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INTEGRATED PRODUCT SERVICE OFFERINGS FOR RAIL AND ROAD INFRASTRUCTURE

– REVIEWING APPLICABILITY IN SWEDEN

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ABSTRACT

This research aims to *explore and propose a more effective management of rail and road infrastructure and the possibility of a more resource-efficient road and rail infrastructure by applying business models based on performance and a life-cycle perspective.*

There is a lack of efficiency in the Swedish rail and road infrastructure industries - at the same time as the availability of the rail tracks and roads is essential. Rail and road infrastructure have long lifetimes, around 40-60 years, and during these decades regular maintenance and reconstruction are needed to ensure proper function. Large amounts of resources are required to construct the infrastructure, and the overall environmental pressure depends substantially on this.

This research is largely based on interviews conducted with the buyer, contractors and design consultants for rail and road infrastructure in Sweden. Literature reviews have been conducted to develop the framework needed to analyze the empirical findings. This research contributes by building on theory in areas such as Integrated Product Service Offerings (IPSOs) and eco-design, and this abstract presents a brief summary of the overall conclusions.

Several challenges for rail and road infrastructure in Sweden have been identified, such as the lack of information and knowledge transfer between different projects and actors. This is due to e.g. the use of traditional short-term contracts and conservative cooperate cultures, creating sub-optimizations in management. Increased collaboration, through e.g. partnering, seems to be a promising way to increase the information and knowledge transfer between actors by increasing trust and interaction. In this way, management would be more effective, and by involving contractors in the design phase, more efficient technical solutions could be developed and used. Additionally, increased involvement by the design consultants and an iterative information loop between design, construction and maintenance could also be beneficial. The research indicates that increased cooperation increases trust. In this way, there is a possibility to remove the detailed requirements that prevent new ways of working.

Rail and road infrastructure have characteristics, such as the resources used and the importance of availability, that are well-suited for IPSOs. This performance-based business model with a life-cycle perspective provides incentives to optimize the use of resources and provide a holistic view for management that is lacking today for rail and road infrastructure.

However, a long-term contract such as an IPSO creates uncertainties. The actors are risk-averse, which is an obstacle in the development of new business models and contract forms. Most of the risks and uncertainties identified are due to lack of experience. This implies that an implementation of IPSOs will have a steep learning curve. Additionally, risk allocation between the actors is important for effective management: too much risk for the suppliers

will make them reluctant in developing new solutions, and they will use a risk premium to cover up for the risk.

Key words: Integrated Product Service Offerings, Product Service Systems, long-term contracts, risk, life-cycle perspective, resource-efficiency

POPULÄRVETENSKAPLIG SAMMANFATTNING

”Tåg som går enligt tidtabellen, året runt!” Svenska tågresenärers dröm och en möjlighet om järnvägen byggs och underhålls på ett mer långsiktigt och genomtänkt sätt.

Genom att använda kontrakt som omfattar järnvägens alla livscyklifaser, t.ex. planering, byggnation, underhåll och drift, finns det möjlighet att förbättra det svenska järnvägssystemets driftsäkerhet och därmed tågens möjlighet att komma fram i tid.

Bakgrunden till problemet med dagens järnväg är att byggnation och underhåll hanteras i separata kontrakt, med separat budget och utan någon egentlig kommunikation emellan de ansvariga avdelningarna på Trafikverket. Kostnadsbesparingar görs t.ex. i byggnationsdelen för att hålla budgeten, men detta påverkar underhållsdelen, som får ta smällarna för spår och ledningar som inte håller längre än den korta garantitiden. Detta orsakar suboptimering av järnvägssystemet, vilket i slutänden drabbar slutkunderna, dvs. resenärerna.

Syftet med forskningen har varit att undersöka möjligheten att göra järnväg- och vägsinfrastruktur mer resurseffektiv. Järnväg och väg har många likheter vilket gör det relevant att analysera båda och se vad de kan lära av varandra.

Forskningen visar att om det redan i byggnationsfasen tas hänsyn till att järnvägen ska underhållas i flera decennier, är det troligt att mer långsiktiga val görs när det gäller material och processer. Tanken är att detta skulle minska totalkostnaden genom att avvägningar kan göras mellan byggnation och underhåll. Bättre planering av underhåll och val av material skulle inte enbart ha en direkt effekt, genom en bättre fungerande järnväg, utan skulle även bidra till en mer hållbar och resurseffektiv järnväg. Ett sätt att uppnå detta är att använda sig av Integrerade Produkt- och Tjänsteerbjudanden, där fokus ligger på resultatet, dvs. funktionen och inte på produkten i sig. För järnväg är förenklat funktionen, ”att se till att tågen kommer fram utan problem”, det viktiga och inte t.ex. antalet slipers och växlar som använts för att komma dit.

