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Business scenarios for Virtual Traffic Lights

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Title: Business scenarios for Virtual Traffic Lights

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Problem description:

Virtual Traffic Lights (VTL) is a novel technology, providing in-vehicle traffic information for cars and is visioned to replace traditional traffic lights in the future. In order to have a successful deployment of VTL, there is a need for a secure and robust communication infrastructure, as well as sustainable business models for the actors involved in the VTL ecosystem. In this master thesis, the student will look into various technological and business aspects of VTL. The general goal is to design and provide a business model for VTL. The objectives include:

- Exploring the current state of VTL, which technologies are required for implementation of VTL and how they fit in with the current Intelligent Transport System (ITS) effort, security issues, socioeconomic gains, and if the departments of traffic in various countries have any plans to implement VTL

- Provide a realistic business model for VTL:

  - Model the actor ecosystem by providing a business model. The business model will explain, among other things:
    * Who are the actors in the ecosystem
    * Who is going to pay for implementation and enabling technologies
    * Are there any revenue streams attached to the implementation of VTL
  - Provide suggestions for migration strategies to enable a streamlined transition from traditional traffic lights to VTL

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Abstract

Virtual Traffic Lights (VTL) is a novel technology which aims to provide ubiquitous traffic intersection control by removing physical traffic lights and placing them inside vehicles. It has already been proven, through simulation, that VTL is capable of significantly increasing traffic flow and reduce CO2-emissions and fuel consumption for individual vehicles.

To ensure a streamlined transition from traditional physical traffic lights to VTL, several issues must be addressed. This thesis addresses the issues regarding the business related aspects and migration of VTL. To provide alternatives for migration and a business model for VTL, the ecosystem of included actors surrounding VTL is presented and explained. Benefits different actors will experience from the introduction of VTL is also presented.

The current state of the adoption of VTL and the technologies to facilitate adoption, is presented along with how central actors might react to different scenarios regarding the adoption of VTL using economic theory. Further, a business model for the service is proposed using the Osterwalder business model canvas. In the business model it is proposed that the company taking VTL to market will work as a software company, and it is proposed to distribute the service as Software As A Service (SAAS).

It is further concluded that the deployment of VTL requires action from governmental level to ensure interoperability and to facilitate ubiquitous deployment. Lastly, further work regarding VTL is proposed based on the research potential discovered through working with the business aspects of the service.

Sammendrag

Virtuelle trafikklys(VTL) er en ny teknologi som har som mål å tilby allstedsnærværende trafikklyskontroll ved å fjerne trafisjonelle trafikklys fra gatene og plassere de inne i bilene. Det har allerede blitt vist, med simulering, at VTL er i stand til å drastisk bedre trafikkflyten og redusere CO_2-utslipp samt bensinforbruk for individuelle biler.

For å forsikre en god overgang fra tradisjonelle trafikklys til VTL, er det flere spørsmål som må adresseres. Denne avhandlingen adresserer spørsmålene relatert til business-aspektene og migrasjonen av VTL. For å kunne foreslå alternativer for migrering, og en businessmodell for VTL blir økosystemet av aktører rundt tjenesten presentert og forklart. Fordelene de forskjellige aktørene opplever ved at VTL blir introdusert blir også presentert.

Den nåværende situasjonen rundt innføringen av VTL og de teknologiene som må ligge til grunn før VTL kan bli implementert blir presentert. I sammenheng med dette vil det bli vist hvordan sentrale aktører vil forholde seg til forskjellige scenarioer som kan oppstå ved innføringen av VTL, ved bruk av økonomisk teori. Videre vil en businessmodell for tjenesten bli presentert ved å bruke Osterwalder-modellen. I businessmodellen blir det foreslått at selskapet som tar VTL til markedet vil operere som et softwareselskap og at tjenesten burde bli distribuert ved å bruke "Software As A Service(SAAS)"-prinsippet.

Videre blir det konkludert at innføringen av VTL krever handling fra sentrale myndigheter for å forsikre interoperabilitet og får å tilrettelegge for en allstedsnærværende innføring. Til slutt blir videre arbeid knyttet til VTL foreslått.

Preface

I would like to thank Harald Øverby and Wantanee Viriyasitavat for great and valuable guidance throughout this master's thesis

I would also like to thank Haakon Garseg Mørk and Haakon Waage for their editorial work and general suggestions for the thesis.

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List of Acronyms

C-ITS Cooperative Intelligent Transport System.

DOT U.S. Department of Transportation.

DSRC Dedicated Short-Range Communication.

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EEIS Energy Efficient Intersection.

EU European Union.

GPS global positioning system.

ISP Internet Service Provider.

ITS Intelligent Transport System.

NHTSA National Highway Traffic Safety Administration.

NTNU Norwegian University of Science and Technology.

OBU on-board unit.

OEM Original Equipment Manufacturer.

RLW Red Light Violation Warning.

RSU road-side unit.

SAAS Software As A Service.

SCATS Sydney Coordinated Adaptive Traffic System.

SCOOT Split Cycle and Offset Optimisation Technique.

SPaT Signal Phase and timing information.

UTOPIA Urban Traffic Control System Architecture.

V2I Vehicle-to-infrastructure.

V2V vehicle-to-vehicle.

VANET Vehicular Ad Hoc Network.

VAS Value Added Service.

VASP Value Added Service Provider.

VTL Virtual Traffic Lights.

Chapter 1

Introduction

1.1 Background and motivation

Intelligent Transport Systems(ITS) are well on their way to being integrated in large parts of the world. Increasingly smart road networks aims at making traffic flow better, improving safety and reducing the carbon footprint caused by traffic.

With road traffic injuries predicted as the third most common cause of death by 2020[10], and CO2-emissions from the transport section being responsible for 31% of the current total emissions in the U.S.[11], there are large incentives for improvement.

The Norwegian Public Roads Administration(NPRA) estimates that intersections governed by traffic lights experience less serious traffic accidents and a total accident reduction of 15-30%. It is also estimated that small improvements in the signal systems can provide large socioeconomic benefits, e.g. better traffic flow which will lower CO2-emissions[12].

VTL is a proposed technology which aims to remove physical traffic lights and putting them inside the vehicles. By doing so, one can obtain ubiquitous traffic intersection control by providing every intersection with traffic lights, created only when needed. In order for this to be realized, several issues must be addressed. Implementing such a service over large geographical areas require a high level of cooperation between the actors involved. This thesis aims at addressing issues regarding the business scenarios for VTL, i.e. modeling the actor ecosystem, providing alternatives for migration scenarios and providing a business model for the service.

1.2 Problem description

Virtual traffic lights (VTL) is a novel technology, providing in-vehicle traffic information to cars and is visioned to replace traditional traffic lights in the future. In order to have a successful deployment of VTL, there is need for secure and robust

communication infrastructure, as well as sustainable business models for the actors involved in the VTL ecosystem. This thesis will mainly focus on the business related aspects regarding VTL, while providing the necessary technological background information. The main goal for this thesis is to model the actor ecosystem, provide migration alternatives for the most central actors and provide a business model for VTL. The problem description has not been changed much after it was first submitted. The only change is that the security issues connected to VTL have not been prioritized.

1.3 Methodology

1.3.1 Background material

To gain knowledge about the necessary technologies, political aspects and related work, background material was located through the use of search engines for scientific papers, i.e. Google scholar[1] and Scopus[2]. For this thesis it was necessary to also understand how legislation, regulations and working processes for road authorities and public authorities are conducted. Two meetings with different employees from the Norwegian Public Road Administration[3] was conducted. One meeting was with Terje Reitaas and Erik Olsen, while the other meeting was with Ørjan Tveit. These meetings served as an introduction to ITS in Norway, how the road authorities in Norway work, as well as providing resources for locating ITS organizations in other parts of the world.

1.3.2 The actor ecosystem

The actor ecosystem of VTL is modeled using insights learned from studying VTL and the organizational structure of similar services as a basis. The model provides an overview of all the actors surrounding the VTL service. All actors are thoroughly explained in chapter 4.

1.3.3 Benefits of VTL

Based on relevant literature, the benefits from the deployment of VTL for each of the actors in the ecosystem are represented.

1.3.4 Migration strategies

Strategies to accelerate and streamline the adoption of VTL, and the necessary technologies required for implementation, are explored using economic principles and

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[1]google.scholar.com
[2]www.scopus.com
[3]www.vegvesen.no

by investigating how other parts of the road network are financed. In this thesis, the decision was made to use economic theory to highlight several migration alternatives rather than going in-depth with one alternative. This is because of the complexity and many uncertainties regarding the market surrounding VTL, which will be further explained in chapter 6, Migration.

1.3.5   Business model

A business model for VTL is proposed using the Osterwalder business model canvas. The business model canvas utilizes 9 building blocks to answer important questions of a company's business model such as 'who are our key partners?' and 'how are we providing value to our customers?

1.4   Limitations

Because of limited time, this thesis will mainly focus on the business related aspects of VTL. Seeing as VTL is a service which might be implemented several years in the future, some assumptions about VTL and the organization surrounding the service have been made. These assumptions are listed in the thesis, where they are relevant.

VTL is a service which aims at providing ubiquitous traffic intersection management. This causes the potential customers of VTL to be very large entities e.g. the European Union (EU). Governments in different countries have different economies and road networks. To limit the scope of this thesis, most examples provided in this thesis might be more viable in Norway than other countries.

Because this thesis will mainly focus on the business aspects of VTL, the security aspects listed in the problem description have been largely ignored.

1.5   Contributions

This thesis provides the following academic contributions:

- A model of the actor ecosystem surrounding VTL, this is found in chapter 4

- A thorough explanation of each actor's role in conjunction with VTL, this is found in chapter 4

- A collection of the benefits VTL provides for each actor in the ecosystem, this is found in chapter 5

- Alternatives for migration to accelerate the adoption rate for enabling technologies and VTL, this is found in chapter 6

- A business model for VTL using Osterwalder's business canvas, this is found in chapter 7

1.6   Outline

This thesis is divided into chapters, a short summary of the contents of each chapter will be presented below.

Chapter 2 will provide the reader with background information necessary to the rest of the thesis. The concept of VTL, other traffic signal control systems and some relevant background theory will be presented.

Chapter 3 will provide an overview of similar work done by other researchers or entities which is relevant to this thesis.

Chapter 4 will present the actor ecosystem and provide a thorough explanation of each actor included in the system.

Chapter 5 will present the benefits each actor in the ecosystem will have from participating in the market surrounding VTL.

Chapter 6 will provide the reader with the current political situation regarding the adoption of ITS and the technology needed for the implementation of VTL. This chapter will also provide alternatives for migration regarding enabling technologies and VTL

Chapter 7 will provide the business model for VTL using the Osterwalder business model canvas.

Chapter 8 will conclude the work done in this thesis, and provide suggestions for further work.

Chapter 2

Background

The aim of this chapter is to provide the reader with the sufficient knowledge to fully understand the Virtual Traffic Lights (VTL) concept, and give insight into how intersections with traffic signals are controlled today. Some relevant theory concepts will also be presented in this chapter.

2.1   Vehicular Ad Hoc Networks

Vehicular Ad Hoc Networks (VANETs) is a type of wireless ad hoc network to provide communications among vehicles and road side equipment. A goal of VANETs is to provide efficient vehicle-to-vehicle (V2V) communication to enable ITS[13]. VANET applications are often split into two categories: ITS applications and comfort applications. ITS applications include applications such as on-board dynamic navigation, cooperative traffic monitoring and analysis of traffic congestion. These applications convey messages either V2V or Vehicle-to-infrastructure (V2I). Mobile nodes in VANETs can also be used to convey information about traffic accidents such that approaching vehicles receive warning. Comfort applications are applications which allow users to communicate with other vehicles or with Internet hosts to improve their comfort, such as VANETs providing Internet connectivity to a user so that e-mail can be accessed. VANETs generally does not rely on fixed infrastructure, but can use infrastructure to assist with e.g. propagation of messages. V2V communication and VANETs are technologies needed for VTL. For VTL, the capabilities to participate in a VANET will be included in an on-board unit(OBU) installed in the vehicle.

2.2   Virtual Traffic Lights

VTL is a technology developed in collaboration between Carnegie Mellon University and the University of Porto. It is a technology that attempts to solve the rising problem of traffic congestion which cost 1% of EUs total GDP in 2010 [14]. With VTL, the traditional roadside traffic lights will be removed and represented with

virtual signs inside each vehicle. These virtual traffic lights will be supported, ideally only by V2V technology, mainly over DSRC radio[15]. Intersections where there are potential conflicts will be managed by vehicles approaching the intersection by creating a VANET between said vehicles.

The implementation of VTL is based on the following assumptions[14]:

- All vehicles must be equipped with DSRC devices

- All vehicles share the same digital road map

- All vehicles have a GPS device that guarantees global time and position synchronization with lane-level accuracy, i.e. the GPS needs to be able to accurately determine which lane a vehicle is driving in

- The security, reliability, and latency of the wireless communication protocol is assumed to be adequate for the requirements of the VTL protocol
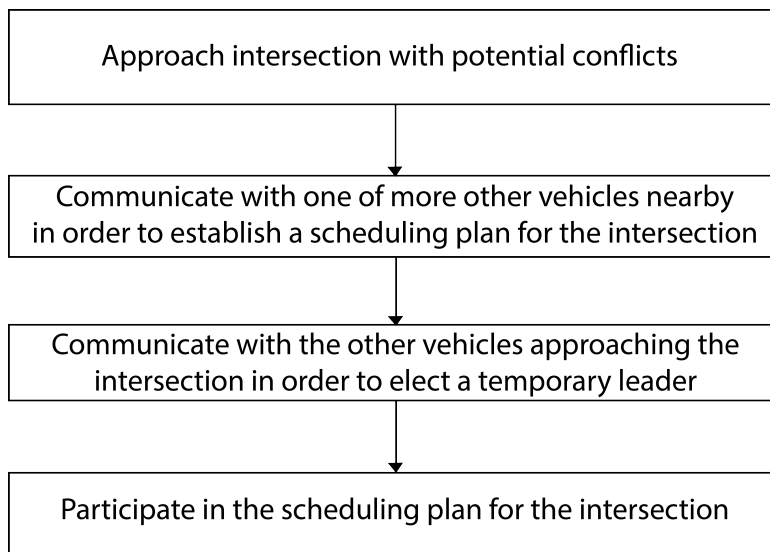
Figure 2.1: Simplified flowchart for a vehicle approaching an intersection, inspired by[1].

The hardware required for VTL to be implemented will installed as an On-Board Unit(OBU) in the vehicles. Figure 2.1 depicts a simplified flowchart for a vehicle approaching an intersection with VTL. The vehicle will continuously transmit beacon-type signals containing information about e.g. the velocity, heading, speed, vehicle-type, prioritization etc[1]. Each vehicle is capable of transmitting and receiving such

messages. If there is a potential conflict zone nearby, the participating vehicles will form a VANET to prepare a scheduling plan for the intersection[1]. The scheduling plan is a plan containing scheduling for when vehicles from the different approaches leading to the intersection will have green or red lights presented. The approaching vehicles have to elect a "leader" which will coordinate the vehicles and ensure the scheduling plan is executed.
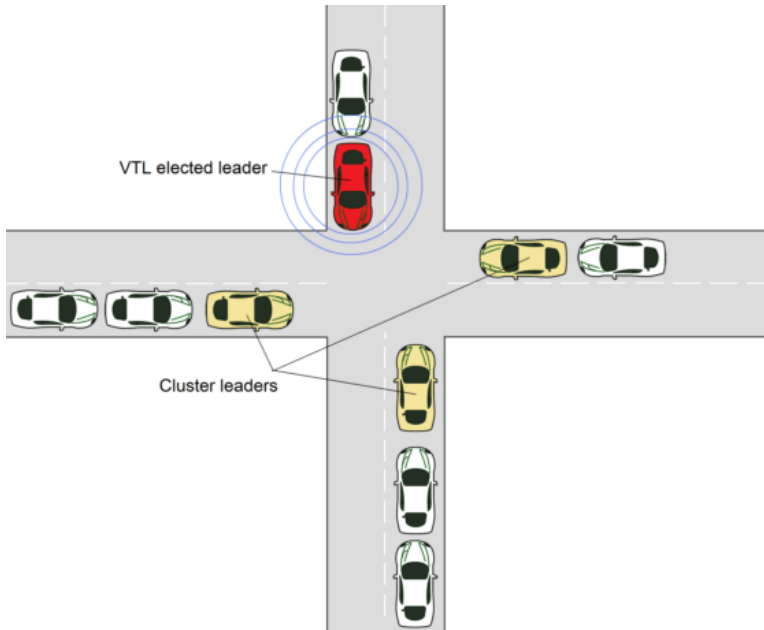
Figure 2.2: Leader election in virtual traffic lights [2].

