The business model dilemma of technology shifts

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A B S T R A C T

Technology shifts are lethal to many manufacturing companies. Previous research indicates that this is not purely a problem of technological innovation, but is also closely related to the inertia of business models and business model innovation. This paper inquires into the dynamics of this intersection between technology and business models. Anchored in a case study in the automotive industry, it reveals how a potential technology shift constitutes a business model dilemma for firms leading in the existing technology. The paper illustrates why technology shifts are so difficult to master and contributes to theory by suggesting that managing technology shifts does not require either technology or service innovation in order to create a viable business model, but instead a compound of both. Furthermore, the paper applies a business model perspective to illustrate the explanatory power of analyzing the challenges of technology shifts faced by incumbent firms.

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1. Introduction

Technology shifts are among the most lethal threats to any successful business. Many historical accounts tell of companies for which the technology that once constituted their competitive advantage eventually became their primary drawback. There are several ex post explanations of the causes of such failures (Arthur, 1989; Foster, 1986; Utterback, 1994). Although some firms have overcome these Schumpeterian winds of creative destruction, it seems profoundly difficult for a mature company facing a potential technology shift to identify the causes of failure and the strategies for success in advance (Abernathy and Clark, 1985). From a managerial point of view, the fundamental question still remains unsolved: Why are these shifts so difficult to manage?

Innovation research generally suggests two alternative strategies: either investing in R&D to radically transform the firm’s technological core competence (Cusumano and Rosenbloom, 1987), or transforming the firm’s value proposition embedding the product in functional sales and product service systems (Vandermerwe and Rada, 1988). The first strategy entails investing in R&D to gain competitive advantage through a stronger technological position, but with a different technology creating the value (Adler, 1989). The second strategy entails forward integration and expanding the value proposition to include a broader scope than a specific core technology (Baines et al., 2009; Mont, 2004).

However, for a company facing a technology shift, both these strategies suffer from inherent uncertainties. The technological innovation strategy enhances successful technological change, but risks creating an obsolete value proposition due to new, emerging customer demands. The “servitization” strategy enhances the company’s ability to match the value proposition with customer demands, but creates the risk that the company may lose its technological competitive edge.

This paper examines the business model dilemma of mature manufacturing companies facing a potential technology shift. Several empirical studies have demonstrated that it is profoundly difficult to exchange one core technology for another (Dosi, 1982; Leonard-Barton, 1992; Utterback, 1994), and awareness is growing that the fundamental challenge of this process is “a business model problem, not a technology problem” (Christensen, 2006: 48). Anchored in a case study of a potential technology shift in the automotive industry, this paper takes this line of reasoning one step further. Using the case as an illustrative example, the paper inquires into the dynamics of the intersection between technology and business models. It reveals why technology shifts are so difficult to master and suggests that discontinuous innovation is not about either technological innovation or service innovation in order to gain a viable business model, but is instead a compound of both. The critical challenge for a company facing a technology shift is overcoming the technology shift as such, while simultaneously crafting a business model matching the unknown competitive context after the shift.

The paper is structured as follows. The next section outlines the paper’s theoretical foundations in the literature on technology shifts, servitization, and business models. We then describe the
methodological approach taken and how the data were gathered and analyzed. The following sections outline and analyze the case of two incumbent premium truck manufacturers facing a probable technology shift to electric road systems (ERS), a technology that might make the current technological regime of the internal combustion engine obsolete. The paper concludes by discussing the business model dilemma of today’s truck manufacturers and suggests business model analysis as a useful way to further explore the dynamics of technology shifts. Finally, implications for research and practice are suggested.

2. Theoretical foundations

In theory, there is a classical distinction between incremental and radical innovation (Schumpeter, 1939). Incremental innovation is competence enhancing and aligned with the progress of the current technological paradigm, while radical innovation tends to destroy competence and lead to a paradigm shift (Abernathy and Clark, 1985; Dosi, 1982). Technological discontinuities are innovations that dramatically advance an industry’s price or performance frontier (Anderson and Tushman, 1990). A discontinuous technological change might make the existing technology obsolete and significantly affect the “firm’s existing investments in technical skills and knowledge, designs, production technique, plant, and equipment” (Utterback, 1994: 200).

Throughout history, successful firms have often experimented with new technologies to forestall their replacement by new firms (Tushman and O’Reilly, 1996). While some firms in mature industries have successfully managed this transformation (cf. Bergek et al., 2013), research has demonstrated many examples of how incumbent firms encounter severe difficulties when facing radical technology change (Foster, 1986; Utterback, 1994; Tushman and O’Reilly, 1996). Established firms tend to focus too much on their existing customers, and consequently do not allocate resources to develop new technologies perceived as less profitable or under-performing (Christensen and Bower, 1996; Sandström, 2010). However, if these new technologies develop, new entrants tend to outcompete established firms, which often fail to respond in time to the threat from disruptive innovations (Christensen, 1997). In such a situation, the established firms’ core competencies become their core rigidities (Leonard-Barton, 1992).

There are several possible responses to discontinuous innovation, for example, focusing on and increasing investments in the established business, ignoring the innovation, or disrupting the discontinuity by counterattacking (Charitou and Markides, 2003). Firms can also be ambidextrous, developing both radical and incremental innovation at the same time (Gibson and Birkinshaw, 2004; Tushman and O’Reilly, 1996), or search for radical technologies exogenous to the focal industry (Datta and Jessup, 2013). According to the innovation literature, the classical approach is to invest in technological R&D to gain competitive advantage through establishing a leading position in the new technology. However, few empirical studies explore such R&D strategies among incumbent companies facing disruptive technological change (Yu and Hang, 2010, 2011).

Servitization is an alternative strategy, recently discussed in innovation theory. Instead of investing in technological R&D, targeting innovation in the value-creating technology, this strategy emphasizes innovation in the value proposition offered the customer (Barnett et al., 2013; Ng et al., 2012). An emerging research discourse examines servitization, but most servitization research has so far not considered discontinuous innovation. The following sections will describe technological innovation strategy, servitization strategy, and then business models as analytical tools for understanding the strategic challenge of firms facing technology shifts.

