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Service-based business models in the Swedish railway industry

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Abstract

Purpose – The purpose is to describe new business opportunities within the Swedish railway industry and to support the development of business models that corresponds with the needs and requirements of Industry 4.0, here denoted as Service Management 4.0.

Design/methodology/approach – The study is an in-depth and descriptive case study of the Swedish railway system with specific focus on a railway vehicle maintainer. Public reports, statistics, internal documents, interviews and dialogues forms the basis for the empirical findings.

Findings – The article describes the complex business environment of the deregulated Swedish railway industry. Main findings are in the form of identified business opportunities and new business model propositions for one of the key actors, a vehicle maintainer.

Originality/value – The article provides valuable understanding of business strategy development within complex business environments and how maintenance related business models could be developed for reaching Service Management 4.0.

Keywords Strategy, Value creation, Decision-making framework, Maintenance services

Paper type Research paper

1. Introduction

The railway transportation industry is characterized by complexity. Viewed as a technical system, it consists of fixed infrastructure as well as rolling equipment that interact with each other, and with the surrounding environment. Technical performance, failure causes and deterioration mechanisms are therefore hard to assess (Johansson and Hassel, 2010; Macchi *et al.*, 2012). As a socio-technical system, it relies on information originated at different sources, of different types and owned by different actors for the management of transportation services (Kans *et al.*, 2016; Rotter *et al.*, 2016). Planning, scheduling and execution of the railway transport services are examples of complex activities within the system. The railway involves many actors, which must be carefully organized and coordinated (Alexandersson *et al.*, 2018). In countries where deregulation of the railway sector has taken place, such as Sweden, the complexities are also seen on the business ecosystem level (Ingwald and Kans, 2016).

The deregulation of Swedish railway begun in 1988 and continued in several steps until 2011, when the traffic was fully deregulated. The number of actors has increased from less than ten to more than a thousand, considering all sub-contractors. During this period, the number of train-kilometers has almost doubled (European Commission, 2014), and the passenger traffic is

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still increasing. The complexity has affected the railway operations as well as the maintenance (Ingwald and Kans, 2016). Due to high capacity utilization in combination with an ageing infrastructure and rolling stock, the maintenance windows becomes tighter and the maintenance demands are hard to fulfill. Effects of disturbances are multiplied throughout the entire system, especially if the disturbances take place in a tight section, i.e. where the capacity usage is intense. In addition, lack of resources, ineffective coordination of actors and poor information handling are some of the problem areas recognized within the railway maintenance area. The tendency is that the actors sub-optimize instead of cooperating. Moreover, traditional contract forms and a conservative buyer's culture result in lack of information and knowledge sharing between the actors (Ingwald and Kans, 2016; Metso and Kans, 2017). Procurement of maintenance is often made in the form of medium-term contracts based on fixed price on defined work in the Swedish railway (Esping and Olsson, 2004). These kinds of contracts are quite inflexible and can easily lead to negotiations for all activities not included in the basic contract (Lingegård, 2014). There is little if no incentives for improving neither maintenance internal effectiveness nor its performance, as the contract is regulated on detailed level (Lingegård, 2014; Abdi *et al.*, 2014). New forms of collaborative contracts have been tested in the Swedish railway industry, see e.g. Esping and Olsson (2004) and Abdi *et al.* (2014) but so far in limited case studies or as preparatory empirical studies. Case studies on performance-based contract forms have also been carried out, see for instance Famurewa *et al.* (2013) and Lingegård (2014). Amongst the major obstacles for enabling collaborative contract forms is the current procedures for government/public procurement including tendering rules, short-term contracts and a risk adverse culture that does not promote collaboration and create sub-optimization (Lingegård, 2014; Ingwald and Kans, 2019). Moreover, a life cycle perspective is required on the assets for the effective management (Randall *et al.*, 2012; Norden *et al.*, 2013; Lingegård, 2014). While this is the situation for railway infrastructure maintenance, the maintenance of rolling stock mainly deals with problems connected to resources, information handling and coordination of actors.

For dealing with complex maintenance environments, holistic approaches are proposed. On the technical level, data-driven maintenance is a way to handle the complexity of multiple interdependent failure modes and advanced diagnostics and prognostics capabilities (Sankavaram *et al.*, 2013; Jantunen *et al.*, 2017). It is also applicable for dealing with information handling and decision-making (Kour *et al.*, 2014; Galar *et al.*, 2016). A value-driven approach on assets puts focus on the asset and its value generating ability rather than on separate life cycle activities such as design, development, operations or maintenance (Kans and Galar, 2017). On the organizational level, the concept of asset management supports the management of assets from a holistic perspective throughout the life cycle (Amadi-Echendu *et al.*, 2010; SIS, 2014). Performance-based and collaborative contract forms and applying an ecosystem perspective on value creation promotes information sharing and collaboration between actors (Esping and Olsson, 2004; Lingegård, 2014; Ingwald and Kans, 2019). A holistic approach connecting the technological development described as Industry 4.0 with service business development in form of utility-driven and integrated value propositions is Service Management 4.0 (Kans and Ingwald, 2016a, b, 2020).

The main purpose of the article is to describe new service-based business opportunities within the Swedish railway industry that take advantage of the current technological developments and business models. This is done in the form of a case study describing the current situation and proposing feasible further directions to reach new business models for railway vehicle maintenance.

The paper disposition is as follows: in Section 2, the theoretical framework of the paper is presented. In Section 3, the study design is accounted for. Sections 4 and 5 describe the situation of Swedish railway first in general and thereafter related to the specific case, i.e. railway vehicle maintenance. Finally, results are discussed, and conclusions are drawn.

2. Theoretical framework

The theoretical framework describes the recent technical development and the development from a business modelling perspective, starting with general descriptions, and thereafter focusing in the operations and maintenance (O&M) activities in the form of maintenance requirements and service business models.

2.1 Current industrial and business trends

Industry 4.0 is seen as the fourth generation of industrial activity characterized by smart equipment, referred to as cyber-physical systems, which are autonomous, interconnected and self-organizing, creating an Internet of things (Lasi *et al.*, 2014). The self-organizing ability allows for flexibility in the manufacturing as well as for increased individualization and customization (Meier *et al.*, 2011). The cyber-physical system is virtually represented in the form of a digital twin, allowing for real-time monitoring and control of the processes, and the big data sets are utilized for increased decision-making capability on operational, tactical as well as strategic level (Kans and Galar, 2017).