If no leader is elected when a vehicle is approaching an intersection where conflict is detected, one must be elected. First, an algorithm should resolve the cluster leaders of each group of vehicles arriving from different lanes. When the cluster leaders have been elected, they should communicate with each other and utilize a leader election algorithm to decide which vehicle should take on the role as leader. The cluster leaders and elected VTL leader are depicted in figure 2.2. The leader should then present his cluster, including himself, with a red light so that a new leader should not have to be elected immediately. The leader executes the scheduling plan until a preset condition, i.e. a timer, applies. If there are no more conflicts in the intersection, the leader concludes the VANET and proceeds through the intersection. Should there still be conflicts in the intersection, the leader passes on its role to another vehicle and proceeds to cross the intersection[16].
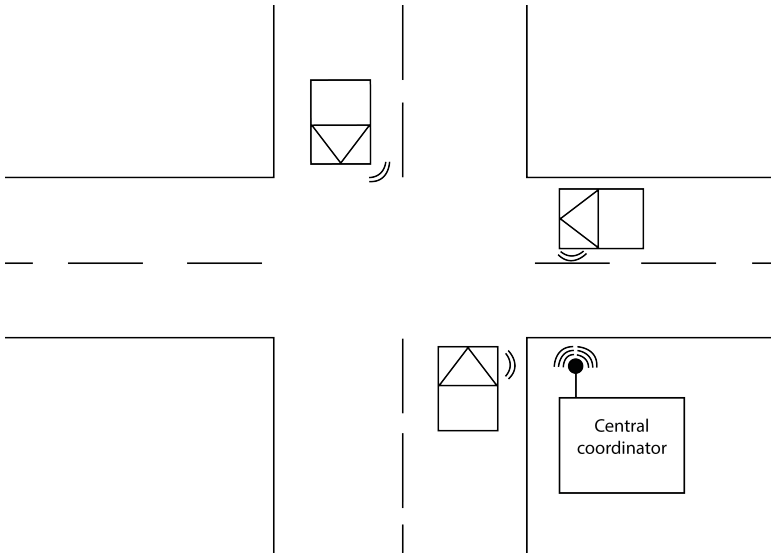
Figure 2.3: Traffic coordinated with VTL through a RSU, inspired by[1].

Figure 2.3 shows a configuration of VTL where a road-side unit (RSU), named "central coordinator" in the figure, is used to coordinate the traffic in the intersection. Such units can be installed in e.g. densely built areas to assist with propagation of signals sent by the vehicles. Such a configuration will also be useful during low penetration of VTL and the required technology, i.e. DSRC. Another solution is to use the cars themselves as RSUs, this has been researched by Tonguz et. al[17]

2.3 Traffic signal control systems

Traffic signals can be managed in several different ways. In its simplest form, traffic lights have a static time interval which controls when there is a red, yellow or green signal presented to a given approach, also called cycle-time or green-split. Adaptive systems utilize different methods and information to manage intersections in a dynamic way to improve traffic flow. In this section different systems, which are deployed to some degree around the world will be presented. This is done to give the reader insight into how traffic signals are controlled today.

2.3.1 Compass 4D

Compass 4D is a project aimed at implementing cooperative ITS services in order to improve road safety, increase energy efficiency and reduce congestion for road transport[18]. Compass 4D is currently in the pilot project state in 7 countries

around Europe, offering three different services, two of which are linked to traffic signalling[19].

Red light violation warning

Red Light Violation Warning (RLW) is a service which aims to lower the severity of intersection accidents by warning the driver if one of the following events is about to occur:

- The driver is about to run a red light

- Another driver in the same intersection is about to run a red light

- An emergency vehicle is approaching the intersection and is likely to run a red light

- The driver is warned while turning, if more than one approach has a green light

- The driver is warned if cyclists/pedestrians are also acting on a green light at the same time as the driver

The data produced by the service can be conveyed by either 802.11p, the V2V and V2I communication protocol, or through 3G/4G from e.g. a traffic management centre.

Energy efficient intersection

The Energy Efficient Intersection (EEIS) service aims to reduce the energy use and vehicle emissions at signalised intersections[19]. By utilizing V2I communication the Signal Phase and timing information (SPaT) can be sent to the vehicle such that it is possible to anticipate the current traffic signal phase. EEIS has the following functions:

- Drivers get information on how to best decelerate towards an intersection based on the current signal phase to induce the most energy efficient speed

- Information about remaining time until a green-light is used to turn the engine on and off

- Information about when the traffic signal will turn green is presented to the driver so that he/she can be ready when the light turns green and time wasted is reduced to a minimum

- EEIS offers the possibility to prioritize certain vehicles in traffic such as emergency vehicles or heavy goods vehicles

EEIS uses the same means of communication as RLW, either 802.11p or 3G/4G.

2.3.2 UTOPIA

Urban Traffic Control System Architecture (UTOPIA) is an adaptive traffic signal management system currently deployed in several cities in Europe including Oslo and Trondheim in Norway.
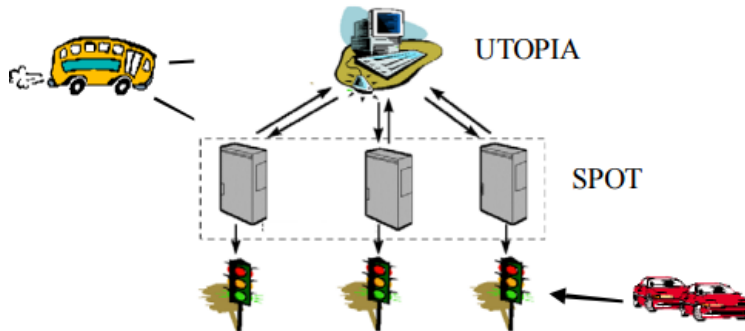
Figure 2.4: UTOPIA[3]

Figure 2.4 depicts how UTOPIA works in practice. The system has two schematic objectives:

- No public transport vehicles should be stopped at signal regulated intersections

- Other traffic should not experience deterioration of traffic flow as a result of the first objective

To achieve this, UTOPIA utilize a distributed approach with three layers. A central unit is used for surveillance and data collection, industrial computers are integrated in local coordination areas to control the optimization of intersections, in its proximity, and the traffic signals. By using detectors, the system analyze the traffic coming from each approach as a basis for optimization [3]. UTOPIA claims to decrease travel times by 15% for private traffic, 50% reduction in queue times and a 10% decrease in emissions and fuel consumption in urban areas[20].

2.3.3 SCATS

Sydney Coordinated Adaptive Traffic System (SCATS) is an adaptive urban traffic management system that synchronizes traffic signals to optimise traffic flow across a

whole city, region or road section [21]. SCATS mainly use inductive loops[22] in the ground to detect vehicles driving through an intersection. It is a real-time system which adapts to the current traffic situation. Rather than optimizing each intersection separately it uses algorithms to streamline traffic in larger areas containing several intersections.

SCATS is a large scale system which has been sold to 27 countries world-wide. A study conducted on a road containing 21 intersections, in Sydney Australia, over 24 hours showed that SCATS reduced travel time by 28%, traffic stops by 25% and a potential reduction in CO_2 emission by 15%[23].

2.3.4   SCOOT

Split Cycle and Offset Optimisation Technique (SCOOT) is an adaptive traffic signal control system which uses vehicle detectors to determine a queue estimate and optimise traffic signals. When the system detects a vehicle it computes the time the vehicle will use to reach the intersection at normal cruising speed.
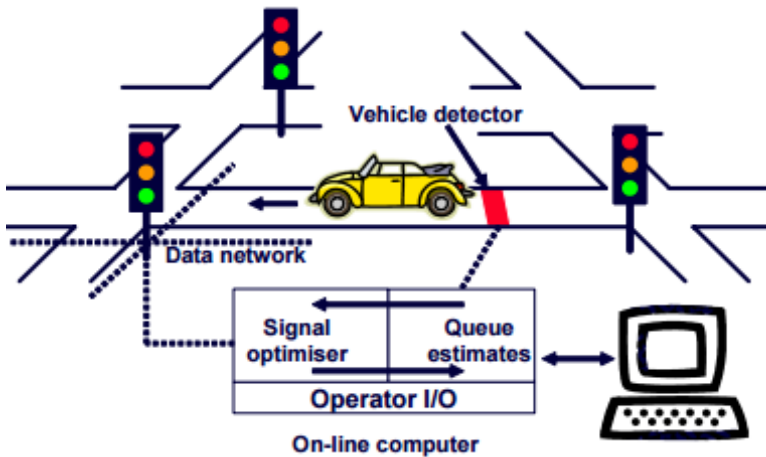
Figure 2.5: The SCOOT system simplified [4].

Figure 2.5 depicts a simplified version of the SCOOT system. The data gathered from detected vehicles is used to compute three key traffic control parameters: the green-split for each approach at each junction, the time between adjacent signals (offset) and the time dedicated to each approach in each intersection (cycle time)[4]. With these parameters SCOOT optimizes the intersections within the working area of the service.

SCOOT has been demonstrated in 14 countries and claims to reduce traffic delays with over 20%[4]. The system also has the possibility for public transport priority and incident detection.

2.4   Network externalities and critical mass

There exists many goods where a user gains increased utility if other consumers own the same good. This utility increase can come in several forms. A consumer would not experience much utility from owning a cellphone if he/she was the only person in the world with a phone, the consumer would gain increased utility for each additional user purchasing a cellphone because of the increased network[24]. This type of utility increase is known as a direct network externality where a consumer experiences a direct advantage from increasing amount of users in a network. There are several indirect effects as well; a user purchasing a specific gaming system will be concerned with the amount of people purchasing the same system because the companies developing software for the gaming systems will look for the platforms where they can achieve the largest profits. A gaming system with low sales will probably have less software developed for it, causing the utility for its users to be lower as a result of few consumers in the network.

Rogers defines critical mass as: "the point at which enough individuals have adopted an innovation that the innovation's further rate of adoption becomes self-sustaining"[6]. Critical mass is especially important in innovations where network externalities are present as each additional user joining the network towards the critical mass point will gain utility from the other users already in the system. A user joining the network will not only increase the utility for users already in the network, but also lower the threshold for future adopters to join the network[6]. Critical mass is a way of formalizing the "chicken and egg"-paradox; consumers refuse to enter a market because the installed user base is too small, and the installed user base is too small because an insufficient amount of consumers have entered the market[25].

Figure 2.6 depicts a demand curve with quantity Q based on expected quantity Q^x, for a given price, in a market with network externalities. One can see that when the expected quantity sold is zero, the actual quantity demanded will also be zero. With increasing expected demand, the curve will shift upwards. The shift will be steep at first, as one additional user when the network is small will have a larger positive network effect than an additional user when there are already many users in the network. The expected demand curve will flatten out as each additional user brings less benefit for the other users. The red, 45°, line represents where expected quantity equals actual quantity. between point C and H the expected demand is higher than the actual demand, to compensate for this, actual demand will be driven up all the way to point H where there will be an equilibrium. As can be seen from the figure
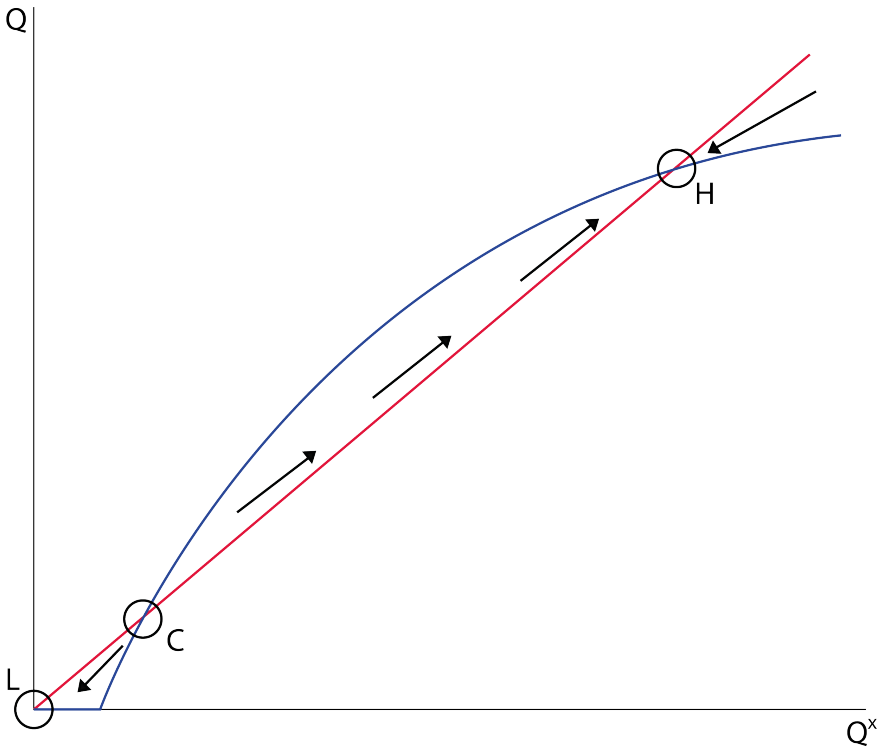
Figure 2.6: Quantity demanded based on expected quantity, with a given price, in a market with network externalities[5]

there are 3 equilibria in this market; L, C, and H. The equilibrium existing at point C has a different characteristic than the other equilibria. If one additional user joins the network at point C, the market will be driven towards H. If however, one user decides to leave the market at this point the market will be driven down to L. C is defined as an unstable equilibrium, and can be seen as a presentation of the critical mass. If the market manages to obtain enough users to surpass the critical mass, the market will be driven towards a stable state where it is self-sustaining. Should the market fail to do so, the market will never take off beyond the critical mass and end in a market-failure[5].

Network externalities and critical mass for VTL

Network externalities and critical mass can be applied to many different markets. For VTL, and V2V communication as a whole, it can be seen that it is a market exhibiting direct positive network externalities. A consumer purchasing a vehicle

with V2V communication capabilities will have little utility if it is the only vehicle with such capabilities. For each additional user purchasing a vehicle capable of V2V communication, the utility for all the users in the network will grow as well as increasing incentives for new users to join the network of V2V communication enabled vehicles. As will be further explained explained in section 6.1, one of the biggest challenges facing the adoption of VTL is getting the penetration rate of DSRC devices in vehicles to a percentage where VTL becomes viable.
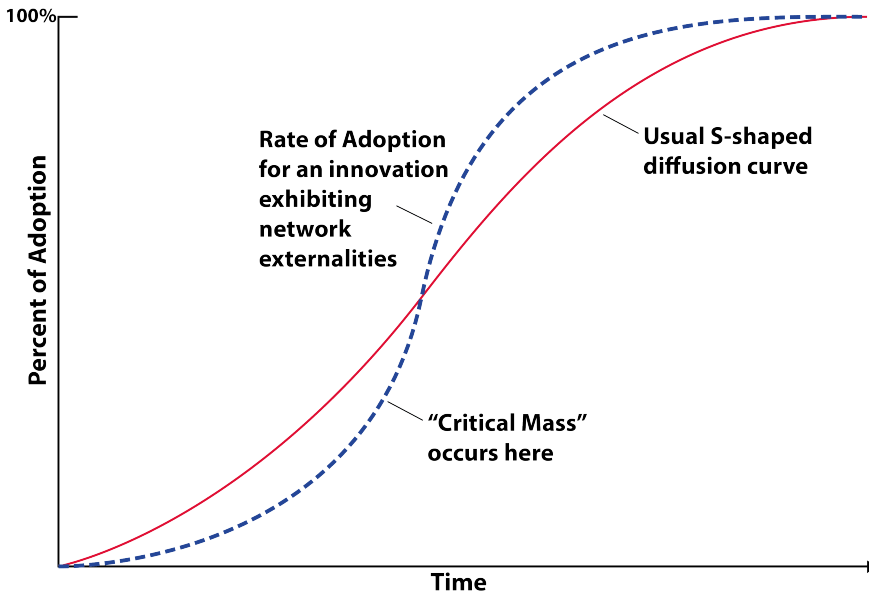
Figure 2.7: The rate of adoption for usual innovations and innovations exhibiting network externalities, showing the critical mass. inspired by [6].

Figure 2.7 depicts the rate of adoption for an innovation exhibiting network externalities compared to regular innovation, as a function of adoption percentage and time. This graph can be applied to the adoption of V2V enabled vehicles to get an idea of how the adoption rate of DSRC devices might look. It is vital for the stakeholders in the ecosystem to provide means to reach the critical mass to avoid a market failure. Such means can be e.g. providing increased subsidies for early adopters or bundling the DSRC device with the vehicle.

