my master thesis at Volvo in Gothenburg, and for supporting me throughout the whole process at Volvo. Despite their full agendas, they always made time available to discuss my project and to have weekly meetings to help me further and to brainstorm about my research. Also, I would like to thank the whole Steer-by-Wire team at Volvo, for always making time for me to answer my hundreds of questions about the system, so that I could understand it completely. Additionally, I would like to thank my fellow board members of Young Volvo Cars for making my time at Volvo even more fun.

Furthermore, I would like to thank my family for their engagement, for giving me all the self-confidence I needed, and for supporting me in exploring every opportunity to develop myself further. And lastly, I would like to thank my friends and boyfriend for their support and interest in my project, for giving me some nice distractions at the moments I could really use it, and for making my whole student life a great time to look back on.

Maxime Belgers

Abstract

The automotive industry is currently facing a revolution. There is a transition going on from a traditional car to the car of the future, and that requires new breakthrough technology innovations, such as Autonomous Driving (AD) and Steer-by-Wire (SbW). More insight is required in the main benefits and sacrifices of SbW, so that car manufacturers can successfully introduce this new technology in their products.

The main purpose of this master thesis is to obtain systematic evidence for Volvo Cars regarding the customer value perceptions of the SbW system, to maximize the value of the new technology. It describes the main benefits and sacrifices of SbW, and presents an estimation of the customer price of AD and SbW, since the full potential of SbW can only be reached in combination with AD. Thereafter, a customer value research is conducted, both qualitatively and quantitatively, to measure and assess the perceptions of Volvo customers regarding the added value of SbW.

Based on the analysis and interpretations of the results of the customer value research, respondents appear to be quite positive about SbW. They see more benefits than sacrifices of the new steering technology, and more than 70% would be comfortable using it. However, respondents indicated concerns regarding the reliability of the system, and want to know more about the back-up system in case of a system failure. Furthermore, it appeared that respondents are more interested in the safety of the system, than the higher price.

Regarding the positive results of the customer value research, it is recommended for Volvo to offer SbW as a standard steering system in all new car models to increase its brand uniqueness. This impact can be further enlarged by investigating if potential customers are willing to switch to the Volvo brand due to its SbW system.

Executive summary

This thesis report describes research on the customer perceived added value of a new technology: Steer-by-Wire, a new steering technology. Customer perceived value of a new technology is defined as the difference between the benefits and the sacrifices perceived by customers (Slater, 1997; Berry & Yadav, 1996; Ravald & Grönroos, 1996; Slater, 1996; Haas, 1995; Mazumdar, 1993; Slater & Narver, 1992; Narver & Slater, 1990; Day, 1990; Zeithaml, 1988). The research is conducted at Volvo Cars, a Swedish automobile company that has a focus on innovation and world-leading safety technology. There is a transition going on from a traditional car to the car of the future, and that requires new breakthrough technology innovations, such as Autonomous Driving (AD) and Steer-by-Wire (SbW). With SbW, the steering system of the car is being controlled by electronic systems, replacing the mechanical controls. That offers several benefits for the driver, although, the full potential of SbW can only be reached in combination with AD.

The key problem addressed in this thesis involves the adoption of the new SbW technology by the Volvo customer. Customer perceptions of the new steering technology SbW are unknown. Also, customers may not yet see the benefits of the new steering technology and therefore might not appreciate its added value. This calls for methods to measure how Volvo customers perceive the added value of the SbW system in the context of existing or new vehicle platforms at Volvo Cars, to maximize the value of the new technology. In order to achieve this, the following central question is researched:

How do Volvo customers perceive the added value of the Steer-by-Wire (SbW) system compared to a conventional steering system?

Different benefits and sacrifices of SbW were found in scientific literature, both for Volvo and the customer. However, this study focuses on the customer. The benefits and sacrifices for the customer were discussed several times during brainstorm and feedback sessions with different experts at Volvo (among others: steering experts, price experts, development process experts, and market intelligence experts). This has led to three main benefits of SbW: improved safety, design freedom, and improved driving experience. On the other hand, two main sacrifices of SbW were found: higher costs, and changed driving experience (see Figure 1). Another important aspect of the value of a new product is the price. If a new product has value, customers are willing to pay the price for it. For SbW, a competitor analysis is conducted to make a price estimation. The estimated customer price of SbW is €2,079, as an optional feature in a non-AD car. The estimated price of the AD feature is €12,000. If SbW is combined with AD, the price of SbW will be lower, since some of the components of SbW are already present in an AD car.

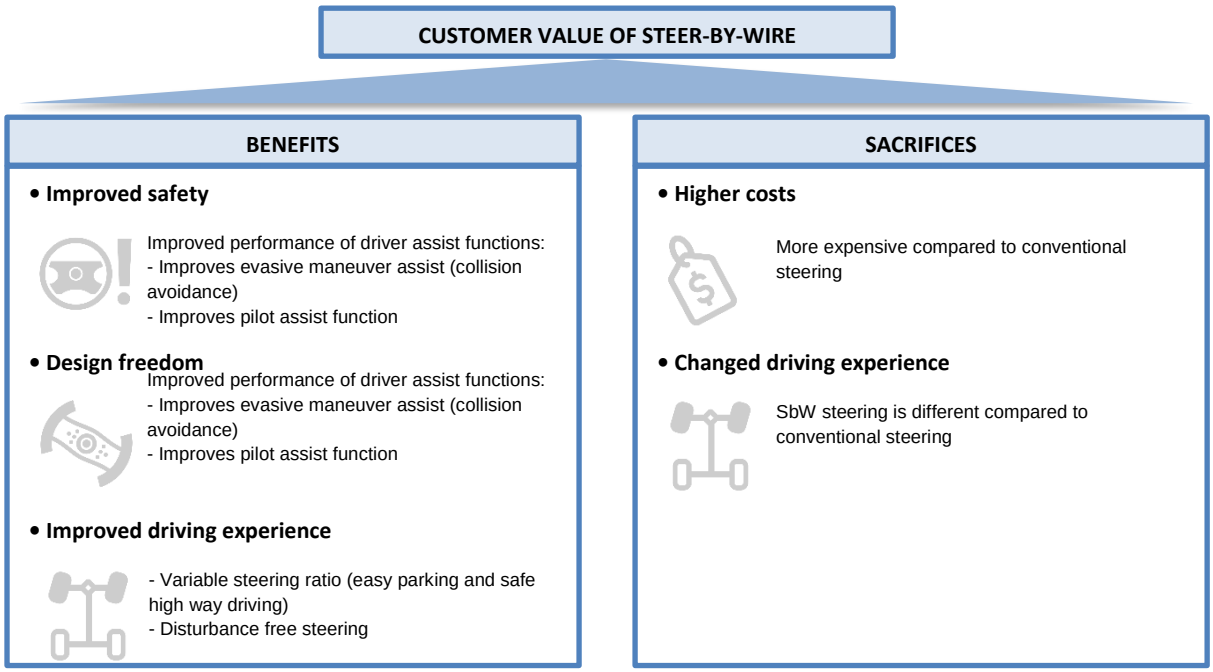

Figure 1: Main benefits and sacrifices of SbW

To measure customer perceptions of the SbW system, data was collected via questionnaires and interviews with Volvo customers. Europe, US, and China are Volvo's biggest markets, and count for 86% of the total sales market, so the aim was to collect data from these markets. In the US, the survey was sent to a random sample of 1,000 customers of the database 'Voice of Volvo' who regularly fill in surveys for Volvo, and 455 responses were received. This database does not exist in China and Europe, so only 5 Chinese survey responses were received, and 4 European Volvo customers were interviewed. Due to the low response rate in China and Europe, the US sample is the main dataset for the analysis.

Overall, findings show that US respondents appear to see the value of the SbW system. They indicated that safety is the most imported benefit (important to 90% of the respondents), followed by respectively, driving experience and design. They also see more benefits than sacrifices of SbW. However, 33% of the respondents indicated major concerns about the reliability of the system. Too little is known about the redundant system that takes over in case of a system failure. It can thus be concluded that customers do see the added value of the SbW system compared to a conventional steering system, but they need to be assured about the redundant system to be convinced that it is reliable. On the other hand, the results of this research are timely. Developments in the automotive industry are expected to be fast, and new mobility solutions are on its way. Also, markets are changing rapidly, and so is consumer behavior. After one year, consumers might be more used to the idea that cars can drive autonomously, which will probably make them even more enthusiastic about SbW. Since the customer value research results of China and Europe do not show substantial differences compared to results from US, one can say that respondents in the US sample of

this study are probably similar to the global population of Volvo customers. However, sample sizes for both the Chinese as well as the European sample were too low to draw a valid conclusion at this.

This thesis report results in several recommendations for Volvo to improve the added value of SbW:

- **Offer SbW in a package** – For example, a business or comfort package. This makes the price increase less visible to customers.
- **Supply SbW as a standard feature** – This study shows that more than 70% of the US customers is positive about SbW, so Volvo should start offering it as soon as possible. This will decrease costs for Volvo, and that will decrease the customer price. In that way, the remaining 30% of the negative customers will become more positive.
- **Offer SbW together with AD** – Customers indicated that they are more interested in 'the full package', so a combination of SbW and AD.
- **Focus on safety when communicating to customers regarding SbW** – Volvo is global leader in automotive safety, and most customers choose a Volvo for that reason. It is therefore important to explain SbW's clear safety improvement compared to conventional steering.
- **Explain the existence of the back-up system** – This study shows that 33% of the respondents do not trust the system yet, since little is known about the back-up system that takes over control in case of a system failure. It is recommended to pay extra attention to the explanation of that back-up system.
- **More collaboration and integration between R&D, Marketing, and Sales** – This will have a positive effect on the effectiveness of SbW resources, and the success of SbW. Also, SbW will be more closely aligned with customer needs.
- **Conduct functional concept tests with customers** – Results of the customer value research show that respondents are willing to do test drives for Volvo to give their feedback on SbW. With this feedback the steering system can be improved.
- **Create a 'Voice of Volvo' in Europe and China** – At the moment, Voice of Volvo only exists in the US, but this is an effective way to obtain the voice of the customer, so that their feedback can be integrated in the development of new products. It would be an asset for Volvo to create a Voice of Volvo in Europe and China as well, so that customer feedback can be received from all three biggest markets.

This study identified a research gap in explaining drivers for customer perceptions of SbW. It also describes how Volvo customers value the new steering technology. Automotive companies can benefit from this research and apply it to their own development of new technologies, to improve the customer perceived value of their new product innovations. Lastly, the results in this research show interesting findings on which markets respond to big innovations, and to see that the cost price is less important to customers than expected.

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Abbreviations

AD	Autonomous Driving
DbW	Drive-by-Wire
ECU	Electronic Control Unit
RWA	Road Wheel Actuator
SbW	Steer-by-Wire
SWA	Steering Wheel Actuator

1. Introduction

This report describes research on the customer perceived added value of a new technology: Steer-by-Wire, a new steering technology. Customer perceived value of a new technology is defined as the difference between the benefits and the sacrifices perceived by customers (Slater, 1997; Berry & Yadav, 1996; Ravald & Grönroos, 1996; Slater, 1996; Haas, 1995; Mazumdar, 1993; Slater & Narver, 1992; Narver & Slater, 1990; Day, 1990; Zeithaml, 1988). The research is the result of a master thesis project at Eindhoven University of Technology, in collaboration with Volvo Cars, a Swedish automobile company that has a focus on innovation and world-leading safety technology. This introductory chapter describes the context of Steer-by-Wire in Section 1.1, followed by the technology of Steer-by-Wire in Section 1.2, the problem is described in Section 1.3, and the scope of this thesis in Section 1.4. Research questions are formulated and presented in Section 1.5, and Section 1.6 describes the research approach and outline of the report. Finally, Section 1.7 explains the company background of Volvo Cars, introducing its cars, and explaining the development process of Steer-by-Wire.

1.1 Context

The automotive industry is currently facing significant changes driven by technology shifts, digitalization, and changing consumer behaviors. There is a transition going on from a traditional car to the car of the future. Cars of the future will have, among others: autonomous driving features, and Drive-by-Wire systems (Volvo internal experts). These systems enable cars to implement Steer-by-Wire. The term By-Wire might be familiar to aviation enthusiasts, since airplanes have used systems called "Fly-by-Wire" since the 1990s. That technology, just like Drive-by-Wire, uses electrical wires to control the normal operations of a plane. Over the years, computers and electronics have been integrated into modern cars. If drivers can get accustomed to the idea, drive-by-wire systems have the potential to increase safety, functionality, and comfort during the drive (Fuller, 2009).

The automobile industry is currently working on new *Drive-by-Wire* (DbW) systems. In these systems, mechanical and hydraulic subsystems, such as steering, braking, and suspension, are being replaced by electronic actuators, controllers, and sensors. Applying electronic technology, such as DbW systems, has clear benefits: opportunities for enhanced passenger safety, and improved overall performance and driving convenience (Tavoosi et al., 2014).

Driving automation is a driver and enabler for a fully redundant steering system, and the need to separate between the steering wheel input and the wheel angle control. This is achieved through a *Steer-by-Wire* (SbW) system. It consists of a steering wheel actuator (SWA) that reads the steering input from the driver and provides torque feedback to the driver, and a road wheel actuator (RWA) that steers the wheels. Thus, sensors detect the movements of the steering wheel and send information to a microprocessor. Then, the computer sends commands to actuators on the axles, which turn according to the driver's directions (Yang,

2017). Figure 2 shows an example of a basic SbW system architecture. It consists of (1) a steering wheel angle sensor, (2) resistance torque actuator, (3) steering actuator, (4) front wheel angle sensor, (5) electronic control units (ECUs), and (6) some conventional sensors to monitor vehicle speed, and lateral acceleration (Hayama et al., 2010). SbW would be essential in autonomous vehicles, since is allows the vehicle to easily control its own direction without additional and complicated hardware (Kingston, 2018).

SbW systems are a relatively new innovation compared to the traditional mechanical, hydraulic, or electric steering systems that are currently being used in motor vehicles. The system will fully be ready for autonomous driving, because the wheels can be steered independently of the steering wheel position, which is well prepared for the future. Another particular potential benefit of the SbW system is increased design freedom for the interior design. The electromechanical components occupy less place in comparison with the mechanical counterparts, and the control modules can be placed wherever the design permits, making it easy to vary from right to left hand driving cars, so less variety in vehicle development and production (Yang, 2017).

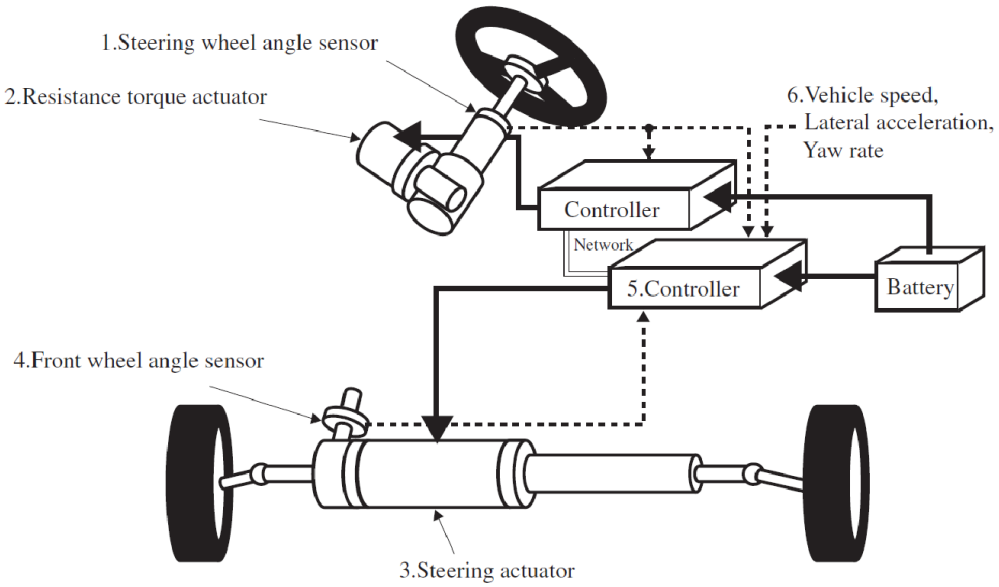

Figure 2: Baseline SbW system structure (Hayama et al., 2010, 10)

In 2013, the world's first automotive SbW system was revealed in the Infiniti Q50, manufactured by Nissan. Infinity had several reasons for developing this system, named 'Direct Adaptive Steering', namely that it responds faster compared to a conventional steering system, and that it reduces unwanted vibrations and kickback at the wheels. Infinity also highlighted that the SbW system would be essential in autonomous driving vehicles, since it would allow the car to easily control its direction without complicated hardware. The Infinity SbW system proved to be unpopular with consumers, because of its unnatural steering feel. Thereafter, there was some recalls, causing Infinity to consider to stop producing this system

completely, but it continued with the configuration, and is still available in the Infinity Q50 and Q60.

However, Infinity's SbW system still contains a mechanical linkage between the wheels and the rack. In case of a system failure, a clutch engages to couple the wheels to the rack. This gives the driver manual control in case of a system failure, but it also negates some of the potential benefits of the SbW system, like reduced weight. At the moment, other prototype SbW systems have been demonstrated, and several other companies are researching the option of full SbW systems without the mechanical backup (Kingston, 2018).

1.2 Steer-by-Wire technology

In SbW systems, part of DbW, the conventional mechanical interface between the steering wheel and the front wheels is replaced with electronic actuators. The elimination of parts, such as the steering column, gear box and hydraulic pump, provides advantages including saving energy, decreasing noise and vibration, reducing weight, and removing environmentally hazardous hydraulic fluids. Moreover, in front-end collisions, the danger of a driver being crushed will be reduced, because there is no steering column (Tavoosi et al., 2014).

In case of a system failure, a SbW system requires a secondary or backup activation mechanism. This backup mechanism should be based on differentiated redundant systems. With a conventional steering system, the mechanical connection between the steering wheel and the wheels serves as the backup steering mechanism. With a SbW system, the backup steering mechanism cannot rely on a mechanical connection between the steering wheel and the wheels (for example via the steering column), because the goal of SbW is to remove this mechanical connection. SbW experts have focused on developing fault-tolerant systems based on redundancy, which is the duplication of components and modules. In case of a system failure, the redundant systems take over control. This solution is also used in aircrafts. A downside of applying redundant systems is a significant increase of complexity and costs (Dominguez-Garcia et al., 2004).

One benefit of SbW is its active steering capability: the ability to change the driver's steering input to improve maneuverability or stability. Therefore, research institutes and the automotive industry pay considerable attention to the potential benefits of SbW systems, particularly for improving vehicle handling behavior. Over the last two decades, various studies of control of vehicle handling and stability using SBW architecture (Tavoosi et al., 2014) have been conducted. Since the SbW system implies no mechanical connection between the steering rack and the steering wheel, several benefits can be realized (see appendix A). The main disadvantages of the SbW system are the additional cost of the feedback motor, and the increased redundancy required for fallback mechanisms in case of system faults (Volvo internal experts).

1.3 Company background

This research is conducted in cooperation with Volvo Cars, a Swedish car brand, selling cars in about 100 countries. As can be seen in Figure 3, the company is divided into different departments. The department where SbW is being developed is part of the Steering-Art team and the Research & Development department.

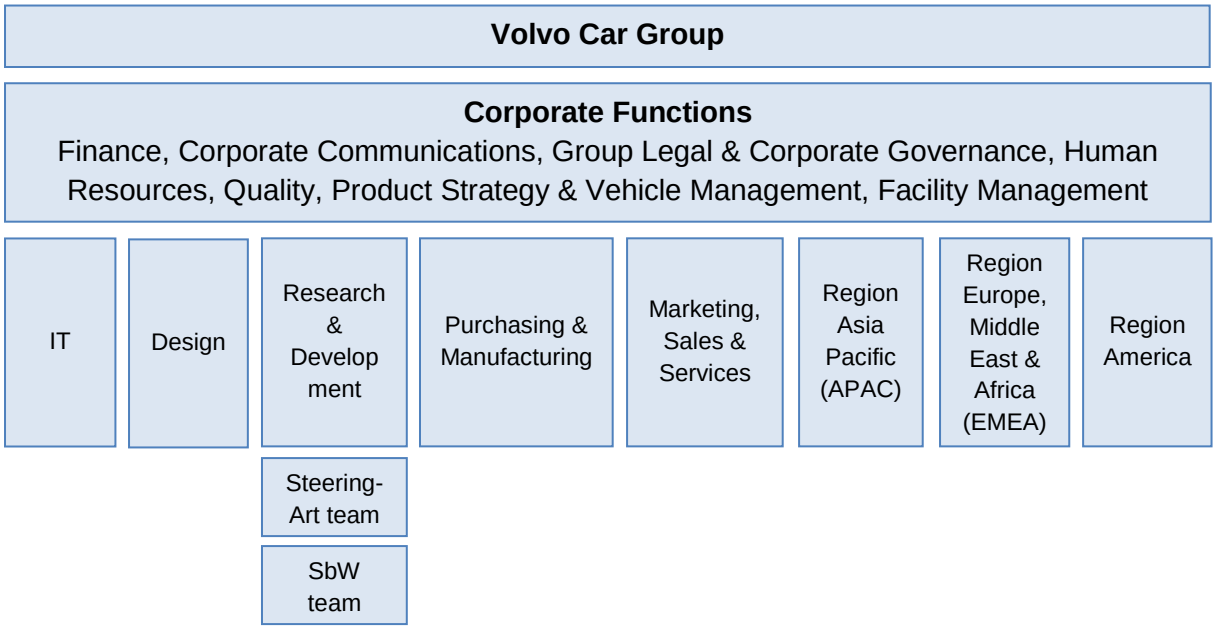

Figure 3: Volvo's organizational structure (Volvo internal documents)

Volvo's biggest markets are: Europe with 50% of Volvo's retail sales, China with 20% sales, United States with 16% sales, and other continents with 14% sales in 2017 (Volvo Car Group, 2017). The first Volvo car rolled off the Gothenburg production line in Sweden in 1927. Since then, Volvo Car Group has been a global leader in automotive safety technology and innovation. Volvo has committed to the vision that no one should be seriously injured or killed in a new Volvo car by 2020, and to put 1 million electrified vehicles on the roads by 2025. The company's corporate and brand strategy 'Designed Around You' puts people at the center and is a foundation and a guide for the business, the products, and the corporate culture. Volvo Cars produces premium-segment car models in three versions: sedans (S60, S90), versatile estates (V40, V60, V90) and SUV vehicles (XC40, XC60, XC90), as can be seen in Figure 4, with retail sales of 20% sedans (S-line), 34% versatile estates (V-line), and 46% SUV vehicles (XC-line). Volvo's mission is to be the world's most progressive and desired premium car company and to make people's lives less complicated (Volvo Car Group, 2018).

Figure 4: Volvo car models

1.3.1 Autonomous driving development at Volvo Cars

As one of the most innovative car manufacturers, Volvo Cars is also one of the pioneers in autonomous driving. DbW, like SbW, is one of the key preconditions for semi-autonomous or fully autonomous driving (self-driving) cars. SbW would be essential in autonomous cars, since it allows the vehicle to easily control its direction without additional, complicated hardware (Kingston, 2018). On the other hand, autonomous driving is also a key feature to make the most out of SbW. A non-autonomous driving car with SbW has less benefits than an autonomous driving car with SbW. Therefore, the full potential of SbW can rather be reached in combination with AD.

Autonomous driving (AD) has the potential to unlock a number of benefits for the mobility consumer, such as to create a more safe traffic environment, enable a more efficient utilization of vehicles, and to free up valuable time for the consumer. The most advanced cars, in terms of AD, that can be seen on the roads today are partially automated (semi-autonomous). Table 1 summarizes the most important differences between semi-autonomous and autonomous driving. The development in this field is expected to be fast. The benefits of highly and fully autonomous cars are likely to be extremely significant, and so large demand from customers can be expected.

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Table 1: Differences between semi-autonomous and autonomous driving (Volvo internal documents)

Semi-autonomous driving (current: Pilot Assist)	Autonomous driving (future: IntelliSafe Autopilot)
The car can drive itself (accelerate, brake & steer) to a limited extent, i.e., supports the driver with keeping the distance to the vehicle in front and keeping the car in the lane in speeds up to 30 mph (XC90). However the driver remains responsible for monitoring, supervision, and over all operation of the vehicle and is expected to actively participate in the driving.	The car drives itself (accelerates, brakes & steers), and the driver is not responsible for monitoring, supervision, and over all operation of the vehicle.
The driver is always legally responsible for driving the vehicle ("driver in the loop", "hands on the wheel, eyes on the road, mind on driving").	The driver will not be responsible for driving the vehicle when in autonomous mode ("driver out of the loop").
The customer benefits a reconvenience, peace of mind and feeling of control.	The customer benefit will be the freedom to engage in other activities (relax, create, entertainment, etc) in autonomous mode.
This is currently legal, since it does not change the basic assumption of a (licenced) driver always being responsible.	There is currently no legal framework (except for testing, in certain jurisdictions).
These features have been launched and will continue to launch in increments (certain speeds, certain scenarios, etc).	This may launch in increments (certain speeds, scenarios, conditions, applications, markets).

1.3.2 Steer-by-Wire development at Volvo Cars

New product development processes at Volvo Cars usually follow a top-down approach, were Market Intelligence comes up with a list of customer requirements, discusses this with Attributes Councils who formulate customer needs, and Attributes Councils discuss this with the Advanced Engineering teams who develop the means (see Figure 5). The new product processes are iterative processes, where quality and functionality are continuously improved. The Market Intelligence department of Volvo asks customers about their requirements in a customer research. This leads to a list of customer requirements. Thereafter, Market Intelligence discusses these requirements with Attributes Councils (engineers), and the Attributes Councils interpret the desired customer behavior to formulate their needs (see Figure 5). After discussing the needs with the attributes councils, the Advanced Engineering team comes up with a solution to the needs.

In the case of SbW, the development process is not that different from any other new product process at Volvo Cars. Market Intelligence executed a customer research and came up with a

list of requirements (disturbance free steering, easy parking, a more agile way of driving, and safety). After that, Attributes Councils interpreted these requirements and formulated their needs in engineering terms: new seating positions for AD, personalized settings, reduced high speed response and linearity, and variable steering ratio. Finally, the Advanced Engineering team came up with the answer to the customer requirements: Steer-by-Wire.

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Also, customer research resulted in customer requirements as safety, easy parking, and a more agile way of driving, and competitors started developing SbW as well. The development of Autonomous Driving, customer requirements which could be solved by SbW, and increasing competitiveness were the reasons Volvo started the SbW project again. With SbW, Volvo wants to have a competitive advantage over the competition, while keeping its high status when it comes to safety and innovativeness *(source: Volvo internal experts)*.

This top-down approach is a process of several years, so it is important to check if SbW is still the right solution to the customer requirements drafted by Market Intelligence. That will be investigated in this research.

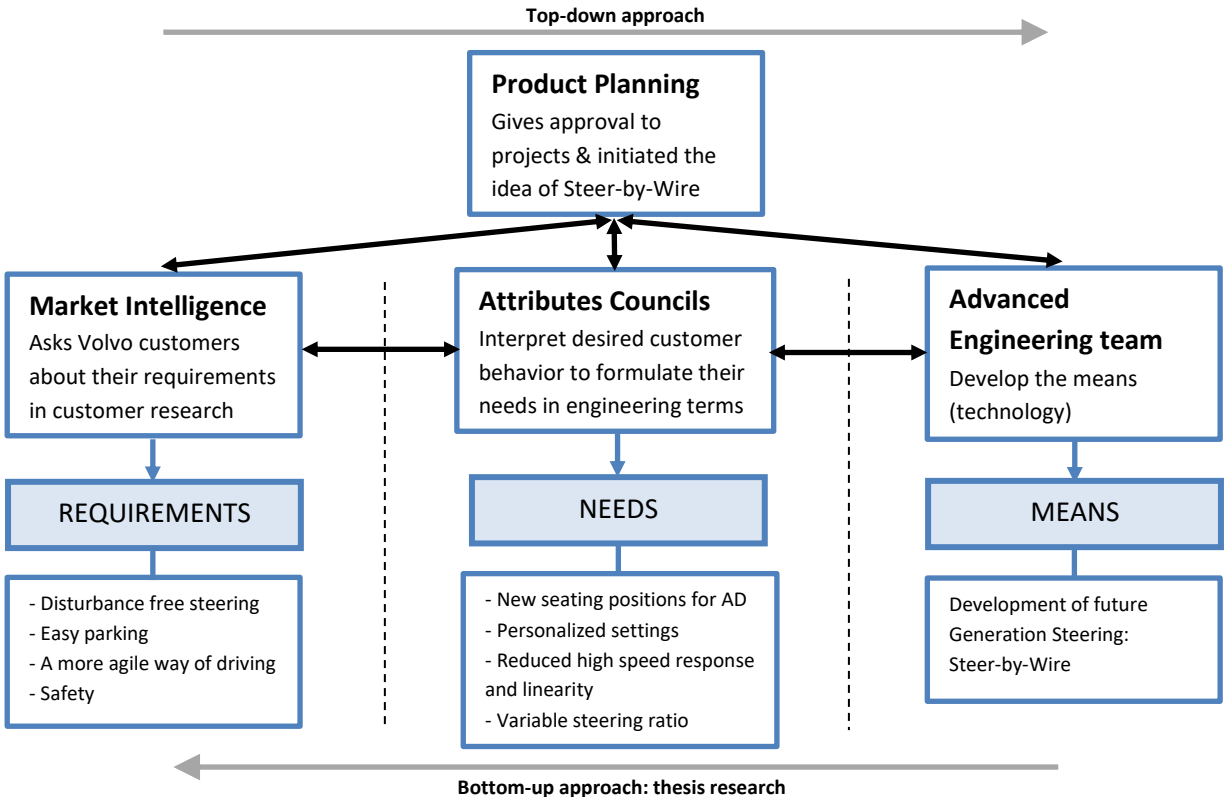

Figure 5: Development process of SbW at Volvo

1.4 Problem description

The key problem addressed in this thesis involves the adoption of the new SbW technology by the customer. Customers need to see the value of this new technology, in order to decide to switch from the old to the new technology.

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On the other hand, there is a market resistance against adoption of the SbW system. This has to do with a psychological barrier among customers to (any) major innovation. The phenomenon that a market resists against an innovation is common (Gourville, 2006). An approach for dealing with this customer resistance would be that Volvo makes the relative benefits of the SbW system so great that they overcome the customer's overweighting of potential losses. Ensuring that the SbW system for the customer clearly outperforms the conventional steering system is the best remedy. It is also important to get customer feedback during the development of a new technology. This early feedback can prevent making unnecessary mistakes (Nijssen, 2014).

