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Vehicle Services

Doctoral Dissertation
by

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Abstract

This thesis contributes to our understanding of the development and diffusion of vehicle services, and to how information technology interacts with forms of organization and business models to undermine or support the development of vehicle services. The overall research question asked in the thesis is: what are the technical, business and organizational prerequisites for the development and diffusion of a rich variety of vehicle services?

The development and diffusion of vehicle services have been empirically investigated by ethnographic field studies, prototype software development and case studies as part of a collaborative practice research approach involving the Volvo Group. Based on ethnographic field studies of current vehicle repair service work, analytical patterns were identified to better understand the core foundation of vehicle services. In the prototype development, a platform was developed, which allowed exploring the technical prerequisites for the development of vehicle services. Two case studies examined, first, the development of IT support for vehicle services and, secondly, the organization of vehicle service development.

The results from all these collaborative practice research activities suggest that the vehicle industry needs to revise its conception of vehicle services as services extending product features in favor of vehicle services enriching the use of the vehicle. Thus, the thesis argues that the lack of vehicle services, rather than being just a question of technical nature, can only be remedied by a change of perspective from products to services, which in turn influences the choice of technology, forms of organization and underlying business models.

Vehicle services are here conceptualized as services interacting across the ecosystem of vehicle stakeholders to enrich the customer's use of the vehicle. Hence, to be really useful, vehicle services must roam organizational and technical boundaries and cannot be treated as properties of the vehicle. This requires vehicle manufacturers to adopt appropriate forms of technology and organization. The concept of information infrastructure is shown to be appropriate since it allows separating services from shared infrastructural resources. Such a separation also allows opening up the development of vehicle services to other service providers. Open innovation is described as a suitable form of opening up the innovation and development of vehicle

services to a larger group of service providers. The thesis argues that these three prerequisites – business model, technology and organization – have to closely interact to facilitate the development and diffusion of a rich variety of vehicle services.

The general contribution of the thesis is to show how product oriented industries have to revise their proprietary mindset in favor of an open attitude to successfully engage in the development of services.

Keywords: *vehicle services, information infrastructure, open innovation, prototyping, field studies.*

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Vehicle Services: Overview and Summary

1 Introduction

> *"Truck manufacturers, like private car manufacturers, have realized that the battle for the customer no longer is about who offers the nicest vehicle, most horse powers or the fanciest roof spoiler. It is about attracting the customer by taking care of him during the vehicle's lifecycle." (Director at Volvo Group)*

The diffusion of services is probably one of the most significant phenomena affecting the structure of modern economies during the last decades. If the first half of the 20th century in Europe was characterized by industrialization through mass production and distribution of products, the last decades were significant for the emergence of a service economy, extending or even replacing product industries. This development is also highly visible in many European cities where the city skyline were once dominated by factories now replaced by office complexes. Lindholmen Science Park, where much of this thesis work has been physically located, is an example of this development. The shipyard industry has been replaced by a technology intensive service industry and blue collar by white collar workers. Shipyards have disappeared from Europe, but the vehicle industry still exists with its factories, product development and millions of vehicles produced each year. However, the vehicle industry is currently experiencing a deep crisis followed by fundamental structural changes that still are difficult to estimate.

Even though vehicle manufacturers are currently facing extraordinary sales drops resulting in overproduction, job cuts or even threatening their existence, the economic trend of services is highly relevant and should be considered central to the structural changes the vehicle industry is facing. Vehicle manufacturers around the world are trying to expand their operations into the service business. There are several reasons for this: servicing the customer throughout the vehicle's lifecycle, obtaining a steady cash flow from services, increasing sales and an increased demand from customers for services, to give some examples. Financial services, such as lease contracts, provide successful examples of how vehicle manufacturers have extended their business to include services usually offered by financial institutions. However, the ambition is to extend the service portfolio to cover even larger

parts of the vehicle's lifecycle. Hence, the traditional business model of selling vehicles and spare parts is about to change. This thesis aims to explore this transition from products to services by focusing on necessary prerequisites.

As the development in vehicle technology during the last two decades reveals, IT has a significant role to play in the transformation of the vehicle industry, with novel services and business models. Sensor technology, on-board processing units and wireless communication facilities have transformed the vehicle from an autonomous and mechanical object to a networked and digitalized object. In their effort to increase the range of vehicle services, manufacturers have identified the digitalized and connected vehicle as core foundation for vehicle services. So far, most vehicle manufacturers have implemented vehicle services. General Motors, for instance, offers vehicle diagnostics, crash detection and vehicle positioning through its subsidiary OnStar. Mercedes-Benz Trucks offers vehicle services under the brand of FleetBoard and Volvo Trucks through Dynafleet, to name a few initiatives. During the "dot-com bubble", the vehicle industry made large investments in vehicle services with the ambition to connect the vehicle to the Internet. Promising joint ventures across business sectors, for instance the Volvo Group partnering in the year 2000 with Ericsson and Telia, the former state monopolist of telecommunication, are examples of how vehicle services were attracting not only vehicle manufacturers. Research analysts identified vehicle services such as remote diagnostics, crash detection, software update, vehicle tracking, and rear-seat entertainment as promising future services (Gartner, 2002).

However, despite technologies in place, vehicle manufacturers investing in research and development activities and third party service providers showing great interest in developing vehicle services, the diffusion of vehicle services is limited and the turnover from vehicle services is still dominated by traditional repair workshop services. In other words, the expected growth of vehicle services has not been realized and the vehicle industry is struggling with adding new services to their portfolio. The interest of other industries in vehicle services has declined too, and the Volvo Group's joint venture ended with the telecommunication partners leaving the venture, which has now been integrated into Volvo as a business unit.

Nevertheless the concept of vehicle services remains highly topical since vehicles have a large impact on society but are, from an information sharing perspective, only loosely integrated with their environment. Internet has increased the possibilities of sharing information, cooperating in use, innovation and development, among different organizations to increase competitiveness. To the vehicle industry this implies to understand the vehicle as actor in a broader context, e.g. representing a large value to be financed and insured, being part of food and other just-in-time critical production processes, contributing to environmental pollution, affecting road users by accidents, and constituting the workplace for many people. The digitalization of the vehicle along with the diffusion of wireless communication facilities allows sharing real time information about the vehicle with these different stakeholders. Thus the future potential of vehicle services is still high, even though vehicle manufacturers may have had difficulties to develop and market such services.

Academic research has also addressed the development of vehicle services, focusing on technologies enabling such services (Ai, Sun, Huang, & Qiao, 2007; Campos, Mills, & Graves, 2002; Lu, Chen, & Hamilton, 2000; Van der Perre, 2006). Even though academic research has been engaged in technical issues, challenges of standardization and social interaction aspects of vehicle services, the thesis argues that these initiatives remain fragmented and do not provide a comprehensive understanding of how to facilitate the development of vehicle services.

1.1 Research aim and question

The aim of this thesis is to gain a deeper understanding of the concept of vehicle services, by exploring it from three different perspectives: business, technology, and organization. The business perspective allows exploring general business models and how these may generate value to provide necessary returns on investment. The study of technology focuses on different platforms to support the development, distribution and operation of vehicle services. Finally, the organizational aspect contributes by understanding how to manage vehicle services to create appropriate organizations for innovation, development and distribution of services.

The question is how these three different aspects contribute to increase the variety of vehicle services rather than why particular services have failed. Thus, the thesis shall contribute to our understanding of the fundamental drivers of vehicle service development and innovation rather than bringing forward particular examples of services. Accordingly, this thesis addresses the following research question:

> *What are the technical, business and organizational prerequisites for the development and diffusion of a rich variety of vehicle services?*

In the light of the deep crisis the vehicle industry currently is experiencing, this thesis should be considered as a contribution to improve current product focused business models, but also to facilitate those radical changes of business models, technology and vehicle usage the vehicle industry may be facing. Furthermore, the vehicle industry exemplifies a product oriented industry moving towards a servitization of business and therefore provides a valuable setting to investigate the role of technology, and in particular information technology (IT), in such development more generally. The knowledge gained is of increasing importance to other product oriented businesses where products become part of ubiquitous computing environments (see e.g. Jonsson, Westergren, & Holmström, 2008).

1.2 Structure of the thesis

This thesis is composed of two main parts, a cover paper and a selection of papers. The cover paper provides a theoretical framing of this work and analyzes the individual papers' research contributions to synthesize them into a more general contribution. In the cover paper, an introduction to vehicle services is followed by a section on how theory of services, information infrastructure and open innovation make up the theoretical framing in moving from vehicles to vehicle services. This is followed by an account of the research method, succeeded by a summary of how the individual research articles contribute to the thesis. The cover paper ends with a discussion of research implications and a conclusion highlighting the contributions and future avenues of research.

The second part of the thesis includes five individual papers. Four papers have been published at international peer reviewed conferences

and the fifth paper has been submitted to a conference. Apart from being formatted to fit the thesis layout, the papers are presented in the order they originally were published. One paper is co-authored with Fredrik Ljungberg and one with Bo Dahlbom, both acting as supervisors of the thesis. The last paper is co-authored with Björn Remneland (School of business, economics and law) and Magnus Holmqvist (Volvo IT), which exemplifies the cross-disciplinary nature of this research and the industrial collaboration of this thesis. The papers included are:

Kuschel, J., & Ljungberg, F. (2004). Decentralized Remote Diagnostics: A Study of Diagnostics in the Marine Industry. In S. Fincher, P. Markopoulos, D. Moore & R. Ruddell (Eds.), *People and Computers XVIII: Design for Life* (pp. 211-226). London: Springer.

Kuschel, J. (2005). A Conceptual Framework for Remote Vehicle Diagnostics Services: Customer Experienced Needs as Core Business. *Accepted for publication and presented at the 5th International Conference on Mobile Business*. Copenhagen, Denmark.[1]

Kuschel, J., & Dahlbom, B. (2007). Mobile Services for Vehicles. In *the proceedings of the 15th European Conference on Information Systems*, St. Gallen, Switzerland, pp. 1863-1874.