The capabilities of Industry 4.0 brings new business opportunities in the form of increased product and service customization as well as added value through after sales services (Merier *et al.*, 2011; Kans and Ingwald, 2016a, b), but for these innovations to succeed they must be coordinated with and reflected in the strategic business models (Kans and Ingwald, 2016a, b). Consequently, business modelling has gained increased attention as a means to develop and sustain the competitiveness (Lasi *et al.*, 2014). Business models defines how business should be conducted, for example in the form of strategies, market segments, product platforms, resource requirements, customer relations and value creation mechanisms (Osterwalder and Pigneur, 2010). The business models are assessed by their ability to satisfy the needs and expectations of the customer in terms of product and service quality (Bergman and Klefsjö, 2001).

The traditional business approach is providing physical products or services, i.e. a product-oriented or service-oriented business model, but the characteristics of the value proposition is rapidly changing. Research on value propositions that combine products and services is therefore growing (Kans and Ingwald, 2016a, b), e.g. in form of Product service systems (Meier *et al.*, 2011; Durugbo, 2013), servitization (Kujala *et al.*, 2011; Visnjic Kastalli and Van Looy, 2013), or service infusion in manufacturing companies (Kowalkowski *et al.*, 2013). This trend is a manifestation of the knowledge intensive and service focused industry where the product is sold together with services in an integrated offering, and the function or performance of the product becomes the value proposition (Meier *et al.*, 2011; Durugbo, 2013). Products could also be equipped with embedded intelligence so that all after sales activities could be planned and performed based on real conditions, i.e. based on field data (Allmendinger and Lombreglia, 2005). The number of opportunities for activities and interaction within a given time and/or spatial dimension is denoted as the density of an offering (Normann and Ramirez, 1995). One aspect is the number of activities that must be performed to take part of the customer offering and another is how close the offering is in time and space. The density of value propositions has increased in recent years because of the use of Internet for promoting, selling and distributing customer offerings; today's customer will perform fewer activities and physical movements to obtain a particular product. The density of an offering is also related to the complexity of actors and activities that are involved in the customer offering. In a traditional production-oriented value chain the value creation process is mainly linear, while a service-based economy it is rather characterized by reciprocity (Normann and Ramirez, 1995).

One way to compete on the market is by focusing on the company's internal strengths in form of competencies and resources (de Wit and Meyer, 1998). The inside-out strategy is often technology-driven assuming that a market need can be filled through technology innovation.

The opposite is the outside-in perspective, which implies that the company focuses on the environment in their development of offerings and their actions using a customer-driven or utility-driven strategy (Karlöf, 2008). The customer-driven approach focuses on customer needs researched and interpreted by the value provider, while a utility-driven strategy assumes interactivity between customers and the value provider. Collaborative contract forms such as performance-based agreements and partnering are examples of interactive customer-seller or client-contractor relationships (Bygballe *et al.*, 2010; Lingegård, 2014).

For positioning the company on the market, it is important to define the role and connections to other actors in the value creating process (Sako, 2012). In the modern business logic companies often interact in complex and geographically dispersed patterns that change over time. The business ecology concept aims to look far beyond the corporation's own sphere, to understand different actors' behavior and consequently adapt its own behavior (Moore, 1993). In a business ecosystem, other actors outside the value chain could be represented, such as government agencies, standardization organizations and politicians, or competitors (Moore, 1993).

2.2 Service Management 4.0

In the era of Industry 4.0, new demands on maintenance will emerge. Dynamics in the planning will be required in order to optimize the production (Iranpoor and Fatemi Ghomi, 2019). A proactive and value-driven approach is foreseen, where maintenance provides value in the form of availability, quality, safety and similar production-related objectives (Stenström *et al.*, 2013; Jasiulewicz-Kaczmarek and Gola, 2019), and problems and disturbances in the production are avoided by appropriate predictive and proactive maintenance (Sankavaram *et al.*, 2013; Jantunen *et al.*, 2017). Maintenance planning and management becomes an integrated part of production planning and management (Iranpoor and Fatemi Ghomi, 2019), calling for an asset management perspective on physical assets (SIS, 2014). The new technologies of Industry 4.0 will have a great positive impact for the effective management of assets, from defining organizational objectives and connecting them to asset management objectives, to the creation of efficient plans and for performance evaluation and improvements (Kans and Galar, 2017). The individual equipment will become smarter and include prognostics and self-healing abilities (Sankavaram *et al.*, 2013; Lee *et al.*, 2014). Intelligence is also built into the actual products that can be identified by RFID-tags and every object in the system is traceable (Kour *et al.*, 2014; Haddud *et al.*, 2015), allowing for efficient identification of assets and spare parts.

The maintenance related business model of Industry 4.0 is a value proposition that goes beyond the physical assets and the requirements on functionality, and where dynamics will become increasingly important. The focus will be on supportability for the production; the main aim of maintenance is not assuring asset functionality but assuring production output (Stenström *et al.*, 2013; Kans and Ingwald, 2016a). The asset is thus seen as an integrated part of a larger system. The maintenance strategy is characterized by dynamics (Kans and Ingwald, 2020). The dynamics could be in time; to find the most optimal time or frequency for maintenance tasks to maximize production performance, or scope; what activities to perform and to which extent, when a maintenance intervention is made. This is supported by proactive maintenance in the form of Service Management 4.0.

In Figure 1, a managerial tool for business model development is found (see Kans and Ingwald, 2016a, b). The tool supports the journey towards Service Management 4.0 by addressing key business dimensions and describing business maturity levels for a service provider. The first three dimensions address the offering and its characteristics, i.e. what type of services are offered (products such as spare parts, services or integrated offerings), the density of the offering (low, high or dynamic depending on the needs of the customer) and the quality dimensions connected with the offering (product dimensions or a combination between product and service), see descriptions in Section 2.1 related to Meier *et al.* (2011),

Dimension	Level 1	Level 2	Level 3	Level 4
Type of offering	Technology	Mainly product	Product and service	Integrated offerings
Density	Low	High	Dynamic	
Quality dimensions	Mainly product		Combination of product and service	
Business development strategy	Technology-driven	Customer-driven	Utility-driven	Dynamic
Strategic perspective	Inside-out		Outside-in	
View on profitability	Productivity	Customer satisfaction	Customer satisfaction / relationships	Relationships (more or less formal)
View on value creation	The own business in focus	Value chain	Value star/network	Ecology

Figure 1.
Business model development framework for achieving Service Management 4.0

Durugbo (2013), Normann and Ramirez (1995) and Bergman and Klefsjö (2001). The next four dimensions describe the strategic perspective of the service providing company in terms of business development strategy (technology-driven, customer-driven, utility-driven, or dynamic based on the true needs of the customer regarding when to act and what to perform) and general strategic approach (inside-out or outside-in) as well as perspectives on profitability (achieved by productivity, by customer satisfaction or by building relationships) and value creation (company centered or supply chain/ecosystem centered), see the descriptions in Section 2.1 related to de Wit and Meyer (1998), Karlöf (2008), Sako (2012) and Moore (1993).