Chapter 3

Related Work

Making traffic more efficient and leave less of a strain on the environment have been the goal of many studies over the last few years. A big part of this revolves around traffic coordination in intersections, as these represent bottlenecks in the traffic system. This chapter will give an overview of related work to this thesis.

3.1 Related Work

Gradinescu et al. proposes an adaptive traffic light model using V2V communication where the vehicles approaching an intersection forwards information about heading, speed, etc. to a control unit residing in the intersection which can then discern if the intersection is crowded or not. Based on this information the control unit formulates optimal cycle times and green-splits for each approach. The authors show, through simulation, a decrease in total delay for vehicles of 28.3%, Fuel consumed by 6.5% and CO_2 emissions by 6.5%[26]. The difference between the work done by Gradinescu et al. and this thesis is that this thesis explicitly address VTL as a mode for intersection management.

Tonguz et al. proposes an implementation of VTL with partial penetration using game theory. The authors utilize a grid-based topology to propose a scheme where some lanes are dedicated only to VTL enabled vehicles. Figure 3.1 depicts an example of such a scheme with three different configurations where the green lanes are only usable by VTL enabled vehicles, while the blue intersections represent where non VTL enabled vehicles are allowed to cross. The authors find that this approach decreases the commute time for VTL enabled vehicles while increasing it for non VTL enabled vehicles, causing incentives for users to obtain a VTL enabled vehicle. The authors also state that the current industry forecasts for the U.S. and Europe predict a 40-50% market penetration of DSRC radios in 2025.

Viriyasitavat et al. propose the same co-existence for accelerating the adoption of VTL in [27] where it is shown, through simulation, that such a scheme can increase
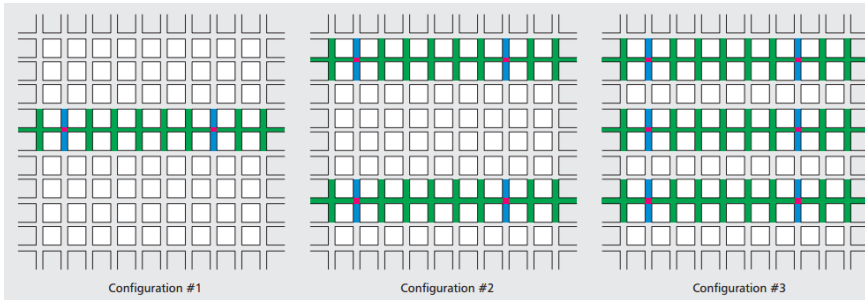
Figure 3.1: An example of different configurations for VTL coexisting with traditional intersection management systems[7]

the average speed of a VTL enabled vehicle by at least 14% while decreasing it by 39% for non VTL enabled vehicles. This proves that this approach will create large incentives for road users to adopt the VTL technology.

Sinha et al. proposes an intersection management system called VTL+. This system is based on the VTL system proposed by ferreira et al.[14], but it utilizes V2I simultaneously to address the issue of how VTL should be adopted. The proposed systems functions the same way as VTL when there are only VTL enabled vehicles in the vicinity of an intersection. When a non VTL enabled vehicle approache the intersection they will be detected by e.g loops, as used in SCOOT and SCATS, and traffic lights in the intersections will provide the non-VTL enabled vehicles with the scheduling plan so that they can traverse the intersections safely together with the VTL enabled vehicles. The authors argue that VTL+ is a more robust system than VTL because it still functions during network failure (the system can always fall back to existing infrastructure) and it uses existing infrastructure to make it possible for pedestrians to cross the intersections[28]. Viriyasitavat et al., Tonguz et al., and Sinha et al. propose partial penetration approaches for VTL using simulation to explore its feasibility. This thesis does not utilize simulation to address migration strategies but rather applies economic theory and how previous road network components have been financed, in conjunction with central actors in the VTL ecosystem to explore migration scenarios.

Tonguz et al. propose to use vehicles as RSUs causing a self-organizing network solution. This is proposed to be an alternative to installing RSUs as a measure to ensure that the coverage for DSRC is sufficient during periods of low penetration rates for DSRC devices, seeing as it is very expensive to deploy RSUs over a large area. The vehicles selected to function as temporary RSUs will have to make brief stops in order do forward messages to nearby vehicles by acting as a communication

bridge. The authors look at the propagation of post-crash messages to determine the effectiveness of the proposed solution. It is concluded that the solution significantly increase message reachability during low penetration rates of DSRC. This however, comes at the cost of vehicles having to stop for a short amount of time to convey these messages[17]. Tonguz et al. propose a way to manage low penetration rates of DSRC while this thesis focuses more on how the penetration rate for DSRC can be accelerated.

Safespot and Compass 4D are organizations providing intersection traffic control. In the preliminary work for their services, the organizations provide reasoning behind and proposals for organizational structure and participating stakeholders for their services [29], [18]. This thesis utilize many of the same strategies as the ones provided in the documents created by these organizations, but they are adapted and changed to encompass VTL.

Osterwalder et al. propose a business model canvas for providing business models to different companies and organizations, using 9 different building blocks. The authors explore business models for several types of companies, many with similar business characteristics as VTL[30]. This thesis uses the business model canvas to propose a business model for VTL.

Chapter 4

Stakeholders

This chapter will Provide an overview of all the stakeholders which will be involved in the adoption of VTL. Figure 4.1 depicts the actor ecosystem with all the participants and their relationships with the other actors. The actors participating in the model will be used as a basis for the migration strategies and Business model described in chapter 6 and 7 respectively.

The model is created by the author on the basis of the business model and organizational structure of Compass 4D[18] and Safespot[29]. These two systems share many of the same characteristics as VTL and they have therefore been adapted into the model seen in figure 4.1, representing actor ecosystem surrounding VTL. To make the model easy to interpret, the actors have been grouped into 5 categories represented by different colors in the model:

- Policy Makers and Regulators

- Technology Suppliers

- Service Enablers

- Service Providers

- Users

These categories are the same as the ones used in the organizational structure of Compass 4D[18]. To ensure that the model is not overly complex, the only service providers represented in the model are VTL and Value Added Service Providers (VASPs). There are other service providers which will be required to make the ITS-ecosystem function properly, such as other safety services e.g. forward collision warning systems. The services themselves are not included in the model, but the data which is relevant for VTL or VASPs is represented through the "Content Provider".

Each actor will be presented under its designated category and it will be explained what functions and responsibility the actor have, which entities the actor will have relationships with, and examples of stakeholders involved.
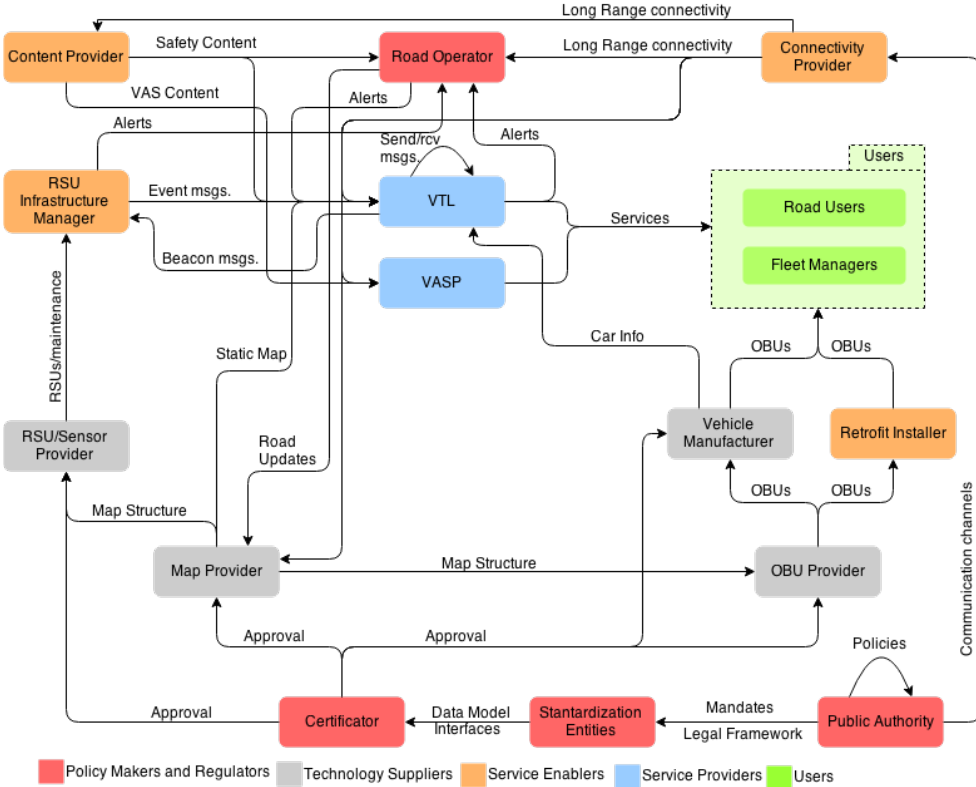
Figure 4.1: A model of the actor ecosystem surrounding VTL

4.1   Policy Makers and Regulators

Policy makers and regulators represents the stakeholders who are responsible for making policies, regulations, mandates, guidelines for standards and making sure that they are enforced in compliance with relevant laws and legislation.

4.1.1   Public Authority

Function and responsibility

Private actors have made large communication-based systems for V2I which have been out on the market for some time e.g. SWARCO[1]. Systems created by private actors often create lock-in effects which ensures that customers stay on their platform. This can cause segmented markets where e.g. one city uses some ITS services from one country while another city is using a different service with completely different data schemes and models making interoperability difficult. To ensure that the market stays interoperable a public authority such as EU or the US department of traffic is required to create standards and mandates. In EU's action plan for deployment of ITS it is acknowledged that the potential of ITS can only be realized if Europe is transformed from the limited and fragmented implementation which is observed today into an EU-wide one [31]. Public authorities have an important role in the adoption of ITS, making policies and creating frameworks to ensure that the market and platforms have interoperability. This is especially important when it comes to safety applications because large differences in safety applications of different countries could make it impossible for vehicles to cross borders and use the traffic networks of other countries.

The public authority should adopt a role where it facilitates the adoption of ITS-systems by gradually removing barriers to interoperability [29]. The innovation of these systems introduce several new areas within everything from legal issues to new technology which the private actors that will be working with the new technology might not have seen before. There is thus a need for guidelines and regulations so that the private actors will be able to cooperate with each other. It is important to have strict guidelines about how one should handle the data gathered by a solution such as VTL, and that the privacy of the users is maintained. Public authority should basically carry out its authority on three fronts [29]:

- Financial support for research initiatives and marketing

- Driving standardization through the issue of mandates for standards ensuring interoperability, including communication, security and privacy issues

- Issuing legislation or laws to guide participating countries towards the introduction of this type of technologies

With the necessary support, private actors will have an easier time ensuring a large-scale market approach with a successful deployment. Even though policies and

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[1]www.swarco.com

regulations will be made at a high level such as EU, these have to be enforced at a lower lever. The public authorities must therefore combine regulations of VTL with their existing legislation at a national and local level. Actions which have to be taken to perform this will be e.g. modifying tort and insurance laws, and traffic rules. Authorities should also set up enforcement strategies, ensuring a safe use of the system. This includes making sure that the V2V and V2I communication is working as it should and that rogue operators are excluded from the system

Relationships

For VTL, public authorities will function as a legislator working under statutory powers, making regulations and policies which is passed on to the standardization entities to create standards. Public authorities will therefore have a relationship with all those who must abide by the laws set by the authority.

Finally, the public authority will have an important part in the financial debate regarding who should pay for the implementation of the system, OBUs and RSUs. As well as negotiating with private actors interested in the market [29].

Stakeholders involved

For VTL, the stakeholders taking on the role of Public Authority is:

- EU

- U.S. Department of Transportation (DOT)

- National Ministries of Transport (for those acting under EU)

- Local Governments entitled to issue rules on traffic circulation and/or grants for communication channels

- National Communication license agencies

4.1.2   Standardization Entities

Function and responsibility

As explained in the last section, public authorities will provide policies and regulations for services such as VTL and other ITS solutions. The development of standards designed to guide actors to enforce these policies is delegated to external organizations[29]. For VTL, the needs for standardization and technical specification might include several aspects of the service such as:

- Communication channels for updating the service remotely

- Ensuring that frequencies dedicated to VTL will not be interrupted by e.g. value adding services on the 5.9GHz DSRC band

- Standards and specification of VTLs place in the ITS architecture

- Threat vulnerability and risk analysis

- How data obtained from VTL should be handled such that the privacy of users is maintained

- specification of map structure and data communication to ensure interoperability

When it comes to standardizing technologies, there are several entities representing different parts of the actor ecosystem. EUCAR works with identifying needs for research and development, and developing frameworks which might be used as basis for new standards for service stakeholders in Europe [29]. ERTICO represents ITS and service stakeholders in Europe. They support work advancing standards promoting interoperability for cooperative services in Europe. For V2V communication there is a non-profit organization called CAR2CAR consortium representing organizations from all parts of the value chain working for standards to ensure safe and reliable V2V communication in the future.

Relationships

Standardization entities receives mandates and policies to create suitable standards. Their relationships consists mainly of interacting with other standardization organizations to collaborate and agree on set standards with all the actors involved such as vehicle manufacturers, Original Equipment Manufacturers (OEMs), OBU providers, infrastructure operators, road operators etc. For VTL this work will ensure Data harmonization and interoperability.

Stakeholders

The stakeholders involved are different standardization entities on different levels such as ETSI[2] on an European level, IEEE[3] at an international level, ERTICO[4] representing industrial industries and e.g. CAR2CAR[5] representing industrial driven EU initiatives[29].

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[2]http://www.etsi.org/
[3]www.ieee.org
[4]www.ertico.com
[5]car-2-car.org

4.1.3   Road Operator

Function and responsibility

The road operator is in charge of managing certain parts of the road network and includes all the activities needed to ensure a correct, safe and efficient use of the road infrastrucute[29]. The road operator is closely linked to the RSU infrastructure manager in figure 4.1, and is therefore mostly concerned with V2I. VTL is a service based on V2V communication, relying 100% on V2V communication will probably not be possible until the penetration of the service and needed hardware has reached 100%. Therefore, the road operator will have an important role in the migration period of VTL, transitioning from traditional road-side traffic lights to relying purely on V2V communication for intersection control.

There is a probability that the road operator and RSUs will play a role after the transition period is over and VTL is operational. In densely built areas there might be need for RSUs to convey messages from vehicles not able to achieve contact with vehicles inbound for the same intersection. Road operators can hold, receive and convey safety related information to vehicles travelling in their network. This will make the road operators have a continuous role in the adoption and operational phases of VTL.

The road operator is responsible for ensuring that all actors in the ecosystem have updated and correct information about the road network governed by the operator. This include e.g. map data, which needs to be in accordance with the actual road network, signs and current information on the road so that providers are issuing correct information to the users of VTL. This is vital to the service as it requires lane level accuracy[14].

Relationships

Road operators can convey safety information and must therefore have a relationship with content providers to obtain this data. In order to convey safety information such as changes in the road network or that maintenance is being done somewhere in the road network, the road operator must obtain long range connectivity from the connectivity provider. As mentioned above there might be densely build areas where V2V communication is difficult and the messages need to be conveyed through RSUs. These areas need to be identified by the road operator and public authorities. Where the jurisitiction of one road operator ends, another will begin. It is important that road operators communicate to ensure that transitioning from one network to another is without complications.

Stakeholders

The stakeholders include[29]:

- Motorway operators

- Tunnel and bridge operators

- Urban road operators

- Road authorities

- Local administration authorities

4.1.4   Certificators

Function and responsibility

The role of the certificators will be to ensure that the components making up the VTL system and the ecosystem of components supporting the service such as RSUs are approved, and ensure that they meet regulations set by the authorities. The certificators must develop methods to test the reliability and security of the applications and equipment, and make sure that they use the same tests on systems placed at different geographical locations to ensure interoperability.

Relationships

The certificators will need to have relationships with the following actors in the actor ecosystem surrounding VTL

- Map providers

- OBU providers

- RSU/sensor providers

- Car manufacturers

Stakeholders

- Private certification entities

- Technical bodies of public approval authorities

4.2   Technology Suppliers

The technology suppliers are the stakeholders which provides the technological devices needed to implement VTL and other services.

4.2.1   RSU/Sensor Provider

Function and responsibility

For VTL, the role of RSU/sensor provider will have a different function based on the penetration rate of VTL and DSRC. For low penetration rates RSUs can be used to convey DSRC messages the necessary range for all intended vehicles to receive them. The provider of these units will have the responsibility of delivering, installing and doing maintenance on the RSUs. For high penetration rates of DSRC the RSUs can be used to convey messages from other safety applications or assist with message propagation in densely built areas.