2.1. Technological innovation strategy and servitization strategy

A company can benefit from a technological innovation strategy in several ways, by creating barriers and controlling premium market segments (Porter, 1985), pioneering new markets (Lieberman and Montgomery, 1998), establishing industry standards and dominant designs (Abernathy and Utterback, 1978), and building favorable market reputations (Zahra, 1996). The underlying message is to gain competitive advantage through investing in R&D, technology, and product development (Utterback, 1994), implying a competitive strategy with technology leadership as the main driver (Porter, 1985).

The technological innovation literature usually assumes that the value-creating technology constitutes the firm’s core competence (Prabhalla and Hamel, 1990). Despite having been heavily questioned (e.g., Cantisani, 2006; Chesbrough, 2003; Kline and Rosenberg, 1986), the general notion is that new technologies are initially developed internally and then brought to a market in which demand already exists or will be created (Brem and Voigt, 2009). The objective is to make commercial use of new knowledge; if successful, this entails an application push on the market, created by a technical capability of the firm; if unsuccessful, this entails developing new technological attributes unwanted by customers or already invented by somebody else (Brem and Voigt, 2009). Hence, the spheres of potential new technologies and of customer demand factors need to be adjusted into mutual alignment. In practice, this is more easily said than done. One suggested management approach is a technology portfolio planning process enabling decisions on how to allocate strategic resources to different technological alternatives based on different future scenarios (Chen et al., 2009; Yu, 2006).

An alternative strategy to technological innovation is to transform the firm’s value proposition by climbing the value chain, embedding the technology in a value proposition of functional sales and product-service systems (Baines et al., 2009; Mont, 2002). Following the increasing significance of services, such manufacturing firm servitization (Vandermerwe and Rada, 1988) has attracted increasing research attention (Santamaria et al., 2012). Attention has shifted from the role of the product itself to the function it provides for its users (Giarini and Stahel, 1993), addressing the need to sell systems encompassing combined products and services (Mont, 2002; Tukker and Tischner, 2006). By aligning technology with the service offering, this servitization strategy presents a way for traditional manufacturing firms to differentiate themselves and achieve competitive advantage. Consequently, by adhering to the functionality of the value proposition for the customer, the company can—at least in theory—liberate itself from the specifics of the product’s technology (cf. Oliva and Kallenberg, 2003).

The servitization literature has focused primarily on the value proposition of firms based on an underlying core technology (Gebauer et al., 2005; Ng et al., 2012). However, although some studies indicate that disruptive innovation may present opportunities to generate new services (Godlevskaja et al., 2011), this has not been validated by empirical research. Instead, the empirical cases often cited, for example, that of Rolls-Royce (Ng et al., 2012), are based on the premise of a permanent and stable core technology around which the services are created (Baines et al., 2009). Few empirical studies address the servitization of manufacturing companies in the context of a technology shift, in which the role of the core technology is diminished (e.g., the empirical ERS case examined here).

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2.2. Technology shifts as business model challenges

In recent years, several studies have emphasized that problems of technology shifts and radical technological change are often related to business model inertia. As concluded by Christensen (2006: 48), the fundamental challenge of disruptive technologies is “a business model problem, not a technology problem”, meaning that the key challenge of technology shifts lies in the interaction between technological development and business model innovation (Markides, 2006; Sandström, 2010). However, while a new business model can be crucial to commercializing and capturing the value of a technological innovation (Chesbrough and Rosenboom, 2002; Teece, 2010), an existing business model can also constitute a lock-in that hinders technology shifts (Tripsas and Gavetti, 2000). There are multiple definitions of what business models are all about (George and Bock, 2010; Zott et al., 2011). The concept originated from computer and system modeling in the early 1970s (Ghaziani and Ventresca, 2005) but has attracted increasing academic attention over the last two decades. The subject became popular during the information technology boom in the late 1990s, in an effort to enhance knowledge of the value-capturing mechanisms of firms doing business on the Internet (Zott et al., 2011). From this context, the term went on to become synonymous with concepts such as “revenue model”, “business idea”, “business concept”, and “economic model” (Magretta, 2002), i.e., the basic elements of every firm’s competitiveness (Wirtz, 2010). The main focus of this discourse was value capture, i.e., how to earn money for the value produced by different revenue models.

The business model concept is also related to the literature on business strategy (Hedman and Kalling, 2003; Porter, 2001). Studies have demonstrated that some business ventures have greater interest in formulating business models than in formulating strategies (Bouwman et al., 2008) and that business models often are shared among competitors in the same industry (Teece, 2010). In this literature, the business model concept is used to complement business strategy (Zott and Amit, 2008) and connects the strategy to its operational implementation (Bouwman et al., 2008; Casadesus-Masanell and Ricart, 2010; Shafer et al., 2005). Following this line of thought, the term business model usually refers to the firm’s value proposition, i.e., what market segments the company targets and the value it creates for what customers. Innovation management scholars have extended the view on business models from emphasizing only value capture and value proposition, to include value creation as well (Zott et al., 2011). The dual concept of value creation and capture focuses on what businesses do and how they do it (Davenport et al., 2006; Zott et al., 2011). Value creation at the firm level includes invention, innovation, R&D, and production as core capabilities (Chesbrough and Rosenboom, 2002; Lepak et al., 2007; Shafer et al., 2005). In light of new technologies, business model innovation could be a measure of the continuous expansion of a potential market (Kodama, 2004), with the strategic resources of the firm and its value network as two important elements of this business model innovation process (Hamel, 2000; Shafer et al., 2005).

