Exploring business models and discontinuous innovation: The transition towards the Electric Road System (ERS)

Tongur, Stefan.
Summary of midterm compilation dissertation

tongur@kth.se
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Opponent: Christian Sandström, Ratio

Supervisor: Mats Engval, KTH
Co-supervisors: Fredrik Lagergren & Henrik Blomgren, KTH
Appended papers
This thesis is based on the following papers:

Paper I

Paper II

Paper III

Proposed papers:
Paper IV
Business model framework - analysing system innovation

Paper V
The development of the electric road system – business models as reverse salient

Paper VI
Institutions setting the strategic agenda and business models in the development of the ERS
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Introduction

How does system innovation, the transition from one technical system to another, come about and affect stakeholders that either are incumbents or new entrants? Why do some incumbent firms manage the associated technical change successfully and other not? And what is the role of business models in this setting? This thesis argues that these questions are relevant for the understanding of how business models are challenged during the discontinuous innovation. The thesis explores the role of business model in discontinuous change in system through a case study illustrating a transition from the conventional road system to the Electrical Road System (ERS).

In the light of system challenges (e.g. in energy, mobility, and communication), the search for technologies that have the potential to transform technical systems has been highly relevant (Elzen et.al., 2004; Smith et.al., 2005). Most of these technologies fail in transforming the system despite having the potential to do so, due to a “lock in” to a technological standard and dominant design (Unruh, 2000; Abernathy and Utterback, 1978). Historical studies account for various cases where new systems have emerged into such dominant design (also called technological momentum) in a period of competition between different standards (Hughes, 1983; Arthur, 1989). Proponents of “history of science” have studied technical change by analysis of how technology, science and society are interrelated (e.g. Hughes, 1983; Latour, 1987; Pinch et.al., 1987). Their focus is on the evolution of the new system and not the transition from the old system to new one, system innovation (Malerba, 2002). Three examples are explored by Geels (2005) that are characterized as system innovations; the transition from propeller engine aircraft to turbojets, from sailing ships to steamships, and from horse-drawn carriages to automobiles. These transitions showed a dynamic interplay at multiple-levels based on the dynamics of innovation.

Innovation studies on technological change have traditionally had two main perspectives; either characterized by creative accumulation or creative destruction (Schumpeter 1934, 1942). Creative accumulation is based on continuous (also called incremental or sustaining) innovations that are competence enhancing and therefore enhance the competitiveness of incumbent firms and increase barriers for new entrants (Tushman & Anderson, 1986). Creative destruction is based on the penetration of discontinuous (also called radical or disruptive) innovations that are competence destroying and cause incumbent firms to be replaced by new entrants (Foster, 1986; Tushman & Anderson 1986). One reason for why incumbent firms have difficulties in managing discontinuous innovation is not technology itself, but rather business models (Christensen, 2006; Markides, 2006). This has creates a need for studies that explore the role of business models in the context of discontinuous innovation (Sandström, 2010).

Although the business model concept lacks a distinct definition, management scholars agree that it is about how business creates value (Amit et.al., 2011; Chesbrough & Rosenbloom, 2002; Osterwalder et.al., 2005). The business model concept could be used as an unit of analysis and a perspective to analyse both activities within and outside firm boundaries (Amit & Zott, 2001; Shafer et.al., 2005). This thesis proposes the business model concept as an analytical framework to explore discontinuous innovation in systems through the elements of value proposition, value creation and value capture.
Studies on discontinuous innovation and system innovation mostly have a retrospective perspective, focusing on the challenges that the new technologies and new entrant poses to the incumbent firms in the established industry. These studies are largely based on documentation by historical events and studies, after the actual change has taken place and the dominant design exists. Thus, the models and theories based on previous research are therefore useful as analytical tools to explain historical events. But the risks for sense making and decreasing the complexity of the phenomena when constructing these concepts, limit their usability when trying to understand how firms that currently experience discontinuous change are affected. Thus, there is a need to explore the dynamics of the phenomena in an on going process, focusing on the dynamics or context of innovation rather than the outcome of innovation.

**Purpose, Research Questions and the Papers**

The purpose is to explore the relationship between business models and discontinuous innovation in the context of system innovation. This research focuses on the strategic challenges and opportunities for the incumbent firm and other stakeholders that arise in the light of discontinuous change. The aim of the thesis is to contribute to the understanding of how business model interplay with discontinuous and system innovation. Business models have been highlighted as the main challenge of incumbent firms in the context of technology shift (Christensen, 2006) but have not received sufficient attention. This research has an incumbent firms perspective – exploring the effects of an emerging new system challenging the dominant technology and business model.

The overall Research Question (RQ) of this research is the following;

*How are business models affected by discontinuous innovation in the system?*

In order to answer the RQ, this thesis address aspects of discontinuous innovation, business models and system innovation through the following sub research questions;

RQ 1: *How does discontinuous innovation affect the competences (value creation) of incumbent firms?*

RQ 2: *How are business models affected by discontinuous?*

RQ 3: *How does system innovation affect business models?*

The sub questions are explored in the three appended papers and in two proposed papers. RQ 1 is addressed in Paper I, which focuses on how value creation is affected by discontinuous innovation. More specifically, Paper I analyses discontinuous innovation at incumbent firms in mature industries through a simultaneous process of competence enhancing and competence destroying activities. This Paper adds to most literature in the innovation field, which focuses on either competence enhancing or competence destroying.

Paper II and Paper III addresses RQ 2. In Paper II, the relationship between business models and technology shifts is analysed. It focuses on how technology shifts affects a firms’ business model from a strategic point of view. Two strategies to manage business model transition are explored through technology strategy or a service strategy. Further, Paper II argues that firms need to combine technology and service strategy to overcome technology shifts. Paper III discusses the value proposition part of the
business model from a servitization perspective. Mainstream literature in servitization assumes that core capabilities are retained when changing to service-oriented business model. Paper III contributes on how business models in servitization are affected by discontinuous innovation.

RQ 3 will be explored in forthcoming Paper IV and Paper V. Paper IV would explore the role of business models in the evolution of large technical system. The hypothesis in Paper IV is that business models act as reverse salient in the emergence of new systems. The system could only be realized with new business models that are viable for the new system. Thus, incumbent firms could explore different strategies in managing business models. Paper V would explore how institutions affect business models in system innovation. This paper would contribute to the understanding of how policy influence incumbent firm business models in the context of discontinuous innovation.

The research is explored through an in-depth case study of the potential transition from the conventional road system to the ERS. The development of the ERS is an example of discontinuous innovation, moving from the diesel engine to ERS powertrain, disrupting the value of the dominant technology for user. It is neither a study of whether the ERS is a good or bad system in comparison to the established transportation system, nor about when or if the system will be implemented. The focus is on how the ERS as an example of discontinuous and system innovation affects business model. Hence, it is an on-going example of how new sociotechnical system emerges and how it affects firms´ technology and business model strategies. In the following, a background to ERS is presented.

**Introduction to the case study**
In 2009 a debate article in the Swedish newspaper SvD, by authors representing a small venture Swedish Electric Roads, the idea of electrifying highways and trucks was proposed. The article was a response to a debate about implementing high-speed trains in Sweden as a way to reduce emissions and oil dependency of e.g. goods transportation. The authors instead meant that electrifying the roads through overhead line technology would be more environmental and economical friendly. Further on, the authors argued that the overhead line technology is well developed and the established infrastructure could be used and thus reducing the investments costs. The article received much attention and one of the authors received a scholarship by the Swedish Transport Administration to further evaluate the possibility of electrifying roads.