Kuschel, J. (2008). The Vehicle Ecosystem. In G. León, A. Bernardos, J. Casar, K. Kautz & J. DeGross (Eds.), IFIP International Federation for Information Processing, Open IT-Based Innovation: Moving Towards Cooperative IT Transfer and Knowledge Diffusion (Vol. 287, pp. 309-322). Boston: Springer.

Kuschel, J., Remneland, B., & Holmqvist, M. (submitted). Open Innovation and Control: A Case from Volvo.

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[1] The research paper has been accepted for publication and has been presented at the 5th International Conference on Mobile Business. However, due to a misadventure by the publisher IEEE the paper has not been included in the proceedings.

2 Vehicle services

Today we can witness a great impact of computers and IT on the production, delivery and consumption of services (Collier, 1983). The supply of IT services ranges from e-government services over internet banking to social network services such as Facebook. The vehicle industry constitutes another domain where the diffusion of IT is supposed to contribute to an increase of services as opposed to the current product focus. These expectations are driven by technical advancements in vehicle electronics and wireless communication technology that allow vehicle operations to be digitalized, automated, easily distributed and shared.

Vehicles of today are equipped with numerous sensors that are interconnected and run by software operated Electronic Control Units (ECUs). The main task of this computer controlled sensor network is to adjust vehicle operations continuously. The control and operation of fuel injection may serve as a suitable example of sensor control, where sensors measure the amount of unburned fuel in each cylinder to optimize the additional amount of fuel to be injected. In addition to managing vehicle operation, any deviations are recognized by the ECUs and logged as error codes. These codes provide valuable insights to product development, to drivers as feedback and, most important, to technicians as part of their diagnostic repair work. Changes may be made to the ECU software and hence change vehicle characteristics affecting the driver experience, fuel consumption or the like.

The different sensors and ECUs form a communication network that operates autonomously and is connected to external resources only during repair service. However, wireless communication facilities have evolved rapidly during the last decade and in Sweden, among other countries, the number of cell phone contracts exceeds the total population. Apart from an enormous popularity of mobile phones, an increasing number of machines are getting connected to the Internet through the mobile phone network. Vehicles account for a considerable part of these machines. By connecting the vehicle to the Internet the vehicle network, i.e. sensors and ECUs, becomes remotely accessible for off-board processes. Vehicle manufacturers have had great expectations in this merger between vehicle electronics and wireless communications. Jameel et al. (1998) denote the development as *Web on Wheels* whereas the vehicle industry often uses *telematics* as

their term. This thesis uses the term *vehicle services*, since it provides a more comprehensive understanding than telematics with its technology and hardware focus. In some of the research articles included in this thesis, other similar terms have been used. These are remote diagnostics, remote vehicle diagnostics and remote vehicle services. Both remote diagnostics and remote vehicle diagnostics denote a subset of vehicle services, i.e. services focusing on remote access of vehicle information to diagnose a vehicle's condition. Vehicle services is used in favor of remote vehicle services since remote denotes a physical distance that is not a prerequisite for what is here referred to as vehicle services.

When studying the advancement of vehicle services, it is apparent that product development departments and Formula One racing teams are used as technical role models. In both cases, data about the vehicle is continuously analysed to either make the racing car faster or to enhance vehicle development. Even though they may represent successful examples of vehicle services, the requirements do not apply to those of a mass market. What this thesis does learn from these examples is the technical feasibility of remote access to vehicle information, which as well drives the commercial development.

Much of the research dealing with vehicle services has focused on the technical feasibility, with a main interest in connectivity and security (see e.g. Bisdikian et al., 2002; Duri et al., 2002). One strand of research reports reference-architectures and implementations of infrastructure. Campos et al. (2002), for example, report a novel reference-architecture for remote diagnostics applications. The reference-architecture builds upon the idea of context-awareness as a means of predicting future action. Both Zhang et al. (2004) and Van der Perre (2006) present platforms and standards of how to manage the delivery and execution of services running on embedded vehicle systems. If technical issues some ten years ago impeded the development of vehicle services, today's technical solutions allow onboard computing, seamless remote communication, secure data transfer and the like. However, despite technologies in place, the services to be run on the platforms have not changed much.

In addition to such technology issues, the standardization of vehicle communication and service interfaces has been addressed. Different organizations and consortia have proposed standardizations to easier share service platforms across different vehicle brands. The Autosar

initiative is an example of how vehicle manufacturers, sub suppliers etc., have agreed upon a shared software architecture for vehicle communication. The FMS-interface is another example of truck manufacturers agreeing upon sharing vehicle information through a common interface to allow, e.g., fleet management systems to function across different truck brands. These standardization initiatives focus on the vehicle industry only. A broader perspective, including system vendors of, e.g., transport management systems, is described by Andersson (2007), who reports from an action research project studying transport information systems, where he identifies a gap between mobile and stationary transport information systems challenging the integration among them. Thus, he outlines the importance of assessing architectural knowledge in bringing these heterogeneous IT bases together to create a ubiquitous computing environment, through which to leverage vehicle services. The alignment of fragmented architectural knowledge, represented by different IT bases, is achieved by a collective effort of standardization, Andersson argues.

Andersson's work can be categorized as representing management information system (MIS) research in general and intelligent transport system (ITS) research in particular. Esbjörnsson (2005) argues for a more social understanding of vehicles and traffic as opposed to the control and surveillance approach found in MIS and ITS research. Hence, he argues for a user-centered design perspective, which is derived from computer supported cooperative work (CSCW) research. Based on the social understanding of vehicle usage, Esbjörnsson (2005) contributes with different service prototypes enhancing the collaboration between road users, drivers and the roadside, and between drivers and people far remote. However, the prototypes presented do not make use of vehicle sensor data, which excludes the vehicle as part of the interaction. Esbjörnsson extends the research of vehicle services by focusing on the vehicle user as part of a social network, which is supported by vehicle services that primarily enhance collaboration.

The drawbacks of the existing research on vehicle services are as follows. First the technology research has shown vehicle services to be technically feasible, but it neglects the value creation of services to businesses and service consumers. Second, Andersson's (2007) approach of bringing together different heterogeneous system owners

to agree upon a common standard to share vehicle sensor data focuses on integration among different existing systems as opposed to facilitating service development. Third, even though Esbjörnsson (2005) provides valuable insights on how to enhance the experience of vehicle riding through IT mediated social interaction, his approach does not address the question of a sustainable business model that would allow the commercial feasibility of such services. This thesis aims to take a broader approach to understand the lack of vehicle services and how to facilitate the innovation of novel services. The research question is thus addressed from three angles that during the course of research have proven to be relevant, i.e. the core understanding of services, technology as enabler, and the organization of vehicle service innovation and development. This approach is also reflected in the choice of theoretical foundations that are discussed in the following section.

3 From vehicles to vehicle services

The review of vehicle services gives a fragmented picture of research that addresses individual issues and thus lacks a comprehensive understanding of how to support the development and diffusion of vehicle services. From an IT perspective the outlined research adopts a system understanding, i.e. focusing on vehicle systems as opposed to vehicle services. For instance the technical strand of research deals with how current vehicle systems can be extended to include secure and efficient remote connectivity. Standardization efforts such as described by Andersson (2007) also reveal a system approach, where the main purpose is to bring different systems together rather than understanding what drives the innovation and development of novel vehicle services. Simply put, these initiatives assume that extending the system infrastructure or bringing existing heterogeneous systems together is what drives vehicle services.

This thesis does not reject the importance of previous research on vehicle services but intends to go beyond the prevailing system thinking. Therefore the lack of vehicle services is addressed by exploring the prerequisites for vehicle services from three different theoretical angles. Service theory, information infrastructure theory and the concept of open innovation are used to theoretically approach the research question. The theories describe three major general trends that have influenced various industries, for instance the telecommunication industry, and may also be applicable to understand challenges in developing vehicle services. Even though the main purpose has been to apply these theories to address the lack of vehicle services, the thesis also provides theoretical contributions to each individual theory and to how the fundamental understanding of services, as opposed to products, affects both the building of information infrastructures and the adoption of open innovation. The following sections give an account of how the three theories are interpreted in the light of this thesis.

3.1 From products to services

> *"The labour of menial servants does not continue the existence of the fund which maintains and employs them. Their maintenance and employment is altogether at the expence of their masters, and the work which they perform is not of a nature to repay that expence.*

> *That work consists in services which perish generally in the very instant of their performance, and does not fix or realize itself in any vendible commodity which can replace the value of their wages and maintenance. The labour, on the contrary, of artificers, manufacturers and merchants, naturally does fix and realize itself in some such vendible commodity" (Smith 1776, p. 376).*

In the late 18th century, the political economist Adam Smith (Smith, 1776) already highlighted the distinction between goods and services. Services however were considered to be of minor economic interest since they were labor intensive and did not leave any economic and vendible value behind. Nevertheless, services and the notion of service economy has become a frequently used terminology to describe modern industrialized economies of today (Fuchs, 1968, 1980). According to Oliva and Kallenberg (2003) there are three main arguments, used in management literature, to add services to products: First, services provide consistent revenue streams resistant to economic variations, secondly, they provide revenue generation from an installed base of products with a long lifecycle, and, thirdly, the profitability of services is higher due to higher margins. However, along with Malleret (2006) and Gebauer et al. (2005), Oliva and Kallenberg (2003) argue that the profitability of services is not obvious in all cases. Gebauer and colleagues (2005) describe the non-profitability of services in manufacturing companies as the service paradox, where investments, increased service offerings and higher costs do not generate higher profits. They argue that managerial challenges are service specific and difficult to meet concerning development processes, marketing, strategy, organization and culture. This is also confirmed by Bowen's (1990) review of management literature.

The problem is that what makes services attractive, namely the fact that they can be personalized, is also what makes it difficult to make them profitable. But services can be automated just like the production of goods has been automated with great success. In fact, when we look closer at services we will see, as argued by Hill (1977), that the automation of the production of goods is really an example of the automation of services. The services involved in the production of goods have been automated with machine technology, but more recently, of course, with an increasing reliance on computer technology. The sorts of services discussed in this thesis can similarly

be automated and in this case IT, and in particular ubiquitous computing, will make it possible to combine the personalization of services with the scalability of automation. This makes services an interesting business case in spite of the warnings by Adam Smith's and in spite of the service paradox.