Although the business model concept has been criticized for being ontologically vague and developed in silos (cf. Al-Debei and Avison, 2010; Zott et al., 2011), it does direct our attention toward the backbone of any successful business, that is, the activities connecting the firm’s technological core to the fulfillment of its customers’ needs (Chesbrough and Rosenboom, 2002). The business model as an analytical concept constitutes a unit of analysis that explicitly spans the traditional boundaries of the focal firm and relates internal value-creation activities to significant features of the firm’s business environment (Stähler, 2001; Zott et al., 2011; Zott and Amit, 2013).

This paper analyzes, from a business model perspective, the case of traditional truck manufacturers facing a probable technology shift. In line with, for example, Shafer et al. (2005), Stähler (2001), Chesbrough and Rosenboom (2002), Al-Debei and Avison (2010), and Johnson et al. (2008), we apply a business model framework comprising the following three components:

1. **Value proposition**, i.e., the value of the products and services that the company offers to its customers;
2. **Value creation**, i.e., how this value is created; and
3. **Value capture**, i.e., how the company retains the value it has created for its customers.

As will be demonstrated in Section 5, the triad of value proposition, value creation, and value capture illustrates how a potential technology shift can constitute a business model dilemma for firms leading in an existing technology.

3. Methodology

3.1. Research setting

This paper is based on an extensive qualitative case study of the Slide-In Electric Road System project (henceforth, “Slide-In”), a public–private development project evaluating the feasibility of electric road system (ERS) technology and identifying barriers to full-scale deployment of the technology in the national road systems (Olsson, 2013a, 2013b). The project gathered key stakeholders holding this new technological system, for example, commercial truck manufacturers (i.e., Scania and Volvo), power utilities, railroad manufacturers, national agencies, road administrations, and universities. The project budget was approximately EUR 4 million, co-financed by various public agencies in Sweden and international industrial partners. The main objectives were to construct an ERS demonstration track and integrate power-transfer technology in the ERS vehicle, to prove the ERS concept of continuously transferring electric power from road to vehicle.

The case study was explorative. Its overall aim was to study the early phases of evolution of a new technological system in real time, i.e., longitudinally follow the actions, discussions, politics, conceptual development, etc., during the system’s emergence. The findings reported here represent some of the results of this case study. We use the case to illustrate a significant empirical phenomenon that had been touched on, but attracted little attention, in earlier research.

3.2. Research design

The Slide-In project was studied over nearly three years (Spring 2010–Fall 2012) to explore a significant empirical phenomenon in depth. The study was inductive in that it departed from an empirical phenomenon (i.e., the potential shift to ERS technology), identified empirical patterns, and reflected on these patterns in light of the existing literature, in order to identify new issues for future research (cf. Glaser and Strauss, 1967). Hence, the aim of the study was to contribute to the development of new theory on technology shift dynamics from a business model perspective, rather than to test established theories in the field (cf. Eisenhardt and Graebner, 2007). The study applied an insider–outsider design (Bartunek and Louis, 1996) with one of the authors acting as the insider closely following the project work, using an ethnographically inspired approach (Fetterman, 2010). The empirical study was part of the insider’s doctoral training. The other author acted as the outsider, reflecting on observations from a distance. The
insider and outsider met periodically to discuss observations, tentative findings, and directions for future empirical work.

The point of departure was the perspective of Scania and Volvo, the two truck manufacturers jointly responsible for coordinating two sub-projects. Both companies are internationally very well known and regarded as influential technological leaders, producing premium trucks for the heavy-duty vehicle market (Dressler and Gleisberg, 2009).

The ERS study context constitutes a hypothetical future technology shift. It is the ambiguity of this situation for the truck manufacturers that is the focus of this paper, i.e., how various experts perceive the potential effects of this potential technology shift, how companies are maneuvering to prepare for it, and why this kind of technology shift seems so profoundly difficult to master beforehand. Consequently, potential strategies for responding to this technology shift, the actions actually undertaken by the two companies, the process of integrating technology and forming partnerships, and the effectiveness of the companies’ various measures are all issues beyond the scope of this paper. The present study is intended to help us understand the business model dilemma of incumbent firms facing a potential technology shift.

3.3. Data collection

As in most qualitative case studies, multiple sources of empirical data were used, including observations, interviews, and written documents (Yin, 2008, 2009), see Table 1. This permitted triangulation (cf. Denzin and Lincoln, 2000; Jack and Raturi, 2006) in which information from one source was correlated with, and its reliability tested against, information from other sources.

Observations were made throughout the study period. The author acting as the insider spent considerable time on site at the truck manufacturers’ offices, acting as a participant observer at formal meetings, informal gatherings, and “small talks” in the organizations. The fieldwork observations were documented in written notes posted in a blog diary.

Interview respondents were selected according to two criteria: first, respondents with key roles in the Slide-In project, reflecting how their respective organizations approached ERS development; second, respondents in strategic positions in organizations that would probably affect or be affected by the technological and commercial aspects of ERS.

Interviews were conducted with respondents from different organizations affected by ERS development, for example, truck manufacturers, electrical power utilities, road administrations, railroad manufacturers, energy agencies, industry experts, and researchers (18 of the interviews were with employees of the two truck manufacturers). All interviews lasted 1–2 h and were audio-recorded. The interviews were semi-structured, each guided by a written interview guide with preset topics and open-ended questions. As the case study evolved and our understanding increased, the interview guides were successively developed. In addition, due to the longitudinal nature of the case study, the interview guides were dynamically adapted to cover the evolution of the Slide-In project as well as events and unexpected experiences associated with it. The primary aim was to understand respondent perceptions of the ERS scenario, and its implications for existing technologies, businesses, markets, and stakeholders.

Various documents regarding policy, project agreements, feasibility studies, and technological details were gathered and studied. The main purpose of the document study was to deepen our understanding of the context of the Slide-In project and of the various actors’ objectives.