The Swedish truck manufacturers Volvo and Scania responded to the debate of electrifying roads with the overhead line technology, by initiating a pre-study to explore alternative electrification technologies. The firm’s representatives argued that it was too early to choose a technical standard as the debate article suggested. Scania and Volvo developed a platform with different stakeholders in the transportation system, both private and public, for discussing future standardisation process of electrification technology. At this stage both Scania and Volvo were planning on starting up projects within this area. Scania intended to evaluate technology for inductive power transfer in motion with the train company Bombardier, while Volvo intended to evaluate


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conductive power transfer from the road in motion with the Swedish venture Elways. The pre-study was financed by Vinnova (The Swedish Governmental Agency for Innovation Systems) with 1.5 million.

The pre-study showed that both inductive and conductive technology from the ground were less developed but more promising compared to overhead lines (as these technologies could potentially be applied for electrifying passenger vehicles as well). Instead of electrifying the roads through the overhead line technology, alternative technologies should be evaluated and a wide range of stakeholders should be included in the process. Hence, the pre-study resulted in a research application called the Slide-In program, which aimed to further evaluate these technologies. The application was granted and partially financed by the Swedish Energy Agency (through the FFI program, fordonstutveckling och innovation) with SEK 24 million and is now on-going and ends in the summer of 2013. The purpose of the Slide-In program is to evaluate different technologies for continuous power transfer from the roads. The technology is simulated for trucks on the highway E4 between Göteborg and Stockholm. There are two subprojects: “Slide-In inductive” with Scania and Bombardier as key stakeholders, and “Slide-In conductive” with Volvo and the railway company Alstom. Other project members include the Swedish energy company Vattenfall, the Swedish Transport administration, the Swedish Energy Agencies, Swedish Electric Roads (as a reference partner), and Universities such as KTH, Chalmers and Lund University.

Apart from the Slide-In program, there are other activities that have emerged in the ERS field (Table 1).

- **Forum** for innovation in the transportation sector (from now on called “forum”) is a network led by the Swedish Energy Agency and Vinnova. Forum has gathered actors concerned with the ERS development. These key actors are developing a roadmap and a vision for Sweden’s role regarding the ERS. Further, the roadmap will be used in EU to influence the future standardisation discussions.
- There are two other ERS projects that are financed by Swedish agencies are Elways and Swedish Electric Roads. Elways have developed and built a 200 meter long electric road (based on conductive technology from the road) in Arlanda, north of Stockholm, and are currently performing tests to evaluate the technology. Swedish Electric Roads are conducting a feasibility study of were to build an ERS first (based on overhead line technology).
- The German railway company Siemens have developed an ERS technology based on the over-headline technology. Siemens have signed a partnership with Scania to develop hybrid trucks with the overhead line technology.
- The Swedish Transportation Administration has announced an innovation procurement of ERS application. In an ambition to construct several demonstration projects in real application environment, the agencies hope to further develop the feasibility of the technology and business model. The ERS field is seen as an

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3 https://transportinnovation.se/about
4 http://www.tv4play.se/program/myheterna?title=skenor_ska_ge_elbilar_stromforsorjning&video_id=2191064
important step for managing the transition to fossil independent transportation system until 2030 and high potential for future export industry.

During the spring 2012, the Swedish transport administration announced an upcoming procurement of different ERS applications. The procurement will demonstrate the following three applications: technical verification of the ERS concept; demonstration of ERS in a realistic road environment; and demonstrate ERS in an actual transportation task in the transport system where it is commercial viable. The aim is to test ERS and create policy directions from technical and legal aspects. The Swedish government has decided the following directive regarding ERS:

“The Transport Administration should take into account that ERS (elektrifierade vägar) could ultimately contribute to a more efficient transportation system with less environmental impact that meets future transportation needs with minimal infrastructure investments. The Transport Administration will propose how a demonstration plant could be built and funded as a collaboration between stakeholders in industry, academia and government.”(Ministry for Enterprise, 2012/13:119 p.23)

<table>
<thead>
<tr>
<th>ERS projects/activities</th>
<th>Period</th>
<th>State budget MSEK</th>
<th>Key Actors</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Study</td>
<td>March 2010 – Aug 2013</td>
<td>1.5</td>
<td>Volvo - Scania</td>
<td>Feasibility study of ERS</td>
</tr>
<tr>
<td>Slide-in program</td>
<td>2010-Aug 2013</td>
<td>24</td>
<td>Industry, agencies &amp; academia</td>
<td>Evaluate ERS trough:</td>
</tr>
<tr>
<td>Slide-In inductive</td>
<td>2010- Aug 2013</td>
<td>Scania – Bombardier</td>
<td>Inductive technology</td>
<td></td>
</tr>
<tr>
<td>Slide-In conductive</td>
<td>2010-Aug 2013</td>
<td>Volvo – Alstom</td>
<td>Conductive technology</td>
<td></td>
</tr>
<tr>
<td>Forum for innovation in the transportation sector – ERS focus</td>
<td>2013-</td>
<td>Agencies, truck manufacturers, energy utility, research institute and</td>
<td>Create roadmap for ERS</td>
<td></td>
</tr>
<tr>
<td>E-highways</td>
<td></td>
<td>Siemens, Scania,</td>
<td>Implement overhead line ERS</td>
<td></td>
</tr>
<tr>
<td>Elways</td>
<td>2012-2013</td>
<td>9</td>
<td>Elways, NCC, KTH</td>
<td>Develop conductive ERS</td>
</tr>
<tr>
<td>Swedish Electric Roads</td>
<td>2012-2013</td>
<td>4</td>
<td>Swedish Electric Roads, Posten, Siemens,</td>
<td>Focus on market, political and legal aspects</td>
</tr>
<tr>
<td>ERS innovation procurement</td>
<td>Spring 2013 - 2015</td>
<td>Agencies, industry &amp; academia</td>
<td>Implement real case ERS demonstrations</td>
<td></td>
</tr>
</tbody>
</table>

Finally, there are also other initiatives globally in Korea, LA, and Canada. The users of the transportation systems could see the benefits in reduced fuel costs while authorities

could accomplish reduced emissions and create new exports. Industrial actors are in the beginning of managing the transition, which will most likely take a long time. However, understanding how business models are affected by the change would be key to be successful in manage the change.

**Thesis outline**

Section 2 of this covering paper presents the research design of the study and the methodological considerations. Theoretical concepts within system innovation, dynamics of innovation and business models are presented in section 3. The following section describes the transition towards the ERS, the implication for stakeholders and presents a business model framework to analyse system innovation. Section 5 summarises the three appended papers while section 6 describes the next steps and implications of the research.
Research design

This research takes an in-depth case study approach (based on the development of the ERS), which is a suitable method for exploratory research aimed at generating new knowledge (Yin, 2008). Conducting a case study is an appropriate research approach to understand and explain phenomenon that are entirely or partly unknown and when there is a large number of different variables and hence complex relationships to be studied (Ruane, 2005). This case study also has a longitudinal approach where the project is followed for a longer time period. The researchers’ role is to lay a puzzle out of all the observations in the case study in order to create a wide-ranging view and understanding of the phenomena.

Empirical data collection and analysis

The collection of empirical material was initiated in the beginning of 2010 and is still on going. The data collection was performed through interviews, observations, analysis of documents and monitoring the field internationally (Table 2). The many sources of data enabled triangulation (Denzin and Lincoln, 2000; Jack and Raturi, 2006), which allows for different data sources to be compared and correlated to one another.