3.1.1 Automation of services

> *"The application of technology to the delivery of mass services may do for services what technology did for mass production. Applied to mass production, it resulted in the presentation of better quality goods of far wider varieties at lower unit prices. With few exceptions, customers no longer expect the maker of goods to custom produce items to individual order." (Regan 1963, p. 62)*

Regan (1963) outlines business areas such as transportation, communication, inventory-control and logistics, but also education and medicine to be suitable for service automation. According to Levitt (1972) the automation of services requires a technological, as opposed to humanistic, approach to the development of services. By this he addresses the labor intensiveness of services, which Smith (1776) complained about, and proposes a manufacturing approach towards services, i.e. to use machines, not people, in producing services. Even though the diffusion of computers at that time was rather low, computer technology was outlined by Regan (1963) as driving technology in the mass production of services. Some decades later, we can say that almost every industry has adopted services, and computer technology has contributed to their automation. The diffusion of the Internet has also had considerable impact on the increase of service automation. Online banking may serve as a good example of this development. Computer technology automated back-office services through automatic data processing, whereas the Internet automated the front-office services offered by the bank, i.e. today's online banking.

> *"Once service 'in the field' receives the same attention as products 'in the factory' a lot of new opportunities become possible". (Levitt 1972, p. 41)*

It goes without saying that the understanding of services has passed through great changes; from being labor intensive and economically perishable, and hence of minor economic interest, to getting

automated and mass produced at low cost and thus profitable. A number of product oriented organizations that have entered the service market, e.g., General Electric Co., IBM Corp., Siemens AG and Hewlett Packard Co. are outlined as success stories of creating growth through services (Sawhney, Balasubramanian, & Krishnan, 2004). However, it is questionable to what extent e.g. IBM's or Hewlett Packard's services can be considered automated since they mainly build on invoicing hours provided by human consultants. A more suitable example of service automation is probably found in Google and its search services, linked to different advertisement services that are totally automated.

Examples such as Google reveal the importance of IT in making services scalable and profitable. Nobel laureate Robert Solow (cited in Brynjolfsson, 1993, p. 67), however, points to the lack of productivity coming with IT: "we see computers everywhere except in the productivity statistics". Brynjolfsson (1993) ascribes this productivity paradox of IT to deficiencies in measuring, but also the fact that IT does not necessarily enhance productivity but the variety and innovation of services. This thesis does not aim to address the shortcomings of services related to productivity, but follows instead Brynjolfsson's (1993) approach in understanding how to increase the variety and innovation of vehicle services through automation and personalization.

3.1.2 Customer vs. product services

The relation between products and services has been widely discussed in the literature. Thus, there are various definitions and categorizations of services that mainly spring from marketing and management research. Judd (1964) proposed a classification of services in rented goods services, owned goods services and non goods services. A similar approach was chosen by Rathmell (1966) who characterizes services by a goods-service continuum along which services can be categorized. More than two decades later, the question of taxonomy remains topical as Bowen (1990) argues there to be a lack of classifications that are based on empirical studies. Based on consumers' perceptions of services, he introduces a taxonomy that is empirically founded and informed by different industries. Hill (1977) defines services as changes made to products or persons, resulting in physical or mental changes. Services can be permanent or transitory and the

changes reversible or irreversible. However, what they have in common is a person's or organization's need at a certain point of time. Similar categorizations have been reemphasized lately. Mathieu (2001) distinguishes between services supporting products (SSP) and services supporting the client's activities when using the product (SSC).

This thesis does not aim to contribute with any additional taxonomical understanding of services or the management of them, but addresses what Vandermerwe and Rada (1988) denote as the servitization of business, i.e. to use services as a competitive tool of differentiation by addressing individual customer problems. Thus, the thesis makes use of Hill's (1977) work, i.e. differentiating between services affecting goods and those affecting persons, which is refined by Mathieu's (2001) categorization of services supporting the product and services supporting the customer. Regarding the management of services, this thesis aims to explore the innovation and development of services, which Brynjolfsson (1993, p. 76) refers to as doing "new things in new ways". However, the management and marketing focus in service research reveals a lack of theoretical understanding of how the development of novel services can be facilitated. This thesis aims to approach this lack by bringing different theoretical concepts together that enable us to understand the vehicle service development springing from the digitalization and connectivity of vehicles.

The characterization of services into, first, services supporting the customer (SSC) and, secondly, services supporting the product (SSP), forms the starting point of the analysis. Based on this interpretation of services, the thesis also looks beyond the traditional automation of services as described in the previous section, i.e. the automation of back-office and front-office services. In looking beyond the traditional automation of services, this work is inspired by Mark Weiser's (1991, p. 66) notion of ubiquitous computing, i.e. technologies that "[…] weave themselves into the fabric of everyday life until they are indistinguishable from it." The modern vehicle of today may probably serve as one of the more mature ubiquitous computing environments, where sensor and computing technology optimize the driving experience without the driver taking notice of the technology. In addition to enhancing the experience of human computer interaction, ubiquitous computing also adds a new dimension to the business-customer relationship as Fano and Gershman (2002) argue. They describe the future of ubiquitous computing as the "eyes and ears" of

service providers, thus increasing the focus on customer needs and addressing them by personalized services that nevertheless are automated. This also requires sharing customer information across multiple service providers to create value, which in turn requires appropriate information technologies and forms of organizations, as section 3.2 and 3.3 will argue below.

3.2 From system to information infrastructure

Initially IT was dominated by system thinking as a way to use it for administrative data processing. However, along with the diffusion of the Internet during the 1990's, ideas of IT as information infrastructure emerged. At first the Internet was outlined as an information infrastructure, foremost due to the attraction gained by the Clinton and Gore administration's visionary report on the new National Information Infrastructure (NII) and its European equivalent, the Bangemann report in 1994. The Internet was described as a communication network bringing together previously dispersed networks to make information ubiquitously available. However, the Internet has turned out to not only provide information at the fingertips but evolve to become the predominant technology for the development and diffusion of a great variety of services. Organizations leveraging services have thus gradually developed an understanding of IT as information infrastructure and abandoned system thinking in favor of a focus on services. One indication of this change has been the popularity of "service-oriented architectures" (SOA), i.e., software architectures enabling easy addition of novel services. Given the nature of the vehicle industry's attempts at vehicle service development it is questionable, in spite of much talk about SOA, whether the concept of information infrastructure has yet been adopted.

The role of technology and particularly IT is evident in vehicle service development as the previous sections on both vehicle services and the automation of services reveal. IT enables the automation and personalization of services, but also the innovation of novel services previously unfeasible to accomplish. Since we can recognize a current lack of vehicle services, this thesis aims to understand the role of IT and thus information infrastructure related to the innovation and development of vehicle services. Why are there so few services? After having introduced a few services already in the 1990s no really new

services have been introduced on the market. This raises an interesting question to be approached by this thesis.

One reason already mentioned might be that the vehicle industry has been focusing too much on IT as systems rather than on IT as services. By treating services as functions of proprietary systems the industry has circumscribed and hampered, rather than encouraged, the innovation and development of vehicle services. Recent theorizing about the properties of information infrastructures, as distinct from information systems, seems to support such an explanation.

Hanseth (2000) outlines three characteristic features of infrastructures: first, their enabling function, secondly, infrastructures being shared by a larger community and, thirdly, their openness. These characteristics address current challenges of vehicle service development. As Hanseth argues the enabling function of infrastructures facilitates new applications as opposed to just improving existing ones. Similarly, Lyytinen and Yoo (2002) argue that information infrastructures serve as important facilitators for such ubiquitous computing environments, which combine social and technical elements.

Considering current technologies supporting vehicle services, one may characterize them as focusing on improvement rather than innovation of novel services. The lack of support to explore new application areas may be explained by the vehicle industry's closeness and lack of cooperation with external vehicle stakeholders more than parts suppliers. Even though previous research (see e.g. Van der Perre, 2006) has addressed the need for software platforms to manage vehicle services securely and efficiently, the socio-technical aspects highlighted by information infrastructure theory have not been considered.

Previous research describes information infrastructures as "a shared, evolving, heterogeneous installed base of IT capabilities among a set of user communities based on open and/or standardized interfaces" (Hanseth & Lyytinen, 2004, p. 2). Based on this description and other previous work by Hanseth, Ciborra and colleagues, Nielsen (2006) identifies four characteristic concepts that can be used to characterize information infrastructures: evolution, control, standards and heterogeneity. Nielsen extends these categorizations by studying the development of information infrastructures rather than the previous characterization of information infrastructures. Since this thesis does not aim to analyze any existing information infrastructures but focuses

on its potential role in facilitating vehicle services, Nielsen's approach of information infrastructure development constitutes the point of departure. He argues that information infrastructures have been described as autonomous, whereas he provides a picture of multiple agencies and different power structures taking influence in and by information infrastructures. Thus, he rejects the description by Star and Ruhleder (1996) of information infrastructures as hidden and becoming visible upon breakdown or Ciborra's (2000) characterization of information infrastructures as out of control and drifting. Nielsen's (2006) understanding of information infrastructure development driven by multiple agencies, is best explained by the following four analytic categories.

Since information infrastructures are characterized by enabling new fields of application, openness and being shared by larger communities, they continuously evolve. Thus, the building blocks of an information infrastructure must be flexible enough so that new functionality can be added to support future services (Nakajima, Fujinami, Tokunaga, & Ishikawa, 2004), even though all future services cannot be known in advance (Edwards, Bellotti, Dey, & Newman, 2003). Modularization is described as favorable to handle such continuous evolution, since gateways allow adding new features before they are integrated as part of the infrastructure (Hanseth & Monteiro, 1998). From a perspective of information infrastructure development, Nielsen (2006) speaks of this process as an interplay between evolution and construction or a political process that controls and guards the stability of an information infrastructure.