At level one the service provider acts with its own business and profitability in focus. The strategic perspective is inside-out, i.e. the company's resources and competences decide the business offering and the profitability is tightly connected to doing more with the available resources in terms of productivity. The offering could be providing spare parts or replacement of components on a fixed cost-based principle. A service provider on level two typically sells maintenance services on a time-based principle and the business is regulated in measurable terms such as amount, size, or frequency. The more service that is sold, the higher the earnings. This is achieved e.g. by wide range and/or customization of contracts (high density), i.e. a customer-centered strategy. The third level is utility-driven, providing maintenance capabilities for meeting the explicit as well as the implicit needs of the customer. The contract is regulated by performance in terms of e.g. availability or reliability. The density is typically high, but the mode differs depending on the customer (dynamic). The number of actors participating in the value creation is also typically high, including contractors and sub-contractors. The offering of level four is an integrated "black box" solution, and the outcome is measured in terms of utility, for instance in produced amount per hour. The business development strategy is dynamic; while a utility-driven strategy is suitable in most cases, a technology-driven strategy might be the best if the provider acts as the expert for a customer that needs to develop their maintenance capabilities. Trust, openness and long-term relationships between seller and buyer is required, as both parts take a business-related risk when entering this kind of contract.

The tool can be used to define the current position and make areas of improvement by moving from a lower level to a higher, or by strengthening the level in which the company currently belong to. Thus, level one and two describes a traditional engineering company where the focus is mainly put on the provided product (maintenance as a technology or product). As a company moves to a higher level, the offering will become increasingly complex and integrated, and the company will act more as a partner in providing value for the end-customer by delivering a function or utility. In this, it moves from productivity as number one priority into viewing customer satisfaction and relations as means to achieve profitability. The relation between the maintenance provider and buyer develops toward a partnering relation, where the combined resources are utilized to get the best effect. The business proposition is an integrated offering focused on functionality and value, and a holistic, life-cycle perspective is used in decision making. Even if the business relation is on long term and built to a great deal on trust, the maintenance provider is aware of the dyadic relationship, but also its positioning as a part of a business ecology that needs attention.

3. Study design

The study was conducted as an innovation project aimed at developing future industrial services, developing innovative IT solutions, and working methods for improving production and maintenance through integrated, data-driven and customized services. Two case companies participated in the project, whereas this article focuses on one, a railway vehicle maintainer. The descriptions are based on public reports, statistics and presentations and information from representatives for the vehicle maintainer. The investigation followed an innovation process inspired by Karlöf (2008) and Normann (2001) comprising three main steps: Mapping of the current state, Business environment analysis, and Value proposition modelling, see Figure 2.

Empirical data was gathered by interviews and dialogues with the case company representatives in two interview sessions. The first session was a structured interview following a prepared interview guide focusing on mapping the current state and finding business opportunities according to steps 1 and 2 in Figure 2 (see Appendix, questions 1.1–2.9). The participants were selected to represent managerial and innovation perspectives and included one technical manager, one business developer and two persons working with technical innovation. The results from the interview were summarized in the form of a narrative, describing the history, current state and identified opportunities. This analysis was based on theories of business modelling and business development, business ecosystems and customer offerings, see Osterwalder and Pigneur (2010), Karlöf (2008), Moore (1993) and Normann and Ramirez (1995). The descriptions were reviewed by the technical manager and business developer for validation purposes, and thereafter discussed during a follow up session covering step 3 in Figure 2 (see Appendix, questions 3.1–3.9). Based on this, solutions were generated by the researchers aiming at future business opportunities. The analysis was achieved using the business model canvas (Osterwalder and Pigneur, 2010) and the tool described in Figure 1.

The third session was in the form of an open dialogue regarding business opportunities and future needs for the purpose of verifying and validating the results. Presentation material describing different future possibilities and scenarios was used as a basis for the discussion. Four representatives from technology management and operations participated in the second session that took place at one of the maintenance workshops in Southern Sweden.

As the study is descriptive in its nature, descriptive analysis and narration are the main output. Therefore, case study results are not presented linearly according to the process in Figure 2. Instead, the narration starts with looking at the business environment and

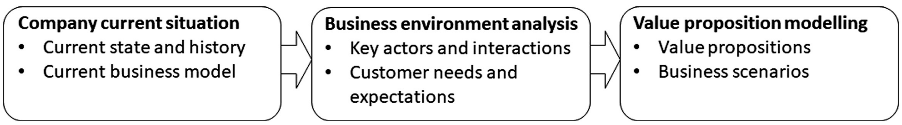


Figure 2.
Study design

thereafter focusing on the internal conditions of the case company. Results connected to the mapping of the current state are mainly found in Section 5.3, results from the business environment analysis are found in Sections 5.1–5.2, and results from the value proposition modelling are found in Sections 5.3–5.4.