Table 2: Data sources of the case study

<table>
<thead>
<tr>
<th>Data source</th>
<th>Actors</th>
<th>Positions</th>
<th>Documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 Interviews</td>
<td>Truck manufacturers</td>
<td>Managers from different departments, CEO of one firm, experts in conventional technology</td>
<td>Audio</td>
</tr>
<tr>
<td>10 Interviews</td>
<td>ERS Stakeholders</td>
<td>Project managers, experts from stakeholders (excluding truck manufacturers)</td>
<td>Audio</td>
</tr>
<tr>
<td>13 Participant observations</td>
<td>Slide-In stakeholders</td>
<td>Project managers, department management and engineers</td>
<td>Notes, blog and extra researcher</td>
</tr>
<tr>
<td>Informal observations (approx. over 25 documented observations)</td>
<td>Truck manufacturers</td>
<td>R&amp;D department of one truck manufacturer</td>
<td>Notes, blog</td>
</tr>
<tr>
<td>Document studies</td>
<td>Agencies, truck manufacturers</td>
<td>Technology, emissions, project details, patents</td>
<td>Internal and formal documents</td>
</tr>
<tr>
<td>Websites, participation at industry conferences, study trip to China</td>
<td>International ERS initiatives</td>
<td>Firms with ERS technology, debates, initiatives</td>
<td>Notes, blog</td>
</tr>
</tbody>
</table>

The interview respondents were selected out of participants in the different ERS projects and activities. They belong to different manager levels at the incumbent truck firms (see appendix 1 for interview list). Since the respondents were part of different projects/activities, their views complement each other and portrait different aspects of the ERS development. The interviews lasted between 1-2 hours and were semi-structured, partly based on an interview guideline with open questions. The questions mainly concerned the challenges and opportunities that the respondent saw in the ERS when it comes to the technology shift and the firm’s business model. The interviews were broad to convey the history of the respondent and its organization. In most cases the interviews were audio recorded and notes were taken continuously during the interview, which enabled analysis directly after the interview. The interviews were
transcribed when the notes were inadequate or when they were found of interest for deeper analysis e.g. with regard to extraction of quotes. The data was then categorized manually (in excel) into different categories covering different subject areas that emerged through the interviews. The categories were not pre-set but emerged as the interviews were analysed. Hence, as additional interviews were made, the categories were modified and/or verified according to the new information.

Documentation about the stakeholders and the related ERS activities were also collected and analysed in order to attain a pre-understanding for the different actors and to complement the information from the interviews.

The observations were made at a large number of meetings within the Slide-In program and the Forum activities. As an observant I followed and documented the discussions during the meetings. Among other things this gave additional information about how the project members relate to the ERS activities and to the other stakeholders. This has also unveiled the challenges and opportunities of the proposed technology shift from today’s transportation system and highlighted business model aspects in the natural context. The observations were also done in different workshops, where I had the role of a participation observant, to elaborate the findings from this study together with the different actors. This allowed for feedback and validation of the findings in this study.

I have also studied how Scania have managed the different ERS projects and activities through observations at their hybrid division over a period of 2 year. On average I spent one full day twice a month there. The focus of the observations was to follow the internal discussions regarding the ERS. The observations also allowed me to study the ERS activities in the natural setting of the truck manufacturer. The observations and interviews at Scania were complemented with interviews and informal discussions at Volvo to strengthen the view of the incumbent firms’ challenges and opportunities in the new technological and business setting.

Methodological considerations
The chosen research approach requires some methodological considerations in order to reflect on the limitations and the strength of this research. This is important as my pre-understanding of the studied phenomena highly reflects my own interpretation of the data and is therefore relevant to the validity of the research.

Personally, I have a quest for knowledge about how incumbent firms affect and are affected by technology shifts through a business model perspective. Although considered to be a vague concept (Baden-Fuller et.al., 2010), business models could be used as a theoretical perspective or lens to unveil structures that could bring the overall understanding of the technology shift phenomena forward (Stähler, 2002. Meanwhile, I am aware of other perspectives that could be applied to this case study that are equally relevant but give different interpretations and findings (e.g. in the field of project management, marketing, policy research, energy management etc.).

When conducting participatory observations my objectivity as a researcher could be questioned. How can I remain objective and neutral in an emerging development of new technological systems that I could affect in my role as a researcher? This question is in
line with a more theory testing approach and a positivistic research view (Alvesson & Sköldberg, 2009). I do not believe that I could be truly objective in my studies and it is neither the purpose of this thesis. As the purpose is to increase knowledge about how technology shifts and business models affect each other, there is a need to portray the complexity in the case and to interpret this in relation to previous theoretical knowledge. Hence, by being part of the project and having thorough data access to the studied phenomena, the validity of the study and the portrayed context increase (Halinen & Törnroos, 2005). Further, being familiar to the respondents could result in them having an increase confidence for me and thus unveiling important information both during formal and informal interviews and observations. However, this could also result in the respondents withholding information not to risk unveiling their strategy to others, as they knew that I was in contact with the different stakeholders. Hence, it has been important for me as a researcher to ensure and respect the confidentiality of sensitive information that is not relevant for the research.

The case study has a historical value, as it is a unique example as it covers events that have the potential of transforming an entire system (of road transportations) and the corresponding industrial dynamics. As a researcher I am only interested in understanding these dynamics. I have no personal opinion in whether the ERS is a system to prefer or not and strive to remain neutral concerning what direction the system takes. Hence, this research is based on the process of the ERS development and is not intended as a feasibility study of how to implement ERS.

A case study has limitations in making general statements. A multiple case study is better suited to compare findings and increase the generalizability of the research. Hence, as much other qualitative research, there is a need to further test and compare the findings of this study with other cases to be able to draw generalizable conclusions. However, by covering an on going development through a case study, this research could give insight and contribute to theory and practice and thus lay foundations for future research (Gummesson, 2003).
Theoretical concepts

Concepts from three theoretical fields are presented in this section that are related to the overall research questions. The system concept is introduced and focuses on the transition from one system to another. The following section explores discontinuous innovation from an industry and firm level and direct attention to business models as the main challenge for incumbent firms. Lastly, the business model concept is presented as a unit of analysis.

Large technical system and system innovation

The concept of systems is used within different research disciplines and is sometimes vaguely treated. The system concept could be used in a hard approach e.g. used as a mathematical method used to optimise activities described as a system through computers (Churchman, 1968). The system concept could also be used in a soft approach (as this thesis does) and include studies that combine society and technology for discussing complex management problems. A large system based on artefacts such as infrastructure, is often described as a technological system and is defined by its function (Kaijser, 1994). In this thesis the system concept is referred to as the soft approach and in line with Thomas Hughes (1987) definition as the following:

“Technological systems contain messy, complex, problem-solving components. They are both socially constructed and society shaping. Among the components in technological systems are physical artefacts, such as the turbo generators, transformers, and transmission lines in electric light and power systems. Technological systems also include organisations, such as manufacturing firms, utility companies, and investments banks, and research programs. Legislative artefacts, such as regulatory laws, can also part be part of technological systems.” (Hughes, 1887 p. 51)

There are many concepts that describe how new technological systems emerge, e.g. ANT, actor network theory; SCOT, social construction of technology; and LTS, large technical systems. The ANT theory has a socio-technical linkage perspective. The theory defines technical artefacts as non-human and studies how they interact with human actors (Latour, 1987). In the SCOT approach, social groups and the embedded contexts that are relevant for technology development are analysed. It is argued that these social groups shape technology through the use of cognitive concepts such as closure and stabilisation (Pinch and Bijker, 1987). In the LTS literature, the technology’s history is analysed through different phases of a life cycle, invention, development, innovation, growth, competition and consolidation, and momentum (Hughes, 1983). There are several types of system builders that are active in different parts of the different phases, e.g. inventor, inventor-entrepreneur, manager-entrepreneurs, financier-entrepreneurs (Hughes, 1987). The concepts salient, reverse salient and critical problem could be used to analyse a large technical system in transition and change (Hughes, 1982). A salient is a bulge in an advancing front line of a system while a reverse salient refers to a part of a front that lags behind. The components that constitute a salient are at the front in a system because they are more technically efficient, more economical and in some way carry forward the development of other components of the system. Similarly, a reverse salient consists of less efficient components that prevent the system of further development of its objectives. Critical problems are defined, according to Hughes, in the context of salient and reverse salient. A definition and solution of a critical problem
brings the variant components of the technological system into equilibrium, at least for the time being (Hughes 1992).