Relationships

The RSU/Sensor provider will have relationships with certificators, so that the units provided can be approved, map providers, to ensure that the units have maps on the correct format and the RSU infrastructure managers which the units should be delivered to.

Stakeholders

- Manufacturers of roadside devices

- Suppliers of telematic systems for roadside devices

- Software developers for roadside systems

4.2.2   Map Provider

Function and responsibility

The map provider is responsible for delivering the map structure to OBUs and RSU providers. This structure should be in accordance with policies and regulations set by the public authorities. For VTL the map provider will deliver continuously updated maps to ensure that they are always up to date with the current road network. The map provider should also comply with changes and new regulations set by the public authorities with updates to the map structure.

As VTL requires lane level accuracy from its GPS and that all participants in the system have the same map [14], it is important that updates from the map provider

is delivered to all the users as soon as they happen so that all vehicles are updated. Users that does not update their maps might be excluded from the system to ensure safety for the other users. One way to accomplish ubiquitous updates is to deliver updates over long range communication, and have it be downloaded as soon as they occur.

Relationships

The map provider will have relationships with the different technological unit manufacturers to deliver map structure and services such as VTL to deliver static maps. map providers will also be governed by policies and regulations and must therefore obtain approvals for their map structure by a certificator.

If a change is made in the road network, the map provider must immediately be notified. And thus the map provider will have strong ties to the road operators.

Stakeholders

The stakeholders will be companies producing digital maps for navigation and location-based services.

4.2.3   OBU Provider

Function and responsibility

The OBU provider will be responsible for delivering the required hardware and systems to run the VTL service. The OBUs should be delivered to the entity carrying the role of installing OBUs in vehicles. This can either be the vehicle manufacturers themselves by integrating the units in the vehicles from production or retrofitting them in older cars, or dedicated retrofit installers.

It is vital for VTL that the OBU contains DSRC capabilities and extremely accurate GPS technology. The OBU providers are essential for a successful deployment of VTL because they determine the cost of their devices. It will be a challenge for the OBU providers to trigger effective economies of scale to eventually reach a critical mass of OBUs in the market [29].

Relationships

As with the other technological devices, OBUs have to be certified by certificators. In addition the OBU providers will have relationships with subcontractors delivering parts for the OBU, the vehicle manufacturers, retrofit installers and map providers.

Stakeholders

The stakeholders will be automitive components suppliers and software developers for the automotive industry

4.2.4   Vehicle Manufacturer

Function and responsibility

The vehicle manufacturer constitutes the role of the entity that manufactures the vehicles on which the VTL service will be installed, either as an integrated device or an aftermarket installation.

Vehicle manufacturers choosing to integrate the OBUs from production, if this is not already mandated, will increase the amount of users having access to VTL and other services such as Value Added Services (VASs). This means that vehicle manufacturers can open their own telematic platforms to offer users not only safety services but also e.g. business services and infotainment.

As with the OBU provider, the vehicle manufacturers will also have an impact on the economic side of the VTL adoption. Vehicle manufacturers can choose to actively participate in several stages of deployment. Supporting the standardization work through standardization entities, being early adopters of technology, lobbying public authorities and supporting research. It is also in the interest of vehicle manufacturers to lower component costs to ensure a widespread market for VTL, V2V communication and other services[29].

In the model shown in figure 4.1 the vehicle manufacturer also takes on the role of providing the VTL service with vehicular data such as velocity, direction etc.

Relationships

Vehicle manufacturers should cooperate to accelerate large scale adoption as this will have commercial implications for the stakeholders.

Stakeholders

The stakeholders will be companies manufacturing vehicles eligible for implementation of VTL

4.3   Service Enablers

This role represents those stakeholders that are supporting the producers of the functionality of the services, or the service providers with the necessary services and

contents [18]. For VTL this can be e.g. safety data from other services or alerts from road operators delivered through infrastructure.

4.3.1   Content Provider

Function and responsibility

In the proposed model of the organizational structure seen in figure 4.1, the content providers assume the role of entities delivering data from other services than VTL and VASs. This can include several types of data based on what kind of other services are present in the ecosystem. For VTL relevant data can include e.g. data from emergency vehicle systems alerting the VTL system of approaching emergency vehicles before they reach the range of the VTL VANET in an intersection, so that the participating vehicles can quickly adapt to the incoming emergency vehicle. Other relevant data include e.g. weather induced road conditions or data from civil defence systems.

Content providers can also provide valuable information to the VASPs ranging from location data to public transport data which can be used to create services with monetary value for the users.

This data will be provided to the OBU either through long range connectivity or DSRC. It is important that the data exchanged between services is secure and that bogus operators are not allowed to alter, interrupt or tamper with information regarding safety. Therefore this communication should be regulated and data sources validated.

Relationships

The content providers will rely on different forms of communication. For supplying e.g. road operators with safety critical data, long range connectivity will be supplied by a connectivity provider. Relationships with receiving parties of the data should also be maintained to establish trust between communicating parties.

Stakeholders

The stakeholders can be grouped into three categories: Safety-related content feeding VTL, non safety data and inputs on road geometry from static map layer updates[29]. Safety-related content:

- Road operators

- Roadside assistance services

- Emergency vehicle operating services

- Weather monitoring centres

- Civil defence

Non-safety:

- Road operators

- Traffic control managers

- Traffic information managers

- Fleet monitoring systems

- Public transport coordination services

- Business directories

Map-related:

- Road operators

- Local public authorities

- Drivers associations

4.3.2   RSU Infrastructure Manager

Function and responsibility

The role of RSU infrastructure manager and road operator will probably be governed under the same entity but it is divided in the proposed model to easier explain the roles. In the VTL ecosystem, the RSU infrastructure manager will serve as an entity operating the infrastructure part of VTL. As explained earlier; road side infrastructure can be used to convey messages originating from VTL.

If an infrastructure supported migration strategy is chosen when adopting VTL, the RSU infrastructure manager will have to make sure that non-VTL vehicles are seeing the same information on road side traffic lights as the VTL enabled vehicles. This means conveying messages from the elected leader at the intersection, and maintaining the infrastructure system so that the correct information is displayed.

Relationships

Relationships of the RSU infrastructure manager include notifying road operators with alerts, conveying event messages to VTL enabled cars, conveying beacon messages and having a relationship with suppliers of the road side equipment.

Stakeholders

Stakeholders can include[29]:

- Road operators

- Companies managing traffic telematics on the behalf of road operators

4.3.3   Connectivity Provider

Function and responsibility

The connectivity provider in this model is an entity providing long range connectivity to stakeholders requiring this. While VTL base its communication on DSRC, it is very likely that long range connectivity will be needed for updating VTL, updating maps, and receiving/sending safety critical information to e.g. road operators.

The responsibilities of the connectivity provider will be to set up communication networks, maintaining these and providing/selling communication channels to requiring entities.

Relationships

- Road operators

- Service providers

- Map providers

- Content providers

Stakeholders

Stakeholders will be Telecom providers and Internet Service Providers (ISPs)

4.3.4   Retrofit Installer

Retrofit installers will fill the role of entities retrofitting vehicles with OBUs. This role exists in the ecosystem because 100% penetration of DSRC will only happen

within a reasonable amount of time if there exists solutions to upgrade existing vehicles in the national car fleet. Only relying on new cars with such technology installed might take a substantial amount of time seeing as the Norwegian car fleet is 10.5 years old on average [32].

Relationships

The retrofit installers will have relationships with OBU providers to obtain the devices, and the end users which need the OBU installed

Stakeholders

The stakeholders will be car workshops with knowledge on how to install OBUs in different vehicles.

4.4   Service Providers

This role represents the stakeholders which deliver services to the end-users. For the proposed model in figure 4.1, VTL and VASPs are listed as service providers. the VASPs are included because they could play a role in the strategic part of the adoption of VTL and DSRC.

4.4.1   VTL

In this chapter, VTL represents the role which the VTL service will have in the actor ecosystem.

Function and responsibility

The VTL service is in the center of the proposed organizational structure. The VTL service will be responsible for providing the user with information and interface to securely traverse intersections based on VTL. How VTL works is explained in chapter 2.

The service will communicate with other vehicles, process data obtained from the vehicle and facilitate scheduling plans for intersections. It is not yet known which entity will have the responsibility for legal issues tied to VTL, but the service owner may have to log events and provide them to road operators.

Relationships

- End-users
- Vehicle manufacturers

- Road operators

- Map providers

- Content providers

- RSU infrastructure manager

Stakeholders

The stakeholders for VTL will be the entity that taking VTL to market and commercializes it.

4.4.2 Value Added Service Provider

Function and responsibility

The role of a VASP includes delivering services that are not safety related. These are important because they help increase the commercial attractiveness of the OBUs[29] by providing services which can improve users' quality of life such as free parking discovery, dynamic navigation, infotainment etc. Such services can be applications that the users download and spend money obtaining. Different vehicle manufacturers can have different platforms on which to procure VASs or it can be a third-party providing the same platform to several vehicle manufacturers.

While such services can increase the public attractiveness of the required devices to implement safety services such as VTL, it is important to ensure that the data sent out by these applications does not interfere with the safety messages from e.g. VTL. Therefore it is important to regulate the communication in such a way to ensure that this does not happen, DSRC have a dedicated safety application sublayer to convey safety messages[15].

Relationships

- End-users purchasing services

- Wireless communication regulators

- Connectivity providers to deliver services to the OBU

Stakeholders

- Companies providing road navigation

- Telecom operators

- Suppliers of commercial services

- Road operators

- Vehicle manufacturers

- Fleet managers

4.5   Users

This role represents the stakeholders which will consume the services provided by the service provider. Either by spending money obtaining services or using security services such as VTL.

4.5.1   Road Users

Function and responsibility

A road user constitutes a stakeholder present inside a vehicle on a road. The user will be the one interpreting messages and data provided by the service providers and deciding how to control the vehicle based on this. As explained earlier, service providers might provide services improving general quality of life or security services. Road users will find value in a security service such as VTL because many road users value safety as their highest priority when driving [33].

From a strategic point of view, road users will be important in ensuring widespread deployment of VTL and DSRC as public acceptance is important for safety applications.

Relationships

Road users will have relationships with the entity providing their vehicles with OBUs and the service providers providing them with services. In addition, vehicle manufacturers will provide the vehicles for the end-users.

Stakeholders

- Private vehicle driver

- Freight vehicle driver

- Emergency vehicle driver

- Public transport driver

- Passengers of e.g. public transport

4.5.2   Fleet Managers

Fleet managers represents the entities overseeing fleets of vehicles such as taxi companies and the emergency vehicle fleet department of a hospital. The fleet managers will purchase devices and services from a business point of view and might have other values than the private road users. Such fleets often consists of vehicles not owned by the drivers, but the entity overseeing operations, therefore it is the fleet managers who decides if they want to enter the market based on the business model proposed by the OBU, and service providers. This makes fleet managers important in the adoption of new ITS technology.

Relationships

The fleet managers will have relationships with the same actors as the road users.

Stakeholders

- Taxi companies

- Emergency vehicle fleets

- Freight vehicle fleets

- Public transport companies

Chapter 5

Benefits of VTL

The previous chapter listed all the actors participating in the actor ecosystem surrounding VTL, this chapter will give the reader insight in the benefits of implementing VTL for each of the presented actors. The chapter will be separated into sections in the same way as chapter 4, where the benefits of each actor will be presented and elaborated.

5.1 Policy Makers and Regulators

Stakeholder	Benefits
Public authority	- Better traffic flow for a country, city, etc. - A more streamlined transport sector - Less pollution - Lower investments in intersections - Reduction of traffic accidents happening in intersections - Prioritization of emergency vehicles and public transport - Potential to create new jobs
Standardization Entity	- No particular benefit other than being able to voice the opinions and needs of their members
Road operator	- Less congestion in the traffic system - Less of the budget spent on setting up and maintaining intersection signal control devices - Reduction of traffic accidents happening in intersections
Certificator	- Potential income from certification work

Table 5.1: Benefits of policy makers and regulators

Table 5.1 show a summary of the benefits policy makers and regulators will experience with the deployment of VTL. With road traffic injuries predicted to being the third

highest cause of death in 2020, policy makers and regulators, and road operators will have large a large incentive to make roads safer[10].

As table 5.1 depicts, there are many potential benefits for public authorities. In the United states in 2008, an estimated 40% of all crashes happened in intersections. This amounts to about 2,300,000 crashes[34]. In intersection related crashes, the largest driver attributed critical reason is inadequate surveillance with 44,1%. Following this are false assumption of others actions(8,4%), turned with obstructed view(7,8%) and illegal maneuvers with 6,8%. With VTL, every traffic intersection will be signal regulated if needed[14], this will cause surveillance to be much less of a problem. The Norwegian road authorities state that the amount of intersection related accidents will be reduced if intersections are regulated by traffic signals. They also state that the accidents where a vehicle is hit from behind might increase, however the important note is that the severity of accidents is reduced[12]. By installing traffic signals in an intersection with four approaches, the amount of accidents can be reduced by about 30%. This number is about 15% for intersections with fewer approaches[12]. Crashes involving emergency vehicles might also diminish with the implementation of VTL. By utilizing schemes and local rules in conjunction with VTL, more than 25% of emergency vehicle accidents can be avoided[35].

The DOT lists "limit environmental impacts" as one of their strategic themes for their ITS strategic plan for 2015-2019[36]. This includes managing traffic flows, speed and congestion better by using technology. Several studies have been conducted on the potential VTL have on improving traffic flows. Sommer et al. show that VTL can improve traffic efficiency in intersections by up to 35% in realistic environments and showing that the speedup remains stable under high communication load scenarios[37]. Ferreira et al. show, with simulation, that VTL has the potential to increase traffic flow, with increasing density, by up to 60% during high vehicle density scenarios[14].

Environmental impacts also include carbon emissions, the European commission estimates that about one fifth of EU's total emission of carbon dioxide comes from road transport[38]. Ferreira et al. conducted a study to determine the impacts VTL would have on carbon emission mitigation. By using simulation, the authors showed that carbon emissions could be reduced by as much as 20% under high density traffic scenarios[39].

The potential for prioritization of vehicles is lucrative, studies show that prioritization of public transport in intersections can decrease travel times by 5-15% and reduce the amount of delays occuring by 40%[12]. When there is a matter of life and death, every second counts. in [35], Viriyasitavat et al. proposes a scheme where VTL in combination with local rules can be utilized to provide emergency vehicles with priority in intersections, the authors produce findings which indicate that emergency

vehicles can save a substantial amount of time, which might even be higher than the paper proposes due to the low amount of intersections currently equipped with traffic signals[35].

One of the goals of VTL is to render traffic signalling truly ubiquitous by making all intersections capable of being signal regulated through VTL. When reviewing the numbers it becomes clear that traditional traffic lights are not scalable if the goal is to equip all intersections with traffic signals; in the U.S. less than 1% of all intersections are equipped with traffic lights (260,000 of 50,000,000)[16]. The cost of installing a traffic light can range from $50,000 to $200,000 based on its complexity, and running the traffic light adds somewhere around $3000 each year[16]. By removing the cost of such infrastructure in the road network, a substantial amount of money can be saved due to the deployment of VTL.

The direct benefits for standardization entities and certificators are not as substantial as those experienced by the public authority and road operators.

5.2 Technology Suppliers

Stakeholder	Benefits
RSU/Sensor provider	- Revenue from sale of RSUs and Sensors
	- Revenue from maintenance of devices
Map provider	- Revenue from sale of map structure
	- Potential revenue from updating static maps
OBU provider	- Revenue from sale of OBU
Vehicle manufacturer	- Possibility to use VTL as marketing for safer vehicles
	- Potential increased revenue from including OBU in vehicles
	- Revenue for retrofitting OBUs in vehicles

Table 5.2: Benefits of technology suppliers

The technology suppliers of the ecosystem will have more revenue driven benefits compared to policy makers and regulators, which are also concerned with the socioeconomic advantages of VTL. As was illustrated in section 5.1, it is very expensive to install and maintain traffic signals. As explained in chapter 4 there might be a need for RSUs in the migration period for VTL. The installation of a simple RSU such as a roadway probe beacon can cost $15,000 in capital expenses and $2,400 in operational expenses each year[17]. If a migration strategy is chosen such that traffic signals and RSUs assist in the migration period and potentially persist after the adoption is complete, RSU/Sensor providers could experience large revenues from the deployment of VTL.