Concluding, the problem is defined as follows:

Volvo customers may not yet see the benefits of the new steering technology Steer-by-Wire and therefore might not appreciate its added value, but Volvo does not have any systematic evidence regarding the customer perceptions of SbW.

1.5 Scope

The scope of this study is defined based on the availability of information and time. The research focuses on the customer perceived added value of SbW. The methods to research how customers perceive the added value of SbW used in this study are questionnaires and interviews with Volvo customers. Methods for calculating the exact added value of the new steering technology (value analysis) are out of the scope of this research. A value analysis aims to give the functions of the new product a certain cost and weight according to its importance for the customer (Tidd et al., n.d.).

The target market for the customer value research are customers from Volvo's biggest markets. Note that this only includes Volvo customers from US, supplemented with customers from China, and Europe. In that way, the results of the customer value research are geographically distributed to be able to draw conclusions on the generalizability of the results. However, this research excludes other markets of Volvo.

Due to time limitations, this study is focused on current Volvo customers. A study on potential Volvo customers who are willing to switch from a different automotive brand to the Volvo car brand due to SbW is out of scope. However, this could be investigated in future research.

1.6 Research questions

This research aims to discover methods to measure how Volvo customers perceive the added value of the SbW system in the context of existing or new vehicle platforms at Volvo Cars, to maximize the value of the new technology. In order to achieve this, the following research question needs to be answered:

How do Volvo customers perceive the added value of the Steer-by-Wire (SbW) system compared to a conventional steering system?

The research will consist of three phases. The first phase starts with a literature review that analyzes theories and methods serving to describe and explain customer perceptions of a new technology, and how these theories and methods can be applied to measure Volvo customer perceptions of the SbW system. The second phase is a customer research on SbW in the biggest markets of Volvo cars (US, China, and Europe) to investigate how Volvo customers perceive the value of this new technology. The customer value research is a combination of qualitative and quantitative research, where qualitative data from China and Europe is compared with quantitative data from US, to see if conclusions from US also count for China and Europe. Thereafter, the outcome of the customer value research in the second phase is linked to the literature of the first phase. The following sub-questions are formulated to provide guidance to answer the main research question:

Q1: Which theories and drivers serve to describe and explain customer perceptions of a new technology? (See Theoretical Background chapter)
Q2: How can we apply theories and drivers to describe and explain customer perceptions of a new technology to measure customer perceptions of the SbW system compared to a conventional steering system? (See Method chapter)
Q3: What do Volvo customers perceive to be the (primary) user benefits of the SbW system, and what are they willing to pay for it; and which Volvo customers are most likely to act as early buyers of automobiles that include the SbW system? (See Results chapter)

1.6.1 Research method per sub-question

In Table 2, the research methods needed to answer every sub-question are given. The first sub-question Q1 is answered in the Theoretical Background chapter. The second sub-question Q2 is answered in the Method chapter, and Q3 will be answered in the Results chapter, based on the application of several research method.

Table 2: Overview of research methodologies per sub research-question

Research question	Research methodology	Techniques/frameworks
Q1: Which theories and methods serve to describe and explain customer perceptions of a new technology?	Literature study	Theory
Q2: How can we apply theories and drivers to describe and explain customer perceptions of a new technology to measure customer perceptions of the SbW system compared to a conventional steering system?	Literature study	- Theory - Expert interviews - Brainstorming
Q3: A) What do Volvo customers perceive to be the (primary) user benefits of the SbW system, and what are they willing to pay for it?	Customer perceived value research	*Data collection methods:* - Expert interviews - Brainwriting - Brainstorming - Interviews - Questionnaire - Documents - Observations
Q3: B) Which Volvo customers are most likely to act as early buyers of automobiles that include the SbW system?	Customer perceived value research	*Data collection methods:* - Expert interviews - Brainwriting - Brainstorming - Interviews - Questionnaire - Documents - Observations

1.7 Research approach

This thesis is a combination of a quantitative and a qualitative study. It starts with a literature research on customer perceived value, the benefits and drawbacks of SbW, the influence of the product price on buying behavior, and early adopters. After that, a customer value research was conducted based on this literature research, by researching the three biggest markets of Volvo Cars: US, China, and Europe. For the quantitative research, a questionnaire was drafted to conduct a customer value research in the US. The outcome of the questionnaire was analyzed to see if a specific customer profile exists that is most interested in SbW, and this is checked by conducting a cluster analysis. Consequently, for the qualitative research, the same questionnaire was sent to Volvo customers in China, and interviews were

held with Volvo customers from Europe. The results of the research in the US were used to compare with the results from China and Europe, to see if results in the US could count for all three markets of Volvo Cars.

1.8 Research outline

After the introduction, the report continues with a literature research on theories and methods that describe and explain customer perceived value of a new technology to answer question 1 in Chapter 2. Chapter 3 describes how customer perceived value of SbW is measured and provides an explanation of the data collection, thereby answering question 2. Furthermore, Chapter 4 describes the results of the customer value research where Volvo customers are asked to give their opinion on the benefits, sacrifices, and price of SbW, and the early adopter of SbW, to provide an answer to question 3 and the main research question. The report continues with Chapter 5, discussing conclusions by answering all research questions, and provides practical recommendations for Volvo Cars. Finally, Chapter 6 reflects on this research (see Figure 6).

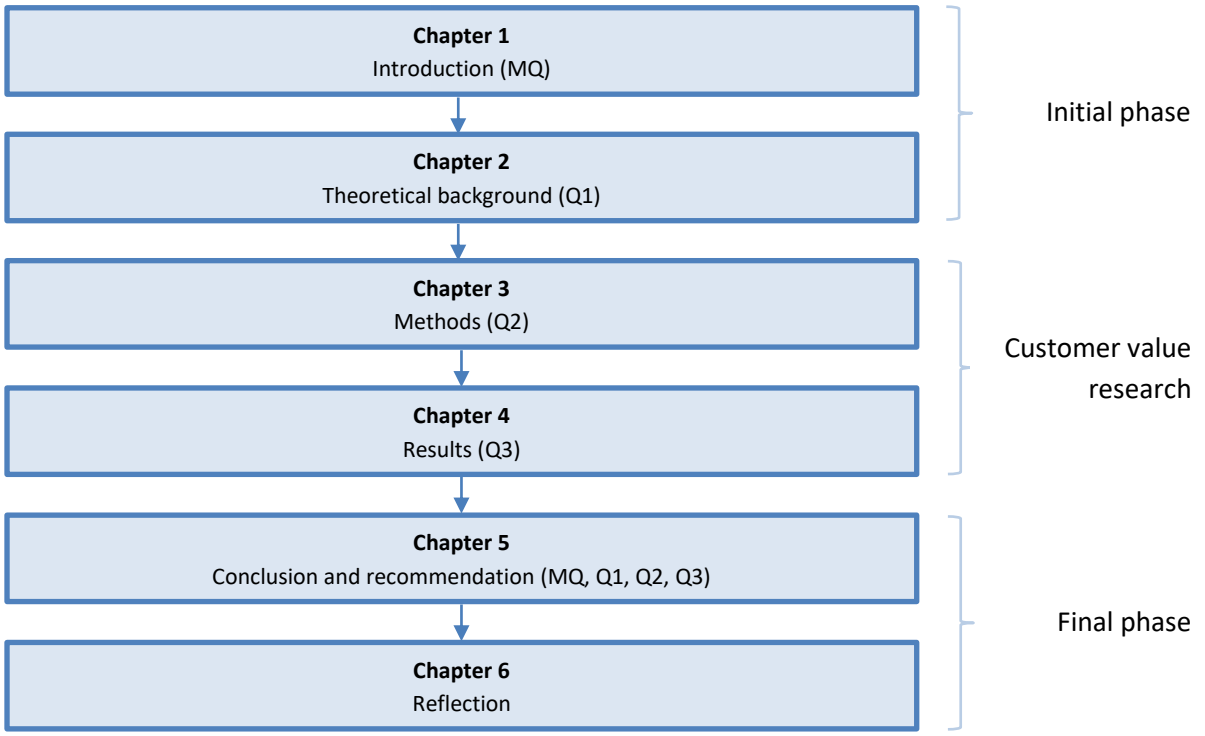

Figure 6: Thesis structure

2. Theoretical background

Theories and methods that describe and explain customer perceived value of a new technology are described in this chapter. First, the notion of customer perceived value and its drivers are discussed in Section 2.1 and 2.2, which acts as the theoretical foundation of this study. Thereafter, the benefits and sacrifices of SbW, price aspects, and early adopters are examined in Section 2.3 to 2.5. The final section describes the conclusion of this chapter, which answers the first sub research question.

2.1 Customer Perceived Value

Volvo customers do not directly see the added value of the SbW system. Therefore, more insight is required in the main benefits and sacrifices of SbW, so that SbW can be successfully introduced. That insight can be obtained by researching the customer perceived added value of SbW. In the literature, different terminologies are used for customer perceived value, or value perceived by customers. Among others, customer perceived value can be defined as the difference between the benefits and the sacrifices (e.g. the total costs) perceived by customers (Slater, 1997; Berry & Yadav, 1996; Ravald & Grönroos, 1996; Slater, 1996; Haas, 1995; Mazumdar, 1993; Slater & Narver, 1992; Narver & Slater, 1990; Day, 1990; Zeithaml, 1988) in terms of their expectations, that is, needs and wants.

The benefit component consists of both tangible and intangible features of a product or service (Terblanche, 2015). According to Parolini (1999), benefits add value to a product or service, because it enhances the customer's performance or experience. Customer sacrifices can be described as the overall monetary and non-monetary costs the customer invests or gives to the supplier in order to complete a transaction or to maintain a relationship with a supplier. Non-monetary costs are the time/effort/energy and conflict invested by the customer to obtain the products or services or to establish a relationship with a supplier (Lapierre, 2018).

Customer perceived value can be seen in other ways as well. For example, Carothers & Adams (1991) argue that many customers count time as their most precious asset, rather than price. Also, according to other researchers (Hunt & Morgan, 1995; Hamel & Prahalad, 1994), customer perceived value consists of only benefits. Because we seek to understand and measure the potential 'resistance' of customers (regarding SbW) as deeply as possible, customer perceived value is defined here in terms of the difference between benefits and sacrifices. As such, this study will concur with the majority of studies, where customer perceived value is defined in terms of its benefit as well as sacrifice components.

2.2 Drivers

Certain drivers can explain customer perceived value; these drivers are important to pay attention to when doing customer value research on the customer perceived added value of

SbW. A research program on customer perceived value (Lapierre, 2018) identified alternative solutions, product quality, product customization, responsiveness, flexibility, reliability, technical competence, supplier's image, trust, and supplier's solidarity with customers as benefits. Price, time/effort/energy, and conflict were identified as sacrifices. Based on this literature, the drivers in Table 3 are drafted.

Table 3: Drivers to explain customer value (Lapierre, 2018)

Value-based drivers identified as benefits	Value-based drivers identified as sacrifices
1. Alternative solutions (product related)	1. Price (product & service related)
2. Product quality (product related)	2. Time/effort/energy (relationship)
3. Product customization (product related)	3. Conflict (relationship related)
4. Responsiveness (service related)	
5. Flexibility (service related)	
6. Reliability (service related)	
7. Technical competence (service related)	
8. Supplier's image (relationship related)	
9. Trust (relationship related)	
10. Supplier solidarity with customers (relationship related)	

2.3 Benefits and sacrifices of Steer-by-Wire

From the viewpoint of SbW, the list of drivers mentioned above is interesting. However, this list is based on customer perceived value in general and not specified and contextualized on a new technology, like SbW. SbW itself has several benefits and sacrifices, although, not all benefits and sacrifices are relevant to the customer. Different benefits and sacrifices of SbW were found in scientific literature, where a distinction is made between benefits and sacrifices for Volvo, and benefits and sacrifices for the customer.

For Volvo, there are several advantages regarding manufacturing and design of SbW compared to a conventional steering system. For example, SbW is simpler to install (LeRoy, 2006), and offers more flexibility in the interior design and the engine compartment of the car. Theoretically, SbW makes it possible to steer the vehicle from anywhere in the car, which is also a customer benefit. Also, with SbW different left and right hand drive variant play no role in vehicle development and production anymore. According to Kreutz (2018), the number of variants can be reduced by more than 80%, which saves a lot of costs. Another benefit of SbW is that the suspension of the car can be optimized in many ways, since influences of driving and braking forces account for the steering feel. Thereafter, SbW creates the basis for additional safety-enhancing driving assist systems (Polmans et al., 2018).

Customers also benefit from the transition from a conventional steering system to SbW. With safety, active safety and passive safety can be distinguished. Active safety systems activate

before an accident takes place, to possibly avoid the accident. Passive safety systems come into play during an accident, for example seatbelts, and airbags. One of the active safety benefits of SbW is increased vehicle stability (Bretz, 2001). By stabilizing the vehicle in critical conditions and sudden maneuvers on the road, SbW improves road holding, with low friction (Tavoosi et al., 2014). Also, during a severe maneuver, the controller can considerably improve vehicle handling with SbW (Tavoosi et al., 2014).

Not only active safety is increased, but also passive safety. The risk of injury to the driver by mechanical steering components is significantly reduced by removing the steering intermediate shaft. (Polmans et al., 2018). That eliminates the risk of the steering column entering the cockpit in the case of a frontal crash (Munir and Koushanfar, 2018). Also, a more ergonomic design can be realized with SbW (LeRoy, 2006), for example by stowing the steering wheel when driving in AD mode. Stowage of the steering wheel in the cockpit can be realized, because the steering wheel does not necessarily needs to rotate with SbW. This allows the driver to use the obtained extra space in front of him in a different way (Polmans et al., 2018). One benefit from a driving experience point of view is that SbW enhances driver comfort by providing a variable steering ratio. This means that the steering ratio between the steering wheel and the road wheels can be adapted according to the driving conditions (for example, a smaller steering ratio during parking and urban driving, compared to a bigger steering ration during driving on highways) (Munir and Koushanfar, 2018). This makes it easier to park, and also safer to drive on the highway.

On the other hand, SbW has some drawbacks for Volvo and for the customer. It is a complex system to develop, and has increasing costs and weight due to high safety requirements and reliability to satisfy the customer (Harrer et al., 2016). Also, there are obvious safety issues to be dealt with by the developers of SbW. One of those issues is calibration, since it is complicated to emulate a natural-feeling hydraulic steering system and its responses. However, it is expected that future developments will in all probability resolve these issues (Kingston, 2018). There will possibly be some resistance to the new technology. Some customers might even be nervous to see how different a SbW car feels compared with an old fashion mechanical system. However, by the time SbW cars start appearing on the roads, much of those doubts can be alleviated by letting customers make a test drive in a SbW car (Johnson, 2013).

A summary of benefits and sacrifices for Volvo as well as for Volvo customers as described above can be found in Appendix A.

2.4 Price

The price customers are willing to pay is an important aspect of the proof of product value. If a new product has value, customers are willing to pay the price for it (Nijssen, 2015). It is estimated that the price of SbW will be higher compared to a conventional steering system.

However, the conventional steering system was never an optional feature for customers, but upgrades of the steering system were introduced as an addition when customers chose for a certain engine. In this way, the price of the conventional steering system was included into the total price of the car, making the price increase less visible for customers (Volvo internal experts).

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In order to estimate the price of SbW as an optional feature in a normal car, a competitor analysis is conducted, as shown in Table 4. For the competitor analysis, the competitive automotive brands BMW, Audi, and Mercedes can be compared with Volvo Cars, since their cars are in the same segment. For the system comparison with SbW, Active Rear-Wheel Steering is chosen, a system that is already available on the market, and an optional feature in cars from BMW, Audi, and Mercedes. Based on competitor's prices of Active Rear-Wheel Steering, Volvo's estimated customer price of SbW will be €2,079. This would be the price of the SbW system if it would become an optional feature in a normal (not AD) car. Therefore, it is important that customers see the value of the SbW system, so that they are willing to pay the higher price.

Table 4: Competitor price analysis

Competitor model	System	Consumer price
BMW X5	Integral Active Steering	€1,335 (optional)*
BMW X6	-	-
BMW X7	Integral Active Steering	€1,335 (optional)*
Audi A7	Dynamic-All-Wheel Steering	€2,661 (optional)**
Audi A8	Dynamic-All-Wheel Steering	€2,732 (package/optional)**
Audi Q7	Dynamic-All-Wheel Steering	€1,612 (optional)**
Audi Q8	Dynamic-All-Wheel Steering	€1,612 (optional)**
Mercedes AMG GT	Active Rear-Wheel Steering	€2,057 (package/optional)***
		€2,079 (average system price)

*BMW Price lists (2019)

**Audi Price lists (2019)

***Mercedes Price lists (2019)

2.5 Early adopters

Customers have different tendencies to adopt a new technology. Based on this, Rogers (2003) developed the technology adoption lifecycle model, consisting of innovators (2.5%), early buyers (13.5%), early majority (34%), late majority (34%), and laggards (16%) (see Figure 7).

The customer group who will adopt the new product first is the innovators, who are technology enthusiasts. They are open to new innovations, who are convinced that it will lead to improvement, and they are willing to try them out. Also early adopters adopt a new product early in the product life cycle. However, early adopters are more rationalistic than innovators, relying on their own intuition and judgement. The early adopters is an interesting customer group, since it is the first customer group who will provide a stable turnover. Thereafter, the early majority will adopt the new product. They can also relate to the new technology, but are more pragmatic than early adopters. They rather wait to see how other people adopt the new technology, and look for references before getting into the market. The late majority are conservatives, who are pessimistic about obtaining value from new technologies. They are also price-sensitive, and will buy the product if costs are controlled and decrease over time. The final customer group is the laggards, who have a negative attitude towards new technology in general.

The idea of the technology adoption lifecycle model is that finally all customers in the marketplace will adopt the new technology. It explains how fast a new innovation will be adopted and how it will be diffused in a market (Nijssen, 2014).

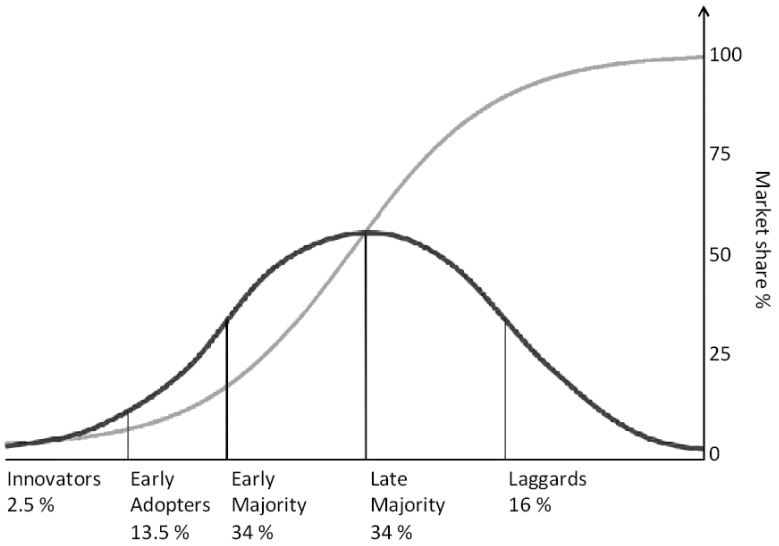

Figure 7: Technology adoption lifecycle (Rogers, 2003)

2.6 Conclusion

After examining theories and methods describing and explaining customer perceived value in this chapter, a conclusion can be drawn on sub-question Q1: *Which theories and methods describe and explain customer perceptions of a new technology?*

Customers will be interested in a new technology if benefits are greater than the sacrifices. According to literature, and as can be seen in Appendix A, SbW has more benefits than sacrifices. That given, a hypothesis can be drawn on the main research question, and the sub-

research questions Q2, and Q3. It is expected that customers will react to the new steering technology positively, and will be interested to adopt this new technology in their cars.

3. Methods

In the previous chapter, the first sub-question has been answered by providing information about theories and methods describing customer perceptions of SbW. In order to apply this information to measure Volvo customer perceptions of the SbW system compared to a conventional system, further research is needed. Therefore, customer data is collected via surveys and interviews which is described in this chapter.

First, the benefits and sacrifices of SbW identified in Section 2.3 were discussed several times during brainstorm- and feedback sessions with different experts, to identify the main benefits and sacrifices for Volvo customers. These main benefits and sacrifices are described in Section 3.1. Second, in Section 3.2 the expert feedback session is described, that was organized to hear ideas from the steering experts on benefits, sacrifices, the target customer, and possible price. Thereafter, customer value research via a survey and interviews is conducted and described in Section 3.3, where Volvo customers were asked to rate the benefits and sacrifices according to their importance, and to possibly add benefits and/or sacrifices. After that, in Section 3.4 a cluster analysis was conducted to identify clusters in the US survey data. Finally, a conclusion of this chapter answering the second sub research question is drawn in Section 3.5.

3.1 Expert interviews

The main benefits and sacrifices as shown in Figure 8 were drafted after making several iterations in the research process. This started with Lapierre's list of drivers explaining customer value (Table 3). After specifying on the new steering technology SbW, different benefits of SbW were found in scientific literature (see Section 2.3 and appendix A). These results were discussed several times during brainstorm- and feedback sessions together with different internal Volvo experts (among others: steering experts, price experts, development process experts, and market intelligence experts), to identify the main benefits and sacrifices for Volvo customers. An overview of these brainstorm- and feedback sessions can be found in Appendix B. That resulted in three main benefits (improved safety, design freedom, and improved driving experience), and two main sacrifices (higher costs, and changed driving experience) of SbW for Volvo customers.

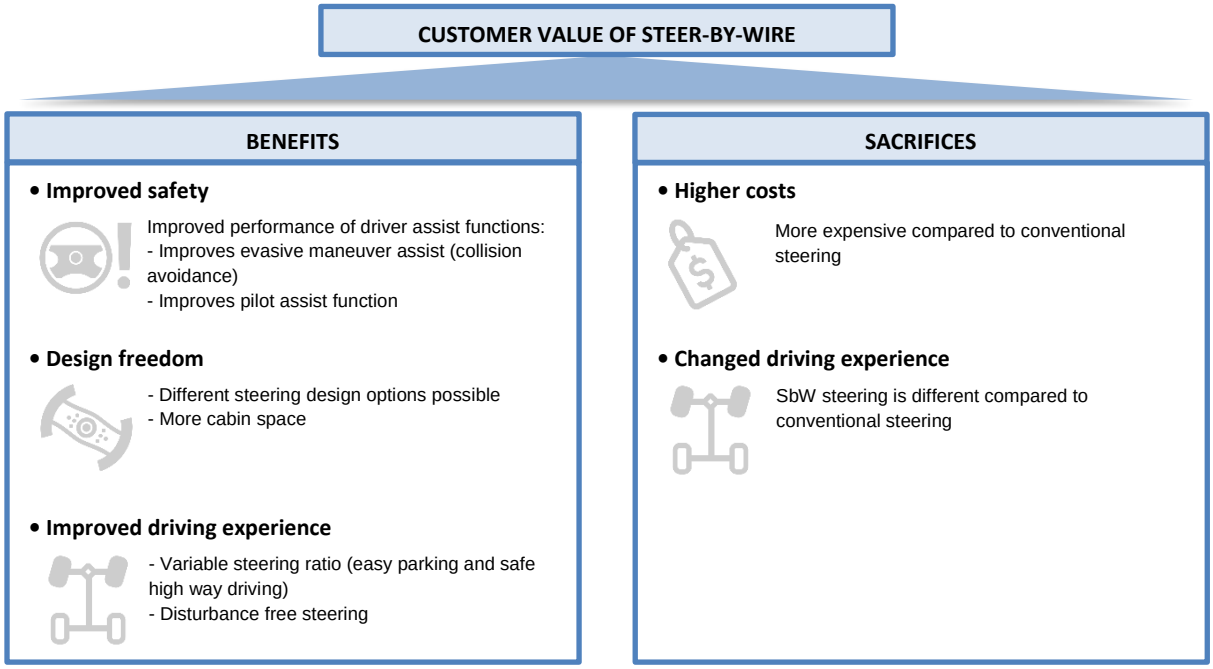

Figure 8: Overview of main benefits and sacrifices of SbW

3.1.1 Improved safety benefit

SbW improves safety by improving performance for driver assist functions. One of those improved driver assist functions is evasive maneuver assist, which helps the driver to steer faster, and more accurately avoid an obstacle and a subsequent skid. This helps in avoiding a collision. Another improved driver assist function is the pilot assist. This function provides the driver with steering assistance, and helps to maintain distance to vehicles in front of the driver.

3.1.2 Design freedom benefit

Also, SbW makes it possible to have different design options. One of those options is a steering wheel that can be stowed when driving in AD mode, giving more cabin space. Other design options are, for example:

- No steering wheel (360c)
- “Silent wheel” in AD mode
- Joystick
- Left- and right wires
- Steering button
- Wheel individual steering, etc.

3.1.3 Improved driving experience benefit

The third main benefit of SbW is improved driving experience. A variable steering ratio makes it possible to park more easily and to drive safer on highways. Thereafter, separation of the

driver input and road disturbances offers disturbance free steering, contributing to improved driving experience. This will result in smoother, and more agile way of driving.

3.1.4 Higher costs sacrifice

On the other hand, one of the main sacrifices of SbW is the costs. SbW will have a higher price for customers compared to a conventional steering system. Based on competitor's prices of the comparative system 'Active Rear-Wheel Steering', Volvo's estimated customer price of SbW will be €2,079. This would be the price of the SbW system if it would become an optional feature in a normal (not AD) car. The conventional steering system was never an optional feature for customers, so customers will pay a higher price for the SbW system.

3.1.5 Changed driving experience sacrifice

Also, for some customers the changed driving experience that comes with SbW can be a benefit, but for other customers it can be a sacrifice. Those customers mostly like a sporty way of driving, and like to feel the road. SbW will somewhat reduce that road feeling to reduce the feeling of road disturbances, resulting in a smoother, more agile way of driving. This was one of the customer requirements found in former research executed by Volvo's Market Intelligence department, as discussed in Chapter 1.7.2: Disturbance free steering, easy parking, a more agile way of driving, and safety.

However, a feedback motor will be built in on the steering wheel. This will still allow drivers to feel the road by sensor input coming from the wheels, to make sure to communicate all important information to the driver, especially road friction. For example, if the road feels slippery in winter conditions, the driver will be notified. In this way, the driver will still be able to feel the road, but unwanted road disturbances as pot holes and uneven roads will be left out. Thereafter, separate driving modes will be developed, so that the driver can chose how much of the road feedback is desired (*Volvo internal experts*).

3.2 Expert feedback session

An innovative feedback event was organized together with 28 people of Volvo's steering-art team (see Figure 3). The goal of this event was to introduce SbW to the team, and to hear ideas from the steering experts on benefits, sacrifices, the target customer, and possible price. The event lasted two hours, and started with a presentation of 45 minutes, where the technological details, and the main benefits and sacrifices of SbW were explained. Thereafter, the brainwriting- and brainstorming sessions started.

Brainwriting is a group idea generation method that stimulates the creativity of the participants. There are many different ways of conducting a brainwriting session. A common way is when the participants first create ideas individually, and then build on each other's ideas under supervision of a moderator.

After the presentation about SbW, the group was divided into 7 groups of 4 people. The following question was presented on the screen: 'What are other most valuable benefits of SbW for customers?'. Participants first created ideas individually on a paper sheet, and then rotated the sheet within the group to build on each other's ideas (brainwriting). After brainwriting for ten minutes, the team came together and one person from every group presented their ideas.

Brainstorming is also a group idea generation method, but the term is generally used for all group ideation sessions. During a brainstorming session, the group works together to generate ideas on a specific topic or problem. There are four rules of brainstorming that should be fulfilled to make it effective: focus on quantity, withhold criticism, welcome unusual ideas, and combine and improve ideas (Volvo internal documents).

During the next round, the group worked together to generate ideas on the main customer benefit of SbW, an early adopter description, and the price of SbW, and made a poster of their results (brainstorming). After brainstorming for 10 minutes, one person from every group presented their poster, and the groups strived to have the most creative and clear poster.

An overview of the plan of the innovative feedback event can be found in Appendix C. After the feedback event with the steering experts, the results of all groups were gathered and checked on useful information.

3.3 Data collection

In order to confirm the main benefits and sacrifices found in scientific literature and discussed with experts, customers were asked to give their opinion on it in interviews and questionnaires. Based on former studies conducted within Volvo Cars (Sigma Sensor, 2017), the following biggest markets of Volvo Cars served as the study markets for the questionnaires and interviews: Europe, US, and China. Europe, US, and China count for 86% of Volvo's total sales market. For the customer value research, a questionnaire and interviews were used as research methods. A PowerPoint presentation was sent to all respondents prior to the questionnaire and interviews, in order to explain the SbW technology to regular Volvo customers with less knowledge of the technology (see Appendix D). The PowerPoint presentation consisted of a brief explanation of the technology, benefits, and sacrifices of SbW.

3.3.1 Sampling procedure and method of data collection

For research in US, a random sample of 1,000 Volvo customers was obtained out of a customer database of 6,525 Volvo customers who regularly fill in surveys for Volvo Cars (Voice of Volvo Cars). After that, a web-based questionnaire was sent to the respondents via e-mail. For research in China, the same questionnaire was sent to five random Volvo customers, and

in Europe, four interviews were executed with Volvo customers. The questionnaire and interviews were also accompanied by the same PowerPoint presentation in Appendix D.

3.3.2 Questionnaire to Volvo customers

Verification of the customer perceived benefits and sacrifices was done using a mailed online questionnaire, consisting of both open and closed questions, for a sample of 1,000 customers from US (see Appendix E). A questionnaire is a research instrument consisting of a series of questions. The purpose of a questionnaire was gathering information from respondents, in this case American and Chinese Volvo customers (McLeod, 2018). Because of the availability of the large Voice of Volvo customer database in the US, the outcome of the questionnaire in the US was used as the primary dataset of this study. To see if these findings can be generalizable for all Volvo customers, the same questionnaire is also sent to five customers from China. The questionnaire consisted of 24 items that measured 6 dimensions (3 benefit dimensions and 2 sacrifice dimensions). These dimensions were mentioned in chapter 3.1, and have been used as input for the survey. For both the US survey and the China survey, the instrument was in English.

3.3.3 Interviews with Volvo customers

In order to see if the findings in the US were generalizable for all Volvo customers, and projectable in Europe, interviews with four European Volvo customers were conducted with customers from Sweden, Germany, and The Netherlands. In customer value research, firms get to understand how customers think by conducting interviews with customers. According to Baarda & De Goede (2006), an interview is especially suitable for when asking for opinions, experiences and feelings, so this was an appropriate method to gain additional and responses from Volvo customers. By conducting an interview it is also possible to ask more questions than with a questionnaire, resulting in more extensive answers. The interview in Sweden was conducted face-to-face, the other interviews were conducted via Skype. For the interviews, an interview guide was drafted, consisting of three parts: Volvo customer type, user benefits and sacrifices of SbW, and the price of SbW (see Appendix H), The interview included the same questions as the survey, to assess the value of the benefits and sacrifices obtained from scientific literature, and brainstorm-and feedback sessions with experts. All four interviews were executed in English.