3.4. Data analysis

Immediately after the interviews, the notes taken were analyzed by restating the main findings when the conversations were still fresh in mind. Next, the audio-recorded interviews were transcribed and examined. After the first round of interviews, the issues discussed were grouped into various categories (Miles and Huberman, 1984). However, if specific issues were found to be unclear during the analysis, despite the written notes and audio recordings, the researcher asked respondents for additional information via e-mail, telephone, or physical meetings.

A similar approach was applied to the observations. In the early phases of research, the observations were part of the insider researcher’s “grand tour” (Fetterman, 2010) of the empirical setting. The observations were conducted as open-mindedly as possible in order to understand the dynamics of the Slide-In project and the problems the various actors were addressing. With a progressively better understanding of the project, the observations made were thematically clustered in the same way as was the interview material.

To validate the results, preliminary findings were reported and discussed at two project workshops at which representatives of all Slide-In project stakeholders were present. While one researcher presented the findings, the other observed and took notes.

4. The empirical case: technology shift in truck manufacturing

4.1. Background

The automotive industry is among the most sophisticated mass-production industries in the world. It is strongly related to technological innovation, advanced production systems, and—in many ways—the modern way of life. Automotive vehicles constitute the fundamental component of modern transportation. Consequently, a large and sophisticated socio-technological system of cars, gas stations, roads, manufacturing plants, service shops, infrastructure providers, building contractors, and legislators has organically evolved, together with many powerful stakeholders, over the last 100 years (Geels, 2002).

| Table 1 | Data sources for the case study. |
|---|---|---|---|
| Data sources | Actors | Respondents/specifiers | Documentation |
| Interviews, 18 | Truck manufacturers | Managers from various departments, CEO of one firm, and experts in conventional technology | Audio recording |
| Participant observations, 13 | Slide-In stakeholders, Truck manufacturers | Project managers, department managers, and engineers R&D department of one truck manufacturer | Notes, blog |
| Informal observations (over 25 documented observations) | Agencies and truck manufacturers | Technology, emissions, project detail, and patent documentation | Internal and formal documents |
| Document study | International ERS initiatives | Firms working on ERS technology, debates, and initiatives | Notes, blog |
| Websites, participation in industry conferences, and study trip to China | |

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Motor vehicles with oil-based propulsion emerged early in the twentieth century with the refinement of the internal combustion engine. The first internal combustion engine was developed by Nikolaus Otto in 1867 and used by Karl Benz in 1885. The engines were originally fueled with biofuel, but with the tripling of American oil production and Fordist mass-production, the modern transportation system based on oil became dominant in the early 1920s (Sperling and Gordon, 2009). Gasoline was cheap and the fuel distribution network expanded dramatically—from 15,000 gasoline stations in 1920 to 46,000 in 1924 in the USA. As people's mobility increased, an infrastructure of roads and highways, gas stations, and service shops was built to connect suburbs and cities across regions and nations.

Despite its significance for the global economy, the automotive industry has long been under strong pressure for technological transformation. The discourses of climate change, global oil resource limits, and energy security have prompted a quest for technological alternatives to classical internal combustion engines for cars, trucks, and buses. In recent decades, the focus of policy makers in regards to the issue of reducing emissions has shifted from the light-vehicle industry (e.g., personal cars with new technologies such as hybrid, battery–electric, plug-in, and fuel cell powertrains) to heavy-duty vehicles, which today produce a third of all emissions in the road transportation sector. Despite large investments in R&D by industry and significant improvements in vehicle energy efficiency, emissions are still increasing globally. This makes it urgent to find and develop effective alternatives to this oil-based technological regime.

### 4.2. Truck manufacturers in the existing technology paradigm

Heavy-duty vehicles (hereafter, “trucks”) are often defined as vehicles heavier than 6 t (Storey and Dixon, 2012). The truck industry is mature and characterized mainly by incremental technical innovation, although at a complex technological level. It is dominated by large companies mass-producing for the premium, budget, and low-cost markets on an international basis (Dressler and Gleisberg, 2009). The industry employs approximately 344,000 people worldwide with revenue of USD 251 billion. The main actors are Daimler Trucks, Volkswagen Group (including Man and Scania), Volvo Group (including Renault, Volvo, and Mack), Paccar, Tata, Ivec, and Ashok Leyland (Dressler and Gleisberg, 2009). The products range from utility-specific vehicles (e.g., buses, fire trucks, and sanitation trucks) to trucks for transporting cargo in general (e.g., for long-haulage, construction, and distribution).

Throughout history, truck manufacturing has constituted a significant element of the automotive industry because of its size and the importance of its products. The road transportation of goods and people is crucial for economic development and complements the other freight modes (e.g., rail, ship, and air transport). The main advantages of road transportation are flexibility, high capacity, and relatively low costs. Trucks are commercial vehicles, sold to commercial customers such as haulage and logistics firms; the vehicles are expected to be durable and reliable and are designed for tough conditions. Although trucks can differ in subtle details, such as external appearance and interior cab design, the basic purpose of the truck is to transport goods as efficiently as possible. From a haulage company's perspective, when buying trucks, the total cost of ownership is one of the most significant considerations, with fuel economy as the main cost driver.

The art of truck manufacturing follows different traditions and logics in different parts of the world. In the United States, customers tailor their trucks according to their preferences by ordering specific components (e.g., engine, transmission, and gears) from different suppliers for final assembly by a truck manufacturing company. In the European market, the tradition is that the customer orders the complete truck from one company, which provides all necessary components. Especially in the premium market segment, served, for example, by Scania and Volvo, truck manufacturers strive to tightly control the complete technical system of the truck, with all its subsystems and components, to ensure premium quality.

#### 4.3. The diesel engine as core technology

The main value-added technology of premium truck manufacturers is related to components such as the internal combustion engine, transmission, chassis, and cab. The chassis is important in making the vehicle robust and adaptable to different applications, while the cab is important for driver safety, comfort, and productivity. However, key industry actors generally agree that the internal combustion engine, which together with the transmission technology defines powertrain features and vehicle performance, constitutes the primary technical core component of the vehicle.