The concepts described above (LTS, ANT and SCOT) distrust the idea of technological determinism - that technology explains technological change (Gessler, 2002). Instead, a “seamless web” of society and technology forms technological change (Hughes, 1987). Technological change is considered as a function of the interactions of different artefacts, such as technological, social, political, historical etc. Thus, the separation of one of these artefacts could therefore not alone explain technological change or economic growth. Further, these concepts focus on the emergence and diffusion of new technologies but they neglect and do not take into consideration the old and conventional technology (Geels, 2004). Thus, they are not appropriate in describing technological replacement, which focus more on economic competition between old and new technologies (Geels, 2004). According to Malerba (2002) the link between how new technological systems (also called sectoral systems) emerges and the link with the previous system needs to be explored in-depth.

Technical transitions and system innovation has received increased attention in recent years due to promising new technologies that have not yet taken off e.g. in automotive and energy technology (Geels, 2005; Loorbak & Rotmans, 2010). Geels (2005) defines a transition from one technological system to another as system innovation. He illustrates system innovation through three case studies that are based on the transitions from a) propeller-piston engine aircraft to turbojets, b) sailing ships to steamships, and c) horse-drawn carriages to automobiles. System innovation is analysed through a multi-level perspective that is based on niche-level, regime level and landscape-level (Geels, 2002). The technological niche level is based on strategic niche management that are separated from the mainstream market, and is the locus for radical innovations. The niche level acts as a level for learning processes for on e.g. technology user preferences, regulation, infrastructure, and production systems (Schot et.al., 1994). In the sociotechnical regime level various actors produce and maintain the sociotechnical system (c.f. Nelson & Winter, 1982; Rip & Kemp, 1998). In the landscape level, actors cannot directly influence the development because the landscape is characterized by wider exogenous environment that affect the sociotechnical development (e.g., globalisation, climate change) (Geels, 2005). System innovations come about through dynamic interplay at these multiple levels.
System innovation could be distinguished by four phases of the technological transition (Rotman et al., 2001) and that take place between the multi level perspectives (Figure 1). Firstly, the predevelopment phase occurs in the niche level in the context of the conventional technical system. Secondly, in the take-off phase the new technology improves according to a technical trajectory and is used in small niche markets. Thirdly, in the breakthrough phase the new technology accelerates into mainstream markets and compete with the established technology. Lastly, the stabilization phase is characterized by a transition from the old to the new technological system, which influences a wider landscape (Geels, 2005; Rotman et al., 2001). These phases are based on the dynamics of innovation (described in the next section), which are more focused on the firm and industry level.

The dynamics of innovation

Why some firms survive and some die in an era of innovation is a key question in studies of innovation management. There are two main different perspectives on technology innovation: either innovation is described as *discontinuous* (in line with radical and disruptive) innovation, including industry shake outs and the emergence of new entrants (Christensen, 1997; Tushman & Anderson, 1986); or innovation is described as *continuous* (or incremental) innovation, including standardization between technologies and incumbent firms and barriers for new entrants (Tushman & Oreilly, 1990). Thus, the two innovation perspectives have different implications for the incumbent firms. Many of these studies have been developed as a response to economists “black box” thinking (Murmman & Frenken, 2006), which overlooked technological phenomena as an explanatory factor for economic growth (Rosenberg, 1982).

The concept of discontinuous innovation is in line with Schumpeter's (1939) concept of radical innovation, which disrupt the continuity of existing technological paradigms and
creates new technological trajectories (Dosi 1982). Trajectories are advances that seem inevitable and predictable (Nelson & Winter, 1977) and follow a S-curve in performance (Foster, 1986). Discontinuous innovations have trajectories that start below but with the potential to exceed the established technology’s S-curve (Foster, 1986; Christensen, 1997). These discontinuous innovations restructure the market and economy through a process of creative destruction (Schumpeter, 1934), with new entrants shaping the new market and established firms struggling to survive. Different examples on technology change that led to a change in the industry structure are presented in table 3 (Lindmark, 2002).

Table 3: Examples of discontinuous innovation (Lindmark, 2002)

<table>
<thead>
<tr>
<th>Industry</th>
<th>Technological change</th>
<th>Effect on industry structure</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semiconductor photolithographic alignment</td>
<td>Four major technological changes</td>
<td>None of major established companies managed to maintain shares</td>
<td>Henderson (1988)</td>
</tr>
<tr>
<td>Mobile telephony</td>
<td>Non-cellular to cellular systems</td>
<td>Disappearance of most established firms</td>
<td>Ehrnberg and Sjöberg (1995)</td>
</tr>
<tr>
<td>Cash Registers</td>
<td>Electro mechanical to electronic</td>
<td>In four years 80% of the market was lost to manufacturers of electronic products</td>
<td>Foster (1986)</td>
</tr>
<tr>
<td>Machine tools</td>
<td>Two transitions: 1) from manual to computerized, numerically controlled machine tools and 2) the introduction of FMS</td>
<td>1) led to a large industry shift where Japanese firms came to dominate the market; 2) had minor effect on industry structure</td>
<td>Ehrnberg and Jacobsson (1993)</td>
</tr>
<tr>
<td>Telephone switches</td>
<td>Several transitions from 1920s to 1970s</td>
<td>Relatively few entries and exits</td>
<td>Granstrand and Själander (1990)</td>
</tr>
<tr>
<td>Automotive industry in the 1920s</td>
<td>Closed body of steel to wooden bodies</td>
<td>Market leader Ford’s and small firms position weakened</td>
<td>Abernathy and Utterback (1978)</td>
</tr>
<tr>
<td>7 industries (se column to the right)</td>
<td>Steam to diesel locomotives, tubes to transistors, fountain to ball-point pens, safety to electric razors, aircraft propellers to jet engines, fossil fuel to nuclear power plant, leather ot PVS to plastics</td>
<td>2 out of 15 incumbent firms managed transitions</td>
<td>Cooper and Schendel (1976)</td>
</tr>
<tr>
<td>Winchester diskdrives</td>
<td>Five successive architectural innovations (14, 8, 5, 25, 3.5, 2.5 inch)</td>
<td>No single company survived, or was able to dominate for more than a few years</td>
<td>Christensen (1997)</td>
</tr>
<tr>
<td>Rubber</td>
<td>Latex foam to polyurethane foam technology</td>
<td>None of the incumbents made transition</td>
<td>Roussel (1984)</td>
</tr>
</tbody>
</table>

The reason for firms struggling to survive when discontinuity occur has been studied from technical, managerial and market aspects. Discontinuous innovation is considered to be competence destroying (Tushman & Anderson, 1990). What once was considered as core competences could instead become the incumbent firms’ core rigidities (Leonard-Barton, 1992). Managers are also reluctant to invest in the new technologies, as customers who instead want the established technology, do not request them (Christensen, 1997). Thus, by focusing on the old value network and ignoring the new technology, incumbent firms are unable to change strategy when the disruptive
technology exceeds the performance/price attributes of the established technology (Rosenbloom & Christensen, 1994).