Control is highlighted as another characteristic of information infrastructures. Whereas Ciborra et al. (2000) describe them as out of control and drifting, Nielsen and Aaanestad (2006) argue for a more nuanced understanding of control. By studying the building of an information infrastructure for mobile services, they show how control over technology is retained, whereas the selection of services and content distributed through the infrastructure is autonomous and out of control. Since the vehicle industry is risk aversive and thus not easily persuaded to give up control over their technology, the possibility of combining control and autonomy should make the concept of information infrastructure interesting to this industry.

Control may also be exercised through the standardization agreements following information infrastructures. Hanseth and Monteiro (1997)

describe standardization as a socio-technical agreement on the properties of information infrastructure interfaces towards other infrastructures or systems. According to Nielsen (2006) standards influence both flexibility and innovation, thus attributing more than technical specifications to standards. Hanseth et al. (1996) have previously described similar observations as the tension between standardization and flexibility in information infrastructures.

Along with evolution, control and standards, heterogeneity is described as an essential characteristic of information infrastructures. Hanseth describes heterogeneity as a precondition for the central role of information infrastructures to support a wide range of usage and activities (Hanseth & Monteiro, 1997). However, the heterogeneity of services requires also a heterogeneous system (Hanseth & Lyytinen, 2004). According to Nielsen (2006) previous research describes the heterogeneity of services as a major challenge in information infrastructure design. Nielsen adds to this understanding by showing how heterogeneity serves as the very condition for information infrastructures to secure their growth. Even though Nielsen (2006) stresses the importance of heterogeneity, it remains unclear how heterogeneity is achieved or even stimulated. To the development of vehicle services this implies to understand how to support a heterogeneous group of infrastructure stakeholders as well as introducing heterogeneity and openness to a homogeneous and closed vehicle industry.

3.3 From closed product innovation to open service innovation

Large parts of the 20th century may be described as decades of inventions, foremost within engineering and medical technology. Surprisingly little attention was paid to innovations by social science researchers those days. The theoretical reasoning was limited to Schumpeter's (1934) thoughts on innovations as new combinations of already existing activities and products. Entrepreneurs embodied a central role in such innovation processes and, hence, the economic development of nations according to Schumpeter. He later extended this concept of *Unternehmergeist*, i.e. highlighting the entrepreneur as individual, by attributing organizations a larger role in the innovation process.

Most organizations have adopted a closed innovation process, where knowledge and ideas are created and managed inside the organization's own knowledge silos without the involvement of external organizations (Chesbrough, 2003). However, starting with von Hippel's (1986) observations of lead users passionately adding innovations to commercial products, new theoretical concepts have been developed to understand how innovations emerge and how companies should enhance their innovation management. Different phenomena, such as globalization and the diffusion of IT, interact and emphasize the importance of openness.

Large companies start to realize that innovations may be found beyond organizational borders, in collaboration with other companies, with research, with innovative small or medium sized enterprises or individuals such as customers. This trend from closed to open innovation has just started and the adoption by the vehicle industry is rather limited compared to other industries. Perhaps this may explain why it has been so difficult to develop a variety of vehicle services.

There are four main concepts that together characterize the current discourse on open innovation: crowd sourcing (Howe, 2006), disruptive innovation (C. M. Christensen, 1997), open innovation (Chesbrough, 2003) and lead user innovation (von Hippel, 1986). Christensen (1997) introduced the notion of disruptive innovation, i.e. technologies that disrupt established markets by suddenly gaining attention even though they may be technically inferior to existing technologies. They succeed since the total offer better applies to customers' demand.

Whereas Christensen (1997) represents a strand of research focusing on how innovations enter markets, another strand deals with understanding innovators and their organization. Crowd sourcing (Howe, 2006), lead user innovation (von Hippel, 1986) and open innovation (Chesbrough, 2003) all share a democratic foundation, a dependence on actor networks and the co-production of innovation in one way or another. Crowd sourcing denotes the decentralized organization of innovation, i.e. not organizing innovation activities around a central innovation management. Von Hippel's (1986) work has largely influenced the current research on open innovation and its related sub-themes. He argues for lead users, as opposed to large corporations, as a vital source of innovation, introducing a democratic theory of innovation.

The fourth concept, open innovation, denotes Chesbrough's (2003) recent conceptualization of the innovation process as open up to the in- and outflow of ideas, as well as utilizing external paths to market innovations. Chesbrough (2003) describes open innovation as basing the innovation process upon explicit cooperation with external sources. Open innovation is thus a reaction towards closed innovation, i.e. knowledge accumulation limited to internal "silo-like" structures. Accordingly, the cross organizational distribution of knowledge as opposed to limitations by organizational boundaries, defines the research and development space in open innovation. Chesbrough (2004) describes this development as paradigmatic and provides four main business models to create value from open innovation (Chesbrough, 2006): hiring external experts, acquisition, spin-off ideas and patent trading.

Based on Chesbrough's (2003) fundamental thoughts, i.e. the mobility of knowledge and ideas, firms should actively search and hire external experts to strengthen their internal innovation processes. This challenges companies to overcome the "not invented here" syndrome (Chesbrough, 2006, p. 24). Secondly, firms may also secure external knowledge and ideas through acquisition, which, in Cisco System's case, replaces research and development with acquisition and development (Chesbrough, 2006).Thirdly, spinning off ideas in new companies is described as a way of capitalizing intellectual property that does not fit into the existing business model or requires support by external partners. Venture capital may have a central role to facilitate spin-offs that may be re-acquired when e.g. technologies are mature enough. Fourthly, patent trading is described by Chesbrough as an effective tool to support open innovation. Patent trading secures revenues on intellectual property as well as allowing others to innovate.

Even though Chesbrough's notion of open innovation has gained wide attention among both practitioners and academics, his conceptualization is schematic when it comes to technology strategies in open innovation. West and Gallagher (2006) study open-source software development as an example of open innovation to understand how to address the challenges of managing open innovation. Thus, they explore how open source software firms approach the three core concepts of open innovation, i.e. how to develop creative ways to exploit internal innovations, how to incorporate external innovations into internal innovation processes,

and how to motivate outsiders to provide a continuous stream of external innovations.

West and Gallagher identify four strategies that open-source software firms adopt: Pooled R&D, spinouts, selling complements, and attracting others to donate complements. What distinguishes these strategies from conventional innovation management is their lack of control and governance, which West and Gallagher (2006, p. 320) consider as the paradox of open innovation, i.e. "why would firms contribute resources, including IP, to projects that will benefit others, including their competitors"?

West and Gallagher's (2006) study of open-source software firms reveals how core technologies are open-sourced to establish them as de facto standards, share costs and attract external contributions, whereas complements interfacing the customer are kept proprietary to allow differentiation. Thus, their work provides a more detailed understanding of the role of IT in open innovation than Chesbrough (2003) work.

One may well wonder to what extent open innovation describes a new phenomenon. Christensen et al. (2005) argue that previous work on the absorptive capacity (Cohen & Levinthal, 1990), i.e. R&D competence to absorb external knowledge, and the cross-disciplinary nature of innovative learning, described by, e.g., von Hippel (1988), cover much of what open innovation is all about.

Nevertheless, open innovation describes well a trend influencing an increasing number of organizations. Van de Ven (2005) argues this to be an effect of an increased complexity of technology innovations which forces organizations to focus on their core competencies and to collaborate with other organizations providing complementary capabilities. The thesis uses open innovation as a third theoretical viewpoint to analyze the organization of vehicle service innovation and development.

4 Research approach

In exploring the research question *"What are the technical, business and organizational prerequisites for the development and diffusion of a rich variety of vehicle services?"*, two major strands of research have influenced my approach. These are: CSCW research and IS research. IS research represents an interest in managerial aspects of information system design, based on a historical focus on accounting and transaction based systems. CSCW in turn, addresses the issues of collaboration among workers by studying social interactions by means of ethnographic field work. By building upon these two traditions, the thesis approaches the research question from two philosophical and methodological standpoints that in part may be considered diametrically opposed. However, in the light of this thesis, this dual approach contributes with a rich understanding, i.e. gaining insights about the details of service work by taking a user perspective, but also providing the broader picture of service management through taking on an organizational perspective.

Furthermore, the thesis builds on the tradition of applied information technology, i.e. the research problem is identified within an application area rather than adopting a theoretical starting point. Thus, theory constitutes a toolbox to understand the application problem. The strength of applied research is to contribute with results of high relevance to the application domain. Benbasat and Zmud (1999) argue that IS research in parts lacks relevance and thus may distance itself from system development. Mathiassen (2002) addresses this problem by presenting the concept of collaborative practice research that recommends close research interaction between practitioners and researchers to enhance the relevance of IS research without giving up the ambition of rigor.

This thesis adopts Mathiassen's collaborative practice research approach, since the research question requires close interactions with the vehicle industry to understand how to facilitate the development of vehicle services. Each of the included individual research papers applies different research methods to gather empirical data. This chapter aims, first, to outline how the different methodological approaches contribute to the overall collaborative practice research approach. Secondly, the research setting is described and, thirdly, an account of the research process is provided.

4.1 Collaborative practice research

As Mathiassen (2002) argues, collaborative practice research requires well functioning relations between research and practice. To achieve this, practitioners have to agree to become research objects and researchers, in turn, have to make sure to improve practices. Furthermore, balancing between research and practice also challenges the structuring and managing of the research process. The researcher has to make sure that in-depth data is collected, interpreted and presented according to proven methods and bodies of knowledge. In other words, the researcher has to make sure to oversee both relevance and rigor (Mathiassen, 2002).

Apart from providing a solid methodological foundation for applied research, collaborative practice research is considered suitable for this research project since it allows eliciting different types of knowledge and thus provides a rich understanding of the research problem. Mathiassen (2002) refers to Vidgen and Braa (1997) and their three forms of knowledge creation to describe the corresponding types of knowledge that are created through collaborative practice research. These are: First, understanding through interpretation, secondly, providing support by means of design and, thirdly, improvement through intervention. According to Mathiassen (2002), collaborative practice research approaches each of these types of knowledge with different methods. Thus, collaborative practice research is made up of action research, experiments, and practice studies. Action research addresses improvement through intervention, experiments aim to design and evaluate novel approaches that would not have come up in an action research setting, and practice studies allow understanding the research object through interpretation.