Diesel engines are traditionally better for trucks than are other engines as they are more durable and have higher torque, while diesel fuel has higher energy density than does gasoline. Since the introduction of the first diesel truck in 1920, the diesel engine has experienced a long series of improvements. Today's diesel engines constitute a highly efficient technology but nonetheless a significant source of emissions. In fact, as illustrated in several of our interviews, the diesel engine is the single component that gives the complete existing truck-transportation system its flexibility and reliability:

The diesel engine is the most difficult and challenging component of the vehicles to secure from a quality and reliability perspective. It is a very complex technology that was developed over the whole last century. (Head of Powertrain Development)

Consequently, the diesel engine constitutes the most important competitive factor for premium truck manufacturers. The customers, mainly haulage contractors transporting goods, emphasize attributes of the engine such as power performance, safety, durability, and reliability. However, with increasing oil prices and continuously increasing political pressure to reduce greenhouse gas emissions, fuel efficiency has long been the primary driver of innovation in the industry, as explained by one of the interviewed engineers:

We improve fuel efficiency as it is what customers are willing to pay for. This is why our objective is the same today as it was in the 1950s—to reduce g/kWh—although the costs of all technological improvements of the engine are continuously increasing. (Senior Diesel Engine Developer)

While many other components and subsystems are purchased from suppliers and assembled into the truck by the truck manufacturer, all key components of the powertrain are developed and manufactured in-house. Both Scania and Volvo indicate that over half of their R&D budgets is allocated to developing diesel-based powertrain technology. As illustrated in the following quotation, it is the complexity of the technology that makes it so difficult to master:

We meet the customers’ needs with a good product. … our customers demand great reliability. Our diesel engines provide reliability and high energy efficiency, and thus low fuel consumption. Since the technology is so complex, we have to invest in it extensively. (Manager Diesel Engine Development)
4.4. Significant after-sales

The traditional logic of premium truck manufacturers has been to sell diesel-engine trucks through contract-based sales processes. Customers typically order from a product catalog, specifying the vehicles according to their preferences, and the sales representative receives a bonus per vehicle sold. The vehicles constitute high investment costs for the customers. If spare parts and maintenance services are needed, the customers can order them from either the truck manufacturer or independent service market actors.

We already have good products, and are not necessarily lacking on the technology side. The challenge is to find new business models in which we feel secure in our product platforms. (Manager Marketing and Sales)

The complexity of diesel engine powertrain technology allows truck manufacturers to play a key role in the after-sales market as well. By ensuring the availability of spare parts and skilled technicians within a well-developed infrastructure of maintenance workshops, the truck manufacturers earn good profits from after-sales. As one interviewed sales managers explained:

We have an important business in the aftermarket as well … When you sell a system, you must deliver hundreds of vehicles and ensure that there is an aftermarket structure with maintenance workshops to support the vehicles. The actor that delivers the most complicated technology is the one that controls the workshops. (Bus Sales Manager)

In recent decades, truck manufacturers have expanded their businesses to include other kinds of services for their customers, for example, truck driving training programs, fuel control systems, systems for logistics and fleet management, leasing schemes, and various financial services. Compared with the traditional logic, these service businesses are conducted more in dialog with customers (e.g., haulage firms) and their customers (e.g., grocery retailers) to improve vehicle operation and fuel efficiency and consequently the profitability for all actors:

For the products to be used most efficiently and to improve, for example, fuel efficiency, we offer services, as the product itself is not enough anymore. Thus, by having better competence in both the product and [related] services, we and our customers can become more competitive. (Manager Marketing and Sales)

Today, various services constitute a significant, expanding, and profitable share of the truck manufacturing business. Major business development efforts are invested in developing new services to be sold as “add-ons” to the trucks. However, if the core technology of the trucks is changed, the conditions for the whole area of service business might become obsolete.

4.5. Problems pushing for technology shift

The present technological paradigm suffers several inherent disadvantages. Ecologically, road transportation accounts for approximately 18% of global greenhouse-gas (GHG) emissions and with increased worldwide economic prosperity, it is predicted that the total GHG emissions from transport will increase (IEA, 2011). The internal combustion engine technology also suffers from significant energy losses: only a fraction (i.e., 30–50%) of the fuel energy is used by the vehicle, the rest being wasted as heat. Road transportation often also leads to traffic congestion, which extends transportation lead times. In addition, noise and local emissions affect air quality and health, causing considerable social harm.

Since approximately 95% of transport fuels (e.g., diesel) are derived from crude oil and used in internal combustion engines, the road transport sector faces profound difficulties in switching to a more sustainable energy source (Mathiesen et al., 2008). Fossil fuel dependency challenges the whole transportation sector as it will represent half of global oil consumption in 2035, with trucks responsible for almost 40% of the increase in global oil demand (IEA, 2012). Consequently, the truck manufacturing industry has long allocated most of its R&D investments to projects exploring, for example, alternative fuels, more sophisticated engine technologies, and improved powertrain dynamics. This is the path of incremental innovation. Alternative biofuels, have demonstrated commercial viability but have insufficient capacity to satisfy the fuel demand in the transport sector and have been criticized for conflicting with the global food supply (Rosillo-Calle and Johnson, 2010).

Another, more radical, way forward is to change the energy source to electricity that is independent of fossil fuels, which calls for the use of electrical or hybrid engines. Electrical vehicles, such as the Nissan Leaf, are being deployed on several markets supported by government policy but face significant business model and infrastructure challenges (Bohnsack et al., 2014; Steinhilber et al., 2013). Contemporary hybrid vehicles, such as the Toyota Prius, combine an internal combustion engine, an electric engine, and a battery, which can recycle and store energy from braking in order to increase energy efficiency. For trucks, however, this hybrid technology is not yet perceived as an effective alternative. Due to technological limitations in battery capacity, hybrid engines for trucks are overly expensive, as well as heavy and bulky, which reduces the trucks’ cargo capacity.