The contrasting perspective to creative destruction is that industry structure is enforced through a process of creative accumulation. Firms introduce innovations that are continuous and in the same field of the technological paradigm (c.f. Kuhn, 1962), and are focused on adjusting imperfection of existing technologies (Dosi, 1982; Rosenberg, 1976). Ende & Kemp (1999) described this in the case of the automobile in the following was:

“Automobile research, for example, is focused on specific goals of enhancing motor power, achieving greater fuel economy, safety, comfort and emission reductions, based on engineering ideas of the relevant techno-economic tradeoffs, which depend on the user needs being established, the nature of the knowledge basis, and system that has been built up around the technology.” (Ende & Kemp, 1999 p.835)

Thus, continuous innovations are path dependent. The technology is characterized by a dominant design that sets a standard in the industry structure (Tushman & Anderson, 1990; Abernathy & Utterback, 1978). Dominant design is not predetermined but come about in the interplay between the market and technology. David (1985) analysed how the typewriter industry became “locked in” to the dominant QWERTY keyboard standard. Early events could trigger the lock in process due to market feedback, which has been illustrated in the Betamax and VHS example (Arthur, 1989). Examples of dominant design are illustrated in Table 4.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Dominant Design</th>
<th>Year of establishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typewriter</td>
<td>Underwood's Model 5; Hess's subsequent innovations</td>
<td>1906</td>
</tr>
<tr>
<td>Automobile</td>
<td>All-steel, closed body</td>
<td>1923</td>
</tr>
<tr>
<td>Television</td>
<td>21-inch set; adoption of RCA's technical standards</td>
<td>1952</td>
</tr>
<tr>
<td>TV tubes</td>
<td>All glass, 21-inch tube</td>
<td>1956</td>
</tr>
<tr>
<td>Transistor</td>
<td>Planar transistor</td>
<td>1959</td>
</tr>
<tr>
<td>Integrated circuit</td>
<td>Multiple designs in rapid successions</td>
<td>-</td>
</tr>
<tr>
<td>Electronic calculator</td>
<td>Calculator on a chip</td>
<td>1971</td>
</tr>
</tbody>
</table>

When a dominant design is challenged by a discontinuous technology, the firms in the established industry could work to improve the old technology. Thus, discontinuous innovation might take long time and characterize by a continuous process. This could be illustrated in the shift from sailing ships towards steam ship that took over 50 years, as the sailing ship technology improved significantly (Utterback 1994). This calls for the need of ambidextrous organisations, being both a defender of the old continuous technology, and an attacker with the new discontinuous technology.
**Business models**

The term business model has a long history. It was first mentioned in an academic journal article in 1957 (Osterwalder et al. 2005) and as early as 1954 in a management book (Drucker, 1954). Business models were used as a modelling tool of business in the computer field and system modelling in the beginning of the 1970’s as a (Ghaziani & Ventresca, 2005; Lehmann-Ortega & Schoetti, 2005). Previous management scholars defined other concepts, similar to business model, such as “business idea”, and “service management system” (Nenonen & Storbacka, 2010). Over the last two decades, increased interest for business models developed as the IT technology developed. This enabled ventures to capture value with design of innovative business models (also referred to as e-business models). While strategy and innovation management scholars have embraced the concept, a consensus of the definition of what the concept is all about is yet to be defined (Zott et al., 2011). Yet, most management researchers agree that the concept is about how business creates value and that it is an important unit of analysis, relevant for both management theory and practice (Wüstenhagen & Boeknke, 2008; Stähler, 2001; Chessbrough & Rosenblook, 2002; Amit & Zott, 2011; Johnson & Suskewics, 2009).

Osterwalder (2005) argues that constructing maps, called business model canvas, enhances viable business models for firms. Business model canvas organise innovations by linking ideas, technologies and economic performance together (Chessbrough, 2013) through nine building blocks; customer segment, value proposition, distribution channels, customer relationships, revenue stream, key resources, key activities, key partnerships and cost structure (Osterwalder, 2010). The basic questions that the business model canvas identifies are what the firm proposes to sell, to whom the value should be delivered, how to create the value and how much the customers’ economic compensation should be. The business model canvas literature has had a practical and entrepreneurial importance since new innovative business model constructs could gain competitive advantage in an industry.

A business model is not a strategy, but the implementation of strategic choices (Bouwman et al., 2008; Shafert et al., 2005) or the complement of a strategy (Zott & Amit, 2008). Casadesus-Masanell & Ricert (2010) use an analogy to illustrate what a business model is and how it differs from strategy and tactics. In the illustration, the design and building of the car represents the strategy, the car itself represent the business model and the driving of the car represents the tactics.

“Different automobile designs have different specific logics of operation - conventional engines operate quite differently from hybrids, and standard transmissions from automatics - and create different value for their ‘stakeholders,’ the drivers e.g. small car or SUV. Automobiles are made of parts - wheels, engines, seats, electronics, windshields, and the like. To assess how well a particular automobile works - or to create a new one - one must consider its components and how they relate to one another, just as, to better understand business models, one needs to understand their component parts and their relationships.” (Casadesus-Masanell & Ricart, 2010, p.197)
The component of the business model used in this thesis build on the notion of *value proposition*, *value creation* and *value capture* (in line with Shafer et al., 2005; Stähler, 2001; Chessbrough & Rosenbloom, 2002; Al-Dubei & Avison, 2010; Johnson et al., 2008).

- **Value proposition** defines what the added value is for the user (and describes what the firm proposes to sell and to whom (Chessbrough, 2010).
- **Value creation** is defined by two components; a firm’s strategic resource, which consist of the core competences, strategic assets, and core processes; and the value network or value chain, which outlines the firm’s suppliers, partners and coalition that complement the firm’s resources (Hamel, 2000; Shafer et al., 2005)
- **Value capture** describes the revenue model and how the business generates its sales revenue (Teece, 2010).

Business models span firm and industry boundaries (Amit & Zott, 2001) since locus of value creation often extend traditional firm or organisational boundaries (Normann, 2001; Santos & Eisenhart, 2005). Hence, business models could be used to analyse the incumbent firms role in system innovation.
The transition towards the Electric Road System, ERS

This chapter illustrates the transition from the conventional road system to the electric road system. Both systems are defined together with the corresponding subsystems (e.g. truck, road, petrol stations, power transfer technology, and power grid) that are in focus in this research. A stakeholder analysis is presented in order to analyse technological and business model implications that arise as a consequence of the transition to the ERS. The analyses in this chapter are based on the interviews and observations made when following the different ERS projects and activities. A future pathway in the PhD process is to further develop these analyses with a much more in depth presentation of the empirical material, for example through descriptions of the observations, interview quotes and relevant documentation.

The conventional road system

The conventional and established transportation system has developed organically over the past century into an essential part of modern society and is strongly connected to economic growth. Vehicles based on the internal combustion engine (from now on called ICE) technology, emerged as the dominant design in the beginning of the 20th century in competition with electric vehicles and steam engines. The early domination of the ICE technology was a consequence of the arrival of the, for the public affordable, T-ford vehicle (which was released in 1908) and cheap oil (Geels, 2005). In the 1920s, ICE trucks based on the diesel engine technology emerged as an alternative to gasoline driven otto engines. Trucks fuelled by diesel were better suited than vehicles driven by gasoline for transportation of goods and people (Flink, 1998). Diesel fuel had a higher energy density than gasoline fuel and the diesel engine was more durable with higher torque than gasoline engines. As the ICE became the dominant technology and people could afford the vehicles, the transportation system evolved through a co-evolutionary process (Schot et.al., 1994).

![Figure 2. Autonomy subsystems in the conventional road system.](image)

The subsystems analysed in this research are petrol stations, ICE based vehicles and roads (Figure 2). The road system has developed into an open system with subsystems that are rather autonomous today. Each subsystem has developed similar standards between the interfaces. For example, trucks could drive on roads in most regions and countries, while being able to tank the similar fuel in the same market place. Consequently, each subsystem has developed into an industry that is path dependent. Further, users and policy makes have also become locked in to the diesel engine technology.
**Stakeholders of the different subsystems**

The **truck manufacturing** industry is a mature industry, characterized by mass production, large-scale markets and incremental innovation. Commercial interests drive the heavy-duty market, with fuel economy as the main driver for innovation. Heavy-duty vehicles are expected to be durable and are designed for tough conditions; they should work for as long as possible with a high workload. Truck manufacturers have technological and market-related knowledge regarding the road transportations with an existing customer base and supplier network. Firms within the truck industry have invested heavily in the internal combustion engine, which constitutes the core technology of the existing transportation system.