3.3.4 Data analysis

For the analysis of the data, mainly descriptive statistics are used, since the purpose is to present the customers' responses to survey items in order to address sub-research question 3 (Statistics Solutions, 2019).

The US survey data was analyzed with the Vision Critical tool of Voice of Volvo. This tool displayed the results of the closed survey questions in charts. The open questions were analyzed and codified, where most frequent similar answers were grouped by a category, as

can be seen in Appendix F. Coding is a method that enables to organize and to group similarly coded data into categories because they share some characteristic (Saldana, 2009). Classification reasoning plus tacit and intuitive senses are used to determine which answers look alike when grouping them together.

To see if one type of Volvo customers is most interested in SbW, the survey data was filtered based on car model, gender, and age. Thereafter, a cluster analysis was executed as a check on the filtered data, and to see if a specific type of customers most interested in SbW would exist.

3.3.4.1 Cluster analysis

In order to group respondents to represent a structure, a cluster analysis can be executed. (Hair et al., 2014) . The R-statistical software program was utilized to conduct a cluster analysis to identify clusters in the US survey data. This cluster analysis could help identify a specific customer type that has certain features that would make it an interesting (e.g. lead) customer of the SbW system.

The raw data was composed of 455 respondents and 20 questions. First, the dataset underwent serious pre-processing in R. Two questions were filtered out due to lack of enough responses, for which the 45% threshold was used. Furthermore, 252 respondents were filtered out due to one or more missing values. The final dataset was composed of responses of 203 participants on 18 questions. A proximity matrix has been calculated using Random Forest algorithm (ntree = 1 million). After transforming into distance matrix, i.e. sqrt(1 - proximity), low 2-dimentional approximation was performed using tSNE algorithm, and results were subsequently visualized (Hair et al., 2014; Wilbik et al., 2013; Volvo internal experts). As can be seen in Appendix F, no clustering structure was evident, thus no specific (preferred) SbW customer type could be identified.

3.3.4.2 Profile of the respondents

In total, 461 completed questionnaires were received. In the US sample, 455 responses were received (see Figure 9), of which 23% female and 77% male. These respondents are driving an S60 (9%), an S90 (4%), a V60 (5%), a V90 (2%), an XC40 (10%), an XC60 (32%), an XC90 (30%), and other (older) Volvo models (8%). In the China sample, 5 responses were received with 20% female and 80% male. The Chinese respondents are driving an S60 (40%) and an XC60 (60%). In the Europe sample, 4 interviews were executed with 25% female and 75% male, driving a V60 (25%), a V90 (25%), an XC60 (25%), and an XC90 (25%).

The response rate in China and Europe was too low to draw a reliable comparison between all three of Volvo's biggest markets regarding the customer perceived value of SbW. Therefore, the US sample will be the main dataset for the analysis in the remainder of this chapter.

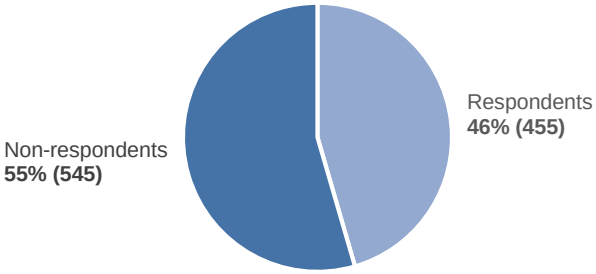

Figure 9: US survey population

Table 5 shows that the response rate hardly differs per Volvo model, so there is hardly any (response rate) bias in terms of what model the customer is currently driving. Because the sample size is rather different for the various Volvo models, the number of respondents differs per model in a range from 10 to 144 (see Table 5 and Figure 10). For example, the V90 (10 respondents) is a new model, while the XC60 (144 respondents) includes both the old model and the new model, so the XC60 is already for a longer time on the US market compared to the V90.

Table 5: US response rate per Volvo model

Volvo customer information	Sample size	Respondents	
Volvo model	Voice of Volvo	Respondents	Response rate
S60	90	40	44%
S90	39	19	49%
V60	45	23	51%
V90	18	10	56%
XC40	99	46	46%
XC60	334	144	43%
XC90	295	135	46%
Other	80	38	48%
Total	**1000**	**455**	**46%**

Another reason for the respondent difference per model is that US customers are more interested in bigger cars, and therefore SUV vehicles (XC40, XC60, and XC90) are more popular on US market. That is also projectable in the global retail sales numbers per model line: S-line (20%), V-line (34%), and XC-line (46%).

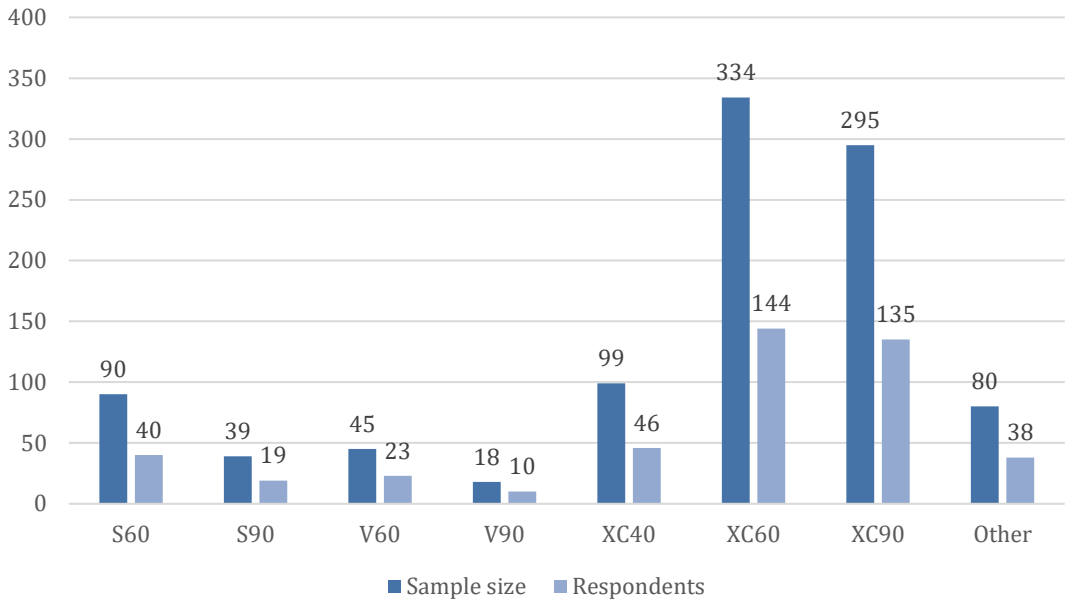

Figure 10: US response rate per Volvo model

Figure 11 shows the age distribution of the respondents. Respondents with a birth year from 1950 to 1979 are over-represented (68% of the respondents), while respondents with a birth year from 1990 and younger and 1939 and older are under-represented. In the Chinese sample, the respondent's age ranges from 30 to 41. The European respondent's age ranges from 44 to 59.

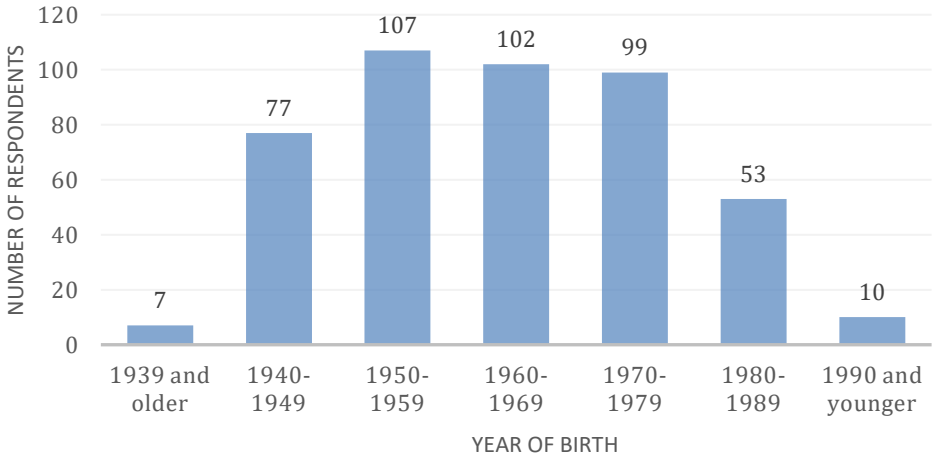

Figure 11: Year of birth distribution of US survey respondents

3.5 Conclusion

This thesis describes customer perceived value of SbW, and explores the benefits and sacrifices of SbW, and price perceived by Volvo customer, as well as the early adopter of SbW.

The value-based drivers identified as benefits and sacrifices discussed in Chapter 2 were used to draft three main benefits (improved safety, design freedom, and improved driving experience), and two main sacrifices (higher costs, and changed driving experience) of SbW for Volvo customers.

For this study, data collected via a questionnaire and interviews with Volvo customers appear to be the most appropriate methods. In the US, the survey was sent to a random sample of 1,000 Volvo customers, obtained out of a customer database of 6,528 Volvo customers. Eventually, 455 responses were received, resulting in a response rate of 46%. The response rate barely differs per Volvo model, so there is hardly any (response rate) bias in terms of what model the customer is currently driving. Thereafter, 5 Chinese survey responses were received, and 4 European Volvo customers were interviewed.

4. Results

This chapter discusses the results of the customer value research in the US, where Volvo customers are asked to give their opinion in a survey on the benefits, sacrifices, and price of SbW, and its potential for early adoption. Results from the customer value research in China and Europe were used to see if the US results can be generalized to all Volvo customers. This gives an answer to sub-research question 3 and the main research question. First, Section 4.1 describes the results regarding (primary) user benefits and sacrifices of SbW. Thereafter, customers' responses regarding the price of SbW are discussed in Section 4.2. Finally, early buyers/adopters of SbW are identified in Section 4.3.

4.1 (Primary) user benefits and sacrifices of Steer-by-Wire

This section describes the customer value research results of the benefits and sacrifices of SbW. Via the survey, US respondents were asked about SbW, to rate the main benefits and sacrifices according to their importance, and to possibly add other benefits and sacrifices.

4.1.1 Survey results

Figure 12 shows the importance of automotive technology to customers. 74% of the respondents had indicated that having the latest technology in their car is important to them. Since most of the respondents are interested in new technology in their cars, it could be concluded that they are most likely also interested in the new steering technology SbW, which gives a positive first sign.

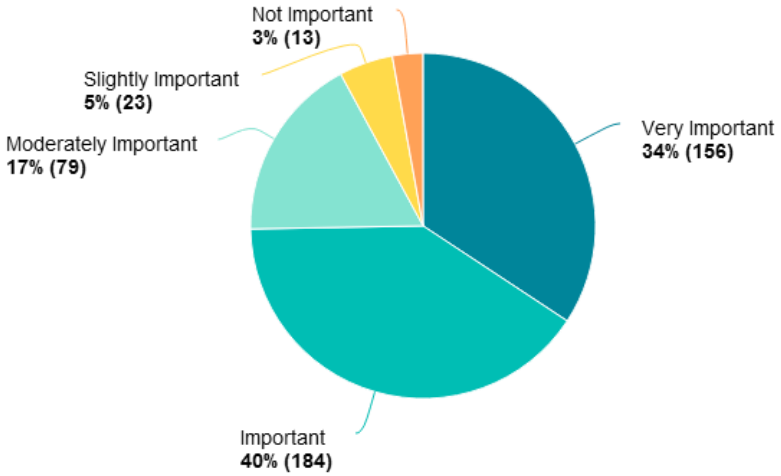

Figure 12: US importance of latest automotive technology

After asking about the latest automotive technology, respondents were asked about their first reaction to SbW. 67% of the respondents indicated that their first reaction to SbW was somewhat positive or very positive. On the other hand, the first reaction to SbW was somewhat negative or very negative to 17% of the respondents (see Figure 13). These results indicate an overall positive first feedback from the respondents on SbW.

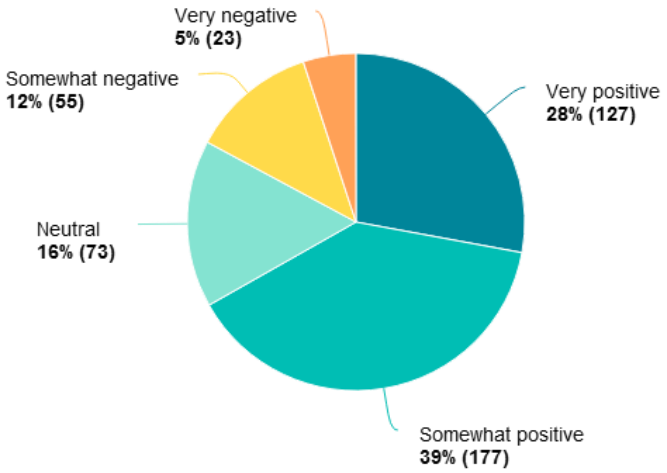

Figure 13: US first reaction to SbW

Customers appear to be quite positive about using SbW. The survey results show that 75% would be comfortable using the new technology (see Figure 14). From the 25% of the respondents who indicated that they would not be comfortable using SbW, 82% (21% in total) indicated that they do not trust the system (yet), or are afraid of not having control of the car, or a combination of both. They want a back-up in case the system would fail. 9% of the negative responses on SbW (2% in total) came from respondents who enjoy driving themselves, and they indicated that for them SbW takes the fun out of the experience of driving. Other answers (both 7%, 2% in total) were about adaptation and cost. Adaptation critiques came from respondents who think they are too old to adapt to the new technology of SbW.

It is remarkable that only 2% of the respondents give higher costs as a negative feedback on SbW.

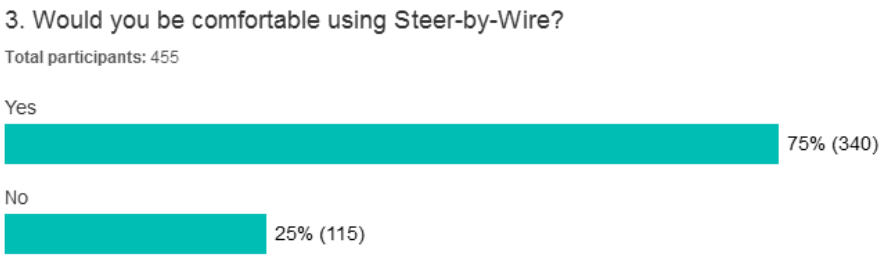

Figure 14: US being comfortable using SbW

Figure 15 shows the importance of SbW benefits according to Volvo customers. Benefits were rated according to their importance to customers. To 90% of the respondents, safety (improved performance for driver assist functions) is important or very important. That is not surprising, since Volvo is global leader in automotive safety technology, and most customers

choose for a Volvo for that reason. Driving experience is rated as second most important benefit to respondents. 71% of the customers indicated that driving experience (variable steering ratio and disturbance free steering) is important or very important to them. Least important is Design (different steering options, design freedom, and more cabin space) to respondents, since 60% indicated Design is very important or important to them.

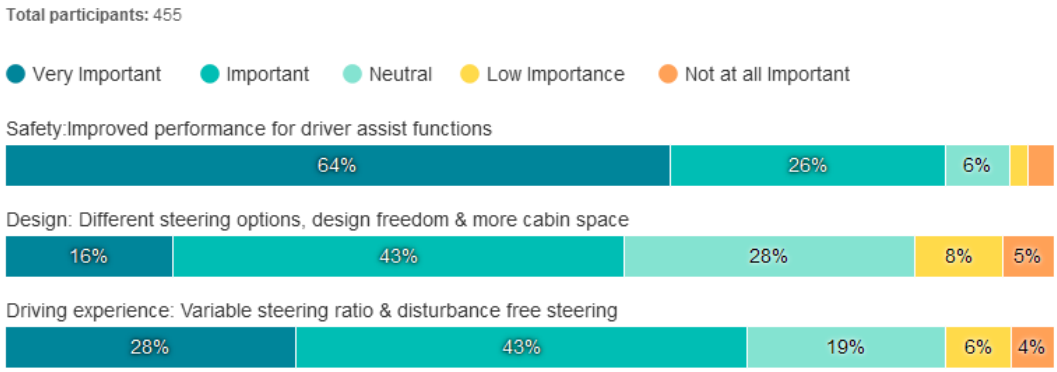

Figure 15: US importance of SbW benefits

Customers were also asked if any other benefits came to mind (see Appendix F). In total, 28% of the respondents filled in various answers. Increased comfort is an additional benefit of SbW according to 7% of the respondents. The most often mentioned reasons for that were less road disturbances (leading to smoother rides), the possibility to relax in the car (leading to a decrease in driver fatigue, especially on long journeys), and the possibility of having their own steering preferences with SbW. 6% of the respondents named safety as an additional benefit, which was already mentioned as a main benefit, but respondents also added that SbW leads to better accidents avoidance, and quicker reaction time. Also, they believe that 'taking the human component out of the equation creates a safer environment'. For 3% of the respondents, the capability for fully autonomous driving is an additional benefit of SbW. Another 3% names cost- and weigh reduction as an additional benefit. They believe that SbW contains less mechanical parts, which leads to less maintenance costs, and weight reduction, which lead to better fuel efficiency. The last 1% mentioned that SbW will create better accessibility for disabled, elderly or low vision drivers. SbW would make them more mobile, and less dependent on others.

Regarding the sacrifices of SbW, respondents are less diversified about the importance. Figure 16 shows that cost (higher compared to a conventional steering system) is important or very important to 66% of the respondents. This seems to be in contrast to what was mentioned earlier, namely that only 2% of the respondents give higher costs as a negative feedback on SbW. However, in this case respondents were specifically asked to give their opinion on the cost sacrifice, while earlier respondents were asked why they would not be interested in SbW. The sacrifice changed driving experience is important or very important to 63% of the respondents.

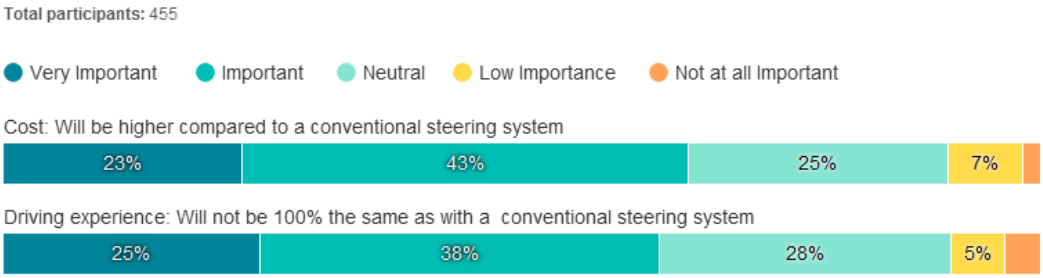

Figure 16: US importance of SbW sacrifices

Also, respondents were asked to fill in other sacrifices than cost and driving experience that came to mind (see appendix F). In total, 42% of respondents filled in other sacrifices of SbW. Most of the concerns of respondents are about trust, losing control, and safety, since 33% of the respondents named this as an additional sacrifice of SbW. Respondents are afraid of losing control, they want to have road feedback to know on what type of terrain they are driving, and they want to know if they drive over obstacles. Another moment respondents want to have road feedback, is when driving in winter conditions. Also, respondents indicated to have problems trusting an electronic system. Cost was mentioned by 4% of the respondents as an additional sacrifice. Although this sacrifice was already mentioned as a main drawback due to higher system costs, respondents expect an increase in cost of maintenance. 2% of the respondents mentioned to expect adaptation problems with SbW, which was mostly mentioned by elderly respondents. Only 1% of the respondents indicate to lose their joy of driving with SbW as an additional sacrifice. They indicated that SbW will take out the fun part of driving, and they think they will have no personal connection to their car anymore.

4.1.1.1 Survey results China

From the Chinese survey results in Appendix G it can be concluded that respondents can accept the new technology of SbW, but need to have a back-up solution in case the system fails. They also indicate safety as their most important benefit of SbW. Driving experience is their second most important benefit, and Design is their third most important benefit. When looking at the sacrifices, respondents indicate that the Cost sacrifice is as equally important as the Driving experience sacrifice. It can be concluded that Chinese survey results show no major differences compared to the results from the US survey, when looking at their perceptions of the benefits and sacrifices of SbW.

4.1.1.2 Interview results Europe

Appendix H shows the interview results with European respondents. Overall, respondents are quite positive about SbW, but they would like to see more tests to be sure that the system is safe, and are therefore not likely to become the early adopters of SbW. Regarding the benefits of SbW, safety is their most important benefit, and respondents also indicated that the lack of the steering column is an important aspect of the safety benefit. In case of an accident, there is a risk of the steering wheel and steering column going into the driver. With SbW,

there are no measures needed to prevent that, so a more rigid cage can be made. Regarding the sacrifices of SbW, respondents indicated that it will be a hurdle to trust the system in the beginning. But once they are used to the system, they will be comfortable with it, so respondents appear to see more benefits than sacrifices of SbW.

4.2 Price of Steer-by-Wire

After asking the US respondents about the benefits and sacrifices of SbW, respondents were asked if they would be interested in buying the SbW system, and what they are willing to pay it. Not only were they asked about the price of SbW, but also about AD, since SbW has more benefits when combined with AD.

4.2.1 Customer choices

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4.2.2 Survey results

First, respondents were asked if they are interested in buying an Autonomous Driving vehicle. 54% of the respondents indicated to be interested in buying an AD vehicle, but 46% of the respondents are not interested (see Figure 17).

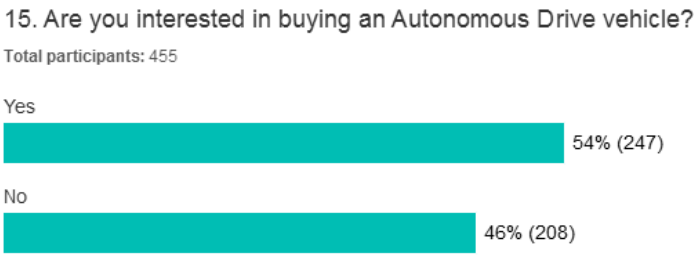

Figure 17: US interest in buying an AD vehicle

36% of the respondents elaborated on their answer why they are not interested in buying an AD vehicle, which shows different results (see Appendix F). Most of the answers were again trust, control, or safety related (19%). Respondents do not trust the AD system yet, and they think it is not proven to be safe yet. They want to see more test results, to gain trust in the AD system. Another frequently named answer was that US does not have clear lane markings and signs everywhere, which makes them believe that AD will not work in US. 11% of the respondents are not interested in AD, because they enjoy driving themselves. Also, 3% of the respondents answered to have troubles with adaptation of SbW, and that they are not ready for this new technology yet. However, they also mentioned that this may change over time. Only 1% of the respondents named cost as a reason not to be interested in buying an AD vehicle, which is a remarkable low number. 4% of the respondents had other reasons why not to be interested in buying an AD vehicle. Most of these answers were related to the fact that

respondents do not see a need, since they are satisfied with their current (recently bought) vehicle.

After that, respondents were asked to give an indication on the additional price they are willing to pay extra for AD. The results in Figure 18 show that respondents are more positive about AD than the results in Figure 16 indicate. Only 38% of the respondents is willing to pay $0 to $5,000 (≈ €4,400). On the contrary, 43% of the respondents is willing to pay $5,000 to $10,000 (≈ €4,400 to €8,800), 15% of the respondents is willing to pay $10,000 to $15,000 (≈ €8,800 to €13,000), and 4% of the respondents is willing to pay $15,000 to $20,000 (≈ €13,000 to €18,000). However, the autonomous driving feature in a Volvo will receive a premium consumer price of approximately €12,000 (Andersson, 2016), and only 19% of the respondents is willing to pay this price for AD.

On the other hand, 62% of the respondents is willing to pay more than €4,400 for AD, so that is quite positive. Also, respondents did not know about this price estimation of AD when filling in the survey, so that could have influenced their response.

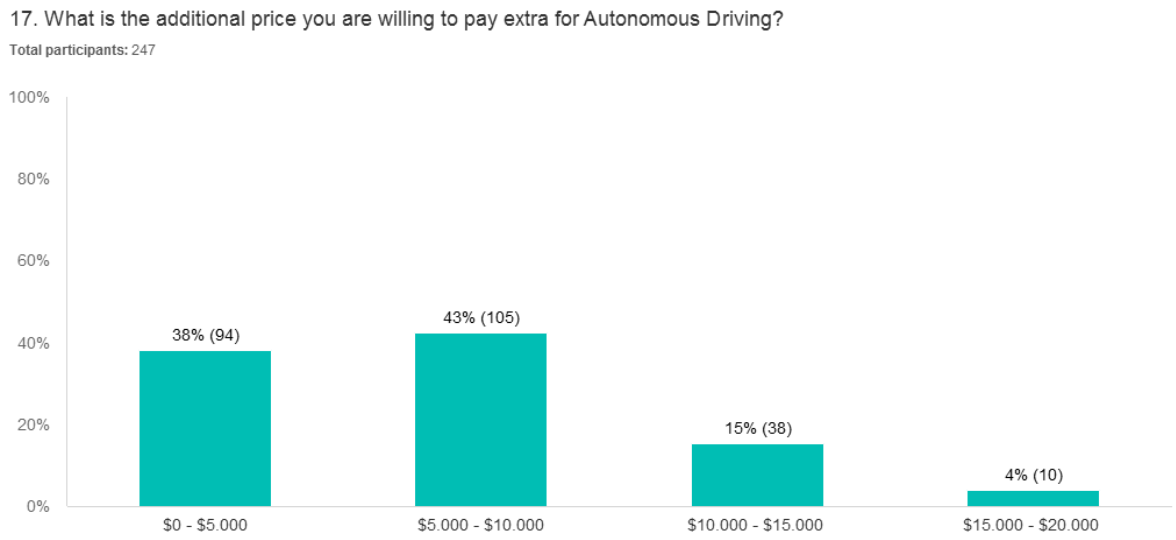

Figure 18: US additional price willing to pay extra for AD

Figure 19 shows the interest of the respondents regarding buying a normal (not AD) car with SbW. The results appear to be quite positive, since 65% of the respondents is interested in buying a SbW vehicle, compared to 35% of the respondents who are not interested. These results indicate that respondents are more interested in buying SbW, than in buying AD.

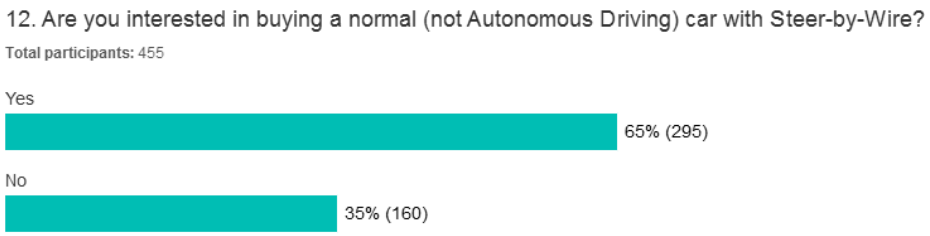

Figure 19: US interest in buying a SbW vehicle

33% of the respondents who were not interested in buying a normal car with SbW, elaborated on their answer. Appendix F shows answers related to adaptation, cost, trust/control/safety, joy, and other reasons. Like with the previous AD answers, 11% of the respondents are not interested in buying a SbW car due to trust, control, or safety reasons. Again here, only 4% of the answers are cost related, whilst in literature this was often mentioned as a big sacrifice of SbW. 3% of the respondents enjoy driving, and like to stay involved themselves during the drive. Another 3% of the respondents think the SbW technology is still too new, and they need to adapt to the idea of SbW first. Most of the responses came from respondents who had other reasons for not being interested in buying a SbW car (12%). They do not want SbW without AD, they want 'the full package or nothing', and would rather wait for the AD versions to arrive. This is a quite positive indication. Also, some respondents are satisfied with the way they are currently steering in their Volvo, and do not see a need for change. Also, some respondents are doubting: they are positive about the idea of SbW, but would like to try it out during a test drive first.

Also, respondents were asked to give an indication on the additional price they are willing to pay extra for SbW in a normal (not AD) car. As can be seen in Figure 20, 22% of the respondents are willing to pay the estimated extra price of €2,079 (≈ $2,400) for SbW. Also here, respondents were not aware of the estimated price of SbW before filling in the survey, what could have influenced their response. Most of the respondents (43%) are willing to pay $0 to $1,000 (≈ €900), 35% of the respondents is willing to pay $1,000 to $2,000 (≈ €900 to €1,800), 16% of the respondents is willing to pay $2,000 to $3,000 (≈ €1,800 to €2,600), 4% of the respondents is willing to pay $3,000 to $4,000 (≈ €2,600 to €3,500), and 2% of the respondents is willing to pay $4,000 to $5,000 (≈ €3,500 to €4,400).

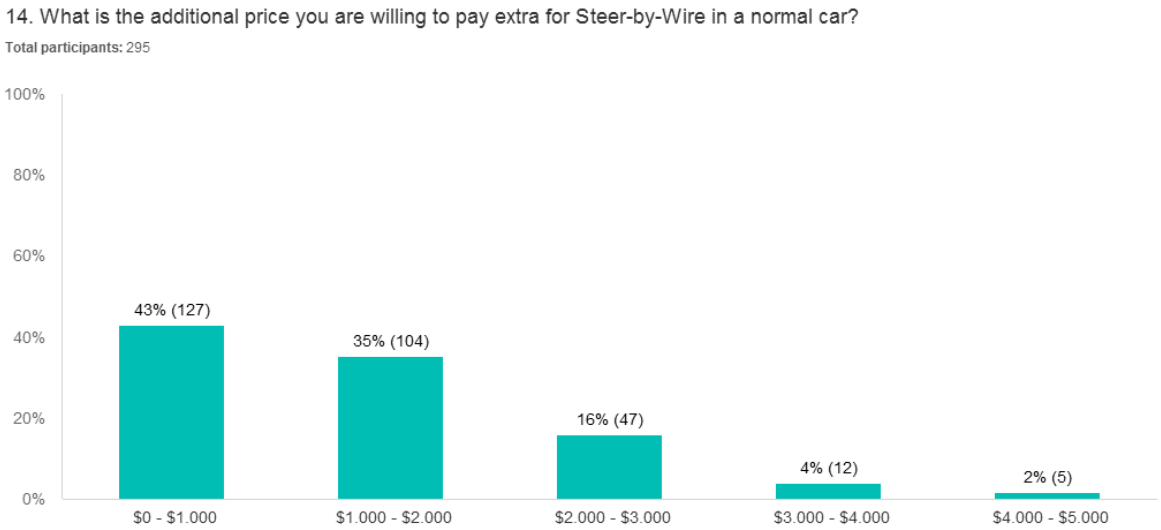

Figure 20: US additional price willing to pay extra for SbW

Figure 21 shows that 87% of the respondents would prefer buying an AD car with SbW, compared to 13% of the respondents who rather prefer buying an AD car without SbW. This indicated that respondents are more interested in 'the full package' of AD and SbW, rather than only AD, or only SbW, as already stated above. These results are not surprising, since a non-autonomous driving car with SbW has less benefits than an autonomous driving car with SbW, and it shows that respondents are aware of that fact.