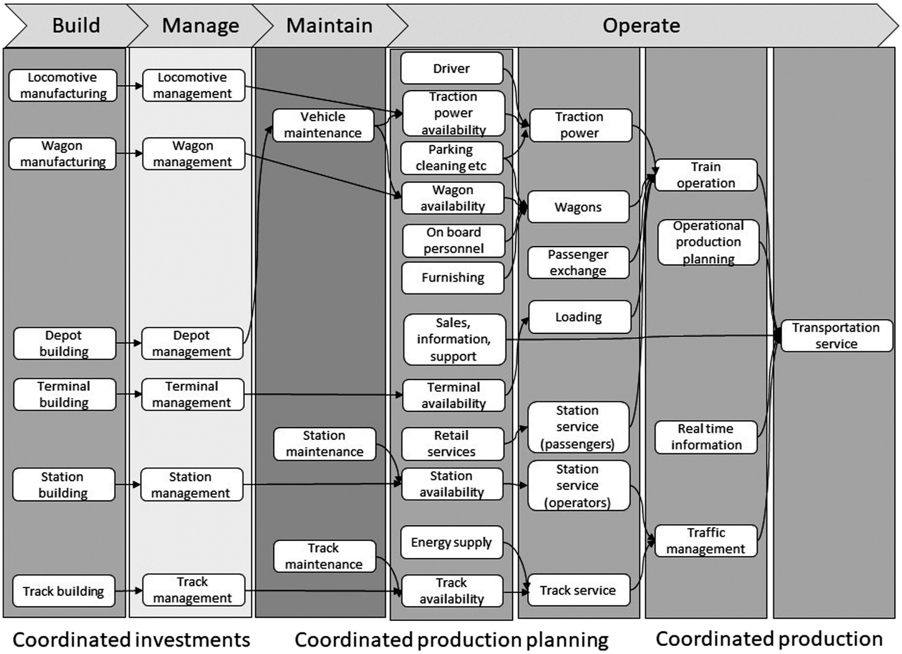
4. The Swedish railway system

This section describes the Swedish railway system in general and thereafter railway maintenance in specific.

4.1 Introduction to the Swedish railway system

1988 was the starting point of the deregulation of the Swedish national railway which was completed in 2011 when the traffic was fully deregulated. The Swedish railway network consists of about 14,200 kilometers of track (Swedish Transport Administration, 2020). During the past decades the number of train-kilometers has increased steadily, mainly in the passenger side, and is around 14,600 million annually in Sweden today (Trafikanalys, 2020b). The Swedish railway transportation service has four main targets: punctuality, capacity, robustness and traffic safety (Swedish Transport Administration, 2020). The target for *punctuality* is 95% of all passenger trains arriving within not later than 5 min behind the timetable. This target has not been met during the past decade, as the punctuality has been around 90%, but a positive change was seen in 2019 when it reached 91.3%. In addition, the customer satisfaction of disruption information is set at 80% for the year 2019 (it has continually been increased from 65% to 80% within the period 2013–2019). The outcomes 2013–2019 has varied between 60 and 70%, and in 2019 it was 71%. *Capacity* reflects the railroad network's ability to handle the demanded transportations. The capacity is highly dependent on the number and type of trains available for traffic. The metric used is capacity utilization, which is measured both for the whole day and for the two-hour period of heaviest traffic. The capacity utilization has decreased overall, but with large variations depending on type of line. For the major lines the load during the two-hour peak has somewhat decreased in 2019. *Robustness*, or operational availability, is measured in service without disruption. For the prioritized tracks the robustness has increased in 2019, while non-prioritized tracks are still facing availability problems, or even increased speed restrictions. The target for robustness is set to app. 99%. While the outcomes 2013–2019 for the total transport system has been around 97.5%, the target has been met for the parts of the system that is under the Swedish Transport Administration's responsibility. The *traffic safety* addresses the network's ability to minimize fatalities and injuries. The target is to halve the number of deaths from 110 in 2010 to 55 in 2020. Even though the annual fatalities have decreased during the period, the target is far from met; the average number of deaths have been around 80 per year. The deaths are due to accidents and suicides, and thus measures to hinder and detect trespassing are mainly applied to reduce the fatalities.

In Figure 3, the main value chain of the Swedish railway is depicted in the form of four main processes: build, manage, maintain and operate. The main outcome of the value chain is the activity "Transportation services." Building relates to the activities of building physical assets necessary for realizing the main activity, such as rolling equipment (locomotives and wagons), buildings (depots, terminals and stations) and infrastructure (mainly tracks). These assets are managed and maintained for being available, reliable and operational. The planning of operations is a complex phase, where physical, personnel and immaterial assets are coordinated for providing train operations and traffic management. Activities are planned and coordinated both vertically and horizontally on the long-term as well as short-term horizon. Coordinated investments are done on the strategic long-term planning scale, while the coordinated production planning is in the annual to weekly horizon, and the coordinated production is a mainly daily operational matter. The timetabling process



Source(s): Adapted from SOU (2013)

Figure 3. The Swedish railway system

involves a high number of actors, resulting in long lead times in the production planning. The timetable process is therefore a yearlong process: the application of capacity utilization is made in springtime, the detailed time plan in October, while the operational timetable takes effect in December (The Swedish Transport Administration, 2014).

4.2 Swedish railway maintenance

The main strategic objectives for Swedish railway maintenance are to prioritize safety-related measures, and to catch up with the huge backlog especially focusing on the highly trafficked tracks (Swedish Transport Administration, 2019). Even if the backlog has decreased generally, there are still incremental work to be done to keep up with the maintenance and reinvestments to keep the infrastructure in good condition. The prioritizations are based on the main objectives of the National Transport System Plan 2018–2029. The total O&M investment volume was 10,536 million Swedish crowns (SEK) in 2019, whereof about half of the volume are direct maintenance operations. The investments have increased during the past years, mainly due to extensive need of reinvestments to solve the problems related to faulty infrastructure (Swedish Transport Administration, 2020). Reinvestments accounts for about a third of the total budget. Maintenance costs are affected by accessibility; access to the railway network is a general problem for maintenance. Preventive maintenance is scheduled during night-time and weekends, but the high rate of failure-based maintenance directly affects the availability, as there are no margins in the capacity allocation for unexpected maintenance. The same situation is seen for reinvestments; the total maintenance costs are lower where reinvestment work could be done on closed-down railway, and high for the parts were reinvestments are impossible due to high capacity demand.

The insufficient maintenance and reinvestments have caused several problems for the Swedish railway infrastructure. The main parts of train delays are related to infrastructure faults and the dominating actor held responsible is the Swedish Transport Administration (Riksrevisionen, 2013), but during the past five years delays due to other reasons, such as trespassing on tracks, have increased (Swedish Transport Administration, 2020).

4.3 The business ecosystem of railway maintenance

The Swedish railway ecosystem has since the deregulation increased from a handful of actors to hundreds of actors involved in one or several key processes and activities. Figure 4 gives an overview of the business ecosystem for Swedish railway maintenance. Stakeholders directly involved in O&M of rolling stock (i.e. main stakeholders for the case described in the next section) are marked in grey while indirect stakeholders, such as infrastructure managers and regulatory bodies, are marked in white.