Vehicle manufacturers will probably gain market opportunities with the deployment of a new technology such as VTL. As explained in chapter 2, a vehicle needs to be equipped with an OBU with DSRC capabilities to utilize the VTL service. Even though new vehicles might be required to implement V2V capabilities, vehicle manufacturers can gain an advantage over its competitors by being a first-mover in the market and taking initiative to accelerate adoption of a new technology[40]. Vehicle manufacturers can also obtain advantages by utilizing the increased safety from implementing VTL as a marketing strategy to sell more vehicles.

The OBU, and map providers will have the benefits of selling their hardware and services to other actors in the ecosystem.

5.3   Service Enablers

Stakeholder	Benefits
Content provider	- Potential revenue from selling data to the VTL service - Potential to use VTL as a springboard for other services
RSU infrastructure manager	- Less infrastructure to maintain by removing physical traffic signals - If private entity: revenue for maintaining RSUs
Connectivity provider	- Revenue for selling connectivity services to actors involved in the VTL ecosystem
Retrofit installers	- Revenue for installing OBUs in vehicles

Table 5.3: Benefits of service enablers

The benefits for the different service enablers are depicted in table 5.3. Based on what kind of data a content provider provides, there is a potential for revenue by selling this data to the VTL service. this can e.g. be a service providing info about emergency vehicles approaching intersections, if this is not already built into the VTL service. If public authorities decide to mandate VTL and OBUs with DSRC in e.g. EU, content providers can springboard their services by populating potential VAS platforms delivered with the OBU.

If a migration approach where RSUs are not prioritized is chosen, a RSU infrastructure manager will have less infrastructure to maintain, and more money to invest in other areas of the road infrastructure which needs improvement.

Connectivity providers and retrofit installers will gain benefits for selling their services, hardware and software to other actors in the ecosystem.

5.4   Service providers

Stakeholder	Benefits
VTL	- Revenue for selling the VTL service based on which business model is chosen
VASP	- Revenue for selling value-added services to customers - No particular benefit directly from the implementation of VTL

Table 5.4: Benefits for the service providers

Table 5.4 show the benefits of the service providers following the deployment of VTL. For the organization taking VTL to market the benefits will be revenue for selling and maintaining the service. Based on which migration strategy is chosen, VASPs might increase their revenue from VTL being implemented by creating a two-sided market with the end users to finance the OBU required to deploy VTL. This approach will be further explained in chapter 6.

5.5   Users

Stakeholder	Benefits
Road users	- Better traffic flow - Less fuel consumption and air pollution - Smaller chance of traffic accidents - Potential for cheaper insurance - Less wear to the vehicle engine
Fleet managers	- Better traffic flow causing a more streamlined operation - Less fuel consumption for the whole fleet, saving expenses - Fewer expenses linked to accidents - Potential for cheaper insurance - Faster reaction time for emergency vehicles

Table 5.5: Benefits for users

From table 5.5 we see that there are several benefits for both the road users and fleet managers following an implementation of VTL. Road users will experience several of the same benefits as the public authorities which was extensively elaborated in section 5.1. The difference between a road user and a public authority is that the public auhtority sees the benefits from a socioeconomic perspective while the road user experiences the benefits mostly as an individual. The collective benefits for all the road users will reflect the benefits of the public authority and road operators.

The same situation is seen for fleet managers. The benefits are similar to the ones experienced by the public authorities, however, the benefits for the fleet managers are driven purely by economic ambition. The only stakeholder this statement is not valid for is fleet managers of emergency vehicles, where time is of the utmost essence and an important benefit from implementing VTL.

Chapter 6

Migration

The preceding chapters have provided an overview of the actors participating in the ecosystem surrounding VTL. In this chapter we will look at how the most central actors can react to different market scenarios regarding the migration period of VTL, using economic theory. Insights regarding the migration from traditional traffic lights to VTL will be presented. Looking at the requirements all vehicles must fulfill in order for VTL to be implemented, listed in chapter 2 and [14], one can implicate that there has to be a period between no cars being viable for VTL and all cars being viable. This is the migration period. This chapter will also present the current situation in Europe and the U.S. regarding ITS and the adoption of V2V communication.

6.1   The current situation

There are many entities dedicated to accelerating the adoption of ITS and services relying on V2V communication such as Ertico[1], Amsterdam Group[2] and the Car 2 Car Communication Consortium[3] in Europe, and the DOT[4] and National Highway Traffic Safety Administration (NHTSA)[5] in the U.S.. Several countries are including ITS in their transport plans e.g. Norway has released guidelines for the new national transport plan, which will last from 2018-2029, where the government express a desire to increase the use of ITS. The Norwegian government also expresses concerns about the lack of interoperability between different systems and requests suggestions for how to overcome administrative barriers. The potential for a digital collaboration platform is proposed to facilitate interoperability between different systems[41].

The largest hurdle for the implementation of VTL will be the penetration rate for the OBU containing DSRC and the technology required for VTL. The problem regarding

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[1]www.ertico.com
[2]www.amsterdamgroup.eu
[3]www.car-2-car.org
[4]http://www.transportation.gov/
[5]www.nhtsa.gov

the penetration rate of DSRC devices is addressed by Tonguz in [16]. Tonguz says the success of VTL can be accelerated by the public authorities by mandating car manufacturers to implement DSRC capabilities in their vehicles[16]. Such mandates have already been discussed in the U.S. and the DOT has proposed legislation to mandate that V2V communication should be implemented in all new cars[42]. This legislation comes a result of a report made by the NHTSA where the benefits, costs, the need for regulation, etc. for implementing V2V communication capabilities is outlined[43]. The NHTSA estimates that the cost of equipping new vehicles with DSRC devices for V2V communication will cost approximately $350 per vehicle. This cost is notably less than other safety equipment currently mandatory in vehicles such as airbags costing approximately $500.

Several issues have been raised in reply to the report written by the NHTSA. Brock et al. writes, in a public interest comment, their concerns regarding the NHTSA report[44]. The NHTSA claims in their report that market failure is likely to happen for the adoption of V2V devices without federal regulation and mandates[43]. This is claimed because of network externalities, and the NHTSA does not believe that there will be enough incentive for vehicle manufacturers to produce V2V communication enabled vehicles, thus regulatory action is required. Brock et. al provides several examples of technologies exhibiting network externalities which did not require regulatory action, such as facsimile [44]. Other issues addressed by Brock et al. includes e.g. how benefits from V2V communication is quantified compared to cost, how the extra cost for installing or purchasing an OBU will effect low-income households, if the benefits for early adopters will be substantial enough to create a stable market and if the technology will have public acceptance due to the privacy concerns which follows a system monitoring information about a vehicle and sending this to other vehicles[44].
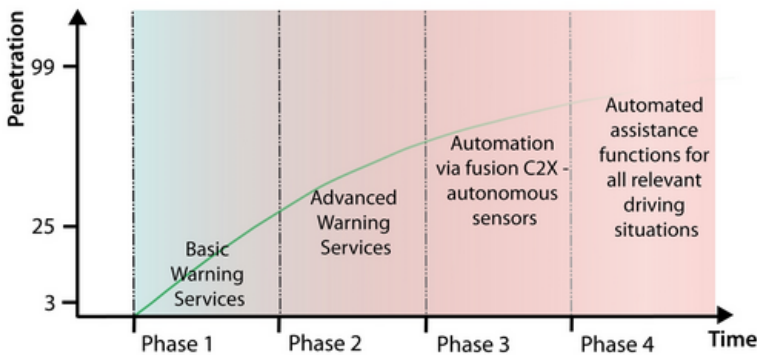

Figure 6.1: Phase concept of ITS deployment[8].

The Amsterdam group have produced a proposal for a road map regarding the deployment of Cooperative Intelligent Transport System (C-ITS) in Europe, this can be seen in figure 6.1. The Amsterdam group proposes an "evolution instead of revolution"-approach to the adoption of C-ITS, meaning that there will be transitioning phase over several years[8]. The road map emphasizes that fast penetration is a goal, however market needs and business models should be taken into account. Technical and operational interoperability, and scalability in conjunction with user oriented services should be the goal of the technology. Two of the recommendations the Amsterdam group has for an accelerated deployment of C-ITS is listed below[8]:

- Develop deployment scenarios for local authorities showing how to move in a cost-effective way from existing systems to cooperative systems

- Develop robust business models for local authorities

As this section has attempted to illuminate, there is a large debate going on in both Europe and the U.S. regarding how ITS and V2V communication should be implemented, who should pay, if regulations are necessary and if they are, to what extent.

6.2   Alternatives for migration

To stimulate the adoption of VTL, the vehicle fleet needs to be equipped with DSRC devices. We define getting 100% penetration of these devices as the largest challenge for the implementation of VTL. The stakeholders, and their relationships, included in the VTL ecosystem were defined in chapter 4. If the stakeholders does not have positive utility by participating in the market, they will choose not to. It is thus important that all the stakeholders have a positive cost-benefit ratio. This section provides alternatives to how different stakeholders can interact with each other such that the market for DSRC devices will reach sufficient penetration, while keeping the stakeholders in the market.

The section will be split into subsections where each subsection explains the alternatives for one central actor. As explained in chapter 1, the approach chosen for this thesis is to highlight several potentially prevalent alternatives regarding the acceleration of the penetration rate for DSRC. Another way of exploring migration alternatives would be to focus only on one alternative and go in-depth with the chosen alternative. The reason that this thesis shed light on several alternatives instead, is because of the complexity of the market surrounding VTL. VTL is a market with stakeholders from both the private and public sector. There are also a substantial amount of stakeholders. Seeing as there are no certainties that VTL will

be implemented, or that one can reach 100% penetration rate of DSRC devices; it was deemed to many uncertain variables to justify focusing on only one migration alternative. Different migration scenarios will be based on different assumptions. These assumptions will be listed where necessary.

6.2.1   Publicly authority

The public authorities have much power when it comes to deciding how new technologies, which will affect large portions of the society, are implemented. Public authorities have the power to enforce mandates or even change legislation to assist in the deployment of new technology. By doing this, public authorities can provide incentives large enough for end users to adopt the technology even before the network externalities experienced by end users are sufficient for the market to reach critical mass. One example of public authorities stimulating adoption of technology providing benefits for the society is how the Norwegian government provides large incentives to every citizen purchasing an electric vehicle.

Electrical vehicles in Norway received benefits because the government signed a climate agenda which included that electrical vehicles would receive benefits lasting until 2017 or until there were 50.000 electrical vehicles on the roads. After either of these limits were reached, the benefits would be reconsidered[45]. The following benefits were given to these vehicles:

- No "one-time-fee" (this is a fee which has to be paid for vehicles when they are purchased, it varies based on weight, type of vehicle and CO2 emissions)

- No taxes for the vehicle on purchase

- Corporations only have to pay half the taxes, on their vehicles, if they use electric vehicles as company cars

- In Norway all vehicle owners must pay a fee for each owned vehicle each year, this fee is much lower with an electrical vehicle

- Free parking on public parking spots

- No road tax

- Can drive in lanes dedicated to public transport

- Free ferry transits

- Free use of public charging stations

After the incentives were introduced, the sale of electrical vehicles increased by a large amount. Looking at the statistics, one can see that the amount of electrical vehicles in Norway has increased from 15 000 to approximately 50 000 in about 1.5 years[46]. It is thus obvious that the incentives provided by the government were a large factor in the penetration of electrical vehicles in Norway. From the list above it can be seen that the incentives provided either made the purchase and/or usage of the vehicle cheaper, and the daily commute more practical for the users, i.e. less congestion in public transport lanes and free parking. These are factors that greatly affect road users travelling every day.

As mentioned, the incentives for electrical vehicles will not last forever. With the explosive increase of such vehicles in Norway, the incentives are, as of May/June 2015, being discussed. Currently, in the capital of Norway, electrical vehicles can not use the public transport lanes unless there are more than one person in the vehicle[47].
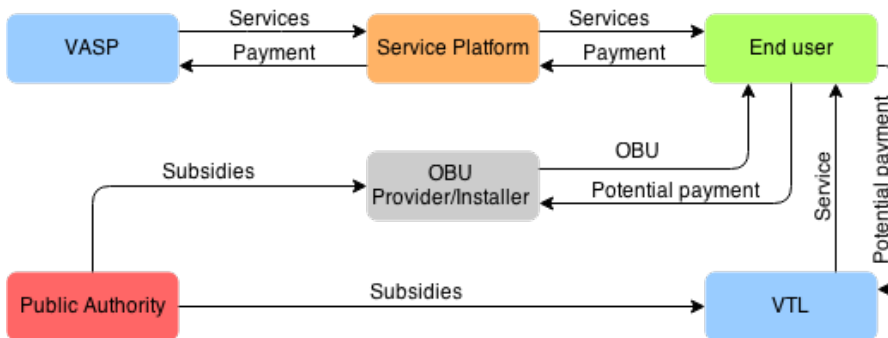
Figure 6.2: Model showing the revenue streams between actors when the public authorities take a central role

For VTL, the willingness of a government to provide incentives might be crucial. As the decision to provide incentives to electrical vehicles was driven by environmental reasons, we can assume that at least the Norwegian government has the potential to provide incentives for new technologies with the capability to improve the environment. The benefits of VTL related to the environment were discussed in chapter 5. Such incentives as the ones listed above can greatly improve the adoption rate of new technology, as seen with the growth in sales of electrical vehicles, and help the market reach critical mass.

Many of the incentives provided to the electrical vehicles could also be applied to vehicles with DSRC installed, such as driving in lanes dedicated to public transport

or cheaper taxes for either the vehicle or just the OBU. It is also possible to prioritize vehicles with DSRC in intersections to further provide incentives for fast penetration. Some incentives, such as driving in the public transport lanes, can be very lucrative to the consumers in an early phase before these lanes become congested with DSRC equipped vehicles, hindering public transport. Other incentives such as being prioritized over regular vehicles in intersections will be viable through the whole migration period.

Figure 6.2 depicts how the revenue streams between actors will flow if the public authorities takes a lot of responsibility in the adoption of VTL. In addition to providing incentives, the public authority can also provide mandates and legislation to vehicle manufacturers and all vehicles driving on the roads. As explained in section 6.1 this is the leading approach in the U.S..

The public authorities will be the entity which decides if VTL should be procured once the penetration rate is sufficient. To pay for the service itself, the public authorities must either subsidise the whole cost, or make the end users help pay for the service through e.g. taxes or surcharges. In Norway, vehicle owners have to pay several taxes and surcharges on their vehicles on a yearly basis, such as the annual motor vehicle tax. Public authorities can provide legislation to increase such taxes so that they include part, or the entire cost of the VTL service. Another way the public authorities can make end users help finance VTL is by employing the strategy used for financing tunnels, bridges and roads in Norway. This strategy uses toll stations set up on different roads. when a car passes the toll station, a sum of money is paid as toll. Public authorities can thus increase these taxes, or set up separate toll stations to help finance the VTL service.

6.2.2   Vehicle manufacturers

This section will elaborate on the role of the vehicle manufacturer in the adoption of DSRC, and apply theory to analyze how a vehicle manufacturer might approach the challenges facing an adoption of new technology. As explained in section 6.1 there is an on-going debate to decide whether DSRC equipment should be included in all new cars by mandate of the government. It is argued that *not* mandating DSRC equipment will not necessarily cause a market failure[44]. We will now look at a simple game to explore this statement, and how a vehicle manufacturer will act if there is no mandate present. The goal of the following example is to show how the required consumer base for a vehicle manufacturer to enter the market for DSRC devices will vary based on the strength of the network externalities.