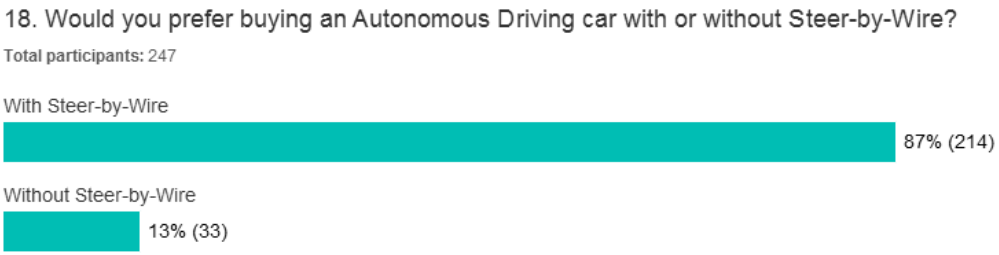

Figure 21: US preference for SbW in an AD car

4.2.2.1 Survey results China

Also from the Chinese survey results a conclusion can be drawn regarding the price of SbW (see Appendix G). Most of the Chinese respondents were interested in buying both a normal (not AD) car with SbW, as well as an AD vehicle. However, they do have concerns regarding trust of the system, and safety. When asking respondents about the price they are willing to pay extra for AD, the most frequently given answer was ¥40,000 to ¥80,000 (≈ €5,200 to €10,400), which is higher compared to the US sample. For the question about what price they are willing to pay extra for SbW, most Chinese respondents indicated the same as in US, namely ¥0 to ¥10,000 (≈ €1,300). Also, most of the Chinese respondents prefer an AD car with

SbW, this outcome is also similar compared to the US sample. Overall, it appears that regarding the price aspect, Chinese survey results show some differences compared to US survey results.

4.2.2.2 Interview results Europe

European interview respondents are quite positive about SbW. This means that they are also willing to pay a higher price for the new steering system (see Appendix H). Nonetheless, regarding their interest in buying an AD car, respondents are divided in their opinions. One respondent uses his Volvo mostly for business travels, and is often distracted by his phone or laptop while driving. AD would be a perfect solution for him, so that he can work during the drive. Another respondent is also interested in AD, but wants to keep an eye on the road in case something goes wrong, so does not fully trust the system yet. Another reason given why one respondent is not quite positive about SbW, is that he fears to get motion sickness when he will do other things during an AD drive. However, regarding SbW, European respondents generally appear to be positive, and would like to have SbW in their next cars.

4.3 Early buyers/adopters of Steer-by-Wire

The results in Chapter 4.1 and 4.2 are overall results from the whole US sample. However, Volvo customers can also be divided in customer groups per car model: S60, S90, V40 (not sold in US), V60, V90, XC40, XC60, and XC90. In this way, an estimation can be made about which Volvo model, and thus which customer group, would be most interested in adopting the SbW system first (early buyer).

4.3.1 Survey results

Table 6 shows respondent's interest in SbW, divided per Volvo car model. At least 70% of the respondents owning an S90, a V90, and an XC90 gave a first reaction to SbW that was positive or very positive. When asking respondents if they would be comfortable using SbW, the respondents owning an S60, a V90, and an XC90 all scored above 80%. Both V90 respondents and XC40 respondents have a 100% score on their preference for SbW in an AD vehicle. This can be explained by the newness of their car, and their preference for the newest automotive technology. Both V90 and XC40 are new Volvo car models, so they have the newest automotive technology in their cars. Shifting and adapting to the new steering technology SbW will be easier for customers owning the newest Volvo model, than for customers owning an older model.

Overall, it can be concluded that the higher segment customer groups, so S90, V90, and XC90, appear most likely to be most interested to be the early buyers of the SbW system. This is not surprising, since income and price paid for a new Volvo car is highly correlated (Volvo internal documents). This can also be related to customers' willingness to buy SbW. The higher segment customer groups have on average a higher income, and will thus be more likely buy a car with SbW than the lower segment customer groups.

Table 6: US SbW interest per Volvo model

	S60 (N=40, 9%)	S90 (N=19, 4%)	V60 (N=23, 5%)	V90 (N=10, 2%)	XC40 (N=46, 10%)	XC60 (N=144, 32%)	XC90 (N=135, 30%)	Other (N=38, 8%)	Total (N=455, 100%)
(Very) important to have latest automotive technology	51%	89%	61%	70%	74%	76%	80%	79%	74%
(Very) positive first reaction to SbW	55%	74%	52%	80%	67%	68%	70%	61%	67%
Comfortable using SbW	68%	84%	65%	80%	74%	75%	80%	63%	75%
Interested in buying AD car	43%	79%	35%	40%	43%	54%	64%	47%	54%
Willing to pay €12,000 for AD	18%	20%	13%	25%	15%	21%	21%	11%	48%
Interested in buying non-AD car with SbW	60%	79%	52%	90%	74%	63%	65%	58%	65%
Willing to pay €2,500 - €5,000 for SbW	4%	0%	0%	0%	9%	8%	5%	5%	17%
Preference for SbW when buying AD car	82%	87%	75%	100%	100%	90%	84%	78%	87%

Lower interest			Higher interest

4.3.1.1 Survey results China

The Chinese sample consists of only XC60 (60%) and S60 (40%) drivers, as can be seen in Appendix G. Between respondents driving an S60 and XC60 no significant difference in their opinion regarding on SbW can be indicated. When comparing the Chinese sample with the US sample, US respondents driving an S60 are overall quite equally distributed regarding their willingness to buy the SbW system. When looking at respondents driving an XC60, US respondents are overall more positive about SbW than Chinese respondents. Nonetheless, it

is difficult to draw a conclusion based on these results, since not all Volvo car models are represented in the sample, and the sample size is too low.

4.3.1.2 Interview results Europe

In the European sample, a V60, a V90, an XC60, and an XC90 are represented. Like in the US sample, in the European sample it can be seen that the higher segment (V90, XC60, and XC90) is willing to pay a higher price for AD and SbW, than the lower segment (V60). Also here, no clear conclusion can be drawn, since not all Volvo car models are represented in the European sample, and the sample size is too low.

4.4. Conclusion

Customer value research was conducted in the US, where Volvo customers were asked to give their opinion on the benefits, sacrifices, and price of SbW, and the early adopter of SbW in a survey. Results from the customer value research in China and Europe were used to see if the US results could count for all Volvo customers. Customers appear to be quite positive about using SbW. The survey results show that 75% would be comfortable using the new technology. From the 25% of the respondents who are not comfortable using SbW, 82% indicated not to trust the system (yet), since little is known about a back-up system in case of a system failure.

First, respondents were asked about SbW, to rate the main benefits and sacrifices according to their importance, and to possibly add other benefits and sacrifices. The safety benefit of SbW (improved performance for driver assist functions) is rated as most important to 90% of the respondents. That is not surprising, since most customers choose for a Volvo for safety reasons. The sacrifices of SbW, 'higher cost' and 'changed driving experience', were rated almost equally important (≈ 65%) to respondents. It is remarkable that only 2% of the respondents give higher costs as a negative feedback on SbW, so cost does not appear to be an important sacrifice to respondents. Regarding the price of SbW, only 22% of the respondents is willing to pay the estimated price of SbW (€2,079). Also for AD, only 19% of the respondents are willing to pay the actual price (€12,000). However, regarding AD, respondents show more willingness to pay a higher price, than for SbW.

Most likely, the higher segment customer groups, so S90, V90, and XC90, will be the early buyers of the SbW system. This is not surprising, since the higher segment customer groups have a higher income, and will thus be more likely buy a car with SbW than the lower segment customer groups. Additionally, V90 and XC40 drivers can be expected to become early adopters of SbW. Both V90 and XC40 are new Volvo car models, so they have the newest automotive technology in their cars, and they will thus be more interested in SbW than customers owning an older Volvo model.

Since the customer value research results of China and Europe do not show substantial differences compared to results from US, one can say that respondents in the US sample of this study are probably similar to the global population of Volvo customers. However, sample sizes for both the Chinese as well as the European sample were too low to draw a valid conclusion at this.

Overall, findings show that respondents appear to see the benefits of the SbW system. They indicated that safety is the most imported benefit, followed by respectively, driving experience and design. However, respondents also indicated major concerns about the reliability of the system. Too little is known about the redundant system that takes over in case of a system failure. It can thus be concluded that customers do see the added value of the SbW system compared to a conventional steering system, but they need to be assured about the redundant system to be convinced that it is reliable.

On the other hand, the results of this research are timely. Developments in the automotive industry are expected to be fast, and new mobility solutions are on its way. Also, markets are changing rapidly, and so is consumer behavior. After one year, consumers might be more used to the idea that cars can drive autonomously, which will probably make them even more enthusiastic about SbW.

5. Conclusions and recommendations

In this chapter, the main findings of this study are discussed and the performed research is reflected. The conclusion and discussion in Section 5.1 puts the main research question into perspective, and discusses the results from the previous Chapter 4. Section 5.2 describes how this research can contribute to academic literature. Section 5.3 discusses limitations of this research, and describes directions for future research, following from the current study. Lastly, Section 5.4 discusses several recommendations regarding the customer perceived added value of SbW for Volvo.

5.1 Conclusion and discussion

This thesis studies the front-end development of a new steering technology in the automotive industry: Steer-by-Wire. The development of the SbW system represents a problem, impacting the customer perceived value of SbW. Although developers of the system are already convinced of the benefits and value of the SbW system, they do not have any systematic evidence regarding customer perceptions of SbW. To maximize the value of this new technology, a customer value research was conducted where respondents were asked to give their response on the SbW system, answering the main research question:

How do Volvo customers perceive the added value of the Steer-by-Wire (SbW) system compared to a conventional steering system?

In order to provide guidance to answer the main research question, the following sub research questions were answered:

Q1: Which theories and drivers serve to describe and explain customer perceptions of a new technology? (See Theoretical Background chapter)
Q2: How can we apply theories and drivers to describe and explain customer perceptions of a new technology to measure customer perceptions of the SbW system compared to a conventional steering system? (See Method chapter)
Q3: What do Volvo customers perceive to be the (primary) user benefits of the SbW system, and what are they willing to pay for it; and which Volvo customers are most likely to act as early buyers of automobiles that include the SbW system? (See Findings chapter)

To provide an answer to the first sub research question, a literature research was conducted on the subjects customer perceived value, the benefits and drawbacks of SbW, the influence of the SbW price on buying behavior, and early adopters. According to the literature, customers will see value in a new technology if benefits are greater than the sacrifices. The value-based drivers identified as benefits and sacrifices of customer value were used to draft three main benefits (improved safety, design freedom, and improved driving experience), and

two main sacrifices (higher costs, and changed driving experience) of SbW for Volvo customers. The other research questions were answered with a customer value research among Volvo customers based on the literature research. A questionnaire was distributed among 1,000 US Volvo customers, which resulted in a sample of 455 respondents. Thereafter, 5 Chinese Volvo customers filled in the same questionnaire, and interviews were conducted with 4 European Volvo customers, to see if these findings can be generalizable for all Volvo customers.

The results show interesting findings on the customer perceived added value of SbW. Regarding the benefits of SbW, 'increased safety' is the most important benefit to the respondents (90%), followed by 'improved driving experience' (71%), and 'design freedom' (60%). Regarding the sacrifices of SbW, respondents were less diversified, since respondents rated higher cost and changed driving experience almost equally important (respectively 66% and 63%). This implies that the benefits of SbW are more important to the respondents than the sacrifices.

Regarding the price of SbW, most respondents (43%) indicated that they are willing to pay €0 to €900, although it is estimated that SbW will cost €2,079, and only 22% of the respondents is willing to pay that estimated price. Respondents were also asked about the price of AD, since SbW has more benefits when combined with AD. 54% of the respondents indicated to be interested in buying an AD vehicle, but 46% of the respondents are not interested. Most respondents (43%) indicated that they are willing to pay €4,400 to €8,800 extra for the AD feature. However, the AD feature in a Volvo will receive a premium consumer price of approximately €12,000 (Andersson, 2016), and only 19% of the respondents is willing to pay this price for AD. Nonetheless, 87% of the respondents prefers buying an AD car with SbW, compared to only 13% who prefers buying an AD car without SbW. This indicated that respondents are more interested in 'the full package' of AD and SbW, rather than only AD, or only SbW. It appears that respondents are aware of the fact that SbW has more benefits when combined with AD.

However, 25% of the respondents indicated that they would not be comfortable using SbW. From these respondents, 82% (21% in total) indicated that they do not trust the system (yet), and want to have a back-up system in their car in case the system would fail. Another frequently mentioned response why respondents are not interested in buying SbW is that they do not want SbW without AD. They want 'the full package or nothing', and would rather wait for the AD versions to arrive. Also, 36% of the respondents elaborated on their answer why they are not interested in buying an AD vehicle (see Appendix F). Most of the answers were trust, control, or safety related (19%). Respondents do not trust the AD system yet, and they think it is not proven to be safe yet. They want to see more test results, to gain trust in the AD system.

Regarding the early adopter of the SbW system, cluster analysis could not identify a specific (preferred) SbW customer type. On the other hand, customer value research showed that the higher segment of Volvo customer groups, so S90, V90, and XC90, will most likely act as the early buyers of the SbW system. This can be explained due to the fact that income and price paid for a new Volvo car is highly correlated. Since the higher segment customer groups have on average a higher income, they will more likely buy a car with SbW than the lower segment customer groups. Additionally, V90 and XC40 drivers can be expected to become early adopters of SbW. Both V90 and XC40 are new Volvo car models, so they have the newest automotive technology in their cars, and they will thus be more interested in SbW than customers owning an older Volvo model.

Additionally, customer value research was conducted with Chinese and European Volvo customers. These results did not show substantial differences compared to results from US. Therefore, it can be concluded that respondents in the US sample of this study are probably similar to the global population of Volvo customers. However, sample sizes for both the Chinese as well as the European sample were too low to draw a valid conclusion at this.

Also, a conclusion can be drawn regarding the customer requirements found in former research executed by Volvo's Market Intelligence department, as discussed in Chapter 1.7.2: Disturbance free steering, easy parking, a more agile way of driving, and safety. The results of this research show that safety is the most important requirement, followed by improved driving experience, and design freedom. It can thus be concluded that the outcome of this research is quite in line with former customer requirements drafted by Market Intelligence.

To summarize, this thesis explored the customer perceived added value of the new steering technology SbW for Volvo. Based on the analysis and the interpretation of the results, it can be stated that the SbW system adds value to the Volvo customer, since customers see more benefits than sacrifices of the system. However, the aspect of increased safety needs to be explained in more detail, as well as the existence of the back-up system in case of a system failure.

5.2 Academic contribution

The literature study executed as a preparation of this research identified a research gap in explaining drivers for customer perceptions of the new steering technology SbW. Many studies focus on customer perceived value in general, which are not specified and contextualized on a new technology, like SbW. Although many benefits and sacrifices of SbW can be found in scientific literature, not all benefits and sacrifices are relevant to the customer. In this study, a distinction is made between benefits and sacrifices for Volvo, and benefits and sacrifices for the customer (see Appendix A), where the focus lies on the added value of SbW for the customer. The results of the customer value research showed that SbW has three main benefits (improved safety, design freedom, and improved driving experience),

and two main sacrifices (higher costs, and changed driving experience) for Volvo customers. Consequently, this research contributes to the literature by providing a case study in the automotive industry regarding drivers explaining customer perceptions of the new steering technology SbW.

Thereafter, this study was inspired by innovation management fields of research, and the research group of innovation, technology entrepreneurship, and marketing. It applied methods from these fields to investigate the customer perceived added value of a new technology in the front-end of a development process in the automotive industry. In that way, this research is an applied engineering research, focused on the client (Volvo Cars). It combined the departments of R&D, Marketing, and Sales, in order to align the ideas generated closely with customer needs, so that the developed product will have a high market potential.

Additionally, this research describes how Volvo customers value the new steering technology SbW. If other automotive companies have customers falling in the same category as Volvo customers, measurements conducted in this research can be applicable for them as well. It is even possible that other car brands have a bigger interest in certain segments than Volvo itself. Automotive companies can benefit from this research and apply it to their own development of new technologies, to improve the customer perceived value of their new product innovations.

Lastly, the results in this research show interesting findings on which markets respond to big innovations, and to see that the cost price is less important to customers than expected. Companies in other industries than the automotive industry can learn from this research how new technology innovations are strongly appreciated by the majority of a market, and that customers accept the new technology more easily if they know it has more benefits than sacrifices for them, and thus adds value. It is important for companies to focus on that in setting up their marketing strategy.

5.3 Limitations

The current study is subject to different limitations. The most important limitation includes customer data availability and accessibility. When the research was started, no customer data was available for the project. In order to do a customer perceived value comparison between Volvo's biggest markets, sufficient data was needed from Volvo customers from Europe, China, and US.

Also, in order to see if the findings in the US were generalizable for all Volvo customers, a large sample size from US, Europe and China was preferred. However, only in US sufficient data was available via the Voice of Volvo customer community. Therefore, and due to the fact that this Voice of Volvo customer community does not (yet) exist in Europe and China, a

relatively small sample size of respectively 4 and 5 respondents was collected. As a result of this, one can say that respondents in the US sample of this study are probably similar to the global population of Volvo customers. However, the European and Chinese sample were too low to draw a valid conclusion at this, and to draw a reliable comparison between Volvo's biggest markets regarding customer perceived value of SbW.

In addition, the development of SbW was in the Front-End stage of innovation process when this research was conducted. During that stage, many things are uncertain, and unknown, for example customer prices. This led to some estimations in the research, instead of exact numbers and facts. Moreover, there was no prototype or end product available yet, so customers were not able to assess the technical functioning of the SbW system before filling in the survey. For respondents it was hard to imagine what SbW is really like. If respondents had the opportunity to make a test drive in a SbW car, responses could possibly have been differently.

Another limitation evolves from the fact that it might not have been clear to the respondents that SbW comes with a back-up system, which takes over driving in case of a system failure. Given the number of respondents who indicated that they do not trust the system (yet), and want to have a back-up system in their car in case the system would fail (21%), the presentation sent prior to the survey lacked sufficient elaborative information about the back-up system. This could have biased the responses.

Finally, a limitation of this study concerns the explorative nature of this research, and the limited duration of the research period. As explained in Chapter 4.4, developments in the automotive industry develop in a fast pace. Therefore, the results in this research are subject to a snapshot bias: consumers might be even more enthusiastic about SbW once the development of autonomous driving is more mature. If consumers see and hear more about autonomous driving, the will get more accustomed to the idea of autonomous driving and SbW.

5.3.1 Future research

From the current study, several directions for future research follow. First, this study was mostly based on customer information of US Volvo customers. Future research can execute more customer value research and obtain bigger samples from Europe and China, and also other markets of Volvo. In this way, different markets of Volvo can be compared, in order to see where sales of SbW would be most successful. Especially in China, the developments of autonomous mobility are expected to happen faster than in the Western world (Kuhnert et al., 2017-2018). This would make China a leading market for the transformation to autonomous driving, and thus an interesting market for SbW to do more research.

Another suggestion for future research is to conduct customer value research with customers of competitive automotive brands. This study is only focused on Volvo customers, with the aim to let them switch from a conventional steering system in a Volvo car to a SbW system in a Volvo car. However, it would be interesting to investigate if potential customers who are driving a competitive car will decide to switch to Volvo because of its SbW system. By doing so, it could be researched if, and how much, Volvo's market sales growth can be increased by implementing SbW on all new car models.

Thereafter, a value analysis can be conducted in future research as an additional research instrument to this research (Tidd et al., n.d.). The analysis aims to give the functions of the new product a certain cost and weight according to its importance for the customer. In this way, more insight can be obtained on the costs and the value of the technology can be increased.

Also, future research can contribute by setting up and further developing a business model for the SbW system, including the components: key partners, key activities, cost structure, key resources, customer relationships, value proposition, customer segments, channels, and revenue streams (Osterwalder & Pigneur, 2010). This research can serve as a foundation for the business model. The business model could describe in more detail how SbW can be distributed, how to defend SbW from competitors, and for what price SbW can be sold.

Moreover, other innovations that could be developed around SbW could be investigated in future research. One of the benefits of the SbW system that came out of this research is the design freedom that comes with the development of SbW. Interior design opportunities, and other steering input devices could be further investigated as an addition to this research.

As a final direction, by the time autonomous driving is more developed and customers are more used to the idea of SbW, research results could be different. Therefore, future customer value research over a longer period of time, and at a later moment in the development process, could be interesting. The results can be used to compare with the results from this research, to see if the customer perceived value of SbW is increased.

5.4 Managerial recommendations

From this research, several recommendations follow for Volvo to improve the added value of SbW. Since the development of SbW is in an early stage of the development process, most of the recommendations can be implemented directly.

1. Offer SbW in a package (or certain engine types) on new car models

The conventional steering system was never an optional feature for customers, but upgrades of the steering system were introduced as an addition when customers chose for a certain (more expensive) engine type. In this way, the price of the conventional steering system was

included into the total price of the car, making the price increase less visible for customers. It is recommended to do the same for the introduction of SbW. Not only will the price increase be less visible for customers when SbW is offered as a package, but also the step from conventional steering to SbW will become less visible for customers, making it easier for customers to adapt to the new steering technology. However, from this research it appeared that adaptation is not a very big issue for customers.

2. Supply SbW as a standard feature in new car models

This study shows that more than 70% of US customers are positive about SbW. Therefore, and after offering SbW in certain packages, Volvo should consider supplying SbW as a standard feature in new car models, instead of an optional feature (estimated extra customer price: €2,079). By doing so, the price of SbW for Volvo will decrease, since the price of SbW is determined by the number of SbW systems manufactured. Tooling and development costs can be cut down over much bigger quantities, and Volvo's brand uniqueness will increase. Therefore, the customer price of SbW can also decrease. When the customer price of SbW decreases, the remaining 30% of the customers who are not (yet) positive about SbW, will automatically become more positive. It will be easier for them to accept the new steering technology, resulting in higher sales. Also, if the SbW system becomes a standard feature in all new car models, it will become easier for customers to switch and adapt to autonomous driving. SbW will make the step towards AD smaller, and will prepare customers for the future way of driving a car.

3. Offer SbW together with the AD feature on new car models

Offer the SbW feature together with a fully autonomous driving car. As already stated in the previous chapter, a non-autonomous driving car with SbW has less of the benefits than an autonomous driving car with SbW. Customers indicated that they are more interested in 'the full package', referring to a combination of an AD car with SbW, instead of only an AD car, or only the SbW system. This shows that customers are aware of the fact that an AD car with SbW gives them more benefits than one of the systems separately.

4. Focus on safety when communicating to customers regarding SbW

Volvo is developing SbW with the aim to let customers shift from the conventional steering system to the SbW system. Therefore, customers need a clear explanation of the benefits, especially regarding the most mentioned benefit 'increased safety'. Also, Volvo is global leader in automotive safety technology, and most customers choose a Volvo for that reason. Thus, it is important for Volvo to explain SbW's clear safety improvement compared to a conventional steering system to its customers.

5. Explain the existence of the back-up system when communicating to customers regarding SbW

The survey results show that 75% would be comfortable using the new technology. From the 25% of the respondents who are not comfortable using SbW, 82% indicated not to trust the system (yet), since little is known about a back-up system in case of a system failure. Therefore, it is recommended to pay extra attention to the explanation of the existence of the back-up system when communicating the SbW system to Volvo customers.

6. More collaboration and integration between R&D, Marketing, and Sales departments from beginning of development process

From observations done at Volvo Cars it can be concluded that the collaboration and integration between the R&D department, the marketing department, and the sales department regarding the development of SbW is insufficient. The integration of R&D, marketing, and sales is most important in the first stage of the new product development process, concept development, since the ideas generated will be closely aligned with customer needs, and will have a high market potential. This can be achieved by making cross-functional teams (consistent of people of all three departments) in the first stage. More collaboration and integration between R&D, marketing, and Sales will have a positive effect on the effectiveness of new product development resources, and the new product success (Ernst et al., 2010).

7. Conduct functional concept tests with customers

By conducting functional concept tests, targeted Volvo customers can make a test drive with a Volvo car containing the SbW. In this way, the developers of the system can get a reaction from them to validate and improve the functioning of concepts. Thereafter, the value of different functions and features of SbW can be identified and a choice can be made among different concept alternatives. The results of the customer value research also show that respondents are willing to do test drives for Volvo, to give their feedback on SbW.

8. Create a Voice of Volvo customer community in Europe and China

For the customer value research for US in this study, the online database Voice of Volvo customer community was used: an online database of 6,528 Volvo customers who regularly fill in surveys for Volvo Cars. In this way, the voice of the customer can be integrated in the development of new products or services. At the moment, Voice of Volvo does only exist in the US, with only US Volvo customers in the database. It would be an asset for Volvo if Voice of Volvo could be created in Europe and China as well, so that customer information can be received from all three of Volvo's biggest markets.

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8. Appendix

A. Steer-by-Wire benefits found in literature

Benefits for Volvo	Benefits for Volvo customers
Simpler to install (LeRoy, 2006)	More ergonomic design (LeRoy, 2006)
Greater configurability: carmakers could put a luxury feel into an economy car, or adjust the steering during cruise control operation to be a touch less responsive, so that a sneeze doesn't prompt a lane change. (Bretz, 2001)	Maintain the feel of traditional hydraulics, from a driver's perspective (LeRoy, 2006)
Oore flexibility in the design of the interior of the vehicle as well as in the engine compartment (Polmans et al., 2018)	Improves road holding: stabilize the vehicle in critical conditions and sudden maneuvers on the roads, with low friction (Tavoosi et al., 2014)
Different left and right hand drive variants play no role in vehicle development and production anymore. (Polmans et al., 2018)	The controller can considerably improve vehicle handling during a severe maneuver (Tavoosi et al., 2014)
The suspension can be optimized in many ways, since influences of driving and braking forces account for the steering feel. (Polmans et al., 2018)	Tightens the turning radius (Bretz, 2001)
SbW creates the basis for additional safety-enhancing driver assistance systems (Polmans et al., 2018)	Increases vehicle stability (Bretz, 2001)
- Reduction in number of variants by more than 80% (Kreutz, 2018)	Electronic systems weigh less than hydraulic pumps and mechanical actuators. That translates into improved fuel economy (though just how much is uncertain at this point) (Bretz, 2001)
	From technology perspective: electrically controlled motor uses 5 percent of the energy that the hydraulic system uses. (Bretz, 2001)
	With SbW can be steered from anywhere in the car (Polmans et al., 2018)
	Without direct mechanical connection to the road, the vehicle interior is acoustically completely decoupled. Vibrations and noises are no longer transmitted directly into the cockpit and expensive noise protection measures can be dispensed with. (Polmans et al., 2018)
	Stowage of the steering wheel in the cockpit can be realized, because it does not necessarily have to rotate with SbW. This allows the driver to otherwise use the vacated space in front of him. (Polmans et al., 2018)
	The passive safety is increased because the risk of injury to the driver by mechanical steering components is significantly reduced by eliminating the steering intermediate shaft. (Polmans et al., 2018)
	Crucial for the driving experience and thus directly experienceable are completely new degrees of freedom in the design of the steering by SbW. This results from the resolution of the fixed gear ratio of steering wheel to

	steering gear. An individually adjustable and improved steering feel is the result. (Polmans et al., 2018)
	A SbW system eliminates the risk of steering column entering the cockpit in the event of a frontal crash (Munir and Koushanfar, 2018)
	A SbW system enhances driver comfort by providing a variable steering ratio, that is, the steering ratio between the handwheel and the road wheels can be adapted according to the driving conditions (e.g., smaller steering ratio in parking and urban driving as compared to the driving on freeways) (Munir and Koushanfar, 2018)
	Since steering column is one of the heaviest components in the vehicle, removing the steering column reduces the weight of the vehicle and therefore reduces fuel consumption. (Munir and Koushanfar, 2018)
Sacrifices for Volvo	**Sacrifices for Volvo customers**
Complex system (Harrer et al., 2016)	Increasing costs and weight due to high safety requirements and reliability to satisfy the customer (Harrer et al., 2016)
There will possibly be some resistance to the new technology (Johnson, 2013)	Customers might be nervous to see how different a steer-by-wire car feels compared with an old fashion mechanical system (Johnson, 2013)
There are obvious safety issues to be dealt with (Kingston, 2018)	
Calibration is an issue, because it is complicated to emulate a natural-feeling hydraulic system and its responses (Kingston, 2018)	

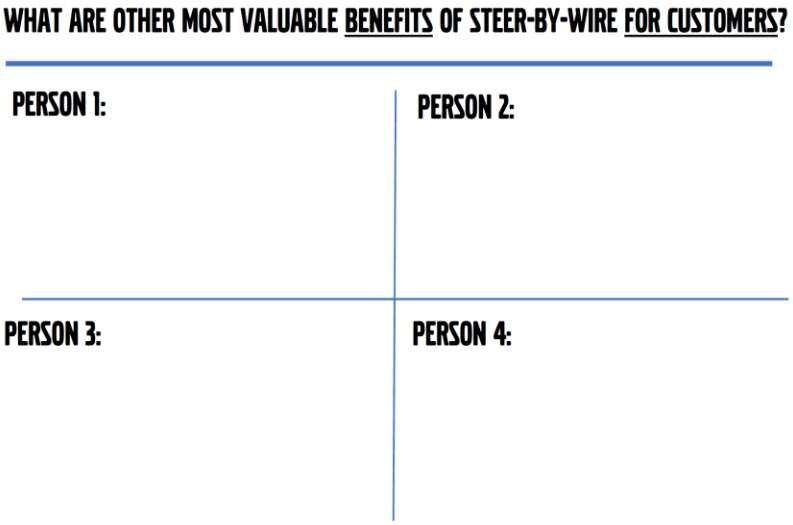
B. Brainstorm- and feedback sessions with Volvo experts