This thesis builds upon ethnographic field studies, case studies, prototyping work and in parts action research. Ethnography and case studies address what Mathiassen (2002) refers to as practice studies. Based on these findings, the prototype work experiments with technologies to explore how to better support the development of vehicle services. Even though this thesis does not include a full action research cycle (Susman & Evered, 1978), the close industrial collaboration over six years in general and case study I (see table 1, pp. 31), spending four month at Volvo, in particular, included activities of interventional character to improve the organization. Participation in

meetings, personal talks, lectures and inquiries have contributed to improvements based on the knowledge gained in the other research activities. As follows the three methodological approaches, i.e. ethnography, prototyping, and case study, are introduced and discussed.

4.1.1 Ethnography

Ethnographic studies started off by English anthropologists visiting foreign cultures and studying them from a distance. These studies have been described as researchers sitting in rocking chairs on verandas, watching natives and taking notes. But soon participant observation, trying to understand foreign cultures by acting in the group themselves, became popular and thus minimizing the distance between researcher and research object.

Apart from observation, the writing of texts is a central part of ethnographic work, both in the field and thereafter (see e.g. Clifford & Marcus, 1986; Hammersley & Atkinsson, 1995; Maanen, 1988). However, different traditions of ethnographic writing have evolved over time. Clifford and Marcus (1986) describe a tendency towards writing that strives to be artistic and loses objectivity, but conclude by arguing that ethnographic writing can be poetic and at the same time keep its objectivity. Van Maanen (1988) introduces confessional writing as opposed to realist tales, as a technique that enables the ethnographer to reflect upon her own situation in the field and thus her influence on the material. Schulze's (2000) ethnography of knowledge workers is probably the most prominent example of confessional ethnography in IS research. Schulze lets the reader take part of her own reflections during the ethnographic work and thus amplifies her findings through confession, from a researcher's perspective, and strengthens the interpretation of her data.

Even though writing up constitutes the original presentation form of ethnographic field data, the use of ethnography in the domain of computer science and system design has instead focused on the analysis of field data to identify design implications related to the detailed observation of certain phenomena. The notion of "quick and dirty ethnography" was introduced by Hughes et al. (1994) to describe such a design approach to ethnography and frequently used by

researchers (see e.g. Ljungberg, 1997) forming the tradition of the new informatics (Dahlbom, 1996).

Despite ethnographies' widespread application in system design, the appropriateness has been questioned by e.g. Anderson (1994). Anderson (1994, p. 17) describes the design implications with which most CSCW research papers conclude, as "generalizations empty for the ethnographer and useless for the designer". Dourish (2001, p. 156) argues likewise and considers most design implications to often be "obvious, insubstantial, or vague" to the design community and "to the sociologists, they deny the richness of the settings to which they refer". Hughes et al (1994, p. 429) characterize the trend as "requirements elicitation" and Anderson (1994, p. 151) claims that "designers do not need ethnography to do what they wish to do" and that going into the field not necessarily implies doing ethnography. According to Anderson, ethnography is a literacy practice, which of course complies with the anthropological interpretation, such as advocated by van Maanen (1988).

However, Wasson (2000) provides an interpretation of ethnography in the design field that very much reflects the understanding and application of ethnography in this thesis. She argues that ethnography enables the designer to investigate "not just what consumers say they do, but what they actually do" (Wasson, 2000, p. 378). Wasson highlights the importance of the self-reflexive and analytic pattern finding part of ethnography forming well grounded interpretations of the observations. This thesis follows in the tradition of CSCW research of using ethnography to ground system design in current work practices. Thus, the thesis does not comply with the traditional understanding of ethnography as writing up field observations, but embodies what Wasson (2000) describes as the analytic interpretation of ethnographic field data.

Two ethnographical studies are part of this thesis work, one studying repair service mechanics in the marine engine industry and the second following mechanics at workshops specialized in truck maintenance. The first study forms the foundation for much of the following empirical work by identifying analytical patterns that are considered decisive to the understanding of services, in particular vehicle services. The second study was conducted four years later to gain a detailed understanding of truck repair work and what parts of the work could be supported by vehicle services. Both ethnographies were inspired by

the idea of cultivation (Dahlbom & Mathiassen, 1993), i.e. to identify and cultivate crucial parts of current work practice. Thus, ethnography is interpreted as a way of grounding and an analytical vehicle rather than reporting on specific field observations.

Nevertheless, the common techniques of ethnographic field data collection have been applied. Field notes, photos and document collections constitute the main body of data collected. The field notes were completed each day to provide a richer description and to bring up resulting questions to be asked. Understanding the work practice of vehicle repair service has been crucial throughout the observation, and for that reason complementary interviews were conducted. The risk of "going native" (Hammersley & Atkinsson, 1995), i.e. to subjectively represent the mechanics' interests is considered to be minimal in this thesis, since the length of each study was limited to not more than a week. The following section describes how the ethnographic studies have influenced the subsequent prototype development.

4.1.2 Prototype development

From a system development perspective, the problem of bridging the gap between ethnography and design is evident. Shapiro (1994) argues that capturing and categorizing the flows of activities is what system designers need for requirement capture, but that this is not a natural part of sociology. Therefore, I agree with Forsythe (1999) arguing that ethnographers should much more focus on inspiring or enabling to rethink designs rather than giving concrete advice in order to fill the gap. There is a tendency towards analyzing ethnographic data from a design perspective, searching for design implications already during the study. This is of course problematic since, as Dourish (2001, p. 156) states, technological design for cooperative work "fails to capture the subtlety and nuance of the setting".

In its attempt to bridge the gap between ethnography and, in this case, service development, the thesis is inspired by three closely related concepts springing from the idea of cultivation (Dahlbom & Mathiassen, 1993). First, the thesis interprets service development as a philosophy of design that is about changing organizations, technology and the usage as described by Dahlbom and Mathiassen (1993). Secondly, people and technology are becoming intertwined, i.e. "you cannot understand the one without understanding the other"

(Dahlbom, 1996, p. 38). Thirdly, the concept of cultivation, i.e. not to change more than necessary in order to not upset the users, fills the gap between ethnography and service development.

The ethnographic data collected in this thesis is both analyzed in a broader context (see paper 2) and specific design implications are implemented by three different prototypes (see paper 3). However, the prototype implementation of design implications does not serve as a result per se, but serves as an analytical vehicle to understand the role of technology design. The development of the first prototype resulted in an embryo for a generic platform exemplifying a possible information infrastructure. Thus, the following prototypes allowed exploring the design and development of vehicle services.

4.1.3 Case study

A case study is performed when one wants an in-depth understanding of phenomena within a specific case. Yin (1984) differentiates between case studies building on single or multiple cases and being of exploratory, descriptive, or explanatory type. This provides six possible setups of case studies. Whereas the single case study focuses on only one case, the multiple case study includes at least two cases that either replicate or contrast the results. Exploratory case studies aim to identify research questions for subsequent studies. Descriptive case studies focus on providing a rich description of the studied phenomenon and explanatory case studies aim to explain cause-effect relations, i.e. explaining how certain activities happened.

This thesis applies the concept of descriptive single case study to provide a detailed understanding of particular phenomena in the vehicle industry. However, the study does not follow Yin's (1984) positivistic interpretation of case study research, but adopts Walsham's (1993) notion of interpretive case study instead. If the positivistic approach understands reality as objectively given and described by measurable properties, the interpretive approach argues reality to be accessible through social constructions such as language and shared meanings. The latter approach is chosen for this study and I choose to not further discuss the differences between these two paradigms since they are diametrically opposed and have been discussed extensively.

Walsham (1995) identifies anthropological studies such as ethnography as a philosophical basis for interpretive case studies. Thus, interpretive case studies focus on the richness or thickness of the data. This allows accessing the subtleties that help to understand what is happening in the particular case. Building upon an anthropological approach, i.e. understanding empirical data as the researcher's own construction, requires researchers to reflect on their philosophical stance, Walsham (1995) argues. The philosophical stance underpinning this thesis is inspired by CSCW research and its underlying philosophy of user focus and collaboration among actors, not taking organizational borders into account.

Furthermore, Walsham (1995) argues that the use of theory in interpretive studies should be carefully considered, since the researcher should enter the field with openness. This work follows an inductive approach, where the choice of theory is determined by the empirical results, i.e. theories are considered as a toolbox to be used for a better understanding of the empirical findings.

Finally, Walsham (1995) outlines four possible outcomes or generalizations from interpretive case studies. These are: Development of concepts, generation of theory, drawing of specific implications, and contribution of rich insights. By referring to Bhaskar (1979), Walsham argues that the generalization should be understood as "tendencies", i.e. focus in interpretive research is on understanding past data rather than predicting future situations. This thesis aims to contribute with a generalization through the development of a concept for vehicle services that springs from rich insights gained from, among others, case studies.

4.2 The empirical context

The empirical work has been conducted in collaboration with the Volvo Group, which is the world's largest producer of heavy-duty power trains and a leading provider of its applications such as trucks, buses, construction equipment, aero, power generation and boats. Sales exceeded 300bn SEK in 2008 and the global presence embraced more than 100.000 employees. The company has its headquarters in Gothenburg, Sweden, and most of its production, research and development in that country. The organizational structure of the

Volvo Group consists of nine business areas that are supported by a number of business units.

Empirical data for this thesis work has been collected in two business areas and two business units. Volvo Trucks and Volvo Penta were selected as business areas and Volvo Parts and Volvo Information Technology (Volvo IT) as business units. Even though Volvo Trucks and Volvo Penta exemplify two different types of vehicles, they nevertheless build on similar heavy-duty power train and software control technologies. Thus, both types of vehicles are affected by the diffusion of ubiquitous computing technologies that transform the vehicle from a mechanic and autonomous object to a networked and digitalized object, forming the technical foundation for a new generation of vehicle services that this thesis aims to explore. The two business units, Volvo Parts and Volvo IT, serve the business areas in this change, along with other business units such as Volvo 3P and Volvo Powertrain.