We assume that a vehicle manufacturer has monopoly and that all their customers are identical. The vehicle manufacturer is faced with the choice of producing cars

with DSRC installed, so that they can communicate with other vehicles or RSUs, or without DSRC. We then have the following parameters:

ξ − Identical consumers which might purchase a vehicle

q − Quantity of vehicles sold

p − Price of a vehicle

β − The basic utility each consumer derives from owning a vehicle

α − Marginal utility for each additional vehicle in the network

μ_d − Unit production cost for a vehicle equipped with a DSRC device

μ_n − Unit production cost for a vehicle without a DSRC device

$$0 \leq \mu_n \leq \mu_d$$

The utility for a consumer will thus be

$$U = \begin{cases} \beta - p + \alpha q & \text{DSRC device installed} \\ \beta - p & \text{no DSRC device installed} \\ 0 & \text{no vehicle purchased} \end{cases}$$

It is further assumed that the consumers knows the total number of vehicles purchased (perfect foresight) and that there are two perfect foresight equilibria $q = 0$ and $q > 0$. Based on these assumptions, the utility of a consumer which is indifferent about entering the market or not can be calculated by setting the utility function to 0. The demand functions for a vehicle without a DSRC device, or with a DSRC device will thus be:

No DSRC devices installed:

$$q = \begin{cases} \xi & \text{if } p \leq \beta \\ 0 & \text{if } p > \beta \end{cases}$$

DSRC devices installed:

$$q = \begin{cases} \xi & \text{if } p \leq \beta + \alpha\xi \\ 0 & \text{if } p > \beta + \alpha\xi \end{cases}$$

Since the vehicle manufacturer is operating as a monopolist, it will maximize its revenue by setting the price of a vehicle equal to the price a consumer is willing to pay. Following the case where DSRC is not installed in the vehicle, the price will be $p = \beta$, and hence the profit equation for the vehicle manufacturer will be:

$$\pi_n = (\beta - \mu_n)\xi$$
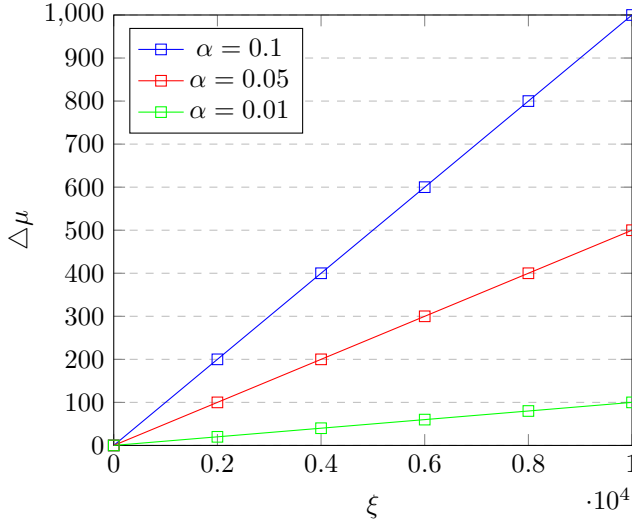
Figure 6.3: Customer base needed for different values of α

In the case where the vehicle manufacturer decides to install DSRC devices; $p = \beta + \alpha\xi$, giving a profit equation:

$$\pi_d = (\beta + \alpha\xi - \mu_d)\xi$$

Comparing the profits from both scenarios, it can be calculated which circumstances must be fulfilled before a vehicle manufacturer chooses to produce compatible vehicles over non-compatible vehicles:

$$(\beta + \alpha\xi - \mu_d)\xi \geq (\beta - \mu_n)\xi$$

Which leads to

$$\triangle\mu = \mu_d - \mu_n \leq \alpha\xi \tag{6.1}$$

Directly interpreting the equation, it is indicated that a vehicle manufacturer will only produce DSRC enabled vehicles if the cost difference between producing the vehicles is less than the gain from the network externalities. What this means is that the positive effects a vehicle manufacturer experience from consumers having DSRC enabled vehicles must be sufficiently large so that it is worth the extra cost of producing these vehicles. Such effects can be e.g. higher willingness to pay from consumers or a more attractive service platform for third parties to develop services on. What this example show is that there might be need for regulations to get DSRC to penetrate the market if the network externalities are not sufficiently strong during low market penetration, so that vehicle manufacturers does not see the value in producing and selling these vehicles, which might cause a market failure.

Figure 6.3 depicts the customer base needed as a function of $\triangle\mu$(the cost difference between manufacturing a vehicle with a DSRC device or not) for different values of α. The graph show that if the marginal utility for each vehicle is low, a large customer base is needed to make the vehicle manufacturer decide to enter the market for DSRC enabled vehicles. This graph does not accurately depict the reality because of the static value of α, this comes as a result of the perfect foresight assumption.

Being the first-mover
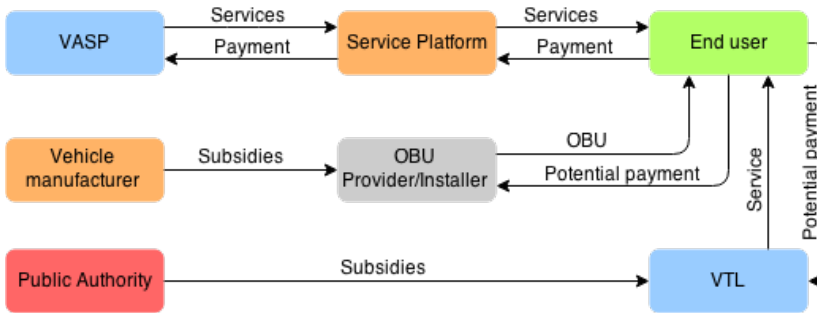
Figure 6.4: Model showing revenue streams when vehicle manufacturers subsidises OBUs

Figure 6.4 show a model where a vehicle manufacturer decides to subsidise the OBUs for their vehicles. We now assume that there has been confirmed a mandate which require all new vehicles to be fitted with DSRC radio, and that the only requirement for the device is that it is able to communicate with V2V safety applications. The vehicle manufacturers must then decide how they want to integrate and distribute the OBUs in their vehicles. Assuming that there are no subsidies from public authorities, vehicle manufacturers must decide if they want to increase their vehicle-prices to compensate for the added cost of producing a vehicle with an OBU, or if they want their prices to remain the same; which might lead to advantages in the market.

One such advantage is the first-mover advantage which have been extensively studied in the field of economics. The key element of a first-mover advantage is an initial asymmetry among competitors, enabling one firm to gain a head start over its rivals[48]. There is however not unified evidence suggesting that first-movers will always be at an advantage[49]. There have been suggested four types of mechanisms that a first mover might experience. Economic mechanisms related to cost advantages for scale and marketing. Preemption mechanisms related to factor inputs, i.e. the first movers gets cheaper raw materials than their competitors and spatial preemption related to preempting competitors by gaining customers in certain geographical

areas. Technological mechanisms related to the product, processes and organizational adaption. Behavioural mechanisms related to differentiation advantages related to e.g. switching costs and product reputation[50].

By providing consumers with OBUs for free, i.e. not raising prices after the mandate, a vehicle manufacturer might be in a favorable position where consumers prefer their vehicles because of the lower prices. The vehicle manufacturer must however be able do economically defend their decision to not incur the cost of the OBUs on their customers. One way to do this is to ensure that consumers are using services from one vehicle provider which are not compatible with others. This can be achieved by being the first-mover in a market to quickly obtain a large user base. By providing a service platform to the consumers where they can create a profile, purchase apps or other VASs, the vehicle manufacturer incurs a lock-in effect on their consumers. A lock-in effect is an effect which tries to prohibit the user from switching to a competitive product without paying switching-costs, e.g. a consumer with an iPhone experiences lock-in by purchasing several apps from Apple's appstore. A lock-in effect comes as a result of switching costs. A switching cost is the negative cost a consumer experiences by switching to a competitive product. Switching costs are most often monetary but can also be psychological or effort-based.
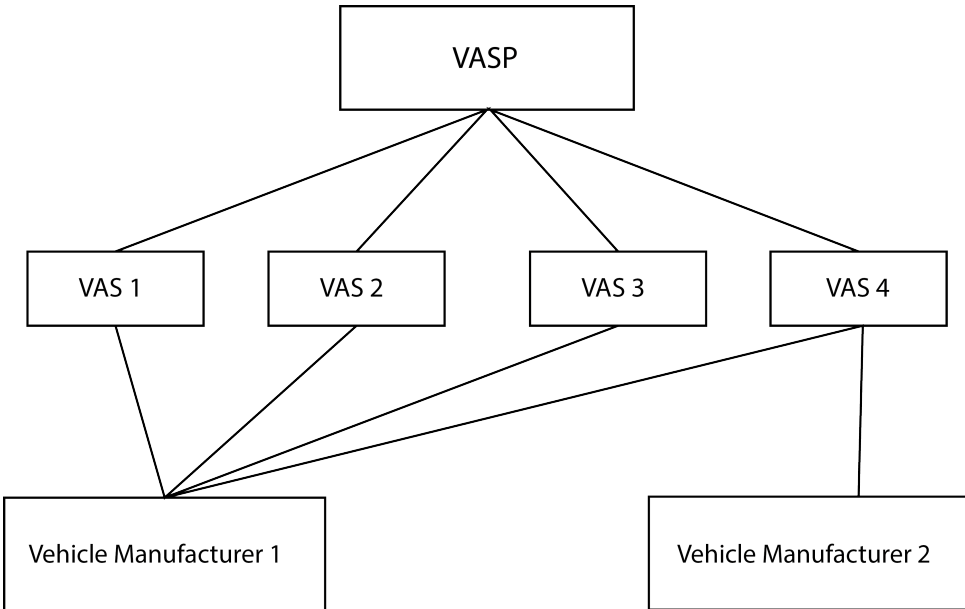

Figure 6.5: Compatibility between a value added service provider and two vehicle manufacturers

Lock-in can be caused by compatibility. Figure 6.5 depicts a situation where a VASP is providing services for vehicle manufacturers. As explained, we assume that a vehicle manufacturer can have their own service platform, for providing services to a user, on their OBUs as long as they are compatible with safety applications such as VTL. In the example shown in figure 6.5, "Vehicle Manufacturer 1" has managed to obtain a much larger market share than "Vehicle Manufacturer 2" e.g. by being a first-mover. The lines between the boxes in the figure represent if a service is compatible with the connected service platform. We see that the VASP provides 4 services; VAS 1-4. Because VM1 has a larger market share, the VASP has a larger monetary incentive to create services compatible with VM1's service platform. This is caused by indirect network effects and can in turn lead to even more consumers choosing to purchase a vehicle from VM1 because of their superior service platform.

The competition between private actors depicted above can cause a faster penetration rate for DSRC and thus VTL. Several vehicle manufacturers already provide telematic service platform in their vehicles, such as Toyota[6], GM[7], BMW[8] and Mercedez Benz[9]. There is no reason not to believe these platforms will be integrated with the OBUs, should they be mandated in vehicles. This also gives vehicle manufacturers the possibility to implement their service platforms in older vehicles through retrofit installs.

6.2.3   Two-sided market

There are several examples of goods being given away for free or at strongly reduced prices[51]. One market type where this kind of strategy is prevalent is two-sided markets. A two-sided market can e.g. be shopping malls, where shoppers can enter the mall for free but the shops have to pay rent. This is lucrative for all parties because 1) the shoppers gain access to a platform where they can purchase products, without having to pay for entry to the platform. 2) The mall gains revenue by collecting rent from the shops in the mall, and 3) the shops gain revenue from selling its products through their shops located in the mall. Such a market is driven by network externalities because each user experiences increased utility for each user located at the other side on the market, i.e. a shop experiences increased utility for each consumer located in the shopping mall and vice versa.

Such markets can also be found in the IT-industry, e.g. Apple lets their users download the app store for free and charges developers a fee for licensing and access to the store where they can sell their apps to consumers. Apple also takes a small portion of the sale of each app. For VTL a two-sided market can help accelerating

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[6]http://www.toyota.com/safety-connect/
[7]http://www.onstar.com
[8]http://www.bmw.com/com/en/owners/navigation/assist_1.html
[9]http://www.mbusa.com/mercedes/mbrace

Value of an extra VASP in the
network, to an End-user

| VASP | Potential fee → | Service Platform | ← Potential fee | End User |

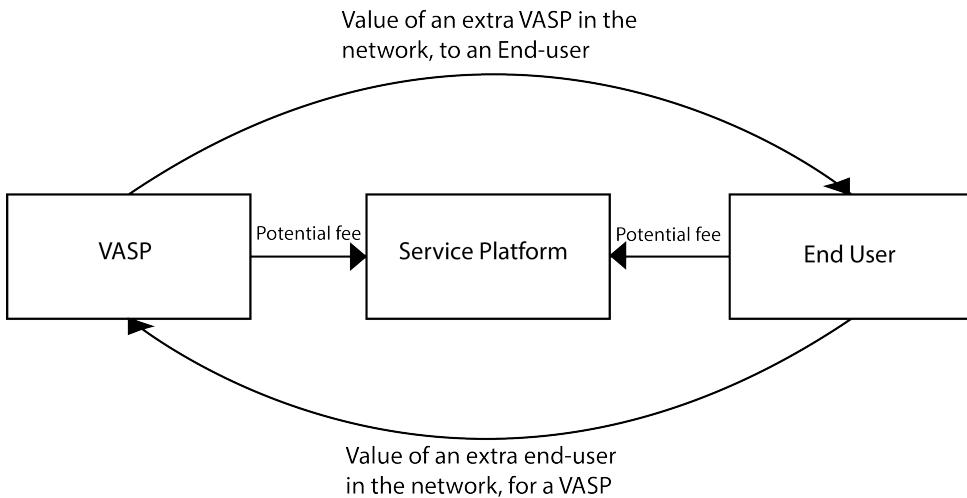Value of an extra end-user
in the network, for a VASP

Figure 6.6: Model of a two-sided market

the adoption of OBUs. The concept of a service platform was briefly introduced in the last section, where a vehicle manufacturer could utilize it to gain a favorable position in the market.

Figure 6.6 depicts how a two-sided market can exist in the VTL ecosystem. While the model does not directly include VTL, it is interesting to examine because it can assist with solving one of the preliminary problems of VTL, namely the penetration rate of DSRC. In this model the service platform is in the center. The service platform can either be owned by a vehicle manufacturer, as explained in the last section, or by an independent third party such as QNX[10], OpenCar[11] or OpenXC[12]. In this market configuration, the service platform is installed on the OBU containing the hardware needed to implement VTL. The owner of a service platform will have to decide on optimal pricing for both the VASPs and end users. If it is financially viable, the OBU can be given away for free to end users while the VASPs have to pay a fee for accessing the end users. Once an end user is connected to the service platform, the VASPs can offer their services to the end users. Such services can either be free, paid by lump-sum fees or subscription based. Examples of VASs can be Parking assist or dynamic GPS based on traffic.

As the value in such a market is created by the users positioned at each side of

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[10]http://www.qnx.com/
[11]http://www.opencar.com/
[12]http://openxcplatform.com/

the market, it will be important for the different service platforms to gain enough traction for their platform and attract as many users on each side as possible, i.e. a mall without customers will never get shops to pay rent to set up their shops there.
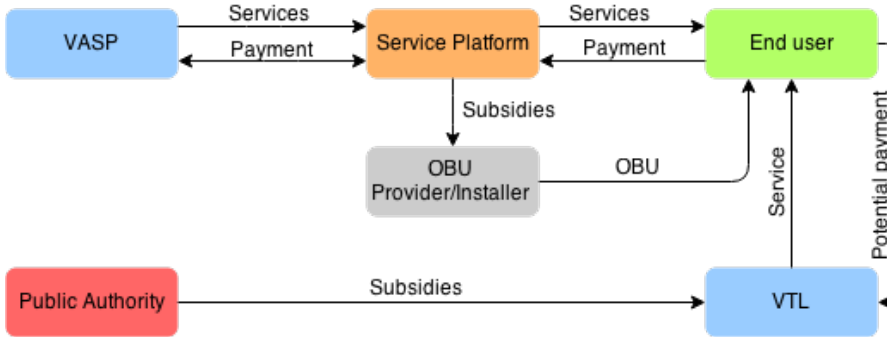
Figure 6.7: Model of revenue streams with the two-sided market approach

Figure 6.7 show how the revenue streams between actors in such a market would flow. The service platform will be the most central part of such a market configuration. By providing OBUs to the end users, either for free or subsidised, they facilitate the adoption of VTL through accelerating the adoption of the required vehicular technology. The incentives for a service platform will thus be the revenue collected from VASPs and end users. Based on the choice of business model, the service platform will try to maximize their profits while at the same time creating a sustainable marketplace for the VASPs and end users.

6.2.4   End users

The end users are the group of stakeholders which will ultimately use VTL actively when travelling on the roads. Based on the actions taken by the public authorities, vehicle manufacturers and other actors in the ecosystem, the end users have to make a choice whether to procure a VTL enabled vehicle or not. If the public authorities choose to not subsidise VTL or DSRC devices, the end users will have to pay more. The same holds for the actions of the vehicles manufacturers. Each end user has individual preferences and criteria which will need to be fulfilled for the user to enter the market. In this section it will be explained how the end users of VTL will react to different scenarios in the migration period for VTL.