Meeting date	Volvo expert(s) position
September 6, 2018	Weekly meeting SbW experts
September 7, 2018	Innovation expert
September 13, 2018	Weekly meeting SbW experts
September 18, 2018	Extra meeting SbW experts
September 18, 2018	Price expert
September 20, 2018	Weekly meeting SbW experts
September 25, 2018	Tire expert
September 27, 2018	Weekly meeting SbW experts
October 4, 2018	Weekly meeting SbW experts
October 11, 2018	Weekly meeting SbW experts
October 17, 2018	Market Intelligence experts
October 18, 2018	Weekly meeting SbW experts
October 19, 2018	Extra meeting SbW experts
October 24, 2018	Marketing seminar
October 25, 2018	Weekly meeting SbW experts
November 1, 2018	Weekly meeting SbW experts
November 7, 2018	Extra meeting SbW & innovation experts
November 8, 2018	Weekly meeting SbW experts
November 13, 2018	Extra meeting SbW experts
November 15, 2018	Weekly meeting SbW experts
November 19, 2018	Product planning & development process expert
November 22, 2018	Weekly meeting SbW experts
November 23, 2018	Marketing seminar
November 26, 2018	Extra meeting SbW & innovation experts
November 28, 2018	Extra meeting SbW experts
November 29, 2018	Innovation activity with steering experts
December 4, 2018	Product planning & development process expert
December 6, 2018	Weekly meeting SbW experts
December 13, 2018	Weekly meeting SbW experts
December 20, 2018	Weekly meeting SbW experts
December 27, 2018	Weekly meeting SbW experts
January 3, 2019	Weekly meeting SbW experts
January 10, 2019	Weekly meeting SbW experts
January 14, 2019	Extra meeting SbW experts
January 14, 2019	Tire expert
January 15, 2019	Marketing expert Spain (Skype)
January 15, 2019	Data science expert
January 17, 2019	Weekly meeting SbW experts
January 24, 2019	Weekly meeting SbW experts
January 25, 2019	Price expert
January 28, 2019	Tire expert
January 28, 2019	Steering expert
January 31, 2019	Weekly meeting SbW experts
February 7, 2019	Weekly meeting SbW experts

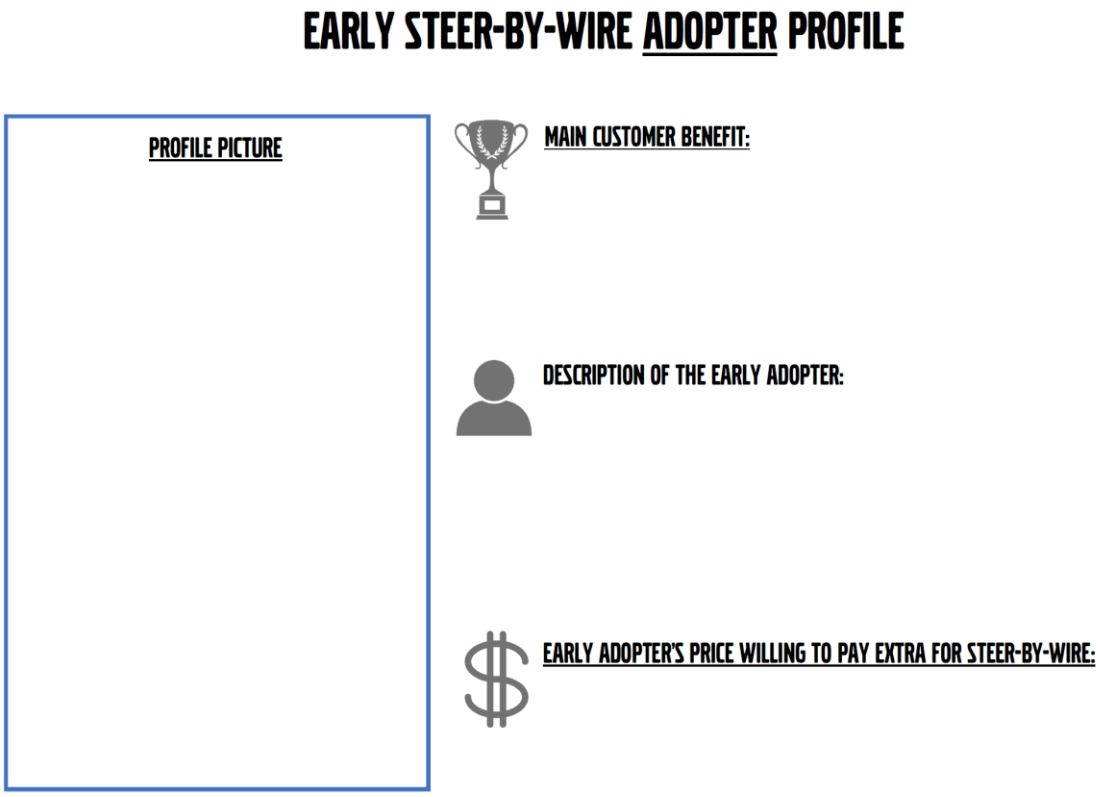
C. Innovative feedback event

Activity	Duration
Presentation SbW	45 minutes
Brainwriting session	10 minutes
Presenting brainwriting results	15 minutes
Brainstorming session	10 minutes
Presenting brainstorming results	15 minutes
Closure of the event	10 minutes

Brainwriting template (A3 size):



Brainstorming template (A3 size):



D. PowerPoint presentation sent to respondents

STEER-BY-WIRE

Improvements on Safety, Design, and Driving Experience

2018 MASTER THESIS: CUSTOMER PERCEIVED VALUE OF STEER-BY-WIRE (MAXIME BELGERS) 1

STEER-BY-WIRE

In a Steer-By-Wire (SbW) system, the conventional mechanical connection between the steering wheel and the front wheels (such as the steering column, gear box and hydraulic pump) is replaced with electronic actuators (see picture 2 & 3).

Timeline

2018	2021	2024	2027
	Introduction of Autonomous Driving cars	Introduction of Steer-by-Wire	All new Volvo cars will be Autonomous Driving cars

Source: Nexteer

2018 MASTER THESIS: CUSTOMER PERCEIVED VALUE OF STEER-BY-WIRE (MAXIME BELGERS) 2

STEER-BY-WIRE

With SbW, there is no mechanical connection between the wheel in your hands and the wheels on the street, just electric signals. Sensors detect the movements of the steering wheel and send information to a microprocessor. The computer then sends commands to actuators on the axles, which turn according to the driver's directions. Replacing the mechanical connection by wires, has several benefits for you as a driver.

Source: Nexteer

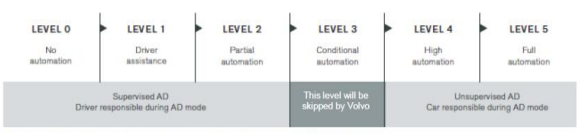
2018 MASTER THESIS: CUSTOMER PERCEIVED VALUE OF STEER-BY-WIRE (MAXIME BELGERS) 3

AUTONOMOUS DRIVING

Drive-by-Wire, like Steer-by-Wire, is one of the key preconditions for semi-autonomous or fully autonomous driving (self-driving) cars.

Autonomous driving (AD) has the potential to unlock a number of benefits for the mobility consumer such as;

(1) to create a more safe traffic environment,
(2) enable a more efficient utilization of vehicles, and
(3) to free up valuable time for the consumer.

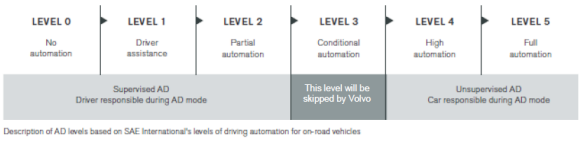


Description of AD levels based on SAE International's levels of driving automation for on-road vehicles

Source: Volvo Car Group – Annual Report 2017

AUTONOMOUS DRIVING

The most advanced cars, in terms of AD, we see on the roads today are partially automated (Level 2). The development in this field is expected to be fast. The benefits of highly and fully autonomous cars are likely to be extremely significant, and so large demand from consumers can be expected. Volvo Cars plans to have a fully autonomous car commercially available by 2021.



Description of AD levels based on SAE International's levels of driving automation for on-road vehicles

Source: Volvo Car Group – Annual Report 2017

CAR OF THE FUTURE

The automotive industry is currently facing significant changes driven by technology shifts, digitalization, and changing consumer behaviors.

There is a transition going on from a traditional car to the car of the future. Cars of the future will have, among others: Autonomous driving features, and Drive-by-Wire systems. These systems enable cars to implement Steer-by-Wire.

Source: Volvo Car Group – Annual Report 2017

CAR OF THE FUTURE

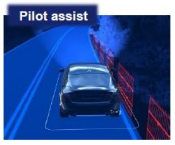
The term By-Wire might be familiar to aviation enthusiasts, since airplanes have used systems called "fly-by-wire" since the 1990s. That technology, just like Drive-by-Wire, uses electrical wires to control the normal operations of a plane.
Over the years, computers and electronics have been integrated into modern cars. If drivers could get accustomed to the idea, drive-by-wire systems have the potential to increase safety, functionality, and comfort during the drive.

Source: Volvo Car Group – Annual Report 2017

BENEFITS OF STEER-BY-WIRE

Safety

Improves performance for driver assist functions:
- Improves evasive maneuver assist (collision avoidance)
  Helps the driver to steer faster, and more accurately avoid an obstacle and a subsequent skid.
- Improves pilot assist function
  Provides with steering assistance and helps to maintain distance to vehicles in front of you.



Design

- Different steering design options / design freedom
- More cabin space

Driving experience

- Variable steering ratio
- Disturbance free steering

DRAWBACKS?

Cost

- The cost of SbW will be higher compared to a conventional steering system

Driving experience

- Driving experience will not be 100% the same as with a conventional steering
- Road feedback delay

VIDEO

Driving with Steer-by-Wire compared to conventional steering. Please click the Play button or link below, or copy the link in your browser

https://youtu.be/6UlTYHSvf94

E. Questionnaire

Steer-by-Wire

Dear customer,

Thank you for participating in this study. Your contribution is valuable for our research on customer perceived added value of Steer-by-Wire. We will ask you about the benefits and drawbacks of Steer-by-Wire, and what price you are willing to pay for the system. The questionnaire will take approximately 10 minutes.

The results of this questionnaire will not be released in any individually identifiable form. They will be treated strictly confidential, and will only be used for scientific purposes.

At the end of the questionnaire, your will be asked to provide your email address if you are interested in receiving the results of our research.

If you have any questions, please contact Maxime Belgers (maxime.belgers@volvocars.com).
* Required

Volvo customer type

1. **Gender** *
Mark only one answer below.
Female
Male
Prefer not to say
Other:

2. **Age**

3. **Country** *

4. **Driving the following Volvo model** *
Mark only one answer below.
S60
S90
V40
V60
V90
XC40
XC60
XC90
Other:

5. **Interested in new technology in cars:** *
Mark only one answer below.
Yes
No

User benefits of Steer-by-Wire

6. **What is your first reaction to Steer-by-Wire?** *
Mark only one answer below.
Very positive
Somewhat positive
Neutral
Somewhat negative
Very negative

7. **Would you be comfortable using Steer-by-Wire?** *
Mark only one answer below.
Yes
No

8. **Why (not)?** *

9. **How would you rate the benefits of Steer-by-Wire?** *
Mark only one answer per row below.

Safety: Improved performance for driver assist functions	Very important / Important Neutral / Low importance / Not at all important
Design: Different steering options, design freedom & more cabin space	Very important / Important Neutral / Low importance / Not at all important
Driving experience: Variable steering ratio & disturbance free steering	Very important / Important Neutral / Low importance / Not at all important

10. **Do you see other benefits of Steer-by-Wire?**

11. **How would you rate the drawbacks of Steer-by-Wire?** *
Mark only one answer per row below.

Cost: Will be higher compared to a conventional steering system	Very important / Important Neutral / Low importance / Not at all important
Driving experience: Will not be 100% the same as with a conventional steering system	Very important / Important Neutral / Low importance / Not at all important

12. **Do you see other drawbacks of Steer-by-Wire?**

13. **Would you like to do other things while driving your car?** *
Mark only one answer below.
Yes
No

14. **If 'yes' (1): Assume your car can drive autonomously; What would you like to do while driving? E.g. use your phone/tablet/laptop, eating, sleeping, working, etc.**

15. **If 'yes' (2): Assume your car can drive autonomously; Would it be useful to you to remove the steering wheel in your car, so that you have more cabin space?**
Mark only one answer below.
Yes
No

Price of Steer-by-Wire

16. **Are you interested in buying a normal (not Autonomous Driving) car with Steer-by-Wire?** *
Mark only one answer below.
Yes
No

17. **Why (not)?** *

18. **What is the additional price you are willing to pay extra for Steer-by-Wire in a normal car?***
Mark only one answer below.
Not interested in buying a normal car with Steer-by-Wire
$0 - $1.000
$1.000 - $2.000
$2.000 - $3.000
$3.000 - $4.000
$4.000 - $5.000

19. **Are you interested in buying an Autonomous Driving car?** *
Mark only one answer below.
Yes
No

20. **Why (not)?** *

21. **What is the additional price you are willing to pay extra for Autonomous Driving?** *
Mark only one answer below.
Not interested in buying an Autonomous Driving car
$0 - $5.000
$5.000 - $10.000
$10.000 - €15.000
$15.000 - $20.000

22. **Would you prefer buying an Autonomous Driving car with or without Steer-by-Wire?** *
Mark only one answer below.
Not interested in buying an Autonomous Driving car
With Steer-by-Wire
Without Steer-by-Wire

23. **Do you have any other questions, comments, or concerns?** *

24. **Are you interested in receiving the results of our research? If yes, please provide your email address below.**

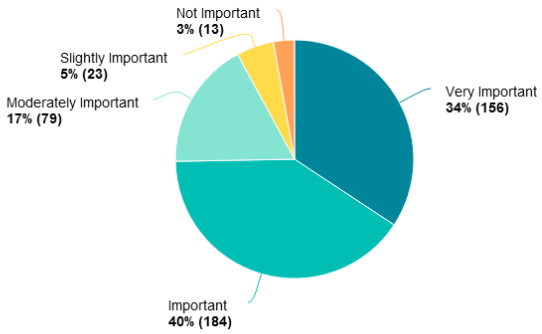
F. Survey results USA

Multiple choice questions:

Single Choice-New tech

1. How important is having the latest technology in your car?

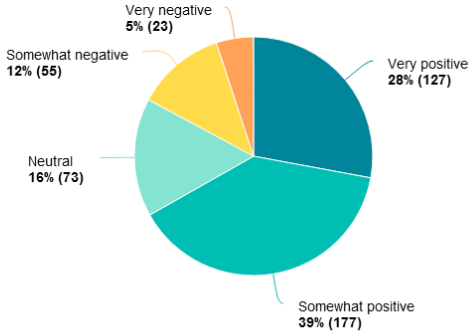
Total participants: 455



Single Choice-First Reaction Steer by wire

2. What is your first reaction to Steer by Wire?

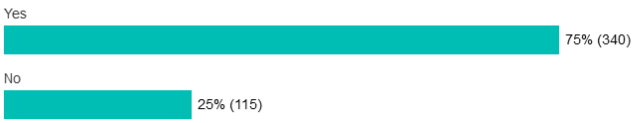
Total participants: 455



Single Choice-Comfort Using

3. Would you be comfortable using Steer-by-Wire?

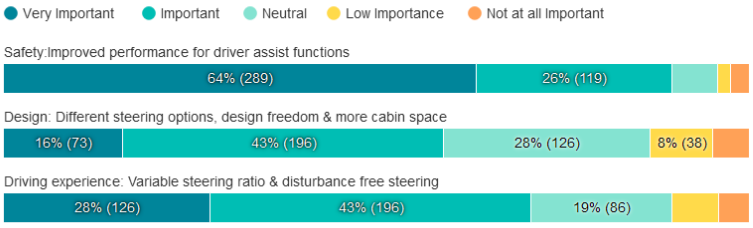
Total participants: 455



Single Choice Grid- Rate Benfits

5. How would you rate the benefits of Steer-by-Wire? Mark only one answer per row below.

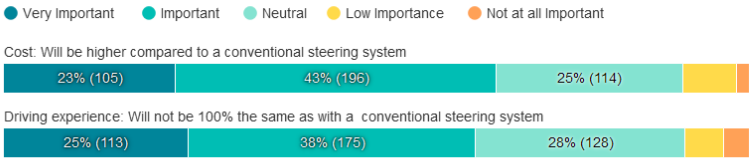
Total participants: 455



Single Choice Grid- Drawbacks

7. How would you rate the "drawbacks' of Steer-by-Wire? Mark only one answer per row below.

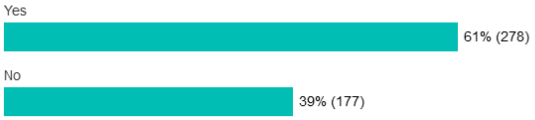
Total participants: 455



Single Choice-Other things while driving

9. In the future, would you be open to being able to do other activities (sleep, work etc) while your car drives autonomously?

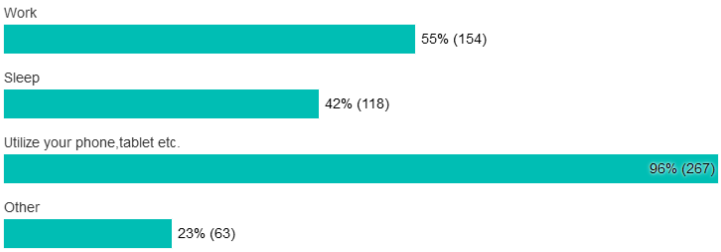
Total participants: 455



Multiple Choice-Choice while car is AD

10. Assume your car can drive autonomously; What would you like to do while driving? Please select all that apply

Total participants: 278



Single Choice-Remove Steering Wheel, yes or No

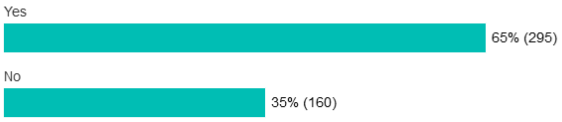
11. Assume your car can drive autonomously; Would it be useful to you to remove the steering wheel in your car, so that you have more cabin space?

Total participants: 278

Single Choice- Int Purch Steer by Wire

12. Are you interested in buying a normal (not Autonomous Driving) car with Steer-by-Wire?

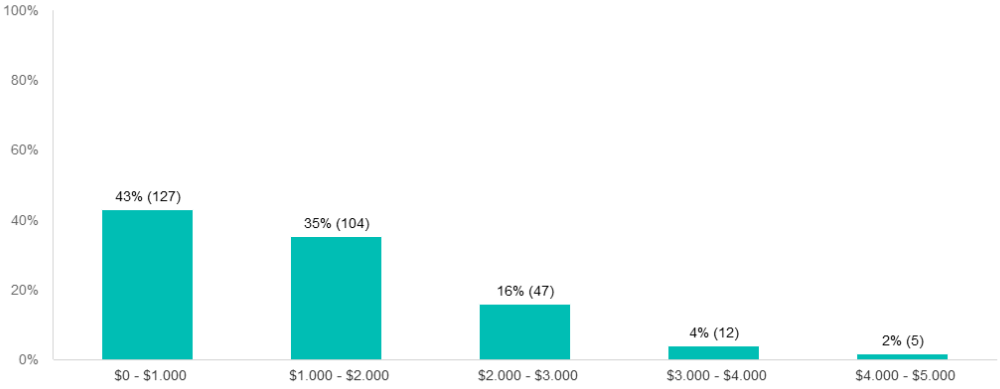
Total participants: 455



Single Choice

14. What is the additional price you are willing to pay extra for Steer-by-Wire in a normal car?

Total participants: 295



Single Choice-Interest AD

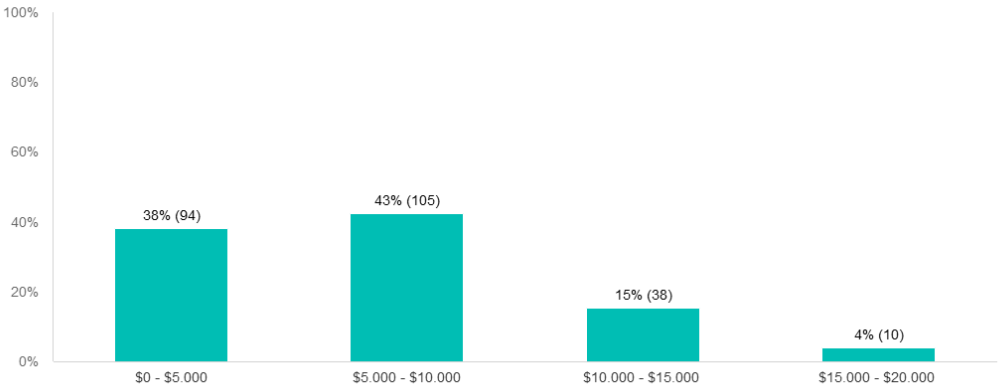
15. Are you interested in buying an Autonomous Drive vehicle?

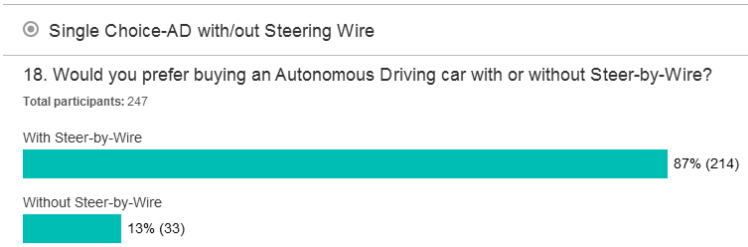
Total participants: 455

Single Choice-Price AD

17. What is the additional price you are willing to pay extra for Autonomous Driving?

Total participants: 247





	S60 (N=40, 9%)	S90 (N=19, 4%)	V60 (N=23, 5%)	V90 (N=10, 2%)	XC40 (N=46, 10%)	XC60 (N=144, 32%)	XC90 (N=135, 30%)	Other (N=38, 8%)	Total (N=455, 100%)
Comfortable using SbW	68%	84%	65%	80%	74%	75%	80%	63%	75%
Interested in buying non-AD car with SbW	60%	79%	52%	90%	74%	63%	65%	58%	65%
Preference for SbW when buying AD car	82%	87%	75%	100%	100%	90%	84%	78%	87%

Open questions:

Short Answer-Why Not (Open End)

4. Why would you not be comfortable using Steer by Wire?

Total answers: 115 (25%)	Adaptation	Cost	Trust/control	Enjoy driving
Share of total answers	7 (6%)	7 (6%)	94 (82%)	9 (8%)
Share of total participants	2%	2%	21%	2%
Short Answer-Why Not				
It was stated the steering experience would be slightly different than. I wonder how long it would take to adapt to new steering. I've been driving for 55 years.				
Higher cost, possible computer error or mechanical failure				
untested. current Volvo detection is unreliable				
The more electronics we allow into our cars the more entry points we allow for hackers. Also electronics Tend to be less stable than mechanical parts. I also appreciate the feel of the road.				
I want control of the driving conditions.				
Really don't see the need for it and do not trust it				
Not proven				
lack of control				
I view driving as an interactive endeavor which I very much enjoy. I want to "drive" the car; otherwise I'd take a bus or Uber/Lyft service so I do not want to have an autonomous vehicle.				
Two systems that should always have a mechanical fail-safe - brakes and steering. Also, completely isolating the driver from the feel of the road is just not wise, especially in adverse conditions.				
Unproven technology.				
With all electric tech comes the greater posdibility of signal failure and intentional interference by malevolent players or other occuring forms of interference with signals. Good, but risky.				
i feel an analog feedback is needed and would be somewhat scary without it				
The steering on my older Volvos (2006-13) work just fine. The new technology costs a lot more and then there are the repair costs when they fail.				
All cars on the road must be equipped or Steer by Wire could become dangerous.				
I would be afraid of not having control of the car if there is a technical problem.				
Not acclimated to it yet				
Worry about security/safety if the vehicles computer is hacked, could the steering be compromised. Prefer the feel of mechanical system. Unsure about reliability.				
Power failure or sensor failure. Recent Boeing plane crash is an example of sensor failure causing a crash				
sudden system failure				
Not sure the technology is sufficiently advanced to utilize				
I want to stay with traditional steering. Why do I need something to steer for me?				
Totally dependent on computer, hard to diagnose problems, more expensive part(s) to replace				
I like to drive myself, I'm willing to steer, look out the window for hazards, etc.				
I would worry about the signal getting interrupted. Losing control of the vehicle.				

A concern with the road response delay.				
I'm too old.				
I prefer to be in control!				
Takes the fun out of the experience of driving.				
Too many things that could go wrong!				
I love a 5 speed stick-shift car if I could get one. I like to feel the road.				
Prefer a practical demonstration of the difference and safety testing results.				
Lack of control				
Likely failure due to software. Mechanical connection to wheels is far more reliable.				
If anything like your first generation Sensus system, it will be very buggy and not have a large enough processor to handle all of the needed commands at the same time.				
I would just need to experience it before purchasing.				
not necessary to use it. not feel safe to use it based on ur description				
What happens when the wireless contact is interrupted? What is the backup for this type steering to prevent these unintended consequences if the wireless is disrupted?				
less control and if computer 'blinks out' we would be at harm				
Concerned about safety and the slow response of the system.				
Am an older person and want to be in complete control.				
Until it is perfected, I would not want to use it. Even my current Volvo has issues reacting to cars by way of the camera. The fear of computer error at high rates of speed would make me hesitant.				
Don't get it. I've been driving for nearly 60 years. Old dog, new tricks, no thanks.				
Not confident				
there should be another option like maybe. i like to see how it performs and perceive the benefits. what are the safeguards in case of system failure				
I prefer mechanical connections to computer ones for reliability and user input				
Prefer better driver control and feedback				
I would like to see the technology developed and implemented for an extended Time before I used it				
Would like to see reliability and safety statistics				
This is reminiscent of the Boeing 737 Lion air crash, where some programmer/engineer decided what the response should be to an anomoly. The current driver assist is not particularly useful				
This is a new technology for which I would not want to be an early adopter due to unknown "teething" issues and loss of road feel.				
No failsafe				
Having never used it, would try it before I accepted fully. I have had issues with my computer on three of the four Volvo's I have owned				
It's just another system run by a computer that can fail. I loose power steering I can still control the car.				
Relaying on electronics for steering sounds like a recipe for disaster! And why would this be more expensive when you're using less hardware & replacing with software. Seems more like a gimmick 2 me				
I like to be in control				
car electronics fail. don't want to be in that position.				
This is yet another "computer" function that can be instantly gone when the car computer malfunctions. I have had this happen with 2 of my Volvos; nothing worse than a car instantly not working.				
If you an electrical brake down you would have no control of your car steering.				
Lack of control.				

Need some safety data first.				
I would prefer a maybe or it depends option to answer. I prefer immediate feedback and road feel if I had to use the wheel. The company that provides that will get my business.				
steering computer failure would be disastrous and we all know from experience that Volvo computer technology is poor and highly subject to mal functioning and failure on an almost daily basis				
While I understand that it could be helpful to some drivers I prefer the conventional method plus I would not want to pay the additional cost for a car with that system.				
I have heard negative coverage in the news about semi autonomous cars crashing and killing people.				
Safety. Don't believe it's been tested enough yet				
Why do I even need or want a car if I have no connection or involvement....no experience, just a passenger??				
probability of unexpected failure of electrical gizmos is high over life of car. Reliable design and manufacture is critical. Very low percentage of failure is still unacceptable.				
It seems like it could fail and I have no control over vehicle. Also, my current steering wheel is not inconvenient, unresponsive, or uncomfortable, so why would I pay more for something different?				
Lack of trust in system. I like to be in control on vehicle. Seems like someone could hack it. Dirt, oil, grease on roads could affect the electronics, cameras, etc.				
I am not totally comfortable with new technology				
Higher expense. No feedback from the road to the steering wheel				
I have already disabled many of the safety features in my 2019 Volvo. One horrible thing is the way the car stops/turns off when it perceives danger. There have been times with no danger...				
I drive is stop light to stop light traffic. Doesn't make me feel safe. Maybe for drivers on highway.				
Concerned with accuracy and durability of the components in as a system.				
I want to feel manually in control of the vehicle.				
Everything is computer generated and sometimes you need to rely on yourself and not the computer, this is one.				
Too many ways to die. If the motor goes out I die. If a short cause a hard over I die. If my dog chewed off the wrong wire IDie. I ain't betting my life on a motor.				
Unknown...any delays that may occur in steering				
Loss of mechanical control when electronic glitches happen (it is a Volvo after all). Loss of steering feel.				
Soley technology based scares me				
It's not in my nature to "trust" a machine . . . I'd have to see others that I know test it and tell me about their experiences to change my mind.				
I am concerned that drivers in OTHER CARS would pose a problem to me on the road. I've been driving for a long time and new takes a while to adopt, but I look forward to it.				
Reliability on technology				
Concern about ability to steer the car during power failure (mechanical power steering works when the engine is off and the key is in run position). What is the emergency backup?				
Lack of control				
I feel more confidence in a mechanical linkage than an electronic one. Although either can fail, my experience is that software fails much more frequently than hardware.				
electrical signal interruptions would cause loss of control.				
you cannot feel the road				
If it malfunctions I may die.				
I've never used before.				

I would be worried about losing control of the vehicle if there was a power or computer failure of the car without a mechanical connection to the steering rack.				
Old school is better for this type of system				
I am a fan of the driving experience and I believe that this is a further reduction of the experience.				
I would to make their are no recalls				
technology breakdown				
Mostly because I've been driving for over 55 yrs now and it would be difficult to train my brain otherwise....				
lag in response time. not being able to "feel" the road.				
I much prefer a mechanical connection to the road. SbW would also not give proper "road feel" which is critical in determining changes in road conditions (i.e. black ice).				
need alot more information and ability to test it				
other drivers				
I would be nervous that since it's not connected to the car, something can happy with the "electronic" part of it. What if the signals or whatever is communications slows down, gets no sign, etc.				
As a senior citizen I think it would be very difficult to adjust to something as radical as that.				
Additional cost. What effects resulting from Electro Magnetic Pulse and whether it would disable "steer by wire"?				
Not enough information available to inform matters of liability, training on the system, and less than total steer by wire options.				
I like control. That is also why I still drive a 2001 T5S60 Five speed				
I like the feeling of driving which has been stated would be lessened by Steer by Wire. That's half the fun of having a high performance car. Also, what happens if it fails? Are you stranded?				
Possibly would like to try in the future, after more testing, but not now?				
I've been in cars that adjust to the road lines and they seem to struggle in the winter - I would also feel like I didn't have complete control of my car if the computer were to malfunction.				
have to know more about safety of it with regard to emergency situations, potential system failures, cost to repair. Would need to try it myself and have much more info.				
Don’t see the need for it. More components to the system bring more failure points. Sounds like a solution looking for a problem to solve. Simplicity always better than complexity.				