The conventional road system was developed in symbiosis between auto manufacturers and **petroleum firms**. The petroleum business is a high capital accumulating industry with large, often national owned, multinational companies. In recent decades, the emphasis has been on increasing fuel quality and searching for alternative fuels in order to reduce emissions. The oil industry is currently challenged by the fact that many of the large oil sources are located in politically instable areas in combination with the fears for a maximum level of petroleum extraction (referred to as peak-oil. This has led to a search for unconventional oil sources (such as oil sands in Canada or deep water oil in Antarctic).

Road owners, which often are public actors, finance and procure the roads in collaboration with **construction firms**. The construction firms compete on contracts to deliver road construction based on quality, time delivery and costs. Hence project management, budgeting and material purchasing are essential competences of a road construction firm. The life durance, environmental impact and safety are key issues of the roads.

Mobility of goods and people is essential for the society and a key issue for **state and agencies**. The industrial sectors’ competitiveness is dependent on efficient transportations for delivering and receiving goods while mobility is a cornerstone of the economy. Investments are needed in infrastructure to meet the transportation needs of society, and are largely financed though taxes. The state, through agencies and regulatory entities, need to ensure that the negative environmental impact from the road transport system is mitigated.

The **users** of the transportation system are both commercial and private vehicle owners. Commercial vehicle owners, such as cargo firms and bus companies have three main costs: vehicle investments, personnel costs and energy costs. The cargo industry is characterized by low margins as a consequence of low consumer prices and strong bargain power of retailers. Multinational cargo firms transport goods over different modes such as ferry, trains, flight and railway. Due to the flexibility of the motorized vehicle (they can be used for different purposes such as highways for longer transportations but also for regional and local use), road transportations are increasing steadily. Increased societal awareness about pollutions combined with increased fuel costs for the users are main incentives for the transformation to the ERS.

**Driving forces for change**

Although the transportation system currently is considered as locked-in to fossil fuel energy and ICE technology (Unruh, 2000) there are several driving forces for a new transportation system and technology. Increased concerns of climate change, energy security and increased fuel prices have created a demand among society and industry
for more energy efficient technology that cause less green house emissions and reduce fuel costs. During recent decades, the focus of policy makers has turned from new technologies that have made advancements in reducing emissions in passenger cars (e.g. hybrids, battery electric vehicles and plug-in, fuel cells) towards technologies aimed at trucks and buses as they represents one of the sectors where emissions are constantly increasing. Roughly, there have been two alternatives to fossil fuels: keeping the ICE but shifting to alternative fuels (such as biofuels) or shifting to an electric power train\(^7\). Alternative fuels have demonstrated commercial viability but have lacked in the capacity to satisfy the fuel demand in the transport sector. These types of fuels have also been highlighted for conflicting with the global food supply (Callé & Johnson, 2010). Electric powertrains and hybrid vehicles (use of more than one power source) have not proved commercial viability at a large scale for trucks because of their low battery capacity. Electrifying roads and transferring power vehicles from an external fuel source has emerged as a realistic scenario to solve the challenges of the conventional transportation system.

**ERS - A new technological paradigm**

The ERS can be described as electrified roads that support dynamic power transfer to the vehicles (Figure 3). ERS has the following subsystems: the road, the truck (based on an ERS powertrain), power transfer technology, and the power grid and stations. The basic principle is to power an electric engine within the vehicle from an external power source that is built into the road infrastructure. The electrical power is transmitted while the vehicle is in motion through a pick-up assembled to the vehicle in a similar way as for a trolley bus. The roads would be accessible for both vehicles with ERS-propulsion as well as conventional fossil fuelled vehicles. Further on, the ERS-vehicles would be equipped with a small battery and a potentially smaller diesel engine to allow a flexible system where vehicles could drive outside the electric road network on conventional roads. (Paper II)

![Figure 3](image)

**Figure 3. Integrated subsystems in the electric road system**

In the beginning of the ERS deployment, while the system is still rather immature, the system will be more suitable for closed transportation systems. Rather than open ones closed systems could be resembled in bus loops or within mining transportation where the routes are predictive and relatively easy to service and maintain. In open systems,

\(^7\) Depending on the energy balance, electricity is not necessary better than fossil fuel from an environmental aspect. However, by pushing for more sustainable technologies in the vehicles, regulators amongst other claim that an increased demand will create a pull for greener produced electricity.
such as regional and long distance transportation, the coverage of electric roads have to be more extensive over regions and nations. This would assume that the interfaces between the different subsystems would be standardized in a regional and international level.

While the basic principle for the ERS is dynamic power transfer technology from the road to the vehicle, the technological standard for transferring power is not developed yet. Currently there are three main concepts in electrifying the roads: over-headline, conductive underneath or inductive. Each technology has its cons and pros and is developed and marketed by different firms (Appendix 2). Most of these firms are from the railway industry and could be considered as new entrant to the road transportation system.

The ERS could be an enabler for the integration between the transportation system and other systems such as information and communication technology (ICT) and electric smart grid. ICT technology could be helpful for the vehicle to communicate with other vehicles to avoid crashes and enable automated technologies, such as platooning (vehicles without drivers) and could be integrated with the electric grid for metering and billing of the electricity use.

**Stakeholders implications**

For the truck manufacturers, power electrification could be seen as a body builder (building application on the truck chassis). This means that the truck should manage electrification independent of which power transfer technology that becomes the standard. However the vehicle will be more integrated with the infrastructure in the new system compared to the conventional road system, as it needs to be developed and connected with the other subsystems. In the beginning of the ERS deployment, ERS could mature in a niche market for different applications (such as mining and bus system). However, in the long term, ERS could come in to mainstream markets of the truck manufacturers (such as long haulage). The role and value of the core competence for the truck manufacturers, currently being the diesel engine, could change with a switch to the ERS. This would also affect the customer value and service network. Thus, a shift to ERS would require the truck manufacturers to acquire new competencies and new business models (Paper II).

**Petroleum firms** will most probably continue to play a significant role with ERS (electrified roads and batteries would not be able to supply the whole road transportation system). The role of these firms could however change, from being the dominating fuel supplier, to a secondary fuel supplier. If vehicles do not need to tank as frequently as today, petroleum companies will lose their sale volumes and the number of customers would decrease. This might turn the petroleum firms into new businesses, and the established tank-station networks might complement their current businesses with new applications, such as quick charging and battery swapping.

One of the main implications for construction firms is to ensure safety and endurance in controlling the construction and properties of the electric roads. As an actor with experience of large projects, construction firms could take the role of integrating the transfer technologies as well as the electric grid into the road construction. Furthermore, the issue of financing new ERS projects might open a new market for public-private partnerships, where construction firms (or other private real estate owners), build and operate electric roads on contracts for public agencies.
The main motivations behind the ERS for the state and agencies is to reduce environmental impacts, oil imports and increase energy efficiency by switching from fossil to electric fuel. All other stakeholders have pointed out that the state and agencies have a key role as facilitators when it comes to investing in infrastructure. The loss in oil taxes and currency savings from oil imports could require new national and international policies. The transition to the ERS might change the financing and owning structure of these roads in order to share the risks and opportunities with private actors that will benefit of new system. The ERS could also be developed as a new export industry in countries that have come far in their development of this technology, such as Sweden, Germany and Korea. Hence, investing in the development of the ERS could result in a new market and thus increased income for states and agencies.