Rogers introduces the concept of product diffusion in his book [6]. He defines the first 2.5% of consumers adopting an innovation as innovators, the following 13.5%

as early adopters and the next 34% as the early majority. The different kinds of adopters are defined, by Rogers, like this: the innovators are individuals which have high social status and are willing to take risks. They have financial liquidity and often ties to other innovators and research communities. Innovators can tolerate to adopt innovations which may ultimately fail. Early adopters are individuals which have higher social status, financial liquidity and have higher education than the late adopters. The early adopters are the group which have the highest degree of opinion leadership, meaning that they can influence other consumers to make choices whether to adopt a technology or not. The early majority adopts an innovation over a significantly longer period of time than the innovators and early adopters. They have above average social status, contact with early adopters and seldom holds a position of opinion leadership[6].
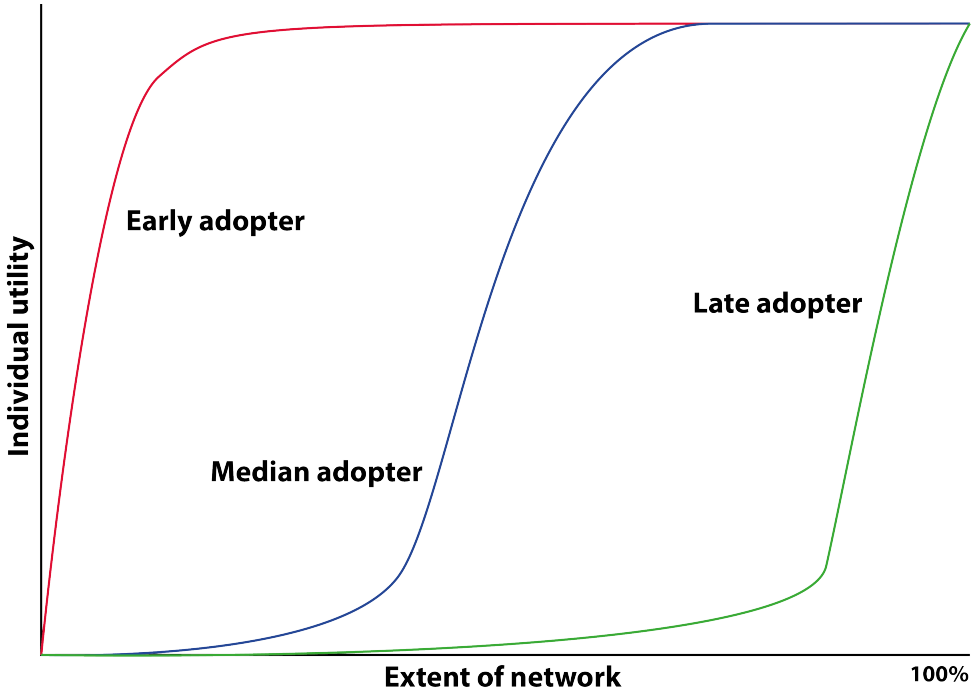
Figure 6.8: Individual utility of end users based on the size of the network, inspired by [9]

For VTL, it will be crucial to get the innovators, early adopters and the early majority to adopt DSRC and VTL to reach critical mass, such that the rest of the population will follow. The difference between these technologies and regular innovations is that they exhibit network externalities. Figure 6.8 depicts the adoption of an innovation

with network externalities. It is seen that early adopters of such technology have a higher individual utility than the median and late adopters. These adopters does not procure the technology solely based on the utility increase from other consumers with the same technology, but rather because the technology provides high individual utility. For DSRC and VTL this might be utility from service platforms, that the early adopter have financial liquidity and wants to increase social status or that he predicts the future value and desires to be early in the market.

It is difficult to say exactly how a market exhibiting network externalities will move, Goolsbe et al. conducted research which showed that people were more inclined to purchase a home computer in areas where there were already many others in close geographical proximity with a home computer[52]. Goldenberg et al. concluded that network effect also might have a "chilling" effect on consumers because they will wait until the market is populated so that the network effects influence their utility in a positive manner[53]. This show that early adopters and sufficient incentives are important for the success of new technology and will play an important role in the adoption of VTL.

Figure 6.2 show a model where the public authority subsidise the OBU and VTL to some extent. However, the end users also have to make a payment to procure the services and hardware. As explained, end users will gain different levels of utility from VTL and thus have different reservation prices to procure the service and necessary hardware, i.e. DSRC radio. We will now look at an example with bundling to investigate how such a strategy might influence the adoption rate of DSRC.

The term commodity bundling was introduced by Adams et al. in [54]. When a company sells two separate goods together at a discounted price it is called bundling. By bundling DSRC device with other technology which an end user would be interested in, the sales of DSRC devices can be increased.

	GPS	DSRC device
John	400	300
Peter	300	400

Table 6.1: Reservation prices for two users contemplating purchasing GPS and/or DSRC

Table 6.1 represents the reservation prices two end users, John and Peter, have for purchasing a specific product. In this example these products are represented by a GPS and a DSRC device for vehicles. John is willing to pay $400 for a GPS and $300 to procure a DSRC device for his vehicle, while Peter is willing to pay the opposite for both devices. We assume that there is a company producing both of

these devices, which need to decide how they should price each of the devices. The potential revenue the company can obtain by selling these devices to John and Peter is:

$$2 * (300 + 400) = 1400$$

The company can choose to be greedy, and set the price of both devices to the maximum willingness to pay experienced in the market, i.e. 400. The company will then have a revenue of:

$$400 * 2 = 800$$

Only John will purchase the GPS and only Peter will purchase the DSRC device, because \$400 is above their respective reservation price for the other devices. To make sure that they sell one of each device to both John and Peter, the company can set the price of both devices to equal the lowest reservation price for each device. The company will then have a revenue of:

$$2 * (300 + 300) = 1200$$

Which is still below the max potential revenue. To obtain the maximal revenue from these two devices, the company has to, either deploy a personalized pricing strategy where each consumer pays his or her max reserve price for each device(which probably is not viable), or bundle the products together and sell them as one. By selling the two devices as one for \$700, the company stays within the maximum combined reserve price for both John an Peter and obtains a revenue of:

$$2 * (700) = 1400$$

As VTL requires lane-level accuracy GPS, the OBU integrated with the necessary technology for VTL will have to contain both DSRC and GPS. The example above show that this might lead to several consumers purchasing the OBU based on their reserve prices for different technologies integrated with the unit.

Chapter 7

Business Model

This chapter will present the business model for the proposed VTL. In the previous chapter different scenarios regarding the migration period for VTL was presented. It was mainly focused on how to obtain a sufficient penetration level for DSRC such that VTL could be deployed. In this chapter it is assumed that 100% penetration is achieved, and that the service is deployed. Based on these assumptions and the information presented previously in this thesis, the business model for the company taking VTL to market will be presented using the Osterwalder business model canvas. This modeling approach is widely used by many coorporations, such as IBM[1] and Deloitte[2][30]. Main points of the canvas will be presented, the interested reader is encouraged to read Osterwalder's book "Business Model Generation"[30] to further understand the concept.

7.1 Osterwalder business model canvas

Osterwalder business model canvas uses 9 building blocks to present and help visualize how a company intends to make money. The purpose of each building block will be presented together with an explanation of what is included in the specific building block for VTL's business model. The proposed business model for VTL is depicted in figure 7.2. It will be thoroughly explained in the following sections.

7.1.1 Key partners

The key partners building block describes the network of necessary suppliers and supporting partners that makes the business model viable. Key partners can be used in different strategic ways to improve the business model, such as alliances between non-competitors or competitors, or buyer-supplier relationships.

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[1]www.ibm.com
[2]www.deloitte.com

For VTL the key partners were meticulously explained in chapter 4. Therefore they will not be explained in detail in this chapter. As can be seen in figure 7.2, the stakeholders included as partners are the ones directly supplying, supporting or enabling the VTL service. The reader is referred to chapter 4 for explanation of each partner's function.

7.1.2   Key resources

The key resources building block contains the most important assets a company needs in order to make the business model work. Key resources can be e.g. production facilities for a physical commodity manufacturer or public trust for a banking service. Key resources can take several forms; physical, intellectual, human or financial.

Another assumption about VTL has been made in order to accurately represent the key resources. Based on the information presented in chapter 6 about the current situation for governmental regulations and mandates for DSRC radio, and ITS in general, it is assumed that VTL is a company selling a software service. Seeing as the discussions regard mandating the required capabilities to facilitate V2V communication but not specific services or service platforms, VTL will most likely be a service which can be implemented or integrated with the mandated OBU. It is therefore also assumed that all the required technology is included in the OBU.

VTL will have several key resources. Being a software company, the developers developing, maintaining and updating the service will be important. The developers will also have to make sure that the service functions properly on all OBUs and that communication flows as intended between vehicular and infrastructure devices. If the VTL technology aims to be able to accurately determine fault in accidents occurring in intersections, a backend will have to be implemented to keep track of events happening in the intersections. This backend could also be used for traffic monitoring in intersections. VTL is intended to be a safety service providing ubiquitous traffic control in intersections. For safety applications it is crucial to have public acceptance and trust in the service. The public would not approve of using a service aimed at keeping traffic safe, if they did not trust that the service could accomplish it. Therefore it is crucial to obtain trust in the VTL service. Finally, the most central resource for the VTL company will be the service itself.

7.1.3   Customer segments

The customer segment building block represents the groups of people or entities which the company aims to reach and serve. A company can group their customers into different segments with different needs, to better represent how each customer segment is served.

VTL has several different customer segments. The customer segments are divided into two main groups; Segments directly providing revenue for the VTL company, marked with blue color, and segments not providing direct revenue for the company, marked with red. Exactly how the revenue streams flow will be explained thoroughly in the section regarding the revenue streams building block. In the proposed model, the public authority will be the actor which procures the service from VTL. The service will then be distributed to the country or city it was procured for.

The non-paying segments are included because they are the entities which create value for the service. Private vehicles, public transport, emergency vehicles and freight/transport vehicles are the segments which will actually use the service and the reason that a service like VTL will be procured, because of the many benefits that follows. A segmentation of customers where some segments pay money directly and some segments use the service for free is not a new phenomenon. Companies like Skype and Google utilize such a strategy by providing free service to some segments, and earning their revenue from the value the free users create or from other segments which pay for advanced services.

7.1.4   Value propositions

The value proposition building block represents how value is created for the different customer segments. By providing benefits and solving needs for a customer segment, a company can acquire paying customers which is crucial for a business to survive.

The different groupings of customer segments was presented in the previous section, this grouping will be used in all relevant building blocks where the content change based on which segment it concerns. The value propositions are thus depicted in red for the end users, and blue for the public authority. Value created by the VTL service was thoroughly explained in chapter 5 and will not be repeated here.

7.1.5   Channels

The channels building block represents how a company is able to deliver the value propositions to its customer segments. Channels can also be used for continuous contact with customers, allowing customers to purchase products and providing service for already purchased products

Being a software company, VTL has to be able to distribute its software to the different customer segments. To facilitate V2V communication between all vehicles in the road network, the service will have to be implemented on all OBUs. One way to accomplish this is to integrate VTL directly with all new OBUs as soon as the service has been procured from the public authorities, and employ a forced update for OBUs already implemented in vehicles. Obtaining contracts and maintaining relationships

with public authorities is crucial for the survival of VTL as a business, seeing as VTL is aimed at ubiquitous traffic intersection control. It is therefore necessary that the VTL company has contact with the public authorities to accomplish this. This contact can be personal meetings, video conferences or similar types of correspondence.

VTL assumes that all vehicles have the same image of the road networks current state, so that conflicts and accidents will not occur. The service must therefore have a way to be updated should there be changes to the service or topology of the road networks. In the proposed model, these updates are delivered over telecom-channels such as 3G or 4G.

7.1.6   Customer relationships

The customer relationships building block represents the type of relationships a company wants to maintain with different customer segments. Customer relationships may be driven by different motivations such as customer acquisition or retention, and it can be of several different types such as personal or communities.

The VTL company will have different relationships with the different groups of customer segments. Firstly, relationship with a public authority must be negotiated. This will result in a contract binding the public authority to using the VTL service. The duration and/or terms for such a contract must be negotiated between the VTL company and the public authorities. When VTL has been procured, it will be implemented throughout the road network. The end users will then have to start using VTL for traversing intersections. End users will not have a direct customer relationship with VTL, they will be locked-in with the service because of regulations from the public authorities.

7.1.7   Revenue streams

The revenue streams building block represents the revenue a company earns from each customer segment. To be successful, a company must be able to determine the willingness to pay a customer segment has for the company's value propositions. Revenue streams can take several forms, such as subscription fees, licensing and asset sale

In the proposed model, the revenue streams seen from the VTL company's point of view will be coming from the public authorities. As explained in chapter 6, the end users might very well be paying for the service one way or another, however the VTL company will only see the money coming directly form the public authorities. Because of this the end users are listed as having free usage of the service, while the public authorities pays a service fee.

VTL can be financed several different ways. The company could choose to sell VTL at a lump-sum fee where the public authorities pay a one time fee to procure the service. The public authorities would then be responsible for the infrastructure of the service and delivering updates to vehicles etc. Support for the service would then be obtained through recurring fees for the duration that VTL is in use.
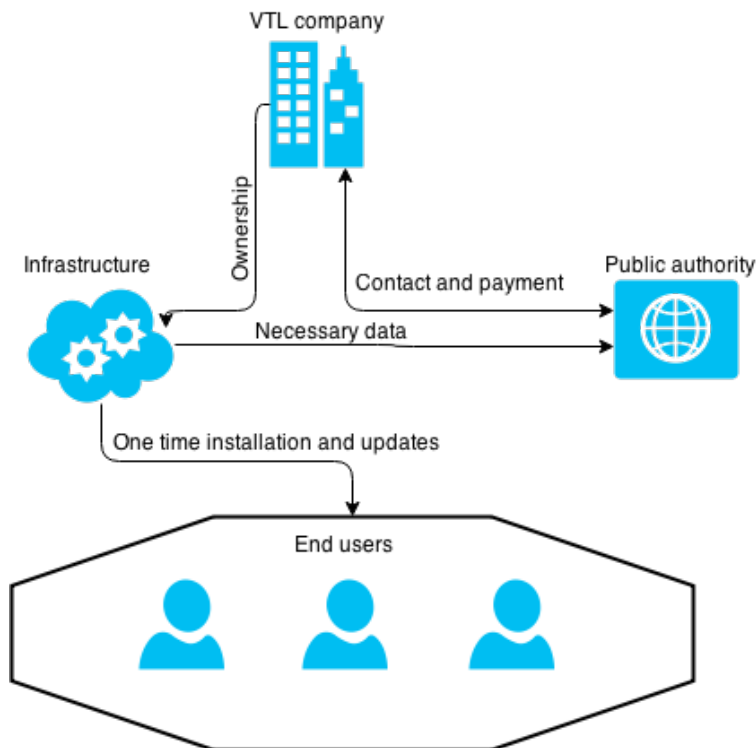
Figure 7.1: Delivering software as a service

However, this thesis propose a different model of collecting revenue for VTL. Software As A Service (SAAS) is an emerging trend in the IT-business sector which has become increasingly popular with rise of cloud computing. This type of business model aims at "lending" a software service to consumers rather than having them buy it, install it on their own systems and run it from there. Being very scalable, SAAS has seen much use in large corporate systems. By not being installed on-site at a corporation but rather in the cloud, SAAS renders on-site compatibility checks and other costly time consuming operations unnecessary. This makes SAAS very favorable for the buyer, and research have shown that companies selling SAAS can increase their revenues[55].

Figure 7.1 depicts the proposed model for revenue streams seen from the VTL company's point of view. The infrastructure will be owned by VTL and the public authorities will pay a recurring service fee to the company. Necessary data will be provided to the public authority and continuous maintaining of the VTL service as well as updates for OBUs will be managed from the company's infrastructure. Seeing as VTL is a safety service running over DSRC, the service will need to be implemented directly on the OBUs to ensure reliable message exchanges. The one time installation could e.g. be provided as a download from the infrastructure.

7.1.8   Key activities

The key activities building block represents the most important activities a company must do to make its business model work. Key activities are used to create and maintain the value propositions in the business model, and can include e.g. production of goods or problem solving.

Maintaining the service includes making sure that the service deliver its value propositions to the customer segments, and ensuring that continuous updates are distributed so that the service function optimally. Being a software company it is important to continuously develop and improve the service to provide a sufficient product for its customer segments. As a safety application it will also be important to immediately patch errors in the service to keep public trust in VTL.

As explained earlier, VTL aims at providing ubiquitous intersection management and removing physical traffic lights. For this to be viable, all vehicles must be equipped with DSRC and have the VTL service implemented. This means that VTL needs to be implemented over a large geopgraphical area such as EU or the U.S.. To sell VTL to such large actors, there is a need for good marketing to be able to penetrate the market and gain traction by serving large customer bases.

7.1.9   Cost structure

The cost structure building block contains all the expenditures a company experiences from operating the business model. Several building blocks in the business model canvas incurs costs, such as the key activities and key resources. It is important to keep the costs lower than the revenue to have a sustainable business model

Based on the other building blocks presented in this chapter, the costs can be easily deduced. VTL needs developers to function, and the developers must be paid. The proposed business model puts management of the service in the hands of the VTL company. This will incur a cost for the company in terms of hardware costs and general software management costs. As pointed out, VTL will need marketing to be able to penetrate the market and this will cause expenditure for the company.