Short Answer-Other Benefits Steer (Open End)

6. Do any other benefits for Steer by Wire come to mind?

Total answers: 96 (28%)	AD	Comfort	Safety	Disabled/ elderly	Costs/ weight
Share of total answers	15 (16%)	34 (35%)	28 (29%)	5 (5%)	15 (16%)
Share of total participants	3%	7%	6%	1%	3%
Short Answer-Other Benefits Steer					
Additional accessibility options.					
All about additional safety.					
Allow more positions for the steering wheel					
Anti-theft; disable steering when car is locked. Analytics; measure reaction speed, other factors.					
As we age, automated driving will be safer than a person with slowing reactions. Not there yet, but will be in 25 years, and I don't want limited mobility.					
Auto sense compensation in the event of a flat or blowout. Potential to make 4-whell steering practical. Lots more.					
Automated driving					
autonomous drive					
Autonomous driving					
Backup if sensors fail or system fails					
Better accessibility for disabled and elderly drivers. The ability to potentially alternate between autonomous and non-autonomous driving modes.					
Better fuel efficiency and less maintenance costs, perhaps.					
better handling in difficult road conditions ex-rain/snow					
capability for automation					
city search / long range driving search / cruise control radar / brake response/ head light technology					
Collision avoidance. Adding the option for 4 wheel steering to enhance maneuverability.					
Comfort, less vribation and noise					
Commercial jets have been using this type technology for several years. It is about time someone had the forethought to apply it to the auto industry. I'm not at all surprised that it is Volvo!					
Competitive advantage vs BMW that integrates more aggressive wheel feedback to driver from road conditions.					
Cost efficiency due to less mechanical parts					
Could help improve crash avoidance situations					
Could the system know if a driver is distracted/has fallen asleep/is having a medical issue and take some sort of remedial action?					
Crash safety improvement, less chance of steering wheel intrusion into cabin					
Customizable driver profiles tied to key fob used.					
Decrease in driver fatigue					
Different steering wheel feedback for the different drivers (i.e. different profiles for each car key).					
Driver can program his/her own steering preferences.					
dynamic mode has more feedback/resistance than standard drive mode					
Effortless steering					
Enabling fully autonomous driving					

eventually instead of a steering wheel taking up so much space we should have more of a joy stick to steer with					
Evolution to autonomous driving. FYI, I thought my 2018 XC60 T8 already has Steer by Wire. ????					
Faster driver response in emergency situation,possible prevention of over- or understeer, skid recovery					
Faster response times, especially in collision avoidance systems.					
Fly by wire has been a tremendous improvement for flight safety and comfort, please make these improvements in surface vehicles too					
Fly-by-wire has been used for years in aviation and met initial resistance. Once SbW becomes mainstream, as in aviation, new applications become apparent and easier to implement.					
Gateway to autonomous driving					
Good for long journeys					
Hopefully a weight reduction with increased fuel economy.					
Hopefully increased reliability with decrease in mechanical parts.					
I am 70 yrs. In 6 yrs this means I (and other elderly people) will be able to be mobile--we will be able to transport to complete every day chores and not depend on others.					
I like the smoother ride					
I struggle with increased the statement that the costs will increase. Did not make sense to me. I would expect costs would to be neutral except for the nonrecurring.					
I would imagine various feedback profiles could simulate driving preference for road feedback.					
I would like the ability to adjust steering feel based on driving conditions, lighter feel for low speed situations, firmer feel for aggressive driving.					
I've been using pilot assist feature as often as possible, and I'm really liking it. Seriously helps remove the stress of driving in high traffic areas and congestion. Looking forward to what's next.					
Improved communication for location applications.					
Is the system lighter? (Fuel economy benefit) Is the system more "mechanically" reliable? (Lower maintenance costs) Can you quantify the vibration dampening benefits to handling and ride comfort?					
it's a good idea for planes but my car does not have 10000 feet to free fall while I debug a loose wire. So no no no.					
Just to aid those with less than stellar driving ability					
less costly replacement parts/labor					
Less distraction					
Less driver fatigue					
less moving parts for maintenance					
Less stress on driver					
Lexury of hands free driving and smoother ride					
Like better (smoother) autopilot function when driving on freeways.					
Looking forward to self driving cars when I am elderly.					
Lower maintenance costs, potentially.					
Maybe could remotely operate car from smart phone ... backing trailer down boat ramp. Would need strong security.					
more design possibilities combined with 4 wheel steering					
More flexibility for perfect steering wheel adjustment and comfort since there are less mechanical restrictions.					
moving towards autonomous cars					
My wife likes minimal steering effort vs my need for heavier feel. Programmable by key? Variable by speed a plus.					
Perhaps reductions in car insurance rates. Less fatigue to driver					
Planes have done this for years - congrats on catching up					
Possibility of better accident avoidance and other driver assistance features.					

Possible lower insurance premiums with more advanced safety features.					
Possible use of haptic feedback at the steering wheel to capture some of the road feel lost by SbW. This “feel” could help to address some of the consumer feedback of “numbness in the steering”.					
Potentially easier to drive					
Preventing driver error					
Quicker response					
reduced fatigue from not having to provide as much river input					
Reduced weight?					
Reductions in mechanical weight in the front end should also translate to slight improvements in mileage, in addition to those improvements from reduced driver steering path variabilities.					
safety					
Safety and feel are the most important so no.					
Safety as the car would drive if the operator was impaired in any way					
Safety. Less worry. Except for ALL the other drivers.					
Same systems exist in modern jets. Has been proven safe and effective					
Self driving cars and					
self driving vehicles					
Should benefit the elderly with driving performance and safety.					
smoother ride					
Steering design changes could lead to significant benefits, e.g. better airbags, smaller steering wheel, lower maintenance issues					
Stepping stone to fully autonomous					
Tactile feedback for other than road conditions- ie emergency alerts. Far out- make driver controls like flying an airplane (yolk) :-)					
Taking the human component out of the equation might create a safer environment.					
The better integration to automated driving is certainly the primary benefit that comes to mind.					
The move toward autonomous driving is appealing.					
The quickness of reaction time is my top benefit. Perhaps another benefit is the stress reducing for the driver.					
This is the same technology that aircraft's use, fly by wire? I like how the direct road contact is not felt, yet if you are in sports mode in your XC90T8, will you still feel the road?					
typically, consistent feedback, less influence from heat or cold conditions. Variable control depending upon speed.					
variable steering control based on speed. possible 4 wheel steering					
weight reduction. It works in aircraft why not cars?					
Would allow those with low vision to drive					

Short Answer-Other Drawbacks (Open End)

8. Do any other drawbacks for Steer-by-Wire come to mind?

Total participants: 173 (42%)	Adaptation	Cost	Trust/ control/ safety	Enjoy driving
Share of total answers	7 (4%)	18 (10%)	151 (87%)	4 (2%)
Share of total participants	2%	4%	33%	1%
Short Answer-Other Drawbacks				
Ability of driver to control vehicle if failure in SbW occurs				
Acceptance of new technology and whether or not it will be safe and accurate				
Already stated, no manual backup is UNACCEPTABLE! You need to be able to move a car with a dead battery. Losing road feel is also unacceptable.				
Are there backup systems in the case of computer failure. In a conventional steering system if hydraulic/electric assist fails it is still connected and you can steer to safety,				
As with any computer, the blue screen of death comes to mind, how would the steering be affected by a computer malfunction?				
Backup for control in the event of computer failure or malfunction.				
can the electronic system be compromised and controlled by external people or systems				
Can't prove it's safer				
Car must have electric power on to steer. This makes pushing an inoperative car and steering it much more difficult.				
Change is hard! Trusting electronics vs tried & true mechanical devices is a big change.				
Component failure. What back-up (contingency/redundancy) systems are planned?				
Computer error is always a concern.				
computer failure				
Computer system stability and security are the most important things.				
Concerned about any technology failures. Will there be a redundant system?				
concerned about losing control over vehicle - especially if/when electronics fail.				
Concerns about what happens if the relay fails. Traditionally, even if power steering goes out, the driver can still work to turn. If steer-by-wire goes out, the driver has lost complete control.				
Connection to the road / road feel is an important safety component so you can adjust your driving style for the conditions (e.g. slow down on rough, uneven pavement).				
Control of vehicle in the event of system failure.				
Cost				
cost				
Could this be hacked. Safety is my 1 concern				
Dependability and cost of repairs would need to be considered?				
Does the vehicle shutdown safely if there is ANY system abnormality detected? Higher cost = more required maintenance? How user friendly will the interface between the vehicle and driver be?				
Driver can't "feel" the road through the steering wheel. For example how can I respond to slippery surfaces if I have no feedback? Also, "by wire" systems cannot fail-safe.				
Drivers learning curve. The amount of hands on it would take to master the system.				

Driving experience most important in sports cars compared to family sedan/SUV but still having feel of the road is important when cornering or in poor road conditions (snow/ice).				
Early technological failures lead to accidents. Mechanical steering keeps drive in total control. If rare glitches in Sensus system repeat in steering, accidents will occur from failures.				
Electronic and electrical failure of the driving system could lead to the car being unmaneuverable. A suggestion is made in the animated film that there was a “backup” system, just not explained.				
electronic failure - more likely than mechanical failure in a steering system				
electronics fail earliest on cars, is there a warranty?				
electronics failure.				
Even if power steering goes out, you can still steer the car. My concern would be the what if it stops working at all at highway speeds.				
Everyone who crashes will blame Volvo and say the car steered itself.				
Fail safe?				
Failure				
Failure of system during driving and what will be the "fail-safe" safety overrides during failures?!				
Failure of the system				
failure redundancy				
Fear of electronic steering versus mechanical.				
Feel of the road through the steering wheel				
feeling of the road conditions compared to themechanical system				
First impressions or "test drive" with variable steering ratios might cause some initial panic or feeling of lack of control.				
Heavy use/trust in electronics. Hope there are no manufacturing defects and that they are installed correctly. Costs skyrocket in other areas including repair shops and routine maintenance.				
How would a driver- using this system- determine hazardous conditions such as black ice? Don’t know how that fine line could be relayed to driver by this method.				
Human element wanting to be in control				
I don’t like the fact that “road feel/ feedback” is reduced or eliminated.				
I grew up in northern Midwest US. There is no system that will mark winter roads piled with snow, or with water than an autopilot car can follow. Impractical!				
I prefer to have some road feel through the steering so I know what the wheels do. I also worry that the steer by wire system will have a significant deadzone or deadspot.				
I would wonder about the long term reliability and repair cost.				
I would worry that Software could fail and cause fatalities. With less involved Drivers-more use of their personal electronic devices, which again, could cause accidents...				
If the driver does not sense dangerous road conditions by the feel, the driver does not get feed back from the steering wheel, he/she may not react to the situation appropriately.				
If the system fails, people die				
I'm most concerned about the delay in "road feel" you mentioned. Steering is the second most important system in a car (after brakes) so it better be bulletproof. Is there redundancy? Fail-safes?				
In case of malfunction will maker indemnify owner for liability? What will warranty look like. Interesting ideas are not always functional.				
In case the engine or electrical system fails while driving, how will I be able to steer the car?				
in todays environment not all roads are the same or have the right conditions for the car to perform safely. how will the system perform in country roads & driveways. i do not see the benefit				
Increased complexity could result in higher repair costs. Reliability will be questioned				
increasing dependence on computer software, potential glitches, bugs, and virus. Potential security threats of car losing contriol				

It has to work - reliability is key				
It is a point of failure from which the driver cannot recover. Must be redundant or fail-safe.				
It is more likely to malfunction than a conventional steering system.				
It will be buggy in first generation if similar to your Sensus system				
It will take some time for initial resistance to fade.				
Just like with semi autonomous CX60 (which I have), it may take a bit of adjusting to the driving experience!				
Just that the current electronics on my Volvo has issues. This is such an important feature that one would not want to have issues with the steering. Right now my vehicle has electronics issues.				
Just the mental change necessary.				
Kudus to Volvo for your insight, forward thinking, and reaching out to consumers for input and feedback. Gives me a level of satisfaction knowing that my inputs may find their way into my next Volvo!				
Lack of road condition feedback can be a big drawback if completely removed				
Lack of road feel response				
Less driver responsibility				
Like any technology, I'd be concerned about its susceptibility to being "hacked."				
Like anything, and with every car, they all drive and feel different. We will adjust, and it will become a normalized feel.				
Like new technology, but still a bit nervous about relying on computers - especially for such an important function and 100%. Would need to know about the backup in case of a malfunction.				
loosing the feel of the road.				
Loss of concept of driver of car - no real road feeling experience. Just become another passenger/commuter for most part.				
Loss of control due to system failure or hack.				
loss of road feel. cannot accurately know the terrain you are driving on				
Maintenance and possible failure of an all electronic system. I haven't had a fully computerized device yet that doesn't need an occasional "reboot" to solve issues.				
maintenance, repair history,				
Maybe too isolated for someone who enjoys driving or not feel sporty enough				
Might as well be in a taxi; no personal connection to car				
modern technology has to be perfected before people will accept it. What happens with an electrical issue causing system failure? There is no manual back up.				
more complexity with electronics = more chance for failure and higher maintenance costs				
More dumb ways to die... Really, you are gonna kill someone if you do this.				
More expensive repair if problems occur. Also, different type of steering problems than from traditional steering equipment.				
More likely to require repair or malfunction?				
More prone to technical issues				
Most concerned about loss of steering "feel"				
Mostly it is a cost issue. I love Volvos and have owned 10 different models between my husband and I. Moving in the direction of luxury is becoming cost prohibitive.				
Multiple electronic system parts/modules that may have the potential of failure with out any mention of backup options or fail safes.				
Must have the same steering feedback as conventional steering				
Need to add redundancy in the event of electronic faults. Possibly need to add backup battery. Significant cost for early adopters. Lots more.				
No failsafe				
no others. cost of repair is daunting				
Not as dependable as mechanical				

Not familiar enough to be totally comfortable.				
Occasionally my conventional car battery fails very quickly how would this affect drivability.”?				
Older drivers may have more trouble adapting than younger/newer drivers				
Older people that have hand issues such as arthritis that may grip the steering wheel differently may cause different responses. Not sure how your system will help them or cause issues?				
Over reliance on technology especially since it can be hacked.				
Perceived safety. It's the same fear people initially had to planes there were fly-by-wire instead of having mechanical linkages. They were feared at first until they became commonplace.				
possibility of hacking or electronic failure				
Possible that failures of steer-by-wire will be greater than for mechanical steering.				
Potential electronic failure of DBW components.				
potential reliability problems				
Potential risk of computer failure. No computer system never fails.				
Potentially very different feedback experience between models, manufacturers, modes = Potential for unexpected or unknown responses; could be difficult for some ppl to quickly adjust. High repair cost				
Power failure				
putting extra trust in software				
reduced "feel" of the road and responsiveness particularly in performance driving situations				
Redundancy/failsafes need to be highlighted to help public acceptance.				
Reliability				
Reliability				
Reliability had better be top notch, maybe with a backup system in case of failure				
Reliability of an electronic vs mechanical system.				
Reliability??				
Relying on another computer system that could possibly fail.				
Repair cost and Volvo maintenance track record is not great.				
Risk of computer malfunction causing loss of steering ability				
Roadfeel, resistance due to obstacles in road, lack of non-power steering backup in case of failure, impossible to use in case of dead battery with car in neutral				
Safety - software/power failure				
Safety and liability of the technology				
Safety and security if the vehicles computer is hacked or malfunctions				
Safety concerns of power loss and concerns of poor feedback from the road.				
Safety if electronics fail.				
Safety of it makes me nervous.				
Safety testing				
safety when concerning computer issues, no fallback in case of failure				
safety which is far kess under AI driving can’t be compared to same AI in autcraft				
Safety, ease of use				
Safety. Lack of mechanical control.				
SBW might require different skills of the driver.				
Seems vulnerable to electronic failure or hacking.				
Since I've never experienced the design, I'd have to try it out. My biggest concern is over safety. How are failure modes addressed..DFMEA.				
Some loss of “road feel”				

Some type of redundant backup will be needed in case of computer/electrical failure so a vehicle can be safely stopped or pulled over.				
Sounds very anxiety producing because it is like being in a plane where you have to rely upon something outside of yourself to be safe.				
Steering feel will be completely artificial				
System failing while driving, how will the car be steered if the battery fails and it needs to be pushed/towed.				
The consequences if it doesn't always work properly.				
The drawbacks are minor compared to the benefits. But an auto enthusiast might be put off by the loss of "road feel" through the steering wheel.				
The lack of connection to the car could mask a problem with the drive train.				
The safety issue is most important and would want more information before making a decision.				
There's always the risk of electrical failure, however small. Electrical failure now could render a driver unable to steer.				
this is a computer based system. i have been in the it business over 30 years and have learned all programs have bugs. not perfect. this could be very dangerous to first adapters				
Trusting the system to do the right thing in any given situation, having glitches or malfunctions.				
unable to steer with power loss? greater potential for failure vs conventional steering mechanism				
unknown software issues impacting performance and immediate responses to potential accidents				
Use in the real world of roads, road conditions, traffic, weather, goofy drivers an totally unanticipated emergencies is questionable. Driver condition (alcohol, drugs, physical emergency) contribute				
want to make sure that 'pilot' is comfortable with little to no feedback				
What are the risks of a misfire within the system? Could it cause crashes?				
What happens if computer fails?				
what happens if the computer fails, or if the camera recognizes something that is not a road line?				
What happens if the power fails or the system reboots? In a crash will I still be able to steer if say I impact a deer at highway speed and need to pull off safely?				
What happens when the computer malfunctions?				
What happens when the electronics fail? What is the fail safe condition?				
What happens when the system fails. Or if you have to move the car when your battery died.				
what if a "wire" malfunctions				
What if the "microprocessor" fails?				
What if the computer fails? I realize there is most likely a second and perhaps a third computer as back and redundancy but it does raise concerns.				
What is emergency backup, ability to steer the car during power failure?				
What is the failsafe mode if the computer or software malfunction. How will we avoid loss of control?				
What is the system fails? Is there a backup?				
When I'm in a car with another driver, I am uncomfortable. I would imagine the Steer-by-Wire will be another "trust" issue.				
Will it still function in pouring rain? Current driver assist strikes to find lane markings on wet surfaces				
will the clutch allow for backup to computer failure or hacking				
Without a physical connection between the steering wheel and the front wheels is there a possibility of loss of steering caused by electrical system or software failure?				
Without assured power backup, total SBW could lead to accidents in cases of complete vehicle power disruptions., which are not common but do occur.				
Won't feel wheel alignment ortire condition.				
worry about maintenance, technical glitch, electrical issue in the car				
Worry of losing steering control with a power failure. Not being able to "feel" the road could lead to more accidents with certain road conditions without exceptional computer systems to compensate.				

Yes...I can't emphasize enough the computer tie-in and no warning if a "turn off" will take place.				

Multiple Choice-Choice while car is AD (Multiple Choice)

11. Assume your car can drive autonomously; What would you like to do while driving? Please select all that apply

Total participants: 63 (23%)	Eat/drink	Socialize	Read	Scenery	Other
Share of total answers	8 (13%)	17 (27%)	12 (19%)	17 (27%)	14 (22%)
Share of total respondents	2%	4%	3%	4%	3%
Multiple Choice-Choice while car is AD - Other					
Access internet functions.					
Actually watch scenery in certain locations.					
Anything except work.					
Anything really.					
Be able to be more engaged in conversations with other passengers without worry of distraction from driving.					
be able to look for unfamiliar target destinations					
Be social with other people					
Drink					
Eat					
Eat					
Eat					
Eat breakfast					
Eat. Converse w/ others.					
Enjoy he company and conversation of others in the car. Perhaps have a beverage and something to eat while the vehicle handles the driving.					
Enjoy scenery while driving					
Enjoy the scenery & journey more.					
Enjoy the scenery, the driving experience, and other occupants					
games with kids talk more with kids without distractions					
Have conversations with friends and family					
Have conversations with other people in the car or enjoy entertainment					
Have sex.					
help kids					
Interact with kids or deal with a fussy baby.					
interact with other passengers					
It. - haha					
just relax when driving					
Look around					
phone calls					
protect driver from normal distracted driving.					
Read					
Read					
read					

Read					
read					
read					
Read a book or enjoy the scenery.					
Read and converse.					
Read books and journals					
Read books and magazines					
Read, converse with other passengers, and/or enjoy scenery					
Read.					
Relax and enjoy the view.					
relax, enjoy surroundings, be alert for drivingproblems					
See more of the countryside.					
see sights, scenery. Things usually missed while driving currently.					
see the sights					
Sightsee					
Site seeing					
Socialize with friends in the vehicle.					
Socialize with other passengers					
Spend time with kids to engage them In activities					
Talk with family and friends who are in the car with me					
talk with the other people in car					
This is exciting, endless possibilities here! I consider this way better than having to fly! My own personal chauffeur!!					
Watch a movie					
watch a movie, it is going there, safety is always number 1, as long as that can be proven, I will buy it.					
Watch entertainment					
Watch movies, play with the kids, eat.... anything you could do on a train					
Watch video info or entertainment.					
View scenery					
View the sites when traveling new places. Engage with other passengers.					
Will be safer if I doze off					
VR					

Short Answer-Why No (Open End)

13. Why are you not interested in buying a normal car with SbW?

Total participants 148 (33%)	Adaptation	Cost	Trust/ control/ safety	Enjoy	Other
Share of total answers	13 (9%)	18 (12%)	52 (35%)	13 (9%)	54 (36%)
Share of total respondents	3%	4%	11%	3%	12%
Short Answer-Why No					
Cost. Time it would take to adapt to a different kind of steering.					
i have a car and prefer the control. My Telsa was much more reliable for autonomous					
More cost for not much benefits.					
It is a bad system and it has many more drawbacks than advantages.					
Cyber security reasons mostly.					
Why have it without autonomy					
Let's just leap to fully autonomous vehicles, can we? Seems like an expensive beta test but o me as a consumer					
The extra cost of that feature only seems worthwhile if it comes with autonomous driving.					
I am totally satisfied with current conventional system					
like driving my car now					
If technology is moving toward Autonomous Driving w/Steer-by-Wire then why not offer the total package. Eventually this will be the standard. Keep up and stay ahead of the competition.					
Not proven.					
lack of control					
no point					
I wish to remain involved and sense the interaction with the road to maximize my driving pleasure.					
Would need to know more (and maybe I will get there) - XC40 is getting me used to the idea of autonomous driving, but still not comfortable with it yet. Guess I have had my PC crash too many times.					
Old habits					
Lack of feel. Cost. The danger of having a by-wire system that cannot fail-safe. I wouldn't trust a system where the steering wheel was not mechanically connected to the steering mechanism.					
only because I have not driven one yet					
Having driven other SBW cars, or cars with no road feel - they are terribly taxing to drive					
would want to wait a few years until it's been tested by normal drivers					
Not in the market at the current time for a new car					
If it's going to need electronics to drive, for me, it's all or nothing. I want the cake and icing.					
Loss of feel for the road. Knowing what the tires are doing.					
Not now, but at alater date,m probably. I have the semi autonomous XC60, which I just got.					
I don't see any advantages at this point in time.					
What are the benefits? Among several key features, the semi autonomous capability is why I bought two XC60s.					
I don't trust the technology					
As explained. Safety for me and others on the road					

I don't trust the technology. Driving is a defensive act - with other drivers not paying attention. It just seems too dangerous					
My current Volvo has all the safety features that I would assume this would bring. To me the additional benefits are realized with a fully autonomous car.					
The drawbacks outweigh the benefits for me.					
Autonomous driving when safe is the way to go					
Not familiar enough with concept.					
don't see the point without autonomous.					
no real advantage except space					
Why change further-too much automation when I have barely figured out how to operate my 2019 XC40?					
I like driving					
I like to drive					
The Safety would need to be proven.					
The added price and a feeling of lose of control and safety issues.					
I'm too old					
No interest					
I love the experience of driving, steering, breaking, all of it.					
These technologies would be good for someone who is blind or intoxicated. I'm just not feeling it right now. I think this would make driving a very passive activity.					
Autonomous driving seems coupled to the purpose here					
That feature alone would not prompt me to buy another car					
I want to be aware and alert and I believe the drive by wire reduces that possibility					
It’s not safe.					
Too many options to fail					
Advantages of steer by wire do NOT outweigh costs and lurking fear that a glitch (as affects Sensus occasionally) will cause car to go into ditch or opposite lane.					
Just not ready to have the car take over for me, while I SLEEP especially.					
no reason to have it if car is not autonomous					
Not buying any new vehicle					
Extra cost with little benefit					
Pilot assist is my favorite part. Otherwise, it’s more expense for no gain.					
I enjoy the driving experience. It is NOT simply transportation.					
It's not perfected enough yet.					
too edgy, I'm 73, so, no thanks					
At my age normal cars are more fun.					
Lack ofconfidence					
I bought the Volvo for Pilot Assist. I’ll never drive a car without it.					
i do not see the benefit , specially when its going to cost more					
I prefer mechanical connections to support the technology of the car. I also don’t want to give up my own control to a computer					
I wouldn’t get all the benefits					
Still want safety record over period of time					
I am not comfortable that the technology is advanced sufficiently for "prime time"					
Loss of road feel is a big negative to me, especially driving in cold and slippery conditions.					
No failsafe					

Id like the benefits					
Not sure					
Benefit does not outweigh cost, SbW benefits are primarily for autonomous driving					
fear of not having full control over vehicle and potential for electronic failures					
not ready for that technology yet. Old school					
at this point I am undecided, so neither yes or no					
The drawbacks outweigh the features.					
Not sure.					
electronics fail.					
Safety					
If I'm going to go with sbw, then I'd like the vehicle to be as automated as possible.					
Don't like the artificial feel					
Not sure cost?					
Autonomous is the driving experience of the future, so I believe that needs to be integrated.					
No real benefit, I assume.					
volvo has proven in our 2017 XC90 that their technology is not reliable					
Driving is a responsible act that you are licensed for. I don't think working or sleeping while driving is appropriate. This would be irresponsible driving to me.					
Why spend more for steer by wire if the vehicle is not autonomous.					
I'm interested in the self driving aspects, not other aspects					
Either all or stick to regular.					
Eliminates personal connection to car					
lack of reliability of electronic controls.					
Again, I don't want to pay more for a car that pretty much does what mine already does with possible increased risk.					
I need autonomous car goiing forward					
Not engaging to drive. More sterile and bland driving experience.					
Can the system be trusted 100% of time?					
Just bought my 2019. Not interested in buying any new Volvo.					
It's meant to be used to drive autonomously					
I'm still getting used to auto pilot. baby steps ... :)					
The cars today is controlled by way too many electronics.					
I need a steering wheel by which I can take over the control and I need no software between me and the wheel. I am a software engineer I know how reliable SW is.					
No maybe option...need to learn more					
Normal steering is fine. Not a problem that needs to be fixed. How about spending some engineering money on making the infotainment quicker to respond.					
not sure					
Not until I trade my current car.					
Too new					
Not in the market for a new car yet					
I'm not necessarily interested, but would if it comes to be.					
It costs more and if there is no manual backup, then it is still UNACCEPTABLE!					