In recent years, however, electric road system technology has emerged as a serious technological alternative, and could resolve the battery challenges facing electric trucks.

4.6. Electric road systems: a new technological paradigm

Electric road systems (ERS) can be described as electrified roads that support continuous or dynamic power transfer to vehicles from the roads on which they are driving. The basic principle is to power an electric engine within the vehicle from an external power source built into the road infrastructure, also called wayside power (Fig. 1). The electrical power is transmitted while the vehicle is in motion, through a current collector attached to the vehicle, similar to that of an electric train. However, since ERS roads have no tracks, they would be accessible both to vehicles with ERS propulsion and to conventional vehicles. Furthermore, an ERS vehicle would be equipped with a small battery and (or) a small internal combustion engine, allowing it to drive on conventional roads outside the ERS network.

Despite the huge infrastructure investments required, key transportation sector actors generally regard ERS technology as a feasible alternative with great potential to significantly reduce
fossil fuel consumption and emissions. Though actors disagree as to the timeframe in which this technology shift may occur (e.g., 10, 20, or 50 years), there is consensus that it is highly probable. However, the transition is expected to take place gradually, starting with smaller experimental and pilot systems, via closed systems (e.g., mining transportation or city bus routes), to major regional and international highway networks. ERS projects are currently ongoing around the world, exploring and evaluating technologies and the possibilities for commercially deploying ERS in various applications (e.g., Pajala, Sweden (Swedish Transport Administration, 2012); Los Angeles and Long Beach, CA, USA (SCAQMD, 2013); Arlanda, Sweden (Elways, 2014); Seoul, South Korea (Suh et al., 2011); Bordeaux, France (Olsson, 2013b); and Mannheim, Germany (Olsson, 2013a).

Some ERS technologies were originally developed in the railway industry for high power applications. Various technological alternatives are available: power can be transferred to the vehicle via overhead transmission lines or via power sources built into the road. (see Fig. 2). Overhead transmission technology is conduction based and the vehicle connects to the transmission lines using a type of pantograph. Ground-based transmission can be either conductive or inductive: if conductive, the vehicle uses a physical power pick-up to connect to an electrified rail in the road; if inductive, power is transferred wirelessly from a coil in the road to a pick-up in the vehicle. The overhead line system is more technologically mature than the ground-based alternatives, but the latter technologies have more potential to be feasible for smaller vehicles, such as passenger cars.

ERS technology would require major investments in physical infrastructure, but, if implemented at full scale, could have significant advantages over the existing transportation system: it is fossil-fuel independent and emissions free; it is more energy efficient and reduces operational costs, electricity being cheaper than fossil fuels; it reduces noise pollution, allowing vehicle operation during off-traffic hours, reducing congestion and evening out energy demand; and it reduces vehicle maintenance costs, since electric engines are simpler and lighter than traditional internal combustion engines. Depending on the energy balance, electricity is not necessarily always preferable from an environmental perspective. However, by pushing for more sustainable technologies in vehicles, policy actors attempt to create a market for more sustainable produced electricity and significantly reduce local emissions.

The main barriers to implementing ERS are related to increased complexities at the system level. The conventional transportation system constitutes an open socio-technological system subject to various standards and regulations and comprises multiple more or less autonomous and complementary subsystems. These subsystems are produced and operated autonomously by different actors, for example, truck manufacturers, construction companies, road authorities, and oil companies. ERS technology requires a more closed system design, in which the subsystems are tightly coupled; for example, the powertrain needs to be tightly integrated with the power-transfer technology, which needs to be integrated with the electric road design, which in its turn needs to be integrated with the regional power grid.

Consequently, there are multiple stakeholders with strong interests in various ERS technologies, for example, vehicle manufacturers concerning the vehicle and its powertrain, railroad manufacturers concerning the power-transfer technology and electric road technology, construction firms concerning the physical infrastructure, and power utilities concerning the electric power supply and power grid operations. In addition, several new services are required in order to manage and operate ERS, for example, payment systems, logistics, driver management, and electricity metering, as well as services to reduce the complexity of the interfaces between the ERS and its customers and users.

4.7. ERS triggering a technology shift

With ERS implementation, established truck manufacturers face a new technology that could disruptively transform the whole industry. Compared with the conventional transportation system, ERS would incorporate new interfaces, technologies, and actors in new roles. Even if investments in ERS started in niche markets for truck manufacturers, they would probably soon affect the main markets in which their volumes and key customers are found. Hence, the traditional competitive advantage of premium truck manufacturers—i.e., mastery of the complicated internal combustion engine technology and its powertrain—could become marginalized and obsolete. Today, it is highly uncertain with what the truck manufacturers should replace this core technological competence. In the interviews, many of the respondents explicitly articulated this feeling of uncertainty; for example:

After a century of success with the complex internal combustion engine, we may enter a new era with new technology and new actors. My concern is that customers will ask for electric powertrains when we are still focusing on diesel engine development. However, if we are to develop electrical vehicles, we need new competences and these will take a long time to create. In the ERS scenario, what is the powertrain like? We don’t have that competence today. (Hybrid Development Manager)
Do we want to get rid of the internal combustion engine? Should we use business models with the combustion engine for the coming 20–30 years? Or should we use business models without the combustion engine? (Project Manager)

The profound challenge is that, while only a few companies in the world can produce diesel engines for heavy-duty vehicles on a commercial basis, electrical engines are relatively cheap commodities available on large-scale markets. Compared with mechanical combustion engines, electrical engines are based on a much less complex technology and are consequently much cheaper to produce, so the introduction of ERS might dramatically change truck manufacturing. Under an ERS regime, diesel engine technology becomes a commodity, largely losing its significance as the core technological competence of the industry. One manufacturer’s CEO pinpointed the problem:

Assume that we don’t produce our own electric engines, which by definition are based on a robust and much simpler technology compared with the diesel engine. New actors might appear that provide these electric machines. Then maybe 50% of the product distinctiveness disappears between our low-end market competitors and us. (CEO Truck Manufacturer)