Volvo Parts and Volvo IT have been chosen as study objects since they better represent the user and IT focus characterizing this thesis. Volvo Parts primarily focuses on the aftermarket which implies a high level of customer interaction. Even though Volvo IT also serves, e.g., the automation of production facilities, providing IT support for vehicle services constitutes a core assignment. This is a result of IT becoming more important for developing vehicle services that are automated and not as labor intensive as workshop services that currently dominate the service portfolio.

By studying two business areas and two business units of one of the leading producer of heavy-duty power train applications, the thesis has gained empirical insights into three major aspects of vehicle services. First, workshop studies at both Volvo Trucks and Volvo Penta have provided a rich empirical context for current service offers, but also insights into a milieu for the distribution and consumption of future vehicle services. Secondly, the thesis has explored technical aspects of vehicle services by developing prototypes and evaluating them in the Volvo context. The prototype development has been conducted in collaboration with Volvo Parts and services building on the prototype platform have been evaluated in both the truck and boat context. Thirdly, strategies of organizing the development of vehicle services and necessary infrastructures have been explored by following an infrastructure development project at Volvo IT.

The empirical context is limited to the Volvo Group, which may have prevented a more diverse understanding that might have been achievable by including more than one vehicle manufacturer. However, by spanning different types of vehicles and including studies of different parts of the organization, the thesis nevertheless contributes with a rich understanding that can be generalized for the vehicle industry. Furthermore, the collaborative practice research approach allows for a deep mutual engagement.

4.3 The research process

The research reported in this thesis is an example of collaborative practice research involving different methods and thus different research activities going on for several years. In table 1 the different data collection activities are presented in a chronological order.

Research activity	**Time period**	**Summary**
Volvo Penta ethnography	2003 – three months	Ethnographic field study at workshops for marine engine repair and back-office support facilities. Results presented in paper I and II.
Prototype I and field trials	2003-2004	Prototype development of remote vehicle diagnostics. The development resulted in a platform for vehicle services and three services building upon it. The platform and services were evaluated in a field trial. Results presented in paper III.
Prototype II	2004-2005	Prototype development of a remote software update service. Two workshops were held in relation to the prototype work including the researcher, master students and practitioners. Results presented in paper III.
Prototype III	2005	Master students developing a vehicle service based on the service platform to explore both

		the collaborative aspect of remote vehicle diagnostics and the feasibility of the service platform. The ten week project was concluded with a workshop including practitioners. Results presented in paper III.
Refactoring of platform	2003-2006	Based on knowledge gained from the prototype work, the service platform was continuously refactored.
Volvo IT – case study I	2007 – four months	A case study at Volvo IT, where I spent four months full time to be part of a vehicle service infrastructure development project as researcher. Results presented in paper IV.
Volvo Truck Europe service centers - ethnography	2007 – one week	Ethnographic field study of repair workshops in five different European countries. Results presented in paper IV.
Volvo IT – case study II	2008-2011	A longitudinal case study exploring open innovation at Volvo with a certain focus on open innovation in the light of vehicle manufacturers transforming their business model from products to vehicle services. Preliminary results presented in paper V.

Table 1: The research process

The research process lasting from 2003 to 2009 can be characterized by three main themes that have been followed. These are workplace studies of service provision, technology studies, and studies of organizing vehicle service development. As follows these three themes are used to give a detailed outline of the research process.

The thesis project began with an ethnographic workplace study of repair service at Volvo Penta, where service centers and the central support organization were included. The vehicle industry, market

analysts and third party suppliers had highlighted remote vehicle diagnostics as the most promising future vehicle service. Based on this assumption, the ethnographic field study was set up to explore current repair service work that was supposed to be supported or even replaced by remote vehicle diagnostics.

In 2003, repair service work at four different Volvo Penta service centers was observed. To also cover the current remote support of repair technicians, the central support organization located in Gothenburg was included. This study was complemented by an ethnographic study of repair service at six workshops in five different European countries. During these studies field notes and photos documented the day-to-day service work conducted at workshops. Situated interviews complemented the observations providing a rich understanding of the work practice. An analysis of the use of various IT systems to accomplish the service activities was included as well. In studying repair workshops, the aim was to get an understanding of service provisioning and consumption in the vehicle industry.

In 2007, an ethnographic case study was conducted to gain additional insights about the demand of vehicle services at dealerships. Work practices at six dealerships in five European countries were each studied during one day. Complementary questions were asked and workshop managers, salesmen, chief diagnosticians, and service coordinators were interviewed. The empirical data enriched the understanding of future stakeholders of vehicle services.

Based on the findings from the first field study, the first vehicle service prototype was developed. At first, the prototype work aimed to implement a setup of remote diagnostics services to enhance current repair work. However, it soon became obvious that the development of such services shared a number of building blocks that were best thought of as modules of a common service platform. The prototype work, which was run in collaboration with three master students, ended in 2004 with a platform on which vehicle services easily could be developed. This was exemplified by three individual services.

The service platform was then evaluated during two additional prototype development activities between 2004 and 2005. The second prototype engaged a group of four students to develop a remote diagnostics service during five weeks in the autumn of 2004. Since the students used the service platform, they were able to develop a vehicle

service quickly without any specific knowledge about vehicle system communication. The third prototype explored the feasibility of remotely updating the software configuration of an electronic control unit and changing the horse power configuration. Both prototypes were evaluated in workshops at Volvo Penta with focus on the feasibility of a commercial implementation. Based on the result from the prototype development, the platform was revised.

The third theme characterizing the research process is the study of organizational aspects of vehicle service development. Here, the adoption of new technologies and a new business model, i.e. services as opposed to products, was focused on. The first case study was conducted in 2007, when I spent four months at the Volvo IT Innovation Centre.

The case study aimed to follow a vehicle service infrastructure development project to gain insights about how the adoption of new technologies, i.e. the digitalization of the vehicle, and the adoption of new business models, i.e. vehicle services, are managed and organized by a vehicle manufacturer. Being part of the project group as a research representative allowed me to attend and document official project meetings, take part of documents such as presentations and emails and present research findings to facilitate discussions on the topics of information infrastructure, services and openness (open innovation). The physical presence at the Volvo IT office also allowed me to participate at coffee breaks, listening to conversations and joining ad-hoc meetings.

The second case study started late 2008 and will continue until 2011 to study open innovation processes in practice. The vehicle industry, represented by the Volvo Group, makes up one field of application among other being studied. Initial interview data from this longitudinal case study are included in this thesis. The following chapter outlines the research contributions resulting from this collaborative practice research process.

5 Research contributions

The aim of the research presented in this thesis has been to explore the prerequisites for vehicle services to better understand the current lack of such services and thus answer the research question: *"What are the technical, business and organizational prerequisites needed for the development and diffusion of a rich variety of vehicle services?"* Based on empirical insights gained during the course of research, the question has been approached from three different theoretical angles, i.e. the business conceptualization by service theory, the technology through information infrastructure theory and the organization by open innovation theory.

Methodologically the research question has been approached with different methods, objectives and level of focus. The research project started off by studying the details of services by means of ethnography (paper 1). Subsequently the focus was gradually broadened, studying the market of vehicle services (paper 2) followed by approaching the technology through prototype development (paper 3). Finally the organization of vehicle service development (paper 4), with a particular focus on the interaction between technology and the innovation process (paper 5), were studied by means of case studies at a vehicle manufacturer. Both the theoretical approach and research process are reflected in the five individual research papers. As follows, each of the paper is shortly summarized with a focus on its contribution to the overall thesis.

5.1 Individual paper overview

5.1.1 First paper: "Decentralized Remote Diagnostics: A Study of Diagnostics in the Marine Industry"

Remote vehicle diagnostics has gained much attention from the vehicle industry and market analysts, outlining it as one of the most promising future vehicle services. It is also of interest since it addresses vehicle repair, i.e. the most important service currently provided by vehicle manufacturers. Based on an ethnographic field study, including different service workshops and a central back-office support, the paper aims to provide a detailed understanding of vehicle repair services. The study outlines vehicle repair service as a complex endeavor in which the co-location to the vehicle, collaboration

between the actors involved, and the service technician's local knowledge about the customer and the specific vehicle play important roles. The study also shows how vehicle repair service is about identifying problems experienced by customers as opposed to a mere focus on problems identified by the vehicle system. Even though experienced and technical problems certainly overlap in many cases, the distinction highlights the importance of a customer perspective on vehicle services. Furthermore, the paper argues for a decentralized approach to remote vehicle diagnostics which is in contrast to the common idea of remote vehicle diagnostics as centralized and thus replacing the service technicians.

In the light of this thesis, the paper contributes with detailed observations of an application area outlined as important recipient of future vehicle services and hence provides a foundation for the following research articles. However, the main contribution by the paper is made in arguing that vehicle services have to be developed close to the application area, i.e. focusing on the customer as vehicle user rather than the vehicle per se.

5.1.2 Second paper: "A Conceptual Framework for Remote Vehicle Diagnostics Services: Customer Experienced Needs as Core Business"

Based on the ethnographic field study, reported in the previous research article, the second paper aims to understand the notion of vehicle services from a business model or market perspective. Proceeding from the distinction between customer-experienced problems and technical problems, the paper provides an analytical argument to help identify possible future business models. Based on the empirical findings, it argues that customer experienced needs, technical problems and available vehicle services only partially overlap, which results in three business models for vehicle services. These are: value adding services, i.e. services addressing customer problems or needs, transparent services, i.e. technical problems not experienced by customers, and finally service offers that denote those services neither addressing a technical problem nor experienced by customers but constituting a market of vehicle services. Following this conceptualization of business models, the paper argues for appropriate technologies to address the different business models, i.e. technologies going beyond the mere access to remote vehicle data. This implies to

understand ubiquitous computing as a means of increasing personalization of vehicle services rather than a replacement.

The second paper contributes to the thesis by providing a diverse understanding of vehicle services, i.e. those services addressing the vehicle per se and those focusing on customer interaction. Furthermore, the paper emphasizes the need to consider vehicle services in a broader context than in the consumer – vehicle relation. Thus, the ecosystem of vehicle service stakeholders has to be extended beyond the vehicle industry as well.