The overall responsibility is found at the governmental level, and two governmental bodies, Swedish Transport Administration and Swedish Transport Agency, effectuate decisions, rules, and regulations. The Swedish Transport Agency communicates and cooperates with the International regulatory bodies, mainly on European Union level. *The Swedish Transport Administration* is responsible for infrastructure, and is a large client for contractors constructing, managing, and maintaining the infrastructure. Responsibilities include long-term infrastructure planning for road traffic, rail traffic, shipping, and aviation, as well as for the construction and operation of state roads and railways. The maintenance goals are formulated as operation and maintenance performed for the traffic to come forward with the promised delivery of quality now and in the future (Swedish Transport Administration, 2014).

The Swedish Transport Agency is the regulatory body for transports in Sweden and are involved in international and national regulatory development work. The agency sets rules and regulations, give permission, and follow up how rules are complied with. In addition, they have responsibility for market surveillance (market access conditions, competition conditions, and conditions for passengers and freight carriers). They also provide records of railway vehicles and train driving licenses. The Swedish Transport Agency handles several hundreds of contractors, whereof about ten are larger contractors. These contractors often work with sub-contractors, and some contractors are both directly contracted by The Swedish Transport Agency and acting as sub-contractors for other contractors. In total, the number of contractors connected either directly or indirectly to The Swedish Transport Agency are close to a thousand (SOU, 2013). All maintenance contractors must follow the regulations. For rolling stock, permission to use vehicles are needed and the safety regulations must be met.

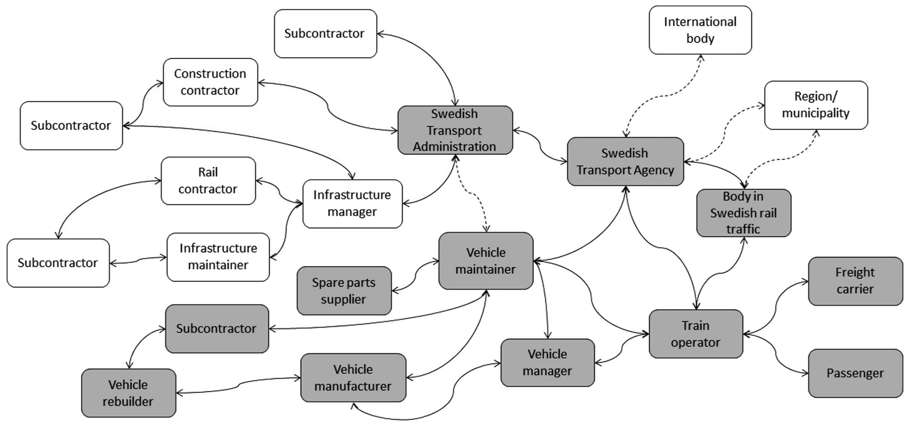


Figure 4.
The business ecosystem of Swedish railway maintenance

The bodies in Swedish railway traffic are directly connected to The Swedish Transport Agency. These actors plan and carry out goods and passenger transportation according to the set quality requirements. In 2019, the total number of bodies in Swedish railway traffic was 38, excluding the Swedish Transport Administration (Trafikanalys, 2020a). The bodies could be in the form of private companies as well as public authorities. In Sweden, the main part is public. Regions and municipalities cooperate with the regional bodies to coordinate inter-regional traffic and with the Swedish Transport Administration for the coordination of construction and maintenance activities. Moreover, the bodies in Swedish rail traffic put quality demands on the railway system in terms of availability (expressed as punctuality and capacity). The customers are mainly of two types: *freights carriers* and *passengers*. In 2019, a total of 73 million tons of goods were carried by train. Main part of the fright is raw material from mining, or forestry products. While the fright traffic is slightly declining, the passenger traffic is constantly growing in Sweden (Trafikanalys, 2020b). A total of 265 million train travels were done in 2019, which equals to 14,617 million kilometers. The quality of the infrastructure affects the perceived customer satisfaction such as punctuality, safety, comfort and competitive pricing. In addition, the vehicle managers being the owners of rolling stock put requirements regarding quality aspects related to the value and life-lengths of the rolling stock.

The actors marked with grey are directly involved in the value creation of vehicle maintenance, which is the chosen delimitation of the study case study presented in the next section. Here, an overall picture of the actors is given, while detailed information is given in the case study. The central actor is the *vehicle maintainer* responsible for the maintenance of rolling stock. Rolling stock refers to vehicles used both for passenger traffic, i.e. engines and trains, and for goods transports, mainly engines. *Subcontractors* support the vehicle maintainers with expert competence and working capacity, while *spare parts suppliers* supply the maintainer with required equipment and spare parts. The *vehicle manufacturers* could act as subcontractors or spare parts suppliers, but in the role of manufacturer, the main supply is technical documentation and maintenance plans. Vehicle maintainers could conduct modification work on rolling stock, i.e. act as a vehicle rebuilder, but actors specialized in this are in Figure 4 denoted as *vehicle rebuilders*. The availability of vehicles is the responsibility of the *vehicle managers*, while the *train operators* are the ones carrying out the transportation service. A train operator could act as vehicle manager, but most often these are separate actors. This all describe a very complex situation for companies to operate in.

5. Case description: new business opportunities within railway vehicle maintenance

In this section, the current business environment of a vehicle maintainer is described as well as new business possibilities and business models strategies, enabling Service Management 4.0. The vehicle maintainer is referred to as MAINT_MAIN in the continuing text.

5.1 Current business environment of the vehicle maintainer

The *vehicle maintainer* MAINT_MAIN operates in a global, deregulated market with several hundred different actors. The main actors are managing authorities such as the Swedish transport administration and the transport agency, competitors, customers and suppliers. The market is well established, so the company faces fierce competition with few opportunities to expand within the existing ecosystem. The number of competitors is relatively small though: a maximum of twenty within the foreseeable future. Competitors include two main actors focusing on the maintenance of passenger vehicles as well as several actors in freight vehicle maintenance. Some of the competitors also acts as *vehicle rebuilders*. Since 2010, one competitor has also been licensed to operate commercial traffic for freight trains, passenger trains and high-speed trains. Vehicle manufacturers are also to some extent competitors. Their main competitive advantage is access to spare parts and technical documentation. MAINT_MAIN's largest customers are in Sweden. The two main customer types are *train operators*, who drive and own vehicles, and *vehicle managers*, who own vehicles and provide operators with trains. In addition, vehicles owned by infrastructure contractors are maintained. An important customer who acts as both manager and operator is OP_1. OP_1 owns Arlanda Express and places high demands on accessibility.