This creates opportunities for new actors and new competition in the heavy-duty vehicle market. With the displacement of internal combustion engine technology in favor of electrical propulsion using an external power supply, the leading truck manufacturers would likely lose control of the traditional key component of the system. Instead, other technologies related to electrical power distribution, vehicle dynamics, freight handling, or infrastructure operations might emerge as the new core competences of road transportation. With the introduction of ERS, new actors will likely emerge and the roles of established actors will likely change. Several respondents expressed their frustration with this ambiguity:

Who is the most suitable actor to sell vehicles in the ERS scenario? It may not be the conventional actors. The real question is how much of the added value are [the truck manufacturers] creating in the future system. When will it be interesting for our business? (Hybrid Development Manager)

What should [our company] do at a strategic level? Do we think that electrical machines should be our core competence? (Project Manager)

When we succeed in having an appropriate business model for the technology, then I believe that we can build such things [as electric road systems]. (CEO Truck Manufacturer)

There is a common concern that ERS might significantly affect the businesses of truck manufacturers, but how these companies should respond and what strategic direction they should choose are highly ambiguous questions. The crucial questions concern what the core ERS technology will be and who will control it.

5. A probable business model change and dilemma

When implemented at a large scale, many customers (e.g., haulage firms) might find ERS technology a competitive substitute for traditional diesel engine trucks. For customers, this means an incremental change in how goods are transported, but with significant impact on fuel costs and emissions. For the truck manufacturers, however, it constitutes a fundamental, radical shift in both technology and the services provided. ERS creates a competitive future landscape, the likely contours of which are profoundly ambiguous today.

Under the existing paradigm, with the diesel engine as the core technology of the transportation system, truck manufacturers such as Scania and Volvo have enjoyed great success. Assuming that the attributes appreciated by customers of the current paradigm are also important in the ERS paradigm (e.g., energy efficiency, drivability, and reliability), one alternative for truck manufacturers is to extend their core technological competence from diesel engine powertrains to ERS-based powertrains. In this way, they would maintain control of their current position in the value network. Consequently, such a strategy requires that the traditional emphasis in R&D technologies related to internal combustion engines be reallocated to various ERS technologies, for example, electric machines, energy storage, and control systems.

The most probable scenario is that the technology shift will change the value network profoundly. ERS constitutes a new system with new technologies, roles, and interfaces: for example, the ERS powertrain is more integrated with other subsystems (e.g., the roads, fuel supply, and billing system) than is the diesel engine-based powertrain. Since electric engines are much cheaper and more energy efficient than are diesel engines, the energy efficiency of the truck will likely disappear as the order-winning value proposition. The energy efficiency of the system will instead be more dependent on the emissions from electricity generation and power transfer technology. In addition, electric engines do not require as much servicing and maintenance as do diesel engines. Thus, with the present core technology and add-on services losing value for customers, it is unclear what the value capture would be like in the future scenario.

With ERS implemented at full scale, truck manufacturers’ traditional business logic must change if they are to succeed in the new market. Instead of buying trucks, future customers might buy transport solutions or subscribe to ERS services provided by one or several road system operators. Instead of selling expensive trucks based on diesel engine technology, the future business of truck manufacturers might be to provide flexible transportation solutions, functional transportation services, and other related service concepts, based on their knowledge of vehicle operations rather than vehicle technology as such.

Consequently, an alternative for the truck manufacturers is to fully adapt to servitization by offering a portfolio of various services built around transporting goods and people. This would let the truck manufacturers integrate their businesses with the operators of the installed base of sold vehicles. In this strategy, vehicle propulsion is no longer at the company’s core: the powertrain has become a commodity, and ERS technology has been developed and integrated with suppliers to fit the various interfaces of the new system. In this scenario, the core competences of the truck manufacturer would be knowledge of customer behavior, truck operations, logistics, fleet management, and how to provide various related services.

This quest to become a provider of transportation solutions creates new ways of doing business. The focus will be on how to exploit accumulated information and customer relationships. The strategy would allow the firm to develop a new business model with a relevant value proposition independent of the core technology. Integrating forward and taking over parts of customers’ traditional business operations would allow differentiation in relation to competitors and new entrants. However, whether today’s truck manufacturers are well suited to competitively providing such services is an open question.

The empirical case boils down to one open, but fundamental, question: How will a technology shift to ERS challenge the business models of incumbent firms? Applying the framework of value proposition–value creation–value capture proposed in Section 2.2 further exposes the various elements of this business model dilemma.
Under the present technological paradigm, the value creation of the studied truck manufacturers is based on advanced technological know-how in developing and manufacturing trucks built around the diesel engine powertrain. As premium brands, their value proposition encompasses engine power, energy efficiency, drivability, reliability, and prestige. Furthermore, the value capture is based on sales of trucks as traditional products, and on after-sales of spare parts, maintenance, and other service packages as add-ons to the truck (see Table 2).

Facing a potential technology shift, truck manufacturers must make a difficult choice that could profoundly affect their business model. If they continue with their current technological innovation strategy (i.e., creating value in a mode similar to the present one, but with another core technology), their business model risks becoming outdated, offering a value proposition that few customers will demand in the future. If the companies, on the other hand, change their business model in line with servitization, in order to have a relevant value proposition in the future scenario, they risk losing their current technological edge and becoming just two of many service providers offering similar services.

This business model dilemma of the truck manufacturers is summarized in Table 3. In the first alternative, the value creation is perpetual, although relying on a new core technology, while the value proposition and value capture of the business model are unclear. In the second alternative, the value proposition and value capture are well defined in relation to customer needs, while the competitive edge of the value creation element is uncertain. If unresolved, the ambiguities of this dilemma risk hampering the truck manufacturers' potential to succeed in the new technological paradigm.