5.1.3 Third paper: "Mobile Services for Vehicles"

The third research paper builds upon the understanding, gained by the previous paper, of vehicle services as multifaceted and involving different stakeholders with a focus on the customer. The research performed was a three year case study in collaboration with a vehicle manufacturer. The study includes also prototype development along with evaluation workshops. If the first research paper studies a specific vehicle service and the second paper explores the market and different business models for vehicle services, the third paper is about the role of IT. Based on the empirical insights, the paper introduces the concept of information infrastructure to facilitate the development of vehicle services. It is argued that such an infrastructure has to be open to make vehicle services profitable, based on sharing costs, managing risk and including different service providers. However, vehicle manufacturers lack experience of cooperating with other branches of industry to share revenues, they are known to be risk aversive and extremely focused on quality, which makes them reluctant to give up control over an information infrastructure and future vehicle services. The research paper also discusses the tendency of manufacturers to conceive of services as augmenting products, rather than supporting the use of the products, and identifies this as a fundamental motive to avoid openness.

The paper adds to the thesis by taking on an IT perspective to understand hinders and possibilities of vehicle services. To allow for a rich variety of vehicle services and to divide risk caused by failing services among service providers, the paper proposes to separate between services and common infrastructural resources. Hence, the paper contributes by introducing the concept of open information

infrastructure, which invites vehicle manufacturers to open up their innovation and development processes to attract external service providers.

5.1.4 Fourth paper: "The Vehicle Ecosystem"

This paper extends the previous knowledge about the role of IT and in particular information infrastructure, to understand the challenges of introducing the concept to vehicle manufacturers. The paper reports on a case study at the Volvo Group combined with an ethnographic field study of six different truck workshops. The case study focused on studying the development of a platform for vehicle services, which in the light of this thesis was interpreted as an information infrastructure. The ethnographic field study focused on exploring the demand for vehicle services at dealerships, which also included customers. Based on this setup, the research paper provides both organizational issues experienced by the central IT organization of a leading vehicle manufacturer as well as those experienced by the decentralized part of the organization that interfaces the customer.

Four major challenges were identified from the empirical data. First, the need to embrace heterogeneity, i.e. allow for individualizations of vehicle services, secondly, understanding vehicle services as an integrative part to existing processes and services rather than stand-alone applications, thirdly, to consider the vehicle as an actor in a larger ecosystem of stakeholders and, fourthly, being aware of the organizational and technical complexity that is made up of the dependency path. Thus, the study reveals how vehicle manufacturer's conceptualization of services as product features conflicts with the needs of vehicle stakeholders endorsing a more integrative understanding of services. It is argued that this interpretation also affects the conceptualization and design of information infrastructures as either product extensions or interfacing the vehicle towards its wider, cross organizational ecosystem. The latter of course challenges the vehicle industry and current attempts at development of vehicle services.

In the light of the overall thesis, the fourth paper contributes by identifying a tension between the central organization governing the development of IT resources and the decentralized parts of the organization including customers. To understand vehicle services as

serving a heterogeneous ecosystem of vehicle stakeholders challenges the current organization of innovation in the vehicle industry, i.e. the currently closed innovation process as opposed to an open service innovation process.

5.1.5 Fifth paper: "Open Innovation and Control: A Case from Volvo"

If the fourth paper concludes by highlighting the need for open innovation to bring forward the development of vehicle services, the fifth paper aims to more thoroughly address the notion of open innovation and thus explore new ways of organizing the innovation and development of vehicle services. The paper theorizes on an empirical case as an example of open innovation. Even though the case, a joint subsidiary between a vehicle manufacturer and partners from the telecommunication industry to share ideas and paths to market, is an example of the prevailing conceptualization of open innovation, it reveals a lack of openness and innovation.

Using this case, the notion of open innovation is extended by exploring the role of IT in open innovation and thus adding to the theoretical underpinning that has primarily focused on organizational and legal aspects. It is shown how control is manifested through the choice of IT support, thus pointing to the importance of IT for open innovation. Furthermore, the results raise the question of a more complex understanding of control than the one indicated by the simple dichotomy open and closed innovation.

The paper contributes to the thesis by empirically exploring the concept of open innovation in the vehicle industry. By outlining how the choice of IT support may interfere with the management of open innovation and thus highlighting some important interdependencies, the paper also strengthens the multifaceted research approach adopted by this thesis. Thus, vehicle manufacturers have to more carefully align their choice of IT support with their managing strategies. Furthermore, the results indicate a need for IT support which allows a more fine-tuned management of control and openness. As the previous papers reveal, the concept of information infrastructure should be explored as a suitable option since it allows separating services from infrastructure and thus addressing the issues of control and openness outlined by the fifth paper.

5.2 Prerequisites for developing vehicle services

The five papers summarized above, together provide a complex answer to the question why there are so few vehicle services. By addressing the three aspects of business, technology and organization, my research describes important prerequisites necessary for the development of a larger variety of vehicle services. These insights are of value to both the vehicle industry and research communities that share an interest in how technologies, business models and forms of organization relate to the emergence of services in product oriented industries. The prerequisites identified by my research can be summarized as an exhortation to the vehicle industry to move on from its traditional preoccupation with the vehicles as proprietary products towards an understanding of vehicles as open platforms for services. In my research I have identified three dimensions in this change of perspective: service focus, the role of IT, and openness.

5.2.1 Service focus

As outlined in the theoretical account of this thesis, there is a trend towards an increased automation of services based on the utilization of IT. Data processing systems have automated back-office services such as bank clearing and the diffusion of the Internet enables the automation of service provisioning, for instance replacing the bank clerk by online banking. Similar concepts of automation are also approached by the vehicle industry in developing vehicle services. Remote vehicle diagnostics serves as a suitable example in this thesis to describe the vehicle industry's ambition to use sensor technology and the diffusion of wireless communication technologies to automate vehicle services and, in the particular case, replacing the service technician. However, the thesis questions this conceptualization of service automation and highlights the need to reconsider the general business model of vehicle services. It is argued that setting out from the customer's context, instead of the vehicle, is crucial in such a business model. The thesis shows how current vehicle services thus extend product functionalities rather than addressing the customer's use and experience of the vehicle. By this, promising services are excluded that build on identifying or even creating customer demands. Thus, the research papers outline two main challenges for the vehicle industry.

The first challenge is to introduce the idea of customer individualization as opposed to the current product focus. Hence, the vehicle industry has to abandon the current product focus in favor of service focused business models and consider the vehicle as part of a wide spanning ecosystem of stakeholders. Advancements in IT, and in particular ubiquitous computing, provide novel tools to explore services from a customer perspective, i.e. highlighting the individualization or personalization of automated services. Thus, this thesis lays stress on the importance of utilizing IT to improve the quality and richness of automated services by again attending to the individual characteristics of services. By this, the thesis provides implications for future research in service development, i.e. how to proceed after the automation of back-office and front-office service components.

The second challenge following the customer focus of vehicle services is the need to open up the service development and provisioning to other stakeholders. Taking on the notion of ecosystem as future market, the thesis argues that there will be a rich variety of vehicle services that not necessarily are provided by vehicle manufacturers only. However, this requires vehicle manufacturers to adopt new ways of organization that allow opening up the necessary innovation spaces. The following two sections provide a more detailed account of technologies and concepts of organization needed to address the two challenges.

5.2.2 The role of IT

Previous research has shown that sensor technology combined with onboard computing and wireless communication facilities can deliver a precise account of the technical status and circumstances of a vehicle. However, conceptualizing vehicle services as services supporting the customer's use of the vehicle requires additional IT solutions that support the contextualization of the vehicle as part of a wide spanning ecosystem of stakeholders. In other words, the thesis highlights the demand for a technology that connects vehicle information to information sources not necessarily stemming from the vehicle or the manufacturer.

The thesis also argues that this opening up of the vehicle as a platform for a rich variety of services is not mainly a question of connectivity

and information standardization, but of providing an IT platform that allows for a high level of interaction between different vehicle service developers sharing common sources of technology and information. The thesis work reveals, however, that vehicle manufacturers conceptualize IT as systems, something that does not provide the necessary openness for future, innovative services. Thus, the thesis proposes to replace the prevailing idea of systems with that of infrastructure as foundation for future vehicle services. An infrastructure supports the development of services by a heterogeneous and distributed group of developers, but centralizes common building blocks to share costs. Infrastructure technology will make possible the development of an indefinable number of services rather than a handful of killer applications. If vehicle services are to be evolutionary and heterogeneous they have to be supported by an infrastructure rather than being properties of systems.

Even though previous research describes heterogeneity as the very condition to information infrastructure development, there remains a lack of understanding of how to encourage such heterogeneity. This thesis makes two contributions to increase the understanding of heterogeneity. In the first place, the need to understand the role of information infrastructures as supporting the integration of a product (the vehicle) into its contextual setting rather than exposing or extending its product features. Secondly, encouraging a heterogeneity of vehicle services requires an open approach to the organization of service development.

Hence, the thesis reveals how the choice of IT support for vehicle services closely correlates with the conceptualization of the business model and organization management.

5.2.3 Openness

If the interorganizational ecosystem of vehicle stakeholders is the future market for vehicle services, then we need a different approach to organizing the development of such services, the thesis argues. Open innovation, i.e. to share the innovation space among the vehicle ecosystem's stakeholders, is proposed as a way of organizing vehicle service innovation and development. The current product focused and closed innovation process adopted by vehicle manufacturers does not take into account the necessary customer and service focus of vehicle

services that requires cooperation between different industries to bring forward a variety of services. Even though such heterogeneity of services is best achieved by open innovation, i.e. to open up the innovation process to idea exchange and to share paths to market, there is a resistance to do so among vehicle manufacturers. For security and economic reasons, they want to keep control over the vehicle systems, but also control over the business model, as described by Andersson (2006).

Rather than losing control, vehicle manufacturers may benefit from the innovation capacity embodied by the numerous stakeholders that make up the ecosystem vehicles are part of. This requires making a distinction between vehicle services and information infrastructure that is different from the current system approach. By separating services and infrastructure, vehicle manufacturers should take on the role as provider of infrastructural services.