Det är dock inte helt enkelt att införa den här typen av kontrakt. Både Trafikverket och entreprenörerna saknar idag kunskap och erfarenhet om hur kontrakten bör utformas när det gäller t.ex. riskhantering och kvalitetskrav. Vidare är både Trafikverket och entreprenörerna, särskilt för järnväg, obenägna att ta risker, vilket bidrar till en förändringströghet i branschen.

För vägsidan har det gjorts försök med den här typen av livscykelkontrakt. Även om det inte har fungerat optimalt kan erfarenheterna användas för att utveckla kontrakt för järnvägsidan.

Forskningen pekar på att ökat samarbete ger ökat förtroende mellan infrastrukturaktörerna. Vidare har entreprenörerna mycket erfarenhet som Trafikverket inte har och som skulle kunna användas för att förbättra infrastrukturen. Detta kräver dock att entreprenörerna är

med från början när designen görs och inte enbart under själva byggnationen och underhållet. Ökat samarbete i projekten mellan Trafikverket och entreprenörerna, för att skapa mer interaktion och utbyte av erfarenheter, ger potential att göra både hanteringen av och själva infrastrukturen mer effektiva.

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Sofia Lingegård

Linköping, August 2014

APPENDED PAPERS

- Paper 1:** Lingegård S., Lindahl, M., Svensson, N., 2011. PSS for Rail and Road Infrastructure, in: Hesselbach, J., Herrmann, C. (Eds.), *Functional Thinking for Value Creation*, Proceedings of the 3rd CIRP International Conference on IPS². Springer, Braunschweig.
- Paper 2:** Lingegård, S., Lindahl, M., 2014b. Integrated Product Service Offerings for Rail Infrastructure - Benefits and Challenges Regarding Knowledge Transfer and Cultural Change in a Swedish Case. Early version presented at Greening of Industry Network Conference, 2012 Linköping. Accepted for *Journal of Cleaner Production*.
- Paper 3:** Lingegård, S., Svensson, N., 2014. Scenarios for Resource-Efficient Rail Infrastructure - Applying Integrated Product Service Offerings, The 6th CIRP Conference on Industrial Product-Service Systems. Elsevier, Windsor, Canada.
- Paper 4:** Lingegård, S., 2014. Partnering - a Way to Reach Resource-Efficient and Effective Road Infrastructure Projects Through Increased Information and Knowledge Transfer? Draft.
- Paper 5:** Lingegård, S., Lindahl, M., 2014a. Identification of Risks related to Integrated Product Service Offerings of Rail Infrastructure - A Swedish Case. Accepted for book: *Through-life Engineering Services: Motivation, Theory and Practice*. Springer.

RELATED PUBLICATIONS

- Lingegård, S., 2012. Integrated Product Service Offerings for Rail Infrastructure: potential benefits and challenges, Licentiate, Environmental Technology and Management, Department of Management and Engineering. Linköping University, Linköping.
- Lingegård S., Lindahl M., Sundin E., 2010. Organizational changes in connection with IPSO. Paper presented at the CIRP's 2nd IPS² Conference, Linköping, 14-15 April, Linköping,
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- Lingegård S. 2014. Ger ökad samverkan en mer resurseffektiv anläggning? Undersökning av Väg 55/56, Östra förbifarten, Katrineholm [Will increased coopertion result in a more resource efficient construction?]. Department of Managment and Engineering, Linköping University

THESIS OUTLINE

The cover thesis includes Chapters 1-7, while the appended Papers 1-5 and a case report can be found in Appendix I. Appendix II includes the interviews guides for each study.

Part	Chapter/Paper	Content/Paper title
Cover thesis	1. Introduction	Introducing the empirical problem and key literature
	2. Methodology	Description of methodological choices
	3. Frame of reference	Theoretical framework used in the research
	4. Rail and road infrastructure	Historical background, contract used and actors involved
	5. Paper overview	Presentation of key results
	6. Discussion	Discussion of research questions and concluding discussion
	7. Conclusions	Conclusions, contributions and future research
Appendix I	Paper 1	PSS for Rail and Road Infrastructure
	Paper 2	Integrated Product Service Offerings for Rail Infrastructure - Benefits and Challenges Regarding Knowledge Transfer and Cultural Change in a Swedish Case
	Paper 3	Scenarios for Resource-Efficient Rail Infrastructure - Applying Integrated Product Service Offerings
	Paper 4	Partnering – A Way to Reach Resource-Efficient and Effective Road Infrastructure Projects through Increased Information and Knowledge Transfer?
	Paper 5	Identification of Risks Related to Integrated Product Service Offerings of Rail Infrastructure - A Swedish Case
	Case report	Description of Case I and II
Appendix II		Interview guides

DEFINITIONS AND CONCEPTS

The definitions and concepts that are essential for this research are presented here.