6. Discussion

This paper inquires into the dynamics of the intersection between technology shifts and business models. By analyzing the potential technology shift from diesel engine technology to ERS and the implications for the business model of today’s premium truck manufacturers, we identify a strategic dilemma in which incumbent firms’ core technological competence risks becoming obsolete. The dilemma illustrates the problems of choosing between either a technological innovation or a servitization strategy. Furthermore, it illustrates how discontinuous technological innovation affects, and is affected by, a company’s business model. Not only the value it creates, but also the value it proposes and retains.

Although the study has some obvious limitations in its research design, examining only one case of potential technology shift, it provides an in-depth illustration of why technology shifts are so difficult to master. The case reveals the complex interactions between technology and business model innovation and indicates how a strategy of discontinuous technological innovation needs to be aligned with the business models of the future competitive landscape. Assuming that these findings are generally valid, they suggest interesting avenues for future research.

6.1. Technology shifts from a business model perspective

This paper is part of the small, but growing, stream of research into the significance of the interrelationship between technology shifts and business models (Chesbrough, 2010; Christensen, 2006; Markides, 2006). The present findings suggest that when incumbent firms encounter a technology shift they also face a business model dilemma. Firms are not by definition paralyzed by the new technology through their established customers, but have the option of preparing an appropriate strategic response. The business model dilemma illustrated here is a profound strategic problem that, if left unsolved, risks holding back necessary radical changes within the firm’s value proposition, value creation, and value capture processes.

Previous research into technology shifts has focused primarily on the changes in technology. By adding a business model perspective to the analysis, the challenges of incumbent firms facing technological discontinuities are revealed in their full range. However, in many of the classical cases of technology shifts (e.g., Henderson and Clark, 1990; Sandström, 2010; Schumpeter, 1939; Utterback, 1984), the incumbent companies that went out of business did so because they did not adapt their business models to the emerging competitive landscape. The business model framework proposed here, relating the core technology of the firm to its value proposition, value creation, and value capture, enables further inquiry into the complex dynamics of this phenomenon. As illustrated, applying the business model as an analytical concept provides fruitful insights into the challenges of an individual firm facing technology shifts.

Furthermore, while previous research typically applies a retrospective perspective on technology shifts, this study addresses the strategic challenges of firms facing a potential technology shift. This future-oriented perspective on technology shifts reveals the
profound difficulties incumbent firms face when addressing the uncertainties of an ambiguous future. Further research is needed addressing the interrelationship between technological and business model innovation before and during, as well as after, a technology shift occurs.

6.2. Integrating technology innovation and servitization

In previous research, the discourses on technology innovation strategies and servitization strategies have developed separately from each other. With few exceptions (e.g., Chang and Yen, 2012; Nicholas et al., 2013), there has been little interaction between these two discourses. The business model perspective articulated here illustrates the explanatory power of bringing these two strands together, and doing so has implications for research into both technology innovation and servitization.

First, previous research into innovation has tended to solely emphasize technological R&D. However, while technological innovation is necessary to ensure core technological competence, it is not sufficient to ensure competitive advantage. The business model framework proposed here suggests that, in the case of a technology shift, a firm investing solely in a technological innovation strategy risks losing its revenue due to an outdated value proposition. Technology shifts imply that new value attributes will be important for customers in the future, which implies the necessity of new value propositions and new value capture techniques.

This study addresses the lack of studies of R&D strategies for managing disruptive innovation (Yu and Hang, 2010, 2011). It suggests that an R&D strategy aiming for technological leadership during periods of discontinuous innovation risks producing business model ambiguities. Consequently, one implication is that R&D strategy needs to encompass both technological and business model innovation. R&D projects addressing potentially radical technological innovation also need to address potential systemic changes in the firm’s value proposition and value capture.

Second, previous research into servitization has tended to ignore technology, or at least take it for granted. The basic assumption in this discourse is that while firms integrate forward by means of service innovation, their core technology remains stable (Gebauer et al., 2005). The present paper, however, presents a possible case of servitization in which the core technology may become obsolete. The case illustrates that while a servitization strategy might enable an incumbent firm to liberate itself from the possible rigidities of the core technology, adhering to this strategy could threaten the core competencies that constitute the foundation of the firm’s competitive advantage. Lacking an edge in value creation makes the business model easy to imitate by competitors, which, from a long-term perspective, makes it difficult to retain a market-leading position.

One implication for servitization research is that both service innovation and technological innovation should be brought into the analysis. Since servitization usually implies the business model innovation of manufacturing firms transforming themselves into service providers, the role of technology in value creation is a significant issue for future research.

7. Conclusion

This paper illustrates a business model dilemma of manufacturing companies facing a technology shift. It constitutes an initial inquiry into the fundamental managerial question of why technology shifts are so difficult to master. While previous research has emphasized change in technology as the key factor explaining why incumbent firms fail to adapt to a new technological paradigm, this paper suggests the need to understand the dynamics of technology shifts from a business model perspective.

One conclusion is that to survive during technology shifts, firms need to master the complexity of “double ambidexterity,” i.e., not just the ambidexterity to simultaneously foster incremental and radical innovation (Gibson and Birkinshaw, 2004; Tushman and O’Reilly, 1996), but also the ambidexterity to simultaneously advance both technological and business model innovation (e.g., Markides, 2013). Specifically, when developing new technology considered discontinuous, business model aspects need to be brought into the analysis early on. However, how to effectively nurture this integration of exploration and exploitation with technological R&D and business model innovation is an unsolved issue meriting further examination.

A general implication is that we need further studies of technology shifts from a business model perspective. Are there different patterns of business model dynamics in historical cases in which firms have successfully or unsuccessfully managed the technology shift? Do technology shifts differ depending on the industry, nature of the technology, and system level? What are the relationships between technological innovation, service innovation, and business innovation, and what effects do these relationships have on business survival? This paper has provided some empirical insights into the intersection between business models and technology shifts, though many questions remain to be answered.

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