Key Partners	Key activities	Value proposition	Customer Relationships	Customer Segments
• Vehicle manufacturers • Road authorities • Content providers • Insurance companies • OBU providers/ installers • Map providers • RSU managers • Connectivity providers	• Maintain service • Develop and improve service • Marketing **Key Resources** • Developers • Backend • Trust in brand • The VTL service	• Better traffic flow • Less pollution • Lower investments • Accident reduction • Prioritization possibilities • Less fuel consumption • Better traffic flow • Cheaper insurance • Less accidents • Less wear to vehicle	• Contractual • Regulated lock-in **Channels** • Software distribution • Updates over telecom channels • Contact with public authorities	• Public authority • Private vehicles • Public transport • Emergency vehicles • Freight/transport vehicles

Cost Structure	Revenue Streams
• Marketing • Developers • Service management	• Service fee • Free usage

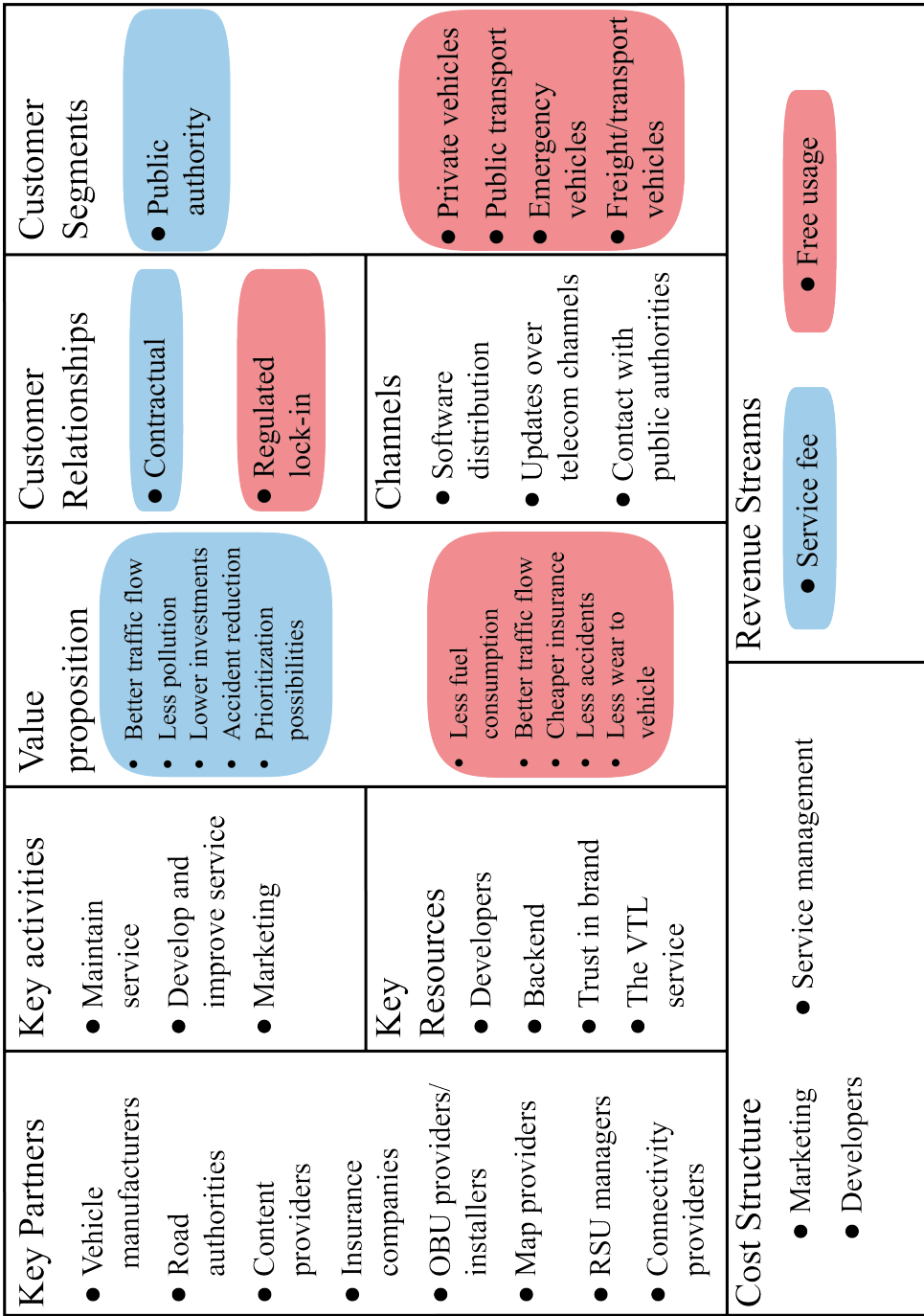**Figure 7.2:** Business model for VTL

8.1   Conclusion

This thesis has explained the concept of VTL and how it will be used to provide ubiquitous and streamlined traffic intersection management for the road network. A thorough explanation of the actors in the ecosystem and how they interact with each other has been presented together with the benefits each actor in the ecosystem will experience from the deployment of VTL.

Information about the current state of VTL and the required technology have been collected and presented. Issues regarding the migration for VTL have been given. It is shown that the biggest issue facing the implementation of VTL is the penetration rate of the V2V communication technology DSRC. Migration scenarios to facilitate an accelerated adoption of DSRC have thus been presented. Central actors have several options to facilitate adoption, a handful such options were presented in chapter 6

A business model for VTL has been proposed using the Osterwalder business model canvas. Using the different building blocks from this canvas, a complete business model was presented in chapter 7. In this chapter it was also proposed that the company taking VTL to market will function as a software company because of the ongoing debate for implementing V2V communication hardware in vehicles. Finally, it was proposed that VTL should be maintained as SAAS

VTL is a technology with a lot of potential to improve the current state of roads all around the world. Facilitating the adoption of the VTL must be done at high governmental levels to ensure interoperability and ubiquitous deployment.

8.2   Further work

Working with this thesis, several areas of potential further work have been discovered. VTL is still in very early stages, and definitive costs of the different requirements

associated with the service are not yet confirmed. There are also several debates ongoing regarding V2V communication. When more information is available it will be interesting to conduct a thorough cost-benefit analysis using real values to accurately depict how value is created for each actor in the VTL ecosystem.

Due to the direction of this thesis, pedestrians and cyclists have not been taken into account when discussing migration strategies, or how VTL will include pedestrians and cyclists when implemented. This work is better suited for a thesis or paper using simulation to explore the feasibility of a migration strategy or directly addressing pedestrians and cyclists in conjunction with VTL.

This thesis defines the marked encompassing VTL as a market exhibiting network externalities. To further explore the market, adoption rates and where critical mass for this technology is found, business dynamics modeling can be used. A thesis or paper exploring the business dynamics of VTL would be interesting to conduct in order to explore this.

Several of the proposed migration strategies highlighted in the chapter regarding related work have only been simulated using road network topologies found in e.g. New York. Road topologies vastly differ in different parts of the world and it is therefore important to ensure that partial penetration approaches are viable for different road topologies. Research using simulation to explore the feasibility of proposed migration strategies could be conducted in order to explore these issues.

References

[1] M. Ferreira, O. Tonguz, R. Fernandes, H. DaConceicao, and W. Viriyasitavat, "Methods and systems for coordinating vehicular traffic using in-vehicle virtual traffic control signals enabled by vehicle-to-vehicle communications," May 9 2013. US Patent App. 13/809,925.

[2] N. Fathollahnejad, E. Villani, R. Pathan, R. Barbosa, and J. Karlsson, "On reliability analysis of leader election protocols for virtual traffic lights," in *Dependable Systems and Networks Workshop (DSN-W), 2013 43rd Annual IEEE/IFIP Conference on*, pp. 1–12, IEEE, 2013.

[3] https://www.sintef.no/globalassets/upload/teknologi__ og__samfunn/veg-og-samferdsel/rapporter/2009/a11625__ rapportprioriteringkristiansandendelig.pdf. Accessed: 2015-16-05.

[4] http://www.scoot-utc.com/documents/1__SCOOT-UTC.pdf. Accessed: 2015-15-05.

[5] http://en.wikibooks.org/wiki/Strategy__for__Information__Markets/Network__ Externalities/Demand__Structure__with__Network__Externalities. Accessed: 2015-19-05.

[6] E. M. Rogers, *Diffusion of innovations*. Simon and Schuster, 2010.

[7] O. K. Tonguz, W. Viriyasitavat, and J. M. Roldan, "Implementing virtual traffic lights with partial penetration: a game-theoretic approach," *Communications Magazine, IEEE*, vol. 52, no. 12, pp. 173–182, 2014.

[8] http://www.amsterdamgroup.eu/. Accessed: 2015-19-05.

[9] G. P. Swann, "The functional form of network effects," *Information Economics and Policy*, vol. 14, no. 3, pp. 417–429, 2002.

[10] M. Peden *et al.*, "World report on road traffic injury prevention," 2004.

[11] http://www.epa.gov/climatechange/ghgemissions/gases/co2.html. Accessed: 2015-05-06.

[12] http://www.vegvesen.no/_attachment/629620/binary/961945?fast_title= ITS-pa-veg_veileder.pdf. Accessed: 2015-16-05.

[13] Y. Wang and F. Li, "Vehicular ad hoc networks," in *Guide to wireless ad hoc networks*, pp. 503–525, Springer, 2009.

[14] M. Ferreira, R. Fernandes, H. Conceição, W. Viriyasitavat, and O. K. Tonguz, "Self-organized traffic control," in *Proceedings of the seventh ACM international workshop on VehiculAr InterNETworking*, pp. 85–90, ACM, 2010.

[15] J. B. Kenney, "Dedicated short-range communications (dsrc) standards in the united states," *Proceedings of the IEEE*, vol. 99, no. 7, pp. 1162–1182, 2011.

[16] O. K. Tonguz, "Biologically inspired solutions to fundamental transportation problems.," *IEEE Communications Magazine*, vol. 49, no. 11, pp. 106–115, 2011.

[17] O. K. Tonguz and W. Viriyasitavat, "Cars as roadside units: a self-organizing network solution," *Communications Magazine, IEEE*, vol. 51, no. 12, pp. 112–120, 2013.

[18] http://www.compass4d.eu/download/compass4d_d6_1_business_model_ early_version_v12_final.pdf. Accessed: 2015-28-04.

[19] http://www.compass4d.eu/en/home/home.htm. Accessed: 2015-15-05.

[20] https://www.swarco.com/stl/Products-Services/Public-Transport/ Infomobility/UTOPIA. Accessed: 2015-16-05.

[21] http://www.scats.com.au/. Accessed: 2015-15-05.

[22] http://www.fhwa.dot.gov/ohim/tvtw/vdstits.pdf. Accessed: 2015-15-05.

[23] http://www.itsinternational.com/sections/cost-benefit-analysis/features/ scats-study-shows-significant-savings/. Accessed: 2015-15-05.

[24] M. L. Katz and C. Shapiro, "Network externalities, competition, and compatibility," *The American economic review*, pp. 424–440, 1985.

[25] C. Himmelberg, "Critical mass and network evolution in telecommunications," in *Toward a competitive telecommunications industry: Selected papers from the 1994 telecommunications policy research conference*, pp. 47–63, 1995.

[26] V. Gradinescu, C. Gorgorin, R. Diaconescu, V. Cristea, and L. Iftode, "Adaptive traffic lights using car-to-car communication," in *Vehicular Technology Conference, 2007. VTC2007-Spring. IEEE 65th*, pp. 21–25, IEEE, 2007.

[27] W. Viriyasitavat, J. M. Roldan, and O. K. Tonguz, "Accelerating the adoption of virtual traffic lights through policy decisions," in *Connected Vehicles and Expo (ICCVE), 2013 International Conference on*, pp. 443–444, IEEE, 2013.

[28] R. Sinha, P. S. Roop, and P. Ranjitkar, "Virtual traffic lights+," *Transportation Research Record: Journal of the Transportation Research Board*, vol. 2381, no. 1, pp. 73–80, 2013.

[29] http://www.safespot-eu.org/documents/SF_D6_3_2_Organisational_ Architecture_-_Final_v3.3.pdf. Accessed: 2015-28-04.

[30] A. Osterwalder and Y. Pigneur, *Business Model Generation: A Handbook For Visionaries, Game Changers, And Challengers Author: Alexander Osterwalder, Yves."*. Wiley, 2010.

[31] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX: 52008DC0886&from=EN. Accessed: 2015-28-04.

[32] http://www.ssb.no/bilreg. Accessed: 2015-13-05.

[33] A. Jarašūniene, "Research into intelligent transport systems (its) technologies and efficiency," *Transport*, vol. 22, no. 2, pp. 61–67, 2007.

[34] E.-H. Choi, "Crash factors in intersection-related crashes: An on-scene perspective," tech. rep., 2010.

[35] W. Viriyasitavat and O. K. Tonguz, "Priority management of emergency vehicles at intersections using self-organized traffic control," in *Vehicular Technology Conference (VTC Fall), 2012 IEEE*, pp. 1–4, IEEE, 2012.

[36] http://www.its.dot.gov/strategicplan.pdf. Accessed: 2015-16-05.

[37] C. Sommer, F. Hagenauer, and F. Dressler, "A networking perspective on self-organizing intersection management," in *Internet of Things (WF-IoT), 2014 IEEE World Forum on*, pp. 230–234, IEEE, 2014.

[38] http://ec.europa.eu/clima/policies/transport/vehicles/index_en.htm. Accessed: 2015-16-05.

[39] M. Ferreira and P. M. d'Orey, "On the impact of virtual traffic lights on carbon emissions mitigation," *Intelligent Transportation Systems, IEEE Transactions on*, vol. 13, no. 1, pp. 284–295, 2012.

[40] R. A. Kerin, P. R. Varadarajan, and R. A. Peterson, "First-mover advantage: A synthesis, conceptual framework, and research propositions," *The Journal of Marketing*, pp. 33–52, 1992.

[41] https://www.regjeringen.no/contentassets/47a6c261d82b4847b0b487d1263ec07b/ ntp_retlin_2015.pdf. Accessed: 2015-19-05.

[42] http://www.dot.gov/briefing-room/us-department-transportation-issues-advance-notice-proposed Accessed: 2015-19-05.

[43] J. Harding, G. Powell, R. Yoon, J. Fikentscher, C. Doyle, D. Sade, M. Lukuc, J. Simons, and J. Wang, "Vehicle-to-vehicle communications: Readiness of v2v technology for application," tech. rep., 2014.

[44] G. Brock W. and L. Scherber M., "Public interest comment on the national highway traffic safety administration's advance notice of proposed rulemaking: Federal motor vehicle safety standards: Vehicle-to-vehicle (v2v) communications," 2014.

[45] https://www.naf.no/tips-og-rad/elbil/politikk-og-elbil/ hvorfor-er-elbil-et-politisk-tema/. Accessed: 2015-01-06.

[46] http://www.gronnbil.no/statistikk/. Accessed: 2015-01-06.

[47] http://www.dagbladet.no/2015/05/27/nyheter/innenriks/elbil/e18/oslo/ 39368372/. Accessed: 2015-01-06.

[48] M. B. Lieberman and D. B. Montgomery, "First-mover advantages," *Strategic management journal*, vol. 9, no. S1, pp. 41–58, 1988.

[49] J. Shamsie, C. Phelps, and J. Kuperman, "Better late than never: A study of late entrants in household electrical equipment," *Strategic Management Journal*, vol. 25, no. 1, pp. 69–84, 2004.

[50] J. G. Frynas, K. Mellahi, and G. A. Pigman, "First mover advantages in international business and firm-specific political resources," *Strategic Management Journal*, vol. 27, no. 4, pp. 321–345, 2006.

[51] G. G. Parker and M. W. Van Alstyne, "Two-sided network effects: A theory of information product design," *Management Science*, vol. 51, no. 10, pp. 1494–1504, 2005.

[52] A. Goolsbee and P. J. Klenow, "Evidence on learning and network externalities in the diffusion of home computers," tech. rep., National bureau of economic research, 1999.

[53] J. Goldenberg, B. Libai, and E. Muller, "The chilling effects of network externalities," *International Journal of Research in Marketing*, vol. 27, no. 1, pp. 4–15, 2010.

[54] W. J. Adams and J. L. Yellen, "Commodity bundling and the burden of monopoly," *The quarterly journal of economics*, pp. 475–498, 1976.

[55] A. Dubey and D. Wagle, "Delivering software as a service," *The McKinsey Quarterly*, vol. 6, no. 2007, p. 2007, 2007.