The suppliers include *subcontractors*, *vehicle manufacturers*, who also sell spare parts and material for vehicle maintenance, as well as several other *suppliers of spare parts*. The number of suppliers is not particularly large, and the limited volumes leads to a situation where suppliers of similar equipment are not keen to compete. Suppliers of expert competence with the permission to perform special tasks on the vehicles are also limited in number and location. Today, several maintenance suppliers share the same workshop facility, which is an integrity problem. This leads to separate changing rooms, screens in the workshop, etc.

The large number of actors makes it difficult for individual actors to position themselves in the value chain, and several actors are responsible for two or more activities. The state-owned OP_1, for example, has the roles of *traffic authority body*, train operator, and vehicle manager. MAINT_1, one of MAINT_MAIN's competitors, is also train operator and subcontractor to MAINT_MAIN. Some actors clearly show ecosystem thinking in their relationships with their business environment. OP_1, for example, expresses the importance of being able to offer customers quality through the customer's customer; "In order for us to be able to keep our customer promises, service thinking must be present at all levels, including our suppliers, and we think that MAINT_MAIN has that. We have had very high accessibility to our trains and a good relationship both with those who perform the maintenance and at management level."

For train operators, the customers' customers are *passengers* and *freight carriers*, while the customers' customers for vehicle owners are train operators and certain traffic authorities for county traffic. MAINT_MAIN does not have much direct contact with the customers' customers (the fright carriers and passengers). If a problem arises, e.g. the train is late or the comfort is poor, the customer turns to the operator in first place. *Vehicle manufacturers* are important actors as they have great influence and have important material and knowledge. MAINT_MAIN as a supplier has several *subcontractors*, e.g. ultrasound testing experts, own subcontractors (within MAINT_MAIN) and consultants, who must be coordinated and considered. The train operators are, in their role as customers, driving actors in MAINT_MAIN's perspective. Among other driving actors are the vehicle manufacturers in that they have access to in-depth technical documentation and technical know-how that does not benefit others. To some extent, MAINT_MAIN has an advantage over vehicle manufacturers; in case of problems where system tests show that it is a built-in error, the burden of proof is on them and not on MAINT_MAIN.

5.2 Interactions between key actors

Figure 5 describes important information flows between key actors (arrows depicting flow direction, and circles referring to type of information according to the legend). Operational and maintenance field data are important information for the manufacturer, as it could be used as input for design and redesign of vehicles. This kind of information is captured mainly from the vehicle manager, but efficient information flows between the manufacturer and the maintainer is today lacking (depicted by a dotted line in the figure). The maintenance provider mainly exchanges information with the vehicle manager and the operator. Important information regards the status of the assets, asset related problems, and the capability of the maintainer to take on maintenance work. Information regarding asset capacity and status are exchanged between the vehicle manager and the operator to plan

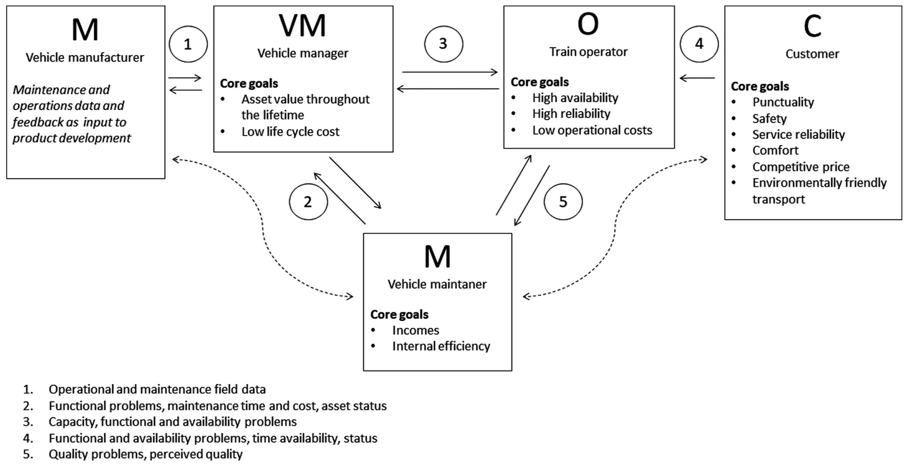


Figure 5.
Information flows and actors' goals

train operations. Customer satisfaction and problems reported by the customer are information that the train operator receives, but information flows between the customer and the maintenance provider are lacking. The large number of actors means obstacles to efficient information management. It is for instance difficult for maintainers and vehicle manufacturers to access relevant feedback from other actors. Even though vehicle manufacturers normally support the collection of real time measurement parameters by adding sensors and other measuring capability to the vehicles, these are not always of real value for the maintainer, as they do not reflect critical failure modes. The life cycle of the maintenance objects is thus difficult to overview and control, and incentives for this may be lacking. This affects the quality of information. For example, in the event of a fault in a vehicle, there is no incentive for good reporting practice from the train operator or vehicle manager; often incomplete causes of error are reported instead, e.g. "Carriage out of power."

The actors' core goals are accounted for in Figure 5. Notable is that the two direct customers of MAIN_MAINT have different goals with the maintenance services: for vehicle managers, asset value and cost minimization in the life cycle perspective is strived for with maintenance, while the operator strives to achieve high availability and reliability while maintaining low operational costs.

5.3 Identified business opportunities

MAINT_MAIN's value proposition consists of vehicle maintenance and vehicle modifications, and the current business model is characterized by product thinking and technology focus. The customer offering is permeated by technical know-how and selling maintenance and is regulated with product-related values such as performance, availability and safety. The business development strategy is technology-driven in the sense that the main goal is to increase internal efficiency, but also customer-driven as offers are adapted to different customer segments. MAINT_MAIN clearly positions itself within the value chain; profitability is achieved through internal efficiency and suitable offers to customers. The market is small but well established: MAINT_MAIN is facing hard competition with few opportunities to expand within the defined area, and profit margins are small. Figure 6 summarizes MAINT_MAIN's current business position and potential for improvement.