If the car is will be autonomous, then I don't a steering wheel. However, as an emergency and cautionary measure, a hidden basic utility steering wheel should be available just in case.					
I'm satisfied with the Volvo I have now.					
This is not a capability I am seeking, at least as presented in your scenario. I want to understand the fail-safe before committing.					
Lack of control					
Because I love my XC90 with auto-pilot.					
the technology is still new					
I'm really quite satisfied with the way the steering in my Volvo and most cars works today. Not concerned about extra space or "design" elements.					
I really like the feel of driving, I would have to test drive a vehicle and see how it felt.					
Just not there yet in my head.					
Don't want to be driving 70 MPH and lose power to the steering system, fuses blow and wires burn into.					
If it malfunctions I may die.					
While I'm not crazy about steer by wire, I understand why it's kind of necessary for autonomous vehicles. Without self-driving ability, I do not see the point to change a proven 100+ year old system.					
Cost					
I think there should have been another option besides yes or no. I'm neutral. Steer by wire is the future. Eventually all cars will have it, so it really does not matter if I want to buy one or not					
I am a fan of the driving experience					
Don’t trust it					
Lack of road feel. Electronic power steering is already less informative.					
Like the semi Autonomois					
Might be good but would have to drive it to tell for sure					
need much more testing					
Not "no", it's "depends". Maybe, but need to know system is absolutely bulletproof. Unclear on advantage if not self-driving. Ultimately we will all have this so will just have to get used to the idea					
Need to learn more about the technology.					
My current XC 60 T6 AWD is barely a year old and I still have a few years left to pay for it before I even think about another car.					
I want to be in control of the driving. What happens of the signal gets interrupted.					
All of the reasons that I have previously listed: Road feel; Cost; Reliability;					
change					
Would like up to date technology					
I would rather wait for the self driving versions to arrive					
I don't expect to purchase another car in my remaining lifetime.					
just purchased XC90					
I like the sensation of driving					
Benefits are lacking with increased cost.					
I have a brand new XC60 with more gadgets than I can become familiar with at the moment					
expense, driving experience, not proven technology					
I’d have to be totally convinced it’s better than conventional steering. I could be persuaded, but would need to try it out under varying conditions					
At present, no. In future, after testing, maybe. Just bought XC40 which I plan to keep for a while also!					
Concern of failure					
Concerns about malfunction					

Not Ready for a lot of this technology.					
Don’t see the value in steer by wire					

Short Answer-Why Not AD (Open End)

16. Why are you not interested in an Autonomous drive vehicle?

Total participants 162 (36%)	Adaptation/ readiness	Cost	Trust/ control/ safety	Enjoy	Other
Share of total answers	15 (9%)	6 (4%)	86 (53%)	52 (32%)	17 (10%)
Share of total respondents	3%	1%	19%	11%	4%
Short Answer-Why Not AD					
It would make me nervous!					
Ask George Orwell					
I still like control					
To new and makes me nervous					
I like to be in control.					
Not ready for that yet.					
Not ready for that just yet...would feel safer if more / all vehicles were autonomous.					
Waiting until the technology is proven					
Don't trust it.					
prefer to do my own driving					
lack of control					
Don't need a new car at this time					
trust					
I enjoy driving but I can appreciate for many they consider it a "chore" and for me, perhaps having autonomous vehicles for "drivers" who prefer to read, text, sleep, will make the roads safer for me.					
Same reasons as I stated before - not quite there yet. That may well change over time, however.					
Never					
I don’t feel safe giving up control					
If I want to be driven somewhere, I'll take a bus or an Uber. There's no point in owning a car and then having the car do all the driving. I can't think of a bleaker future for drivers :(					
not there yet...					
Rural area much snow					
prefer to be in control					
Concern of safety and lack of control. At this point it would just need to be optional to be autonomous on the freeway.					
I enjoy driving and don't trust the technology.					
I like to be in control of the vehicle or at least have the option to do so even if the vehicle has autonomous capabilities.					
Not at this early stage of Autonomous driving development. Would like to continue to monitor this inovation and how it performers over time before I’m ready to come on board.					
Safety					
I enjoy driving cars.					
The US is large, road conditions, lane markings vary & current Pilot Assist only works on well-marked roads. Then there are signs/signals. Until infrastructure is standardized it doesn't work.					

technology is not totally proven. don't want to kill anyone, especially myself!					
Every car on the road must be equipped the same. Must take out human error can not have some equipped and others not.					
I don't believe that, in the USA, there will be adequate infrastructural sophistication & integrity WITHIN MY LIFETIME to support fully-autonomous driving vehicles. I also worry about "the other guy".					
Enjoy driving					
I don't trust the technology yet.					
Driver needs to be aware. I like my current semi autonomous Volvo that assists me. Not drives for me. I've seen mistakes it has made like sensing stopped cars in a left turn lane					
I don't think that people should be out driving a heavy machine capable of killing people and not paying attention					
I like to drive and I'm not yet ready to fully trust these systems.					
where's the fun?					
I am a person who loves to drive, is skilled at it, and find it relaxing to drive on an open road. I also do not trust autonomous vehicles to perform better than I can drive myself.					
Enjoy traditional driving experience					
I don't think the technology is ready. I also enjoy driving. I think it would be most useful for longer trips.					
Satisfied with my XC40.					
I am not sold on the safety factor of this design.					
I like to drive					
Don't trust it					
Driving history (self driver) and lack of trust in a computer-based system.					
I like to drive, my existing technology fucks up all the time, very bad for a car to go offline as it moves along.					
Safety					
Something else to go wrong. Volvo can't even fix my Low Battery Charge error.					
No interest					
Call me when the "Jetson's era" arrives for EVERYONE..					
i enjoy the driving experience					
The technology has not been proven on crowded roads					
Safety not proven.					
Definitely not at this time, I would not feel in control.					
technology, regulatory framework, and infrastructure is still too early					
I like the comfort of having control myself					
Not safe.					
less control and don't feel comfortable with them yet					
I LOVE to drive!					
Not until proven to be safe					
I prefer the positive control that comes with me in the drivers seat.					
Don't need it.					
Not confident it is safe					
I want the control in my hands and enjoy the personal experience of driving.					
Not interested, I like to drive					
Unlike autcraft, there us far too great a safety and security risk					

I like driving					
Technology only in early stages. Autonomous requires clear lane markings and many roads lack these at this time.					
Not sure I think this is safe					
Not yet					
Having control over vehicle is still important - especially while driving defensively from careless drivers out there.					
Computer in control. Nothing can go wrong...can go wrong...can to wrong. Plus I enjoy the driving experience.					
I like driving					
live in the mountains sometimes without center lines or side lines and often over snow packed roads					
Not a must have, but with be interested in new technology that is available. I would spend too much extra for it.					
I like the feeling of driving.					
electronics fail. can't be without a car if the system fails.					
I just cannot overcome the idea of not having control of my vehicle.					
Safety					
I like the driving experience					
I enjoy driving. Otherwise I would take the bus.					
I enjoy the driving experience too much.					
I like driving my Volvo					
Don’t need it					
Volvo has not shown in the 2017 XC90 that they can produce reliable technology that works					
Again, I believe that driving is a responsible act. If we had those vehicles anyone could jump in and drive. The whole licensing and responsibility part gets tossed out. And it would be pricy.					
I love driving so I wouldn't want to give that up					
Presently satisfied with the car I have.					
I own too many vehicles at this time.					
I believe they need to be further tested before I own one					
I don't think I want to give up control.					
Too expensive; eliminates pleasure of owning and driving automobile					
not necessary at this time					
I have seen nothing to indicate foolproof design and manufacture of cars that account for the vast differences in driving conditions that a human driver reacts to.					
technology is not ready yet or widely used					
Don’t have full confidence in them yet.					
Not sure I could make the adjustment to hands off motoring after 60+ years of hands on.					
Already stated reasons, add to those, the extra cost with limited benefit.					
I' gaining trust in the tech but as with airplanes, you need a human pilot constantly monitoring and managing the tech for optimal safety.					
Id like to see other people using them first-i don't need to be so cutting edge ;)					
Driving is a right as well as a pleasure those who don't want to drive shouldn't get behind the wheel					
Adaptive cruise control and lane assistance on long straight roads is fine. I don't believe the state of AI will ever make autonomous safe enough. Weather conditions is one big issue					
I have a semi autonomous vehicle and I do not use the feature					

Because as of now it's science fiction and I enjoy driving					
I like driving. From what I've seen, the driver has to monitor the driving anyway, so why not drive yourself.					
Do not have full faith and trust in a machine.					
safety issues. my age!!					
Need freedom to be able to drive my car					
The cost is prohibitive					
the program is not ready for Main Street America yet....but getting there....I have been driving for 55 years so will be harder for me to trust this system at first					
I enjoy driving. I like the feel of the car and the way vehicle handles.					
I like to drive					
I like to drive.					
Not yet.					
Scary					
As an older person I am not yet ready to put my life in the hands of a vehicle I do not actually control.					
I don't see a reason it's needed.					
Being 70 years young, not likely to be fully functional everywhere.					
Until all cars are autonomous, it doesn't feel safe yet. I don't trust other drivers.					
I love to drive. However I do like some semi-autonomous features like adaptive cruise control.					
I don't like the idea of not being in control. I'm ok with autonomous driving as long as I know that I can take over at any time.					
I like to drive					
Although I appreciate driver assistance features, I don't forsee fully autonomous vehicles being reliable for many years.					
Concerned about safety.					
I want to drive myself					
When all cars ar3 autonomous then I will gladly be interested					
I enjoy driving my Volvo myself and am reluctant to 'out-source' that pleasure!					
still want full control to where. how...i love to drive!					
I still like having control of the car.					
Higher cost over the life of the vehicle. Increased liability risk due to unproven/limited tested technology.					
I enjoy driving					
I like the driving experience.					
Don’t need it, afraid of accidents					
I enjoy driving, actual have a manual transmission for my non vovlo.					
Not ready for this yet - would like to know about backup systems should autonomous drive fail					
I enjoy driving					
needs more testing					
JUST BOUGHT NEW 2018 XC60					
Not at current state of technology. I'm a s/w developer, I know how hard this is. We're nowhere close, yet. Ultimately I would like one but it's 10+ years before they become safe and reliable enough,					
Feel like the technology is still evolving at this point.					

Don't think the technology has been perfected...yet. Plus, I enjoy driving and am not confident that a fully autonomous system will ever be totally safe just like a human driver					
I enjoy driving cars.					
Unproven reliability and too many unknowns for now.					
I refuse to give up control of driving to automation.					
I prefer to drive a vehicle myself.					
Not confident in the technology yet					
I am not ready to pass driving to the car all the time. I do enjoy driving					
I don't think I'm ready for it! It seems neat but it makes me nervous that the steering wheel is not connected					
Takes the fun out of active driving/engaging with my vehicle					
I am very happy with my V90.					
Just bought this one and hope it will last quite a long time.					
like to be in control when things happen					
Technology is too new					
I'm not ready to buy one today but perhaps in the future when the kinks are worked out					
SAFETY!					
I like driving my car.					
I like control and if it is done using any "radio"signals, what happens when connection is broken.					
I enjoy driving					
I like to drive					
Just bought vehicle I want to keep for a few years and the autonomous drive vehicle needs more testing before I am interested.					
Too much technology. What happens with repairing a car when it is ten years, or better old. Will you be able to get replacement parts? Cost of repairs?					
I like to drive					

Short Answer-Final Chance (Open End)

19. Please feel free to share any other thoughts on this topic.

Total participants: 134 (29%)

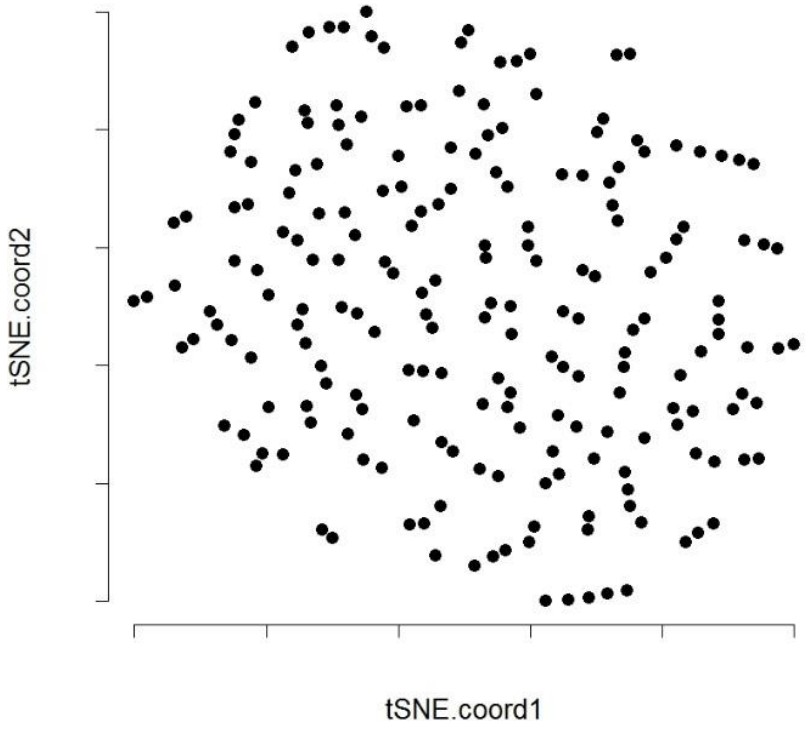
Short Answer-Final Chance
Might be helpful to market that most airliners these days are fly-by-wire, so this is not a fundamentally new technology and very safe.
I think for the purpose of your own peace of mind you need a steering wheel, it gives you a feeling of control...without one you are at the mercy of the car. As stated before if safety is supported by large data and limited incidents, I would later be open to a car with no steering wheel.
The transition from semi-autonomous to fully autonomous will be a huge paradigm shift in the way we understand the concept of a vehicle. I think a gradual approach, keeping certain elements of a car similar to the current driving experience, will allow for greater adoption and less confusion.
I figure you'd bundle both autonomous and steer by wire as a package "autonomous package" or something, then the whole stack would be configurable at once. Or, go all in on steer by wire on all car models to make parts/ assembly pipeline consistent/ swappable, and optionally add/ upsell autonomy.
I'm not sure I would trust the lane keeping abilities, since my car has followed shadows from power lines instead of lines on the road. If I wasn't at the wheel we may have veered into the other lanes.
The autonomous car is still a scary idea in my eyes. Not sure I'm willing to give up all driving control
I'll never own an auto drive style car.
Good to stay ahead of the competition which translate into increased sales volume. Offer this sooner and not later.
Autonomous is great but being able to take control is crucial. This will enable autonomous driving with better control when having to take control.
I appreciate Volvo is a leader in evolving technologies, and I don't want to stay in the dark ages. That said, I need a bit more time and experience before I will feel comfortable giving over complete control to a computer. It is not the driving itself, but what happens if the computer freezes.
By all means push for safety and innovation, but don't abandon drivers in doing so. Isolating drivers and/or removing them from the loop is a huge turn-off for people like me who actually enjoy the act of driving.
We shall see
if there is no steering wheel for the autonomous car I would like an app or computer system to drive the car if it ever becomes necessary
It feels like this should have been years ago - how far away are self driving cars?
If the SbW feature causes the driver to lose the feel for the road with the steering wheel, then I would not be interested in this feature.
Keep doing what Volvo does so well. Safety first, forward thinking, thinking outside the box...
On the face, technological advances are great. But other considerations come in. Such as increasing gap between those who can afford it and those who can't. Sich tech requires infrastructure change. And protecting the vehicles from hacking, signal interference and EMP is a concern.
I am very intrigued and can see the benefits...would be eager to use it in a conventional car
Volvo design and performance have improved a lot, but you need to focus less on technology and more on quality of parts, etc.
If sleeping is going to be an option, obviously you want the ride to be as smooth as possible. So, I don't see why you wouldn't just use steer by wire.
This is a bad idea until all cars and trucks are equipped the same.
I am a skeptic of fully-autonomous driving, again at least in the USA, where there are thousands and thousands of secondary/tertiary roads in everyday use, including gravel roads & jeep trails. The notion of a vehicle without a steering wheel and/or "drivers" who aren't trained to drive, scare me!
I would switch to an autonomous steer by wire when my lease expires and when I think the technology has been well tested.
I am ambivalent about the new technologies that remove driver control. There will need to be solid evidence that it is safer than standard driving to become part of my life.
Being able to sense road condition from the steering wheel (e.g. limit of tire grip, cross wind, etc.) is important even if there exists automated feedback to reject the disturbance. The system may have many information not available to the driver, but driver may also know info not measured by the
I have concerns regarding failure of steer by wire. It'd have to have redundancy and strength to support steering after an impact.
Not really comfortable trusting the system to do the driving, yet!
I'm not terribly clear what the overall benefits of steer by wire will deliver. The tech should drive significant value in performance and safety. Just because it can be done doesn't mean it should be. How hackable is steer by wire? What if all power is lost? Is it subject to interference? Etc.
Focus should be on driver attention not auto control. Can automation look at an intersection and tell if a driver in a car is looking at you and anticipate his pulling out in front of you. I ride a motorcycle and that has saved my life

I was in Arizona earlier this year when report of a pedestrian was killed by an autonomous car - driver wasn't paying attention. Video was very disturbing. And it was a Volvo. I was very disappointed and ashamed to own a Volvo at that time. They covered it well focusing on blaming Uber
I don’t fully understand the difference that this brings in comparison to the land assist feature that is already in my car.
It is a scary proposition: giving up control is difficult. Safety must be proven and guaranteed!
make sure their is an override or redundant back up system in case of power failure or necessary instant response
You are going to keep increasing costs so your vehicles are out of the range of most people
I just am afraid of a system in which all human intervention is lost
I love in Chandler AZ, the hub of self driving cars. They work only under incredibly limited circumstances and need a high level of driver involvement. We are decades away from autonomous cars for the masses.
If Sensus and other things were glitch free- which they are not (and I presume you know what I mean - eg today I had a frozen "media" choice I could not change) then I would have a better view of all electronic SBW. But the wheel is the last thing I want electronic instead of mechanical.
I am not convinced that the technology is safe enough yet for widespread use in public. I see it coming, but I don't think its here yet.
glad to see that Volvo is starting to progress, they seem behind compared with competitors
The future looks exciting!
I already have a Tesla Model 3 with Autopilot functionality. The more vehicles on the road with autonomous driving capability, the safer it will be for all of us.
A car without a steering wheel would freak me out. I’d like the option of steering if needed.
Most interested in using while driving long distances on freeways and highways. Not interested and probably would not use for city driving.
Interesting to watch this tech emerge
main concern is backup computer failure and/or hacking
Cool idea but I like to drive! Although it would be nice to use autonomous driving on the interstate on long road trips
Fly by wire has been in place in aircraft so the transition to automotive technology is natural.
Interesting technology but there is a fear of how the technology/car will function in all weather conditions and road conditions. Safety is my biggest concern. If I don't feel safe then I won't buy in to the new technology and will wait. We bought Volvo because of the safety features. Keep it up!
I think the transition from a regular car with a steering wheel to a fully automated car will take time. There will be a period where you feel like you have no control over the car the way you do now. Also, the emotional connection people have with their cars will be lost to some degree.
My demo video quit playing half way through, so I don’t know if I understand steer by wire completely.
again, this is a very specific solution and i do not have sufficient information to see the value/improvement and safety improvement
The big concern is that, as a society, we are losing our skills to look before we act and instead, depend on the car to tell us. Most drivers can’t parallel park unless the car does it.
Self teanspirters may eventyally be viable but not niw nor at the price they’ll command
I would be highly reluctant to be an autonomous drive guinea pig
Cost is a main concern.
I'd rather see Volvo spending its time on creating a reasonably priced fully electric vehicle that can compete with Tesla.
I hope I can buy my autonomous drive-by-wire Volvo sooner rather than later!
Steering will always be necessary in the event of a malfunction or emergency
I think Volvo is going to be a leader in the automotive industry as technology changes and it is very exciting to be a part of that. Keep up the good work!!!
While I like the safety features on my V60 I do enjoy driving. If I want an autonomous vehicle I will take and Uber.
IMHO...no need to increase the cost for this feature...since it'll be standard within the next 5 years. No interest in SbW
Safety is of paramount importance. That's why I have owned 4 new Volvos in succession.
There is limited elasticity in vehicle pricing. Technology will not be well received at a very steep price possibly causing the shift to a more Uber world (which I would not like to see)
I'd be willing to test an AV in my daily driving in Los Angeles.
I like your cars the way they are and
Volvo technology at least in our 2017 XC90 is not reliable, seldom works as designed so no ready to let go of the steering wheel to Volvo technology
I understand that this is where we are moving toward. My concern is that Volvo is priced out of the conventional market and into high tech/ luxury market only. Which would end my purchase history with Volvo and make me very sad indeed.

I look forward to the day where my Volvo can drive me autonomously and I can use my commuting time for other activities.
Safety is key. If tech fails, the car fails. I'm worried about tech failing whereby the failure causes serious or grave injury
Not sure you properly explained the 2 options for autonomous driving; with and without sbw. I thought autonomous meant you had to have sbw until the last question.
I value and appreciate the experience, skill and intuitive interaction required to drive a luxury car. If that experience is minimized I might as well be in a cab or public transportation. The personal joy and accomplishment of the experience is gone.
What will maintenance/support costs be on something like this compared to traditional?
I'm an aging driver and see autonomous vehicles being able to keep me independently transporting myself with increased safety.
Autonomous cars are interesting but I enjoy driving. I enjoy cars that need to be driven. On a long journey I would be happy to have the car do all the work if the system is proven safe. On short journeys I like driving so would not use the feature. Therefore it has to do both
Autonomous driving is great forward thinking. 100% reliability is necessary. Forcing the issue without vast car and infrastructure development and buy in will be politically unpredictable.
Steering and braking are the 2 most critical components of safe driving. I'm just a bit concerned of loss off steering should the electrical or computer system in the car fails while driving.
As with many Letty's older I get the harder it is to adjust to significant change. And I enjoy driving as it is now.
Apprehensive but exciting!
Glad to see SbW is approaching reality in a car I can buy.
I don't believe the hype. If I ever get hit by an autonomous car I will have no sympathy for the manufacturer or the owner/driver of it. Road conditions, construction, or roads poorly marked (no stripes or lines) seem to break these assumptions.
Some day it will be the only way to drive, but most likely not in my lifetime.
I think the younger generation will be more apt to embrace this technology. I wish you well..
Provide buyer more benefits to driving with steer by wire. ex how would it improve driving in rain ,ice and snow. And I would always want the option to take over driving so some type of steering option would have to be available. ex retractable steering wheel.
My chief concern with autonomous driving cars is that until all cars on the road are equipped, the driving practices of everyone else will hinder the actions of the autonomous car (keeping a safe distance while numerous cars cut you off, etc).
I do not want to die. But When I do I need to die in my own hand.
Please head in another direction. Autonomy is not the future.
Can't come fast enough.
Especially at the onset, it's all about options...Would like to retain option to steer. Also concerned re: diminished driver's experience. I love to drive and will miss the feedback a mechanical connection provides, but know the tradeoff will be necessary and worth it. Chicago traffic is convincing!
Until we have fully autonomous vehicles, a nice compromise would be a controllable steering clutch. It can be set to engage the wheel directly to the steering shaft for driving experience, and decouple for computer control for convenience.
What about speed control, automatic braking & driver controlled steering?
SBW will require fault free software to insure absolute safety. Current most dealer service group do not understand or appreciate software info, updates and issues, even though they are fine with new mechanical and hardware prevalent in New model autos. Start training Service folks on software NOW.
Autonomous driving will be the future, but the world is imperfect and you need options for manually operating your vehicle. While there are many situations in which I wish my car could truly drive itself, I still will want to have the ability to take over control and enjoy the road.
I look forward to learning more!
I think that with the introduction of autonomous cars, it will be important to keep steering wheels and other tradition controls to allow the owner to manually control the vehicle when desired or when necessary. But make the steering wheel have a powered telescopic function to move away from the driver
As an older driver, I'm hesitant to let control go totally to electronic devices
Technology that improves safety and makes driving more enjoyable are welcome but I still want to participate in the driving experience.
I'm willing to be interviewed. Very interested in where you are taking the next generation and want to be helpful. Always willing to take these surveys but they are limiting.
Let me test it - I can give you all the feedback.
Bring it on Volvo! If any company can create an autonomous driving vehicle to compete with Tesla, it's VOLVO! I want it all.
I like the concept of steer by wire for potential safety benefits much like in break by wire.
I hope that research into autonomous vehicles does not slow down innovation in driver *assistance* features. I see those as more helpful and more achievable, at least in the short- and medium-term.
I would think that as autonomous vehicles advance the drive by wire will be part of the package. It will be an adjustment to give up the traditional feel of driving but the safety advances outweigh that loss.
Our infrastructure is not conducive to autonomous driving. It will be many years before our infrastructure is adequate. Today the autonomous driving car would have limited venues of use.

If you would like a customer to test drive on an extended basis, I would be more than willing to participate and log any feedback to Volvo.
MULTIPLE redundant safety systems need to be provided for any mass market steer by wire system to prevent accidents and loss of life if there is a failure of some part of the vehicle that could cause the steer by wire system to not function, or not function properly.
Old school. Trust steer by wire
The line between a driving experience and a virtual experience is narrowing; for now while I love progress I still want to be the driver. And I want cool station wagons!
I can't see autonomous driving being viable untill all cars are autonomous. It's easy to make a car drive safely, but we can't control the other drivers.
Being retired I bought two new cars, XC60 Inscription for my wife and a Dodge Charger 392 Daytona for fun drives. The Volvo is our everyday and trip vehicle. I would consider an all electric version but it must have a min, 250 mile range.
While Autonomous Driving is something I would want, I would love a car that might give me the option to disengage autonomous driving and take control
I like technology and I’m very much looking forward to the future of fully autonomous cars.
I think that the autonomous drive cannot be used everywhere, so I would like to keep the possibility to drive the car if needed.
I would find it very difficult to switch from driver control to autonomous with out an interim step
Very concerned about incomplete implementations lulling people into a false sense of security. Until it's 100% fully autonomous in ALL situations including emergencies, construction,, etc. drivers will still have to pay attention - and they won't, thinking it's "autonomous" when it really isn't.
The important thing is to be sure you got this right.
Seems like steer by wire would be more effective and efficient for autonomous driving.
I'm all thought out for tonight
Would like a steering wheel if there was a computer failure
Pretty cool technology
I'd prefer a safety mode that would allow me to by-pass auto/software dependence if needed. Design team could look at feedback from pilots who have found advanced modes of modern airplanes not satisfying and overlay similar scenarios.
My concern in addition to potential for tragic accidents if a malfunction occurs is that liability laws are not up to speed with the technology. If auto manufacturer takes 100% responsibility for any accidents I still do not want a car that drives me.
One day it will be the way but right now it may be a bridge too far.
True sports cars should remain manual for the driving enthusiast. Commuter cars? Different story- go ahead- make them as hands off as possible. Imagine being stuck in rush hour traffic and actually getting work done or napping while the car gets you thru the boring slog. THAT would be fantastic.
Would like to know cost difference expected. I know little about autonomous vehicles, so am not sure how important the wire steering would be at this time in the industry of autonomous vehicles.
In-between is unsatisfactory. When the tech advances enough so that my car drives itself, I'll be OK with that. Until then, I want to be in control as much as possible and experience driving.
I feel like it would need to be proven that it is more reliable than the conventional method. I also think that if you have an autonomous vehicle you should have a manual override. I think a lot of people are going to have more questions before they buy in to an autonomous vehicle.
Maybe VOLVO should focus on increasing reliability instead of introducing gizmos

Cluster analysis



G. Survey results China

China respondents profile	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5
Gender	Male	Male	Male	Female	Male
Age	41	35	30	33	32
Model	XC60	XC60	S60	XC60	S60
Interested in new technology in cars	Yes	Yes	Yes	Yes	Yes
First reaction SbW	Neutral	Somewhat positive	Neutral	Somewhat positive	Somewhat positive
Comfortable using SbW	No	Yes	No	Yes	Yes
Why (not)	I can accept this new technology but I need backup solution when this system (new technology) failed.			Worried about the maturity of technology	Steering wheel turn over numbers can be reduced, easy to know the position of the wheels. If it can be approved to be very safe, it will be a very good choice.
Safety	Important	Very important	Very important	Very important	Very important
Design	Important	Very important	Low importance	Low importance	Low importance
Driving experience	Important	Very important	Important	Very important	Important
Other benefits	Low weight			If SbW is based on full AD drive, many benefits than a conv steering system. More space to configure stronger, quicker, and robustness processor and redundant system.	
Cost	Very important	Low importance	Important	Important	Very important
Driving experience	Important	Very important	Important	Low importance	Very important
Other drawbacks	None			Worry safety	

Other things while driving	Yes	Yes	Yes	Yes	No
Other things	Can do everything, like cook/etaing/sleeping/...	Use your phone/tablet/laptop, eating, sleeping, working	Use phone, eating, sleeping	Sleep, eating, listen to music, or working if needed	Yes
Remove steering wheel	Yes	Yes	Yes	No	
Non-AD SbW interest	Yes	Yes	No	No	Yes
Why (not)				Is it safe enough?	More expensive en safety not guaranteed
SbW price	0-10.000Y	0-10.000Y	10.000-20.000Y		0-10.000Y
AD interest	Yes	No	Yes	Yes	Yes
Why (not)		I like to have the fun of driving	Curious	Long answer	
AD price	0-40.000Y	40.000-80.000Y	0.40.000Y	40.000-80.000Y	40.000-80.000Y
AD w/wo SbW	None	With	Without	With	With
Other comments	Is there any demo system for this new technology? If yes, please share more information to me.		When will the technology be as mature as the traditional one?	How to realize AD drive in complex road condition? Especially like China	

H. Interview results Europe

Interview guide

- Start interview officially, ask permission for recording.
- Ask if presentation sent is clear.
- Start interview

Volvo Customer Type

1. Gender?
2. Age?
3. Country?
4. Volvo model?
5. Interested in new technology in general?
6. Interested in new technology in cars?

User Benefits & Sacrifices of SbW

7. What is your first reaction to Steer-by-Wire?
8. Would you be comfortable using Steer-by-Wire? Why (not)?
9. What do you think of the benefits of Steer-by-Wire, importance, how would you rate them:
    - Safety (improved performance of driver assist functions)
    - Design (different design options, design freedom & more cabin space)
    - Driving experience (variable steering ratio & disturbance free steering)
10. Do you see other benefits of Steer-by-Wire?
11. What do you think of the sacrifices of Steer-by-Wire, importance, how would you rate them:
    - Cost (will be higher compared to a conventional steering system)
    - Driving experience (will not be 100% the same as with a conventional steering system)
12. Do you see other drawbacks of Steer-by-Wire?
13. Would you like to do other things while driving your car?

If yes:

- Assume your car can drive autonomously; What would you like to do while driving? E.g. use your phone/tablet/laptop, eating, sleeping, working, etc.
- Assume your car can drive autonomously; Would it be useful to you to remove the steering wheel in your car, so that you have more cabin space?

Price of SbW

14. Would you interested in buying a normal (not Autonomous Driving) car with Steer-by-Wire? Why (not)?

If yes:

- What is the additional price you are willing to pay extra for Steer-by-Wire in a normal car?

Range €0 - €5.000

15. Are you interested in buying an Autonomous Driving car? Why (not)?

If yes:

- What is the additional price you are willing to pay extra for Autonomous Driving?

Range €0 - €20.000

- Would you prefer buying an Autonomous Driving car with or without Steer-by-Wire?

16. Other questions, comments, concerns?
17. Interested in receiving the results of our research? If yes, email?

Q = Interviewer
A = Respondent

Interview 1

A: I will try to think as a customer, not so much as an engineer
Q: I have prepared some questions, but maybe I will ask some other questions as well during the interview. First I will try to identify the customer type, so that I will get to know what type will be most interested in SbW, then I will ask about the benefits, sacrifices and price.
A: okay

Customer type
Q: may I ask your age?
A: I am 44
Q: Are you from Sweden?
A: Yes
Q: And which Volvo model are you driving at the moment?
A: I'm driving a V60, from 2011, so it's an older model
Q: Are you interested in new technology in general?
A: It's hard to separate customer and engineer, but you could say that i'm interested in new technology, yes.
Q: Okay, and are you also interested in new technology in cars?
A: yes, of course, that's my profession

Benefits & Sacrifices Steer-by-Wire
Q: What was your first reaction to SbW?
A: Why? That was my first reaction.
Q: Okay, and why was that?
A: As a driver and a consumer I think I'm probably as most people very much dependent on price and things like that so my first thought would be or was that what would this add and what's the cost of it? And I think that's quite generic, that most people will think that first.
Q: And what do you think of it now, now you know more about the technology?
A: It could solve some problems, but from a consumer perspective I'm not convinced that I personally would like to spend extra money on such a thing.
Q: Does that mean you're pretty negative about SbW then?
A: Not negative, but more driven by cost. I'm not the type of person that would be a first adopter, more a second or third wave.
Q: Okay, and would you be comfortable using SbW?
A: For that it's also hard to make a difference between me as an engineer or me as a consumer. If I would drive a SbW car, I would probably be quite curious of the safety mechanism behind it. But that's me as an engineer. If it feels consistent, I think I will feel safe quite fast.
Q: Would that be because you know there is a redundant system behind it?
A: That would be my thought at an engineer. But as a consumer I think if it responds consistently, I will probably quite soon forget that I don't have a mechanical connection between the steering wheel and the road. So I will think about it. If it starts to do things that I'm not used to, than I guess I will react on it.
Q: And what do you think of the benefits of SbW? Because you saw the presentation I've sent, with safety, design, and driving experience as the main benefits of SbW.

A: Yes. But there is also a passive crash test perspective. If you have a steering column, there is a risk of the steering wheel going into the driver in case of a crash, and with SbW you wouldn't need measures to prevent that anymore, so you can make a more rigid cage, so that is also a benefit. But the car can also do things independently from the driver. So I think that's the main advantage. Because most of these active safety functions can be implemented, but the driver can resist that by grabbing the steering wheel. But you don't have that possibility if you have SbW, and that can be a benefit too. If the car needs to think that it needs to steer back to the lane it can do that, so it can take over from the driver.