The users of the ERS could benefit from higher energy efficiency in the vehicles compared to diesel engine trucks and thus potentially lower fuel costs (although the electricity prices are expected to rise). ERS could also constitute an image and brand value to be more environmental friendly than other alternatives. Despite this, cargo firms might be reluctant to change to ERS vehicles if the infrastructure is undeveloped in the sense that flexibility and uptime is still better in the conventional road system. It is yet unclear how much the vehicle prices could be affected due to the ERS equipment and new powertrain technology. There are also uncertainties concerning how and to whom the customer should pay for the usage of the ERS.

Road power technology firms could be firms in the railway industry or entrepreneurs. Railway companies have long experience of designing, producing and delivering complete railway systems, including infrastructure and intelligence. Trams in urban transportation are one of the main markets for these firms. Since the past couple of years railway companies have introduced different technologies for power transfer from roads to vehicles. These firms are now trying to broaden the scope for respective technology, to include urban transportation such as busses and cars, but also trucks and cars on highways. This creates a situation were different technologies are competing with each other. Proponents of the inductive and conductive technologies are pushing for their solution and it is uncertain which solution that will win in the end. In addition, there are several unclear issues concerning how the system will evolve: Will these actors become systems or component providers? Will they sell licences of their components to other actors or will it be exclusive roads? Will they develop alliances with partners to deliver a complete ERS or will they provide generic technologies? And how should the revenues within the new value network be shared?

Power companies produce electricity through different energy sources, e.g. fossil fuels, nuclear and renewables. The traditional way of making money is to sell electric power per kWh to households and companies. In the ERS scenario, electricity will be the new primary vehicle fuel, which opens a new market for the power companies. Designing and delivering power station in connection to the power transfer technology and the road is a potential business of the power companies. The power grid and stations need to be dimensioned based on the amount of power required for the vehicles at the particular road section. The main question for the power companies is: Who will finance the investments in the power subsystem and how should the revenues from the vehicle’s electricity consumption be captured?
Summary of appended papers

Paper I
Traditionally literature on discontinuous innovation has built on the perspective of either creative destruction (called Schumpeter Mark 1) or creative accumulation (called Schumpeter Mark 2). This has implicated that empirical studies in the field of discontinuous innovation have focused on either competence destroying or competence enhancing activities when studying the processes of incumbent firms. The aim of Paper I is to explore the relationship between competence enhancing and competence destroying activities. Paper I has the following research questions: How does discontinuous change affect the competence (technical and non-technical) of incumbent firms? Further, the study explores different mechanisms to have a viable business model in the new market. The paper has an industry perspective as it focuses on the incumbent firms in mature industries and new entrants from other industries. The unit of analysis is on the value creation part of the incumbent firms’ business model.

The study is based on two case studies from two mature industries that are used as complementary as they portray different parts of the discontinuous process. The first case is in the lightning industry, where the incumbent firms (GE, Osram and Philips) have faced a transition from traditional light technologies (such as incandescent and discharge lightning) to LED technology coming from the semiconductor industry. The second case is from the truck industry as incumbent firms (Scania and Volvo) are facing a transition from the ICE based transport system to the electric road technology coming from firms in the railway industry. The LED case is based on a patent analysis and secondary data while the second case is based on interviews and observations.

Paper I find that there are elements of competence-destroying activities in the lightning case. The analysis shows that incumbent firms patented in LED lightning technology several years after semiconductor firms did. Further, the incumbent firms made several acquisitions and created joint ventures with LED technology firms, as they did not have the new technology in-house. Other signs of competence destroying activities were organisational separation of the new business units, a new way of working with glass and metals and more rapid development cycles. In the truck industry the most significant sign of competence destroying is the changing role of the diesel engine. Although the diesel engine and the service network will remain important for customers in the near future, the added value will be reduced significantly. Further, mechanical components such as gearbox and transmission and chemical technology for exhaust treatments would be reduced significantly with electric road powertrains.

Paper I also shows signs of competence enhancing activities. The function knowledge of developing and producing a light source and transportation solution that meets customer needs remains vital. Further, in the lightning industry some technologies were retained such as optics, drivers, electronics and controls. The complementary assets of the firms e.g. distribution channels, brand, understanding of norms and standards remain important for both cases. The patent analyses of the lightning industry showed that 30-40% of traditional patents were related to LED. For the truck firms, the knowledge developed in hybrid powertrains could become crucial for the success of the new powertrains.
The theoretical implication of Paper II is that there is a simultaneous process of creative destruction and creative accumulation. This contrasts the well-established literature stream on innovation and enables better understanding of future change processes. From a practical point of view, incumbent firms do not have to choose going for either the new technology or sticking to the old one. Instead a combination of both processes is necessary to have a viable business model. This could however amount additional challenges for newcomers as they lack the non-technological knowledge.

**Paper II**

Technology shifts are difficult to master for incumbent firms. Several studies have shown how the dominant technology, which has made the firm successful and considered as the core competence, becomes the core rigidity and the primary cause for a setback for competitiveness in the new market. The causes for why a technology shift is so difficult to master in relationship to the business model are hence a relevant area of research, both from a theoretical and a managerial perspective.

The purpose of the paper is to illustrate the business model dilemma of a mature manufacturing company facing a potential technology shift were the systems’ business logic changes. The relationship between technology shifts and business models is analysed through the case study of the transition to the electric road system (ERS) from the truck manufacturers’ perspective (with Volvo and Scania representing firms in the mature truck industry). The research question of the paper was: In what way is the ERS a challenge to the managers of these firms?

Paper II is based on a case study, where the Slide-In program, where truck manufacturers in partnership with railway firms evaluate electric road technology for truck and roads. The data collection is done through observations of project meetings and informal observations at one of the truck manufacturers R&D department. Further, the main source for this paper has been interviews with managers from the truck manufacturers. The interviews reveal how the truck manufacturers encounter the development of the ERS in relation to their existing technology and business model. Further the paper illustrates how and why the transition to the ERS triggers a technology shift and how this affects the business model.

The findings illustrate a business model dilemma. On the one hand the truck manufacturer could decide on taking on a technology leadership strategy to face the transition to the ERS and hence develop ERS propulsion technology. The value creation part of the business model would in this case be to develop and produce trucks built for the new ERS technology. However, it is not clear how the firms should capture the new value or propose it to the customers. On the other hand, a service strategy would give the truck manufacturers a relevant value proposition and value capture built around the transportation solutions. This would however not secure the position of technology leadership and core competence in the new technology and thus could become more vulnerable to new actors in the new system.

Paper II concludes that it is necessary for engineers and business developers to work together when developing strategies for how a firm should manage a potential technology shift successfully in a new competitive landscape. Further on, there needs to
be a combination of technology innovation as well as service innovation simultaneously, in order to gain a viable business model.

**Paper III**
The servitization literature emphasises a shift towards greater service content in firms value propositions. The basic assumption of the servitization literature is that a firm keeps it core capability when moving towards service oriented value propositions or business models. Increased services are economically beneficial as the firm could capitalise on services throughout the product life cycle and as services have higher margins than products and could be used to create a differentiating advantage. Customers demand increased services as the technological complexity rises. The servitization shift has resulted in several service concepts such as a product-service-system (PSS), experiential services, and service dominant logic.

The aim of this study is to explore how servitization strategies are affected by disruptive innovation. The unit of analysis is the value proposition of the business model. One of the most well known examples of successful firms in the servitization area is Rolls Royce as the firm retained the core capability in engine technology and turned into selling power by the hour and increased sales in engine services and maintenance. However, the firm remained its core capability in engine technology and widened its offering to engine service and maintenance. However, it remains a question how this strategy would be affected if the core technology were lost.