Open innovation has been described as mainly a management issue in previous research. The thesis complements the management focus by highlighting the role of IT in open innovation and shows how control is inscribed into technology and thus hindering the organization of services according to open innovation. Hence, the thesis argues that the adoption of open innovation not only is an issue of management and organization, but also of technology design.

6 Discussion

What are the technical, business and organizational prerequisites for the development and diffusion of a rich variety of vehicle services? The thesis contributes by developing an approach which identifies an ensemble of prerequisites for the development of vehicle services that goes beyond the technical focus which characterizes the vehicle industry. This approach makes the development of services not a matter of technology, as previous research may have indicated, but a question of redefining the core business model. Thus, vehicle services should embrace the ecosystem of vehicle stakeholders, which requires appropriate technologies and forms of organization. As follows the findings are discussed and future research avenues are presented.

An increasing part of the population is employed by the service sector and it is often outlined as the driver of economical growth. However, major service sectors, e.g. consultancy or public services, are still in its infancy regarding labor efficiency. We can, however, recognize a trend towards an increased automation of services based on the utilization of IT. Unfortunately, service automation may result in services becoming standardized and thus losing the individual characteristics of manual services. As Levitt (1972) argues, the automation of services requires us to abandon the humanistic interpretation of services in favor of a technocratic understanding. Such an approach to service automation is chosen by the vehicle industry as outlined in the first research paper (chapter 2 below). However, the thesis modifies this idea of technocratic service automation since it neglects interesting business models that spring from conceptualizing vehicle services as services supporting the use of the vehicle rather than vehicle services as additional product features. Hence, the thesis lays the foundation for a novel understanding of vehicle services that requires appropriate technologies and forms of organization. Information infrastructure and open innovation are introduced as concepts that allow including the ecosystem of vehicle stakeholders in providing complementary service resources, developing vehicle services or distributing them.

The development and diffusion of vehicle services has not met our expectations. In consideration of the role vehicles play in today's society, the thesis argues that current vehicle services have not addressed potential avenues of vehicle service diffusion. The digitalization of the vehicle status by means of sensor and wireless

communication technology makes possible the distribution, sharing and manipulation of this contextual information. However, the current approach to vehicle services is limited to a couple of service concepts that are implemented on a system basis. The thesis shows how the system concept means that changes are only possible with large investments and that innovative services need the approval by system owners. If we want vehicle services supporting the customer's use of the vehicle, then we need support for heterogeneous services that share common resources and also include information from other resources than the vehicle. Information infrastructures embody such features and thus provide the foundation for interaction among all the stakeholders in the vehicle ecosystem. Furthermore, the evolutionary nature of information infrastructures allows exploring what Brynjolfsson (1993) denotes as the unknown, i.e. those services that emerge from digitalizing representations of physical objects and merging them with other information resources.

The diffusion of digital technologies currently experienced by the vehicle industry corresponds with two trends that Yoo et al. (2008) describe as also challenging innovation networks. First, the digitization that has resulted in cutting communication costs and in turn allows the distribution of control and coordination activities in innovation networks. Secondly, the digital convergence that allows previously analogue information to be easily exchanged, which results in an increasing amount of heterogeneous knowledge resources easily available in innovation networks. Thus, the vehicle industry is moving from, what Yoo and colleagues denote as, an internal market of innovation to a doubly distributed innovation network. The authors discuss how information infrastructures have to provide appropriate support to doubly distributed innovation networks that embody different cognitive representation models. Thus, the challenge is to coherently map the different cognitive models to each other. This introduces an understanding of IT as providing nodes and connections between different social networks. Hence, the vehicle industry should complement their effort in developing technical networks by identifying and exploring the social networks that may constitute the foundation for future vehicle services.

As Boland et al. (2007) show in their study of a construction project representing a doubly distributed innovation network, innovations are not synchronized across different actors, but form different

asynchronous wakes of innovations, forming an unpredictable innovation space. Managing such unpredictability questions the current system approach advocated by vehicle manufacturers and calls instead for an information infrastructure that brings together different heterogeneous information sources. As the thesis argues this approach has to be followed by the vehicle industry opening up their innovation process and thus adopting the concept of open innovation.

The vehicle industry has not previously been discussed as a possible candidate for open innovation. However, the vehicle industry corresponds well to Gassmann's (2006) five trends that indicate whether open innovation is appropriate to adopt as an innovation model for an industry. The vehicle industry acts on a *global* market with new competitors emerging, but also searching global standards to profit from economies of scale. Finding common standards is also a result of *technology intensity* which has resulted in specializations of suppliers delivering core technologies to almost all manufacturers. The digital convergence allows for *new business models* and as this thesis argues, it is obvious that the vehicle industry is heading for new business models to replace the current product oriented model. The sales of buses, e.g., for public transport is today often combined with transport solutions such as route planning, ticketing and the like, which exemplifies how the vehicle industry has to cope with *technology fusion* requiring interdisciplinary competences. Finally, the vehicle industry has evolved from a focus on production processes, such as Ford's mass production, to a *knowledge leveraging* organization as found in Volvo's vision of leveraging transport solutions.

Since the vehicle industry corresponds well to Gassmann's five developments and trends, this thesis considers open innovation to be promising to the vehicle industry in general and the development of services in particular. As Lichtenthaler and Ernst (2009) argue, there are no evidences that open innovation should be more applicable to certain industries such as those (e.g. chemical, pharmaceutical, electronics or semiconductors) frequently referred to. They instead show that the degree of open innovation depends on the individual organization's strategic decision to adopt open innovation. Even though the vehicle industry maintains a closed innovation process, that is limited to internal innovation activities and controlled interaction with suppliers, the thesis proposes to adopt the concept of open innovation to enrich the innovation process by ideas and concepts that

better represent the activities, businesses, stakeholders etc. that constitute the ecosystem vehicles are part of.

Openness is however a complex phenomenon when including the notion of control as gradual regulator between openness and closeness. In order to move from closed to open innovation, the vehicle industry has to release control. Even though Chesbrough (2003) does not explicitly introduce any gradual differentiation, the practical examples he provides exemplify a gradual understanding of openness. IBM's strategy of IP trading, e.g., provides control through patents, whereas open source software development releases control to the open source community. The thesis reveals how Volvo releases control by spinning off WirelessCar, but retains control through the IT architecture. Thus different dimensions of open innovations should be explored more carefully.

Chesbrough distinguishes between innovation of technologies (Chesbrough, 2003) and innovation of business models to create and capture value (Chesbrough, 2006). Whereas opening the innovation process implies to release control over what to innovate, opening the business model means to release control over the value chain. Information infrastructures release control over the innovation process by definition. They should be generally designed and provide flexibility to evolve, based on heterogeneous stakeholder requirements. Thus information infrastructures do not control, e.g., what services connect to it. However, control over the business model may be inscribed into the setup of ownership of the information infrastructure. Emergent business models such as Apple's App Store or Google Android have aroused interest, regarding shared value creation, increased innovation capabilities but also regarding the question of selective control.

To further explore the development of vehicle services, extensive research efforts are required. This thesis should be considered as an initial approach to question the prevailing business model of the vehicle industry and other product oriented businesses. It is outlined how the digitization of physical products requires rethinking established businesses, technologies and forms of organization. Future research should continue to explore this avenue and focus on questions of shared value creation, infrastructures for shared service resources, and above all creating space for innovation work to explore unexpected opportunities resulting from the digitization of the physical world.

7 Conclusion

Product innovation, product design, product development, product assemblage and product sales represent the traditional core processes of vehicle manufacturers. However, the vehicle industry has shown an increasing interest in refining their product dominated business models by exploring services to, e.g., better address the vehicle life-cycle, increase customer loyalty and secure an even cash-flow. Vehicle repair service is today the most profitable service. However, the diffusion of sensor technology and wireless communication facilities provides the foundation for a range of novel vehicle services that by the vehicle industry are denoted as telematics services and as vehicle services by this thesis. Despite those ubiquitous computing and mobile communication technologies in place, as well as the vehicle industry having explored the area of vehicle services for more than a decade, we still cannot witness any considerable commercial breakthrough. This motivates the following research question asked in this thesis: *What are the technical, business and organizational prerequisites for the development and diffusion of a rich variety of vehicle services?*

By addressing this question from different angles, including both close up explorations and more holistic perspectives, the thesis identifies some important obstacles in current vehicle service development, but points as well to interesting possibilities for the vehicle industry. The thesis identifies three main prerequisites for the development and the diffusion of a rich variety of vehicle services. These are:

- *Service focus* – vehicle manufacturers have to abandon the product focus they have on vehicle services. Thus, in the development of vehicle services they have to address the customer's use of the vehicle as opposed to supporting the product. This means to extend the context of vehicle services beyond the vehicle per se.

- *The role of IT* – The current approach to the development of vehicle services builds upon the understanding of IT as system. This system approach, however, lacks the necessary flexibility and cost sharing qualities. Thus, the thesis proposes an information infrastructure approach to separate clearly between services and shared infrastructural resources. Apart from this specific recommendation, the thesis contributes by

highlighting the role of IT in supporting service focus and open innovation.

- *Openness* – even though the vehicle industry has much experience of cooperation with parts suppliers, outside this traditional production system they tend to revert to a more closed approach. However, vehicle services need an open approach such as that provided by open innovation. By opening up the innovation process, the innovation space can be shared among the various stakeholders representing the ecosystem encompassing vehicles and their users.

IT plays an important role in the development of future vehicle services. However, its important role is socio-technical rather than of a strict technical nature as assumed by most of the previous research. Interpreting the role of IT as information infrastructure, lays the foundation for the creation of a web of services spanning the vehicle ecosystem. Thus the thesis concludes by strengthening what Boland (2007) describes as wakes of innovation that emerge from the colliding of innovation paths of heterogeneous actors. The thesis also confirms similar findings by Henfridsson et al. (2009) who report from digital innovation at a car manufacturer and conclude by identifying cognitive and organizational structures to be more challenging than the physical implementation. To conclude the thesis one may summarize the vehicle industry's challenge in developing vehicle services as an issue of changing the organizational mindset – from products to services.

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Paper one: pp. 61-83
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Paper two: pp. 85-102
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Paper three: pp. 103-124
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Paper five: pp. 145-169
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