Q: So the benefits you name are different from the benefits in the presentation? You name passive safety, and independence of steering wheel from the road.

A: Yes, I guess my point covers all of the benefits in the presentation.

Q: And what do you think of the sacrifices of SbW? Because I named cost and driving experience, because some customers like to feel the road and that's not 100% the same with SbW.

A: I think that depends on what car brand you drive. If you drive a Volvo, steering feel and feeling the road is not a top priority, because a Volvo is already quite isolated from the road. So I think for Volvo owners it will not be a big step. But if you take a BMW owner, than it's a completely different story. It's their trademark that they are agile, and that you're in connection with the environment to a large extent in a BMW. So I think for Volvo drivers driving experience will not be that much of a sacrifice.

Q: And how is that for you?

A: When I buy a car, apart from costs, I prioritize comfort. I think that is quite important, because I try not to drive that much in the city, so when I use the car I drive to our summerhouse or visit friends and family who live on a longer distance, so the typical usage is long distance driving, and then you need to have more comfortable seats, more quiet surrounding, and sportiness is not so important.

Q: but how would you prioritize the sacrifices for yourself?

A: I think driving experience for me is secondary, and I don't think SbW will influence driving comfort at all, so I don't think it's a sacrifice to me at all. I will definitely feel that it's a SbW car, since I work with steering feel, but I don't think it will matter that much that I don't feel the road to some extent, because the seats are still comfortable and the suspension is quite soft.

Q: And do you see any other drawbacks of SbW?

A: Of course the fallback for failure is not back to the driver, and of course there is a risk with that. The fallback is another system, not the driver. The sense that you lose all control of the situation, if you don't have the mechanical connection. It happens that an assistant system of ordinary cars is failing, but if you prepare it's not that big of a deal. You can still steer the car and in moderate speed, it's not even harder or harmful. It can be dangerous if you're not aware of it, and you suddenly come to a short curve, than it can be a little bit dangerous. So that fallback is safer in the sense that you're still in control. But the fact that you as a driver are the fallback if something fails, makes you probably more comfortable, but it doesn't necessarily mean that it's safer. But that might be an issue for me, that I feel less in control if something fails.

Q: Because if something fails, you don't take over but the car is taking over?

A: Yes.

Q: And you don't feel comfortable with that idea?

A: No, I think that's more of us species, we like to be in control.

Q: I can imagine. And while driving, would you like to do other things in the car, for example being on your phone, tablet, or working, or other things?

A: No I'm not commuting in the city so I when I drive it's more like a family thing and it's kind of quality time with the family. When I take the bus I take up my phone and start reading the news and so on, what of course I don't do while driving. But I think that's not a thing I'm longing for while driving. When you sit in a bus you don't have anything else to do so you can do that. But I don't need

to look at my phone and read the news while driving myself. It's okay to drive and not to have that opportunity for me.

Q: Okay, because you said you're a long distance driver, what about that?

Q: But then you talk, and you think, and even when you drive alone, I think it's relaxing and you're always busy with something while driving, so it's a time to reflect.

Q: Okay, so you really enjoy driving and don't really feel like picking up your phone, or sleeping.

A: No, I don't need that.

Q: Okay, can you assume that your car can drive autonomously, what would you like to do while driving?

A: I have motion sickness, and I think that's one of the issues with autonomous driving that not that many people have addressed yet, but that will grow as a topic for studies. When I ride the bus, quite often I get motion sickness so I cannot do anything else.

Q: I can image, I have that too.

A: But sometimes, if you're tired or if you're hungry I think it gets worse so then I don't do anything, so I just look outside. And I think it will not be much difference in a car, so I will probably sit and watch to road ahead.

Q: And maybe if they are can cure that with active suspension, do you think that could help?

A: Yes, but it depends on the type of journey, because you're still contained in a small space, you cannot stand up and walk like in a train for example, so you're quite limited in what you can do. But I guess you can work in a car. But I would not be able to do that.

Q: And sleeping for example?

A: I guess that's the same, I will get motion sickness as well.

Q: And would it be useful for you to remove the steering wheel, when your car can drive autonomously? So that you have more cabin space.

A: People in Sweden, I guess it's the same in The Netherlands, tend to buy bigger cars than they need. So the space inside the car is not really that limited I think. I'm not sure if that space that it would safe in front of me would be that much of a difference. I guess when I wouldn't have the motion sickness, I could have my laptop there, but that's not the case.

Q: Okay then we go the price of SbW.

<u>Price</u>

Q: Would you be interested in buying a normal car, so not autonomous driving, with SbW?

A: I think it's a matter of price. Also, I only bought one car new, usually I buy used cars, and then I buy what that car has. So I would not actively seek for a car with SbW. But perhaps, I don't know, if SbW was available… But I think the price is very crucial.

Q: And what would the additional price you are willing to pay for a SbW in a normal car be?

A: I think it would be a couple of thousand. If I'm going to buy a new car, a couple percent of the price, so five/six thousand kronors perhaps.

Q: So, you are interested in SbW to have it in your car?

A: Yes I am, but the price of these systems will not be that low when it's introduced.

Q: And would you be interested in buying an autonomous driving car?

A: Yes, I would but not the first generation, because I now that the first wave always pays for the development costs.

Q: Even with your motion sickness, and that you enjoy driving yourself?

A: Yes but that's probably because I'm an engineer and I'm just curious, but I would buy when most people on the street have autonomous cars. And also because my wife doesn't have motion sickness so for her it would be different.

Q: And what would be the additional price you would pay extra for autonomous driving?

A: A little bit more than for SbW, so not that much I think. Given the extra cost I know you have to pay for the standard active safety, the radar and camera, it will take long before I would buy it. 10.000/15.000 kronors or something like that, and that would take a long time.

Q: Because autonomous driving will probably cost 120.000 kronors, so does that mean you will wait until that price goes down?
A: Yes I will wait quite a bit, until it's quite mature. But I can see the benefit of having it, and not necessarily paying attention to the road in occasions when you don't feel motion sickness, of course there is a benefit for me. But it's constraint by my motion sickness.
Q: And would you prefer an autonomous driving car with or without SbW, if you buy an autonomous driving car?
A: I don't think it makes sense to have a steering column, it will not be real autonomous if you can intervene in that manner I think. So no.
Q: So you would prefer an autonomous driving car with SbW?
A: Yes, I think so.

Q: Okay then we come to the end of this interview. Do you have any questions, or concerns, or comments?
A: Not really. I used to work for Volvo Cars, as a consultant, 12/13 years ago, and we had SbW cars prototypes back then as well. And I think this thing is very much connected to the autonomous drive hype. I'm not convinced there will be a launch of autonomous driving cars to the extent that I mean autonomous drive where the driver is not responsible for the ride. So I'm not convinced that that will ever happen. But I think SbW will happen.
Q: And why is that you think?
A: Because SbW is from an engineering perspective ridiculously simple to have back-up for and to make it safe, while autonomous driving is infinitely more complex.
Q: Okay, so you think the level 5 of Volvo is not possible?
A: No I think 4 or 5 will not happen.
Q: Not even 4?
A: Perhaps 4 is possible in very special situations, in very dedicated locations perhaps. But I think the dealer is responsible, and I'm not sure that will happen.

Q: Are you interested in receiving the results of this research?
A: Yes, absolutely.
Q: Okay, I will email you the summary at the end, when I'm finished.

Interview 2

A: I'm an Electrical Engineer, and I've been working in automotive for nearly 25 years now. So I'm a gear head to some extent, and steer by wire is a topic I'm quite interested in. So I'm not a typical car driver who probably doesn't know much about it. SbW is a topic that I've been very interested in and I've followed an early attempt by Daimler that didn't go so well, so I understand the engineering aspect of it. Just as a background for you.
Q: Yes that's nice, good to know. So you say that you're not the typical Volvo customer you would say, but I think I can think a lot from you about SbW. Is it okay that I record this interview?
E: absolutely, yes
Q: okay, I will ask you questions about what type of customer you are, and I would like to know what you think of the benefits and sacrifices of SbW, and also some questions about the price. I have prepared some questions, but I will ask you also other questions. Is that okay for you?
A: Yes

Customer type
Q: May I ask you what your age is
A: Yes, I'm 50.
Q: Okay, and you are from Germany, right?
A: Yes.
Q: And which Volvo model are you driving?
A: I'm driving a V90.
Q: Okay, and you've already told me that you're interested in SbW. Are you also interested in new technology in general?
A: Very much, yes.
Q: And are you also interested in new technology in cars? And how important is it for you that you have the latest technology in your car?
A: Very much. My wife just now has a new company car program where she gets a new car every year. And she said: It's not worth the effort of picking a car to drive it for only a year. And I said that would be exactly what I want. A car for a year is enough to understand it, and every year there is something new that is worth trying.
Q: That would be a nice opportunity indeed, to try the latest technology in the car every year.

Benefits & Sacrifices Steer-by-Wire
Q: What was your first reaction to SbW?
A: Critical, very critical. I have learnt to appreciate road feedback. I used to drive a Lotus, a sports car without electric steering, and a very direct road feedback. I find it very interesting how well a sports car transmits a lot of information to the driver. That is a thing that is very exceptional, but also very unimportant is most daily situations if I may say. In 99% of my driving I see a lot of benefit in assisted steering, and specifically with my Volvo, I love the pilot assist. I don't need to steer it myself in most situations, I'm happy when the car does it. But I have a lot of appreciation for the benefit of a direct steering in a sports car, and loosing that is somewhat of a strange thing.
Q: And did you say that the road feeling is unimportant for you?
A: No road feeling is important, as long as I want to have control over the vehicle.
Q: So you would say that with autonomous driving, you're okay with letting that go?
A: Absolutely, yes.
Q: Would you be comfortable using SbW?
A: Absolutely, yes.
Q: But than also only in combination with autonomous driving, so not when you're driving yourself?

A: Yes, I think that's the right way to put it. I haven't driven a SbW car, and the way I look at it is the electric power assist systems that we have today, I can't really tell how much of the feedback that you get from the street is really through the steering column. So I'm not sure if SbW really feels much different the power steering assist that I have in my Volvo today. I'd like to have my car to drive autonomously as much as possible, and then clearly I don't need the steering column. But I'm not sure how that would feel in a current car where most of the time I keep control over the steering myself.

Q: Yes because it will not be 100% the same as with the electric power steering system. But they try to make it the same feeling as much as possible, for 95% the same or something. So you would say that you would be comfortable using SbW?

A: Yes, absolutely.

Q: And why is that exactly? Do you feel safe, or trust the system?

A: Yes, because I believe that very soon the car will be a safer driver than I will be. But that's easy to be said, but it has a lot of consequences. Today, I know that autonomous features of the car are not good enough, so I need to be in control. And that's when I want to have a steering wheel where I'm, if necessary, even forcing against the power steering where I can take control. But I believe that very soon the intelligence of the car will be prominent in a sense that it's better if I don't interfere. And then you might also will leave the steering column out.

Q: So you think in the future you will trust that the system will be good enough, or even better than your own driving?

A: Yes, but you know like everybody else, I know that my own driving is great, but you never know what the other idiots on the road do. They should not be allowed to drive, so they should have to drive autonomous.

Q: And what do you think of the benefits of SbW? Which one do you think is most important to you? For example, we have done some research on the benefits, one is safety, another one is design, and last one is driving experience.

A: I think safety is a big topic. I fully agree of what you have in the presentation. Actually, in the safety I would add the lack of the steering column. Because the steering column in case of an accident is also a source of…. The steering wheel and the steering column can hurt you in the situation of an accident. To not have the steering wheel in the middle of the car would help. So I fully agree to safety, I very much agree to design. That also leads to the fact that driving will develop into a different direction. As I said, the classical steering wheel in a classic mechanical car gives you a lot of feeling with the road. It gives you the feeling to be in control, and keep the car under control. But it is obvious that we're giving away a lot of control in future cars. And then I can imagine for the cases where you can take control, the stowable steering wheel or a joystick are options that are just as good as a steering wheel. So I completely agree with that. Same with driving experience, I clearly see the benefits of that. Always under the assumption that what we're looking for is, I call it a transport convenience. I used to have two cars, where one was my driving car, and the other I called my space shuttle, because I used that for business travels. Most of the time I was on the phone, I wanted to have automatic gears, I wanted to have everything automatic if possible. And that's a driving experience benefit. I disagree with your assumption of cost, because I believe what we see right now is that steering motors are being upgraded to enable autonomous driving, and connected with that be fail-safe, so they have two motors or whatever as a fail-safe option. So what you have today is a steering column ánd an electric motor that can basically do all the steering by itself. I'm sure that once SbW comes into serial production, it will be even cheaper than conventional steering.

Q: Okay, and why do you think that?

A: Because there is a direct cost of the steering column that you can do without. And there is an indirect benefit of less weight in the system. Both of these will be a big advantage. So I think that as soon as SbW is in serial production it will be not more expensive than conventional steering.

Q: Okay, but do you think that the weight is a big difference compared to conventional steering?

A: Yes I believe that the steering column and the steering wheel is maybe 20/30kg, that is quite a bit.

Q: Yes but on the other hand you need a lot of redundant systems as fallback for failure...
A: But these will come anyways. As soon as you go towards level 3 you will have redundancy, even if you have a real steering wheel, everybody wants to be able to let the car drive autonomously as much as possible. And for that you need the redundancy in the systems already. And my main point is that the road feedback delay is an issue as long as you care about it.
Q: Exactly, and do you care about it?
A: No. Let me put it that way, if I care about it than I would buy a sports car for the very few times that I really want to consciously drive. But most of the time you are in traffic situations where you're just going with the flow. Ideally it flows and you're going with the flow. Very often it's also stop and go. In none of these cases I benefit from road feedback at all. The situations where you benefit from road feedback are becoming less and less. In the sense that I rather have the car take care of the vehicles that really can take control.
Q: Okay, because in Germany there are certain roads where you can drive a limitless speed...
A: It is very rare that you can drive to the limits, and it is even rarer that you want to do it. When we question why road feedback is of importance, at the bottom line road feedback is important when you feel in control of vehicle stability. But as a matter of fact vehicle stability is something we have, to most extent, already given away, because stability control will not allow you to go to the limits of the car anyways. So the vehicle takes, through the braking system, already a lot of stability control away from you. So road feedback, in most cases, is really something that makes people feel good for no good reason.
Q: Because you think people will go driving even faster when they are feeling more secure in the car?
A: I just think it's dating back to the times that you required the road feedback. You know, an experienced driver with a direct steering will always understand how much friction he has, how well the car is behaving while driving. But a lot of that is being taken over by electronic stability programs already. And the rest, I don't want anybody to drive the vehicle to the limit in open traffic, so road feedback delay is more an emotional value than a real benefit.
Q: And how is that for you as a driver, what do you see as the most important benefits?
A: I don't think that the drawbacks that you have matter. I am quite convinced that the benefits that you mention in the presentation driving experience are more important than the drawbacks.
Q: To you then, you mean?
A: Yes. I don't think that costs will be an issue, and driving experience doesn't matter anymore in that way. Our driving is dominated by electronics more and more. And I think it's more logical to completely embrace the electronics control acceleration, deceleration, vehicle stability, and also steering. It is giving you a false sense of control if you have a direct steering. I'm happy to have SbW and I don't think that it will feel much different than conventional steering at the end of the day.
Q: But do you actually see any drawbacks of SbW then?
A: One thing that I experienced with my Volvo, I should tell Matthijs Klomp about it, I was driving on the Autobahn in a relatively high speed when suddenly all displays in the car turned black. The first thing that I did was hit the brakes to see if I still had any control of the car, which I had. A situation like that is the very one thing that you would not want with SbW, and in the beginning it will be a hurdle to trust the system. Because when you lose power for whatever reason, that would be everybody's fear.
Q: I can imagine. And what about the redundant system in the car? In case of a failure the fallback mechanism will take it over.
A: Yes I'm an engineer, I trust engineering solutions. The thing is, I let someone else be the guinea pig. With plains, as you also mentioned, all of that is SbW today, and I don't think twice before entering a plane. Now if you would put a car in my driveway and say, 'Hey Martin this is the first Volvo model that's completely SbW. Don't you want to be the first customer for that car?', I would probably think twice. I would say, 'let somebody else do that'. Because there are bugs and I think that it will be completely novel very soon but those systems will have to prove themselves.

Q: So does that mean that you would not be an early adopter of the SbW system?
A: I probably wait a couple of years.
Q: Because you don't trust it yet?
A: Correct.
Q: And in the future, would you be open to be able to do any other activities while your car drives autonomously, for example sleeping or working?
A: Absolutely, yes.
Q: And what would you like to do while driving?
A: First of all, what I already do is I talk on the phone. I talk on the phone a lot. And most people do that, but I believe that very few people realize that it very often takes much more of your attention than you would admit. Specifically business discussions. And what I also do already: I have a new Volvo with pilot assist, which means the car drives quite independently in slow moving highway traffic. I read email, I answer whatsapp messages, and so on, and so on. You're not going to publish it to anybody, it's illegal, I know. I already do a bit of things on the side and definitely if I could rely on the car to drive, I would besides phone calls, emails, messaging, basically do everything that you do on your mobile phone in the car.
Q: And would you also consider working on your laptop, eating, or sleeping for example?
A: Sleeping is the biggest step, isn't it? Eating, definitely. Also working on the laptop, yes, all of that. As a matter of fact, you mention that without a real steering wheel, the steering wheel could go to the side, why not have a big monitor there and a keyboard? If I need to take control, than a small joystick on the side would be sufficient. I don't need to have a big steering wheel for the very few cases where the car probably tells me 'I can't see the lane markings, can you take control?'. That would be much easier without a steering wheel.
Q: Okay so that would be your ideal car?
A: Yes.
Q: And would it also be useful for you to remove the steering wheel in your car so that you have more cabin space to do your work?
A: Absolutely, yes.

<u>Price</u>
Q: Would you be interested in buying a normal car, so not autonomous driving car with SbW?
A: When I look at the benefits, if you give me a normal car that has a steering wheel, and you told me it doesn't have a steering column because it's SbW. Then the big question would be, what benefits do I have? There's just very little that I see as benefits. Safety, probably. The design falls out, because you still have a steering wheel. And on the driving experience I'm not so sure, I have to test it. In simple words: non-autonomous driving with SbW is a no-brainer.
Q: So you would rather have an AD car, with SbW, and without a steering wheel?
A: Correct.
Q: And what would be the additional price you would be willing to pay for that? I guess that you are not willing to pay extra for SbW in a normal car?
A: Indeed.
Q: So what would you be willing to pay extra for an AD car?
A: I take the Volvo V90 that I have now as a basis and I think that full autonomy would be worth, let's say €10.000. A significant sum for me.
Q: And would you prefer buying your autonomous driving car with or without SbW?
A: Clearly with SbW.
Q: And would you be willing to pay for the extra SbW if you have an autonomous driving car?
A: That's a lot of if's and when's. I said 10.000 for the autonomous driving, and that's a big one. Then to have the free space is probably another 1.000/1.500€.

Q: Then I think we have discussed every question that I had. Do you have any other questions, or thoughts on this topic that you are willing to share?
A: Yes I think this is a very very interesting technology. And just as a little philosophical side issue that I see, and that you're probably also thinking about, is that with all the enhancements of technology in years, plains are SbW but with a ton of back-up systems and so on. Automotive technology has to be much more cost efficient. And I think the time where we as humans really give up the steering wheel and the control and the computers, that's going to be a very interesting step. Because right now we discussed would you trust a car to drive autonomously, I believe that once we have autonomously driving cars, will come very quickly to a complete change in the perception where you will be blamed if you drive manually so to speak. Because computers will be better at driving than human beings. So the step to give up the steering wheel has very big implications overall. I'm following this whole development with a lot of interest, and I'm sure you will have fun over the next couple of years to follow what's really coming out of that.
Q: Yes I wonder how fast it will all go with the change to autonomous driving, the change to SbW, and removing the steering wheel, etcetera.
A: Yes that is a big question.
Q: But what do you think it has to do with cost efficiency like you said?
A: I don't think that cost is a problem. That's one aspect. With the plane in the air, what you need to do is ensure that control works most of the time, but still with the pilot at the controls. When we talk about going to autonomous driving, for planes it is very unlikely to hit another plane, in the air it is quite difficult to meet. But on the road, there are so many opportunities to hit something, and it's so difficult to do completely without human input. Plus once you release technology, millions of relatively untrained customers will use it. And that's the big challenge: how can I create a system that is fully proven enough, cheap enough, and reliable enough to stand up in real life for many many years of use. That's a challenge.
Q: Definitely. But I think it's interesting to see that even you as an engineer and fully into the automotive world, are not even going to be the early adopter of the SbW system. So there needs to be a group who is willing to buy it first. I was expecting that you would be one of them, since you're also very positive about the system, but still there is something that holds you against of being the early adopter.
A: Since so many things can go wrong in real driving, the big question is: how can I possibly test a system well enough to ensure that it's safe. And that is exactly the engineer in myself that accepts that nothing is 100% safe. Over time you can get quite close to 100% safety, but expecting that the first product on the road will be 100% safe is a high margin.
Q: Yes definitely. I think I have a good picture of you as a Volvo driver. Actually you're two types of driver, the fun driver and the work driver.
A: Exactly.

Q: I think we are coming to the end of this interview. Would you be interested in receiving as summary of the results of our results?
A: Absolutely, I would be very interested if that is possible.
Q: Okay, then I will send you a summary of the research via email. Thank you very much for your time and feedback.
A: It's been a pleasure, I really much liked it and good luck to you with your research. I hope something interesting comes out of it.

Interview 3

Q: I have sent you a presentation about SbW, is anything unclear about that?
A: Well, I'm not very technical, so I would like to try it out first to give a good opinion about it. That is not possible yet of course, but overall it is clear to me.
Q: Okay, good. We will talk about SbW, a new steering technology that is being developed. It is electronic steering, instead of mechanical steering. We will first talk about you as a Volvo customer, after that about benefits and sacrifices of SbW, and lastly about the price.

Customer type
Q: May I ask your age?
A: I am 59
Q: And your home country?
A: The Netherlands
Q: Which Volvo model do you drive?
A: XC60
Q: Are you interested in new technology in general?
A: Not all technology, only if there is a benefit for me, for example more user friendly, and technology that is making my life easier.
Q: And are you interested in new technology in cars?
A: Yes, if it is useful for me, and has a better quality, and safer, yes.

Benefits & Sacrifices Steer-by-Wire
Q: And what was your first reaction to SbW?
A: My first reaction was that I thought it would be useful for me. I always struggle with parking, and I think SbW is making that easier.
Q: And would you be comfortable using SbW?
A: I think for me I have to get used to it, because I like to have control over my car. But I think it has benefits for me. By the time I'm used to it I think I would be comfortable using it, yes.
Q: Okay, and what do you think of the benefits of SbW you saw in the presentation. Which benefits would be most important to you? So, improved safety, design freedom, and improved driving experience.
A: Safety is my top priority, removing the steering wheel is not necessary for me, and improved driving experience, and easy parking are also important to me. So safety would be most important to me, driving experience is number 2, and design is least important to me.
Q: And do you see any other benefits of SbW?
A: I think you named the most important benefits to me.
Q: Okay, and what about the sacrifices, how important are they to you? For example, costs will be higher compared to a conventional steering system. And to some people, changing driving experience can be a sacrifice, and like to feel the road. But other people like smoother driving.
A: Yes I think driving experience is not so important to me. But regarding the costs, I would pay more if it is useful for me. Mostly I buy used cars, but if I can chose between a used car with or without SbW, I would chose with, also if the used car with SbW is more expensive.
Q: Okay, and do you see any other drawbacks of SbW?
A: No
Q: And when driving, do you want to do any other things than driving?
A: I am someone who never wants to lose control, so I will always check if everything is going well. Perhaps, I can relax for a few minutes, but I would never do anything else, like being on my phone or sleeping. Just relaxing, and enjoying the scenery, but still keeping an eye on the road, so that I can take over if necessary.

Q: Okay, so you like it if your car could drive fully autonomously, but you would still want to check if everything is going well?
A: Yes.
Q: And for example, sleeping or eating?
A: No, definitely not.
Q: Okay, clear.

Price of SbW
Q: I would like to talk about the price of SbW. Would you be interested in buying a normal car, so not autonomous driving, but with SbW?
A: Yes, I think I would like to have it in my next car.
Q: Okay, and why?
A: Because it has benefits compared to existing cars, and I think for me it improves quality of driving.
Q: And what is the extra price you are willing to pay for SbW in a normal car, when the price is between 0 to 5,000 euros?
A: I think for a used car I would pay 4,000 euros extra if it has SbW.
Q: And are you interested in buying an autonomous driving car.
A: I think in a few years yes, when there are more autonomous driving cars on the road.
Q: And why?
A: For safety reasons, I think it is safer.
Q: So you think it is safer when all cars drive autonomously, but still you would like to have control when needed?
A: Yes, but I think I can never 100% let go of control. But this is how I think about it right now. Maybe when all cars are driving autonomously, it would be a different story.
Q: What is the price you are willing to pay extra for autonomous driving cars? That price will be higher. What if you can chose between a normal car, and an autonomous driving car?
A: Good question, I think I would pay 15,000 euros extra for it.
Q: And if you are buying an autonomous driving car, would it be one with or without SbW?
A: In that case I would prefer an autonomous driving car with SbW.

Q: Okay good, than we have discussed all my questions. Do you have any other questions or comments?
A: No, but it is so hard to imagine what it is like, driving with SbW. It should be possible to try a car with SbW, and see how that feels.
Q: And would you be interested in receiving the results of this research?
A: Yes, definitely.
Q: Okay, I will email you a summery when I finish my research.

Interview 4

Q: Is anything unclear about the SbW presentation?
A: No no, it was all clear.
Q: Allright. First I'll explain what kind of questions I'm going to ask. I would like to know more about you as a driver, then I'm going to ask some things about the benefits and sacrifices of SbW, and in the end I'm going to ask about the price.

Customer type
Q: May I ask your age?
A: I am 56
Q: And your home country?
A: The Netherlands
Q: Which Volvo model do you drive?
A: I'm driving an XC90
Q: Okay, and are you interested in new technology in general?
A: Yes, I'm an engineer, so always interested in new technologies.
Q: And are you interested in new technology in cars as well.
A: Yes, also, the more advanced, the more I like it. I think that the car industry is now one of the leading industries in new innovations.

Benefits & Sacrifices Steer-by-Wire
Q: So now we go on to SbW itself. What was your first reaction to SbW?
A: I thought, why not? Because we fly by wire already for centuries.
Q: That's right, it's being used in planes for years as well. And would you be comfortable using SbW?
A: Yes, as soon as I have the confidence that it is reliable, and tested I would be comfortable using it.
Q: And what do you think of the benefits of SbW and its importance for you, how would you rate the benefits safety, design, and driving experience?
A: I think the active and passive safety are the most important things, and that would mean that I can concentrate less on the steering and do some other things at the same time, like watching at the driving schedule, answer messages, listen to music.
Q: Okay, so safety is your most important benefit?
A: Yes
Q: And how about the other benefits, design and driving experience, are they important to you?
A: No not so much, I'm very satisfied with the driving experience I have. Because I now have the adaptive cruise control, plus lane keeping assist, that is already very comfortable.
Q: Okay, and do you see any other benefits of SbW?
A: Yes I think one other benefit is that you can have the freedom to design more space for your legs with SbW. Now, you always see that you step in your car and you have to go underneath the steering column. If it's not there anymore it gives more space and more freedom to move also during the driving.
Q: Yes, that is actually one of the main benefits we mention in the presentation: design. And do you maybe see any additional benefits to that?
A: I think the future car will be more sophisticated, and probably the SbW system gives more possibilities to improve all kinds of safety devices and combinations in the future. It will give more flexibility, will be faster, and more accurate.
Q: And what do you think about the sacrifices of SbW and its importance, cost and driving experience, how would you rate them?
A: I think the sacrifice of SbW is the cost, but the extra safety and extra comfort you get with SbW outweigh the cost I think.

Q: Okay, and do you see any other drawbacks, other than cost and driving experience?
A: The only thing which could also matter is that electronic devices could be sensible for all kinds of influences like radio frequency, or interference or other things that could maybe influence the stability of the system. So this must be properly proven and tested that it is safe.
Q: And when you are in your car, would you like to do other things while driving?
A: Yes, yes. Many of the things you do while driving are very repetitive, doing many things at the same time, keeping distance from other cars, it asks for a lot of concentration that can be taken over by electronic devices, because it is boring.
Q: And what would you like to do while driving, if your car can drive autonomously?
A: I would answer mails, whatapp messages, communicating with the rest of the world, maybe listen to some music, and calling people.
Q: And assume your car can drive autonomously, would it be useful for you to remove the steering wheel so that you can have more cabin space? I thought you already mentioned something about it.
A: Yes, but it seems a little bit frightening that you cannot have control yourself at any time if you need it. So I would like to have something which could be similar to a steering wheel, but I want to be able to take over control very quickly if I need it.
Q: Like what?
A: Maybe a joystick, or a small steering wheel as you see with pallet lift trucks also, that you can steer with a small wheel or whatever.

Price of SbW
Q: Okay, finally I would like to ask you about the price of SbW and AD. Would you be interested in buying a normal, so not AD car, with SbW?
A: Yes, yes, I like new features, it gives more safety, and it's more comfortable.
Q: Okay and what would you be willing to pay for SbW in a car, if I give a range from 0 to 5,000 euros?
A: I think 5,000 is already quite a lot of money, which should be the maximum. But i'm not used to buy special features, but more packages, so buying a business package, or safety package, or whatever.
Q: So what would be a good additional price for you?
A: It should not be more than 5,000 euros, I think until 5,000 is reasonable. There is also a sound system in my car which costs about 3,000 euros, which is nonsense I think, but the steering system is more valuable to me, so I would be willing to pay a higher price for that.
Q: And would you be interested in buying an autonomous driving car?
A: Yes, but till now I'm not convinced that it is completely finalized and ready for the mass production market so far.
Q: Okay, and what is the price you are willing to pay extra for the autonomous driving feature? From 0 to 20,000 euros?
A: I think 20,000 is already the maximum. Because you can buy a lot of electronics for that price. I think I would pay 10% extra for a car with AD.
Q: And would you prefer a car with or without SbW?
A: The normal system we are using in cars right now are very old fashioned and should be replaced by more advanced techniques. If you are combine AD with old fashioned steering techniques, it's like you are combining very high techniques with a steam machine, which is a very strange. So I think it is necessary to use SbW in combination with autonomous driving.

Q: Okay now we are coming to an end with the interview. Do you have any questions or comments or concerns?
A: No.
Q: And are you interested in receiving the results of our research?

A: Yes please.
Q: Okay, then I will send you a summary by email.