Business model: Describes how a business creates and delivers value to customers and how to convert the payments into profits (Biggemann et al., 2013; Kindström and Kowalkowski, 2014).

Buyer: The Swedish Transport Administration, which owns and manages the state-owned road and rail infrastructure in Sweden.

Contract: A contract defines responsibilities, measures compliance, and establishes compensation between the parties (Baron et al., 2014).

Contractors: The companies that perform construction and maintenance work in the construction industry.

Effective: To do the right things (Hill, 2000).

Efficiency: To do things right (Hill, 2000).

Innovation: The management of the activities involved in the process of idea generation, technology development, manufacturing and marketing of a new or improved process or product (Trott, 2012).

Information transfer: Information transferred between different contracts (construction to maintenance, maintenance to maintenance, etc.), or information transferred between different actors (buyer to contractor, design consultant to buyer, etc.). Information is e.g. documentation of site conditions, historical data, maintenance data, and construction data.

Integrated Product Service Offering, IPSO: The IPSO is a further development of Product Service Systems, which is defined as “a system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models” (Mont, 2002). In addition to this, the IPSO has a life-cycle perspective and is an integrated offering that instead of selling physical products provides functions, service and performance (Sundin et al., 2006).

Knowledge integration: The “ability of a project organization to turn knowledge into action” (Dietrich et al., 2010 p. 61). Knowledge is information and skills acquired through experience or education (Graedel, 1996).

Life-cycle: A life-cycle can be described as the concept of product life, and includes the life phases as well as the loops between them. The phases include design/development, resource extraction, production of materials, manufacturing, use and end-of-life activities (Rebitzer et al., 2004). The life-cycle concept is an approach to products,

processes and services where all life-cycle stages have environmental and economic impacts (Fava and Weston, 1997).

Product: A physical product/good is a tangible item that is available on the market and has a market value (Kotler, 2011).

Risk: The term risk in this thesis is defined as “uncertain future events which if they happen will cause significant extra cost or delay” (Barnes, 1983 p. 24).

Service: Services are activities or benefits, tangible or intangible, which are offered for sale or provided in connection with products (Regan, 1963).

Large Technical Systems: Capital-intensive infrastructure with many different technical components as well as a variation of actors and institutions involved (Markard and Truffer, 2006).

Partnering: A long-term commitment between two or more organizations for the purpose of achieving specific business objectives by maximizing the effectiveness of each participant’s resources (Construction Industry Institute, 1991 p. 4).

Public procurement: “The measures taken by a contracting authority with the aim of awarding a contract or concluding a framework agreement regarding products, services or works” (Swedish Competition Authority, 2012 p. 4). Public procurement in Sweden is regulated by the Public Procurement Act, with the aim to use the public funds in the best possible way, and which regulates the public procurement in Sweden (Swedish Competition Authority, 2012).

Uncertainty: Defined as any deviation from the ideal outcome and the actual outcome (Walker et al., 2003), uncertainty can be seen in terms of trade-offs between risk and reward but also as an inability to plan (Eisenhardt, 1989).