The business development strategy for services should be based on the needs of different customer segments. The customers work towards different, and often conflicting goals, which is exemplified in Figure 6. This is a strong indicator to differentiate the offer for specific

	Product thinking (saturated market)		Utility thinking (new possibilities)	
Dimension	**Level 1**	**Level 2**	**Level 3**	**Level 4**
Type of offering	Technology	Mainly product	Product and service	Integrated offerings
Density	Low	High	Dynamic	
Quality dimensions	Mainly product		Combination of product and service	
Business development strategy	Technology-driven	Customer-driven	Utility-driven	Dynamic
Strategic perspective	Inside-out		Outside-in	
View on profitability	Productivity	Customer satisfaction	Customer satisfaction / relationships	Relationships (more or less formal)
View on value creation	The own business in focus	Value chain	Value star/network	Ecology

Figure 6.
MAINT_MAIN's current position and improvement potential

customer segments, which is not fully done at present. Moreover, the existing customer segments are not homogeneous regarding customer needs. Therefore, the customer categorization should be reviewed and based on real needs in terms of value offerings, distribution channels, relationships, or financial ability, see Osterwalder and Pigneur (2010). Providing holistic solutions, i.e. solutions that include operation and maintenance, is an opportunity for MAINT_MAIN, such as combining vehicles (operation) and maintenance in the form of leasing agreements. However, it is difficult at present for MAINT_MAIN to find partners for such combined offers, as well as to expand the business to owning vehicles. A more suitable holistic solution is "Keep the vehicle rolling guarantee," i.e. to be able to provide availability of specific vehicles, in addition to number of vehicles. This solution is suitable for both small and large customers.

As only a few actors with similar offers exist, the market cannot be described as fully competitive. Cooperative forms of agreement such as partnering and profit-sharing agreements fit better in such conditions than in perfect competitive conditions (Hui, 2005). Profit and risk-sharing models, however, are generally not common in this market. Cost-plus models and detailed contracts are commonly applied, and only a few customers have experience of performance-based contracts. Furthermore, as mentioned previously, the large number of total actors means obstacles with efficient information management. It is difficult for especially maintainers and vehicle manufacturers to get relevant feedback from other actors. MAINT_MAIN must rely on indirect information transfer from the end customers, and if the direct customer is a vehicle owner, also from the operator. The information transfer is not complete and too linear. Problems with information transfer between actors affect the ability to create long-term relationships, and thus the ability to work with cooperative contract forms. One option is to reverse the information flow and work proactively, instead of viewing the limited information transfer as a problem. MAINT_MAIN currently has access to information that could be used by, or delivered to, other actors. This opens the possibility of selling information and expert competence as services, e.g. to sell information of the type "Now you have to change the compressor."

MAINT_MAIN's customers have mandate from the government to offer good transport options for passengers and goods. In other words, the customer's customer (the passenger or freight carrier) is an important actor. Linking vehicle maintenance to the national goals can be done in different ways. One is to make the effect of maintenance visible. This is easiest done by highlighting how the work conducted in the workshop affects the customer (and the customer's customer), and the positive benefits of proactive maintenance. "High reliability leads to high availability!" Another option is to focus on comfort and work environment related faults. It is a way to work closer with each other under the motto: "We help each other, together, for a better travel experience." The operators and the customers will be satisfied, and there are no major additional costs included. The responsibility and information flow are rather simple: the operator reports faults, MAINT_MAIN fixes the fault, and the operator approves.

There are good possibilities for MAINT_MAIN to offer dynamics in the maintenance contracts both in terms of time and scope. Regardless of which dimension to focus on, the key measures used for regulating contracts should be reviewed. Backlog of preventive maintenance according to the maintenance plan is one of the current measures that is not suitable in dynamic contracts.

5.4 New business models

In the following, the business opportunities identified in 5.3 are formalized in business models directed towards different customer segments; a (traditional) maintenance contract form, a contract form with focus on utility and quality, and a contract form with focus on value preservation.

5.4.1 Basic maintenance contract (maintenance focus, product focus). Through basic service agreements, MAINT_MAIN can meet the customer's basic needs while streamlining the internal processes. The customers need basic maintenance that is carried out periodically, and which is regulated by price, technical quality, and technical competence. Appropriate technical key figures are total down time (linked to Mean Waiting Time and Mean Time To Repair) and backlog measured in hours or number of orders. Financial key figures are the total cost during the contract period, including price adjustments, as well as cost per defined period and maintenance object. For measuring safety and health, the key indicator "incidents that can be attributed to MAINT_MAIN's work" could be used. The agreement is based on the core competencies of planning and execution of maintenance, and the key resources associated with these activities. No direct key partners are identified for this form of agreement; MAINT_MAIN already has all the resources and expertise required. PROP_1 could be seen as a key partner, as the business requires premises adapted for the purpose. The typical customer for this offer needs basic maintenance and a simple procurement process.

The contract is a standard agreement initiated by MAINT_MAIN and covers preventive periodic maintenance, spare parts and reporting of discovered damage/defects via a fixed price model. In other words, the payment is periodic and is based on estimated costs that arise during the agreement period and a profit margin. Corrective maintenance is handled as a separate business and according to a cost-plus model. Thus, MAINT_MAIN takes a low risk; the customer bears all costs for any stoppages (except for the stops directly caused by poorly performed maintenance). Distribution channels are partly local representatives and partly the existing customer network.

5.4.2 Contract with focus on utility and quality (service focus). This form of agreement is suitable for customers with low maintenance competence and/or understanding combined with high demands on reliability and delivery quality. The latter fits best into the customer category operators. The offer can be compared to a “black box solution” where MAINT_MAIN regulates content and agreements depending on the operating profile. It offers benefits to the customer’s customer (passenger or freight supplier) in the form of availability, comfort and punctuality, which can be regulated with key indicators used to measure the national traffic targets (punctuality, capacity, robustness, safety). For measuring comfort, new key indicators can be developed that also regulate internal vehicle comfort. Maintenance execution quality is measured in total stop time and the number of unrepaired damages. The main offer is vehicle maintenance according to a fixed plan with dynamic activities, or a dynamic plan with fixed activities, depending on the customer’s needs. Key activities, in addition to planning and carrying out maintenance, are information management, diagnosis and prognostics. In addition to maintenance personnel, sales and customer relations are important. The agreement is procured through ordinary procedures and through local representatives, but it is also possible with customized marketing. The offer depends on good information transfer from the customer (and indirectly the customer’s customer), so the operator and the vehicle manager are viewed as key partners.

The contract is a standard agreement that is developed in collaboration with the customer and MAINT_MAIN, or alternatively initiated by MAINT_MAIN. It covers preventive periodic maintenance, corrective maintenance, spare parts, and vehicle information via a dynamic pricing model. The payment is periodic and is based on estimated costs that arise during the agreement period and a risk transfer margin. MAINT_MAIN takes a certain risk of not reaching availability or quality targets, which is reflected in the risk transfer margin. Availability can be regulated by the key indicator “number of trains to traffic,” where the real need for the number of trains or specific trains is not affected, or the real need for availability e.g. in the form of guaranteed availability on specific vehicles or vehicle types when required, or a combination of both. Regardless of how availability is specified, this measure is linked with the operating profile that the agreement is based on. Events outside the operating profile are handled as a separate business transaction and according to a cost-plus model.