The research design is based on a longitudinal case study within the truck industry where truck manufacturers are facing a transition towards the electric road system (ERS). The paper embraces the truck manufacturers perspective and focuses on the simultaneous journey of moving to a service-oriented business model and facing disruptive innovation. On the one hand truck manufacturers are pursuing an increased service-oriented business model, shifting the focus from the truck itself towards selling transportation solutions to customers. On the other hand, the case study of the electric road system illustrates how the truck manufacturer are facing disruptive innovation were the added value of the core capability, the diesel engine, is significantly reduced.

Since much of the servitization literature is based on the assumption that core competence remains an important competitive advantage for manufacturing firms in the new context, there is a need for more research on both the effects of disruptive innovation on servitization and effects of servitization on disruptive innovation. The results in Paper III indicate that the product and functional knowledge of the market and customer could remain important in a service-oriented business model, even when core capabilities are lost. The practical implication is that a firms’ new core capability lies in system integration and network knowledge. A business model transition to PSS may enable the firm to achieve competitive advantage in the new technology system.
Implications and next steps

The overall research question of how business models were affected by discontinuous innovation in the system has been explored through three papers. Until this point the papers have taken an incumbent firm perspective. One contribution is made to the body of literature in business models. This thesis adds to the analysis of business models in the context of discontinuous change. Further, it presents the terms value proposition, value creation and value capture as a synthesis from previous literature that enforce the analytical power of business model.

The implications of this thesis are three folded. Firstly, there is a simultaneous process of competence enhancing and competence destroying in the context of discontinuous innovation in mature industries. This increases the opportunities for firms to adapt their value creation element of the business model while new generating greater challenges for new entrant. Secondly, discontinuous innovation is illustrated as a business model dilemma. Incumbent firms need to develop business model strategies based on both service innovation and technology innovation. Thirdly, while most literature in the servitization assumes that the core value creation of the business model remains, this thesis shows that this is not the case when facing a discontinuous innovation.

In the previous chapter the transition towards the ERS was described through a descriptive comparison of the conventional road system and the ERS and the two systems’ different stakeholders. This illustrates the complexity and different aspects of a system change. To further understand the dynamics of how incumbent firm business models are affected by discontinuous change, it is important to widen the perspective to beyond the incumbent firms. The proposed papers take a system perspective of how discontinuous innovation and business models are related. The focus is to analyse how a transition in a system could affect the business models and shed light on the challenge and opportunities that emerges.

Paper IV

Analysing system innovation through a business model framework

Discontinuous innovation changes the role of value networks (Christensen, 1997). New constellations of actors create the value. This challenges business models and causes incumbent firms to fail from managing discontinuous innovation (Christensen, 2006). However, business model literature has focused more on marketing and entrepreneurship. The models in this literature are not suitable for analysing how incumbent firms are affected by discontinuous innovation. Thus, based on the presented theoretical concepts and the case study of the ERS, a business model framework has been developed to analyse the opportunities and challenges that could arise with a transition from one technological system to another (figure 1). The framework gives a perspective on what opportunities and challenges that stakeholders face during system innovation.

The framework has so far been created and used through the ERS illustrating the complexity of system innovation (Appendix 3). This paper intends to explore the model through other similar cases. The framework has a value chain perspective. It gives
insight to the challenges about what value is, how value is created and who could capture the value in the new system. The framework should be used through three steps. First, identifying the subsystems that should be considered as the most important ones and those that could be considered as of complementary sub system. Second, identify stakeholders in multiple levels; system designer, subsystem provider or system user. Thirdly, the business model of each stakeholder is analysed and illustrated through the business model component of value proposition, value creation and value capture.

Fig. X: The business model framework

The business model framework of the conventional system should be compared to the new systems business model to illustrate the challenges and opportunities that arise when managing new discontinuous innovation in systems. The overall value of the system could change for the users and thus affect how the system should be designed. This would affect the subsystem providers, as established industries might not have sufficient value in the new system compared to the conventional one. Consequently, established firms might need to change their business model to deliver adequate value to continue grow and manage with the technology change.

Paper V
The development of the electric road system – business models as reverse salient
This paper is based on the empirical description about the evolution of the ERS. The paper follows concepts of Hughes (1983) and Geels (2005) about Large Technical Systems and system innovation. This as an example of how new infrastructure emerges and how it affects the strategic agenda of different stakeholders. The technological development is a driver for the change but is not the main factor that holds the system back. Instead this study argues that the business models are the main factor that holds the system back for its potential. This study could compare the development of the ERS with other examples (e.g. the electrifications of power network, the electrification of the railway system in Sweden, the development of the mobile communications) that include systemic change and affect established commercial and technical interests. What insights from other cases could help us to understand the future trajectory of the ERS?
And what has the role of business models been in other similar cases. This study contributes to the business model and LTS literature. Traditionally the focus has been on social, political and technical aspects of this process. Though, this study has a business model perspective and uses the analogy of reverse salient as a metaphor for exploring business model in system innovation.

**Paper VI**

**Institutions setting the strategic agenda and affecting business models – the case of the ERS**

This paper explores how institutions affect business models in discontinuous and system innovation. Discontinuous innovation has been studied thoroughly from the firm level with focus on incumbent firm. The associated research has shown that incumbent firms have difficulties in managing the discontinuity, as it is a business model challenge. Business models could either be developed by single actors or in consortium. This paper explores business models in the strategic agenda of agencies during system innovation. More specifically, the role of the agencies and government is explored and related to the incumbents firms strategy and business model. This would contribute in the understanding of how new business model on a system level come about. Therefore this study examines what role institutions play in the strategic development of ERS. It analyses what the first mover advantage and the late follower strategy has for consequences in the competitiveness of incumbent firms.
References


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### Appendix 1. Respondents

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Appendix 2. ERS technologies

Over-headline technology
The over-headline technology is the most developed power transfer technology. It is mainly used for railway trains but also trolley buses. It is associated with high-energy efficiency capacity but also low degree of flexibility. The technology is not appropriate for passenger vehicles as it is too high in the air and thus suitable for electrifying trucks and buses. The system has a well-established technology interface and could be open for different actors. The pantograph is the subsystem that is most immature and critical in the over-headline solution. Siemens and Swedish Electric Roads are promoting this technology. Picture 2 and 3 illustrate Siemens technology through the Siemens E-highway in Berlin and through a concept vehicle together with Scania.

Figure 1 (left). Siemens ERS technology on a test track in Berlin. Figure 2 (right) : Scania and Siemens truck collaboration. (Gustavsson, H., Scania)

Conductive technology
The conductive technology from underneath is based on a rail paced in or on the road surface. The vehicles are equipped with a pick-up that has physical contact to the rail in the road. The rail is connected the electric grid and powerstations along the roadside. The rail is segmented so that it is only powered when a vehicle is above it. If the vehicle is still or has a low speed the energy efficiency will be low and consequently the system will be off. The pick-up is automated to auto detect and follow the rail despite vehicle movements. The technology could potentially be used for both light and heavy vehicles. This technology has been developed by Alstom and Elways and is illustrated in Figur 3-5.

Figure 3: Elways technology with conductive power transfer from the road. (Elways.se)
Figure 4-5: Volvo & Alstom collaboration in Slide-In conductive (Sebestyen, R., Volvo).

**Inductive underneath**

The inductive technology is mostly developed for static charging. The technology could also be adopted in a dynamic approach creating a ERS. The has an advantage as it does not require physical contact since the transmitter is under the road surface the technology is not as vulnerable to different weather conditions and hinders on the road. The downside of the technology is that is requires extensive investments cost. The technology is developed by Bombardier. Scania and Bombardier are integrating the pick up in a Scania truck within the Slide-In project. Further, safety issues regarding the

Figure 6-7. Scania and Bombardier collaboration in Slide-In Gustavsson, H., Scania)
Appendix 3. Business model framework – analysing ERS

Business model framework – the existing system

Business model framework – the electric road system, ERS