TABLE OF CONTENT

1. INTRODUCTION	1
1.1 Introduction to the rail and road infrastructure industry	2
1.1.1 Performance-based business models with a life-cycle perspective	2
1.1.2 Multiple actors involved	3
1.1.3 Organizational change in a risk-averse industry	3
1.1.4 Introduction to the Swedish case	4
1.2 Aim and research questions	4
1.3 Limitations	7
2. METHODOLOGY	9
2.1 Overall Research Design	10
2.1.1 Unit of Analysis	10
2.1.2 Approach	10
2.2 Research process	11
2.3 Initial literature study	12
2.4 Study 1: IPSOs for Rail Infrastructure	12
2.4.1 Interviews in Study 1	13
2.4.2 Survey in Study 1	15
2.4.3 Focus group in Study 1	16
2.5 Study 2: Scenarios for railway infrastructure	16
2.6 Study 3: Three realized projects	18
2.6.1 The Katrineholm project: collaboration and partnering	18
2.6.2 Road and rail projects with new perspectives	19
2.7 Methods for data collection	21
2.7.1 Literature reviews	21
2.7.2 Interview studies	21
2.8 Research Design for each Research Question	22
2.8.1 RQ1: What are the current primary challenges regarding the management of rail and road infrastructure concerning design, construction and maintenance?	22
2.8.2 RQ2: In what ways could a life-cycle perspective affect the resource efficiency of rail and road infrastructure?	23
2.8.3 RQ3: How can information and knowledge sharing between actors contribute to more resource-efficient solutions and more effective management for rail and road infrastructure?	24
2.8.4 RQ4: What are the uncertainties and risks from the actors' perspective when using business models based on performance and a life-cycle perspective for rail and road infrastructure, and how can they be managed?	24
2.9 Overall research quality	24
2.9.1 Methods triangulation	25
2.9.2 Analyst triangulation	26
2.9.3 Theory triangulation	27
2.9.4 Transferability	27
3. FRAME OF REFERENCE	29
3.1 Life-cycle perspective	30
3.2 Integrated Product Service Offerings	32

3.2.1	Drivers for IPSOs.....	33
3.2.2	Industry examples of IPSO implementation.....	34
3.3	Organizational change.....	35
3.3.1	The providing organization.....	36
3.3.2	The buying organization.....	36
3.4	Provider-buyer relationships.....	37
3.4.1	Collaboration between actors.....	37
3.4.2	Trust.....	37
3.4.3	Power.....	38
3.5	Partnering in the construction industry – a formalized relationship.....	39
3.5.1	<i>Different types of partnering</i>	39
3.5.2	Successful partnering.....	40
3.5.3	<i>Challenges in partnering</i>	40
3.6	Risk and uncertainty.....	41
3.6.1	Risk attitude in the construction industry.....	41
3.6.2	Long-term contracts and uncertainty.....	42
3.6.3	Risk allocation between contracting parties.....	42
4.	RAIL AND ROAD INFRASTRUCTURE – AN OVERVIEW.....	45
4.1	An historical review of the rail infrastructure in Sweden.....	46
4.2	An historical review of the road infrastructure in Sweden.....	46
4.3	The rail and road infrastructure in Sweden today.....	47
4.3.1	The procurement process.....	47
4.3.2	The contracts used.....	49
4.3.3	The status of the infrastructure.....	51
4.4	The environmental impact from the infrastructure.....	52
4.5	Rail and road infrastructure abroad.....	52
4.5.1	Road infrastructure in Finland.....	52
4.5.2	Road infrastructure in the Netherlands.....	52
4.5.3	Rail infrastructure in the Netherlands.....	53
4.5.4	The case of the rail infrastructure in the UK.....	53
5.	APPENDED PAPERS AND CASE REPORT.....	55
5.1	Paper 1 – PSS contracts for rail and road infrastructure.....	56
5.1.1	Aim and method.....	56
5.1.2	Main contributions.....	56
5.2	Paper 2 – Integrated Product Service Offerings for Rail Infrastructure – Benefits and Challenges Regarding Knowledge Transfer and Cultural Change in a Swedish Case.....	57
5.2.1	Aim and method.....	57
5.2.2	Main contributions.....	58
5.3	Paper 3 – Scenarios for Resource-Efficient Rail Infrastructure – Applying Integrated Product Service Offerings.....	59
5.3.1	Aim and methods.....	59
5.3.2	Main contributions.....	59
5.4	Paper 4 – Partnering – a Way to Reach Resource- Efficient and Effective Road Infrastructure Projects through Increased Information and Knowledge Transfer?.....	60
5.4.1	Aim and method.....	61
5.4.2	Main contributions.....	61
5.5	Paper 5 – Identification of Risks related to Integrated Product Service Offerings of Rail Infrastructure – A Swedish Case.....	62