5.4.3 Contract with focus on utility and value preservation (system focus). This type of agreement is suitable for an actor who understands maintenance and wants to influence the collaboration, and who has high demands on reliability and life cycle cost (LCC) optimization. The latter fits well with vehicle managers. The offer focuses on delivering benefits in the form of value preservation of vehicles expressed in life cycle cost optimization, robustness, and reliability. The agreement is regulated partly with the help of technical key indicators that reflect reliability (the number of stopping faults caused by poor maintenance), and partly with financial key indicators that reflect the preservation of value (cost compared to LCC). Availability and quality are still important aspects that contribute to value preservation, and key indicators reflecting this are needed, especially to follow up the work internally. MAINT_MAIN delivers vehicle maintenance according to a fixed plan based on dynamic activities and vehicle information. The information is used by the vehicle manager directly, but an information transfer to the vehicle manufacturer is also an option, either via the manager or directly from MAINT_MAIN. The information allows for design improvements that can further increase value over a lifetime. In addition to vehicle managers and manufacturers, the operator is an important key partner in the context of information transfer. Key activities are planning and carrying out maintenance, information management, diagnosis and prognostics. Key resources are maintenance personnel, sales, customer relations and project coordinators. In other words, resources and activities do not differ between this form of agreement and the one that focuses on availability and quality.

This type of contract is developed in close collaboration with the customer and assumes a close and long-term relationship. It covers preventive periodic maintenance, corrective maintenance, spare parts and vehicle information via a dynamic price model, and with a possibility of profit sharing (such as in partnering based contracts). The payment is periodic and is based on estimated costs that arise during the agreement period and a risk transfer margin. If the costs are less than the target costs, a certain part of the profit can be shared with the customer. MAINT_MAIN takes a risk of not reaching the agreed utility if the actual needs of the vehicle have not been fully understood, which is reflected in the risk transfer margin.

6. Discussion and conclusions

The concept of Service Management 4.0 describes a direction towards service-based business models that are in alignment with Industry 4.0. Service Management 4.0 focuses on the value proposition and how it supports the true needs of the customer, as well as the needs of the end users, i.e. passengers and companies dependent on freight transport. This implies moving from a traditional value chain perspective to an ecosystem perspective, where the complexities of the business environment are studied from a holistic system perspective, and customer segmentation are based on the needs of both the direct customer, and the customer's customer. The case study depicted a complex ecosystem, including actors with different or conflicting goals, and insufficient information. Dynamics in the business proposition with respect to when maintenance is conducted, or what to maintain at a specific occasion, is one way to meet the different customer needs without adding complexity to the contract structure (Kans and Ingwald, 2020). The proposed contract forms are reflecting such logic, in that they all are based on the core competencies of the maintainer while being offerings that reflects the needs of specific customers.

Another key feature of Service Management 4.0 is the integrated and value-driven view on maintenance and other after sales services. This view is shared among providers and customers. Maintenance should be seen as a means to reach the core business goals, and not as an add-on to a product, or as a cost center for the customer. This is achieved by focusing on the value of the service, and integrated value offerings where maintenance forms an integrated part of the offer, in the form of performance-based and long-term relationships regulated in holistic contracts (Meier *et al.*, 2011; Durugbo, 2013; Kans and Ingwald, 2016a). To succeed with this, the maintainer, i.e. the case company, must be viewed as a key partner by the customer and the flow of relevant information must be guaranteed, and suitable key performance indications should be defined for the regulation of contracts, as proposed in Kans and Ingwald (2019).

The delimitation of the in-depth case study was vehicle maintenance in the Swedish railway ecosystem. For achieving a broader perspective, further studies could focus on other aspects, such as infrastructure maintenance or railway operations. Another prospective direction is to address the railway maintenance in an international context, as maintenance objectives of availability and safety are similar (Macchi *et al.*, 2012; Patricio, 2019) while the market situation differs between countries e.g. with respect to regulation (Alexandersson and Rigas, 2013).

The change of business strategy towards Service Management 4.0 is challenging. Therefore, support is needed, e.g. in the form of the business model development tool (see Figure 1). Using the tool, the current position could be determined, as well as the possibilities to move towards value-driven and utility-based business models. The tool covers the characteristics of the value proposition as well as the business strategy and could be used in addition to other business modeling tools, such as the business model canvas developed by Osterwalder and Pigneur (2010). The innovation process in Figure 2, supported by the questions in Appendix, describes a generic approach towards business model innovation and could be utilized in other contexts than the railway industry, or for other service-based ecosystems. Studies within other areas of infrastructure services, such as management and maintenance of roads or bridges, or for building and facility maintenance, are interesting areas of further research.

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Appendix
Interview template

(1) *Company current situation and history*

(1.1) What history does the company have and how does the company look like today (quantitative information)?

(1.2) Which internal actors are affected by and affect the value proposition process?

(1.3) What does the company provide for overall value and function?

(1.4) What are the key resources, key activities and processes of the company?

(1.5) Who are the most important actors in realizing the offer?

(1.6) Which key partners do the company have?

(2) *Business environment*

(2.1) Who are the direct customers, suppliers, competitors and other actors?

(2.2) How are these connected to each other?

(2.3) Who are the customers' customers?

(2.4) Who are the driving or controlling actors?

(2.5) What are the named and unnamed customer needs?

(2.6) What benefit can the company give the customer (or the customer's customer)?

(2.7) What conditions (e.g. technology platform) are needed at the customer?

(2.8) What does the customer's business environment look like? What other actors can offer the same benefit?

(2.9) Are there several customers with similar needs?

(3) *Value proposition modelling*

(3.1) How should the customer's needs be described in a formal offer?

(3.2) How should the offer be packaged?

(3.3) How should the offer be distributed?

(3.4) How should the benefit be measured (key figures that regulate the offer)?

(3.5) Are there the resources/assets needed to offer the customer what it needs?

(3.6) If resources are lacking, can these be obtained, and if so, what is required?

(3.7) What costs and revenues are linked to the value proposition, and is there a balance between them?

(3.8) What new business opportunities (scenarios) could be developed?

(3.9) What opportunities are there to expand existing offers?

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