5.5.1	Aim and method	62
5.5.2	Main contributions	63
5.6	Case report	64
5.6.1	Case I: Riksväg 50 – a type of IPSO contract	64
5.6.2	Case II: Bana Motala-Mjölby: Design-Build contract	65
6.	DISCUSSION	67
6.1	Introduction to IPSOs for rail and road infrastructure	68
6.2	Current challenges for Swedish rail and road infrastructure	69
6.2.1	The use of traditional contracts	69
6.2.2	Lack of information and knowledge transfer	70
6.2.3	Corporate culture	71
6.3	Exploring a life-cycle perspective for resource efficiency	71
6.3.1	Analysis of realized projects	72
6.3.2	A life-cycle perspective for continuity	73
6.3.3	Scenarios for future life-cycle projects	74
6.3.4	The size and length of the IPSOs	74
6.3.5	Organizational change	75
6.4	Information and knowledge sharing	77
6.4.1	Information asymmetry between the actors	78
6.4.2	Improved information transfer	78
6.4.3	Synthesized information flows for contracts	79
6.5	Risk aspects and risk management	81
6.5.1	Contract length and uncertainties	81
6.5.2	Performance requirements and evaluation	82
6.5.3	Risk allocation	83
6.5.4	Collaboration as a mean to increase trust	84
7.	CONCLUSIONS, CONTRIBUTIONS AND FUTURE RESEARCH	87
7.1	Current primary challenges regarding the management of rail and road infrastructure concerning design, construction and maintenance	88
7.2	Ways a life-cycle perspective could affect the resource efficiency for rail and road infrastructure	88
7.3	How information and knowledge sharing between actors can contribute to more resource-efficient solutions and more effective management for rail and road infrastructure	89
7.4	Uncertainties and risks from the actors' perspective when using business models based on performance and a life-cycle perspective for rail and road infrastructure, and how these can be managed	89
7.5	Overall conclusions	90
7.6	Transferability of the conclusions	90
7.7	Theoretical contributions	91
7.7.1	Integrated Product Service System / Product Service System	91
7.7.2	Eco-design	92
7.7.3	Contributions to other related research fields	92
7.8	Practical implications	92
7.8.1	Organizational synergies and learning potential	92
7.8.2	Embrace the life-cycle perspective	92
7.8.3	Collaboration possibilities	93
7.9	Suggestions for future research	93

8. REFERENCES	95
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APPENDIX I – PAPPERS AND CASE REPORT

Paper 1: Lingegård S., Lindahl, M., Svensson, N., 2011. PSS for Rail and Road Infrastructure.

Paper 2: Lingegård, S., Lindahl, M., 2014b. Integrated Product Service Offerings for Rail Infrastructure – Benefits and Challenges Regarding Knowledge Transfer and Cultural Change in a Swedish Case.

Paper 3: Lingegård, S., Svensson, N., 2014. Scenarios for Resource-Efficient Rail Infrastructure – Applying Integrated Product Service Offerings.

Paper 4: Lingegård, S., 2014. Partnering – a Way to Reach Resource-Efficient and Effective Road Infrastructure Projects through Increased information and Knowledge Transfer?

Paper 5: Lingegård, S., Lindahl, M., 2014a. Identification of Risks related to Integrated Product Service Offerings of Rail Infrastructure – A Swedish Case.

APPENDIX II – INTERVIEW GUIDES

Interview guides, study 1

Interview guide, study 2

Interview guides, study 3

LIST OF FIGURES

Figure 1: Graph illustrating the cost profile for rail and road infrastructure. Modified from Nilsson (2009).	30
Figure 2: The relation between “Freedom of action”, “Product knowledge” and “Modification cost” known as the design paradox (Lindahl and Tingström, 2000).	31
Figure 3: Rail and road infrastructure in Sweden, a) showing the state-owned roads while b) illustrating the state-owned railway (The Swedish Transport Administration, 2014).	48
Figure 4: The progress in contract types according to the vision of the STA. Figure based on Sjöstrand (2014) and Finnra (2003).	49
Figure 5: Illustration of traditional Design-Bid-Build contracts as well as two cycles of maintenance contracts for the infrastructure. For Design-Build contracts the responsibility for the construction phase is shared by the STA and the contractor.	49
Figure 6: Schematic figure illustrating an IPSO contract for rail infrastructure (Lingegård, 2012).	58
Figure 7: Illustration of two scenarios for rail infrastructure: a) Choice of track type, b) Choice of number of tracks.	60
Figure 8: Information and communication flows between the actors in the project. The striped shapes in orange to the right in the figure are part of the contractor’s organization, while the green shapes represents the buyer. The oval boxes represent the respondents.	62
Figure 9: Illustration of the flows of information and knowledge as well as the interaction between the actors. The numbers in the figure denote the following: 1) Traditional contracts in general; 2) Maintenance contracts 3) Design-Build for rail project; 4) Partnering for road construction project; 5) IPSO for road project; and 6) Theoretical IPSO.	80

LIST OF TABLES

Table 1: Presentation of the papers, conferences and journals included in this research.	11
Table 2: Respondents within the STA.	13
Table 3: Respondents among the contractors.	14
Table 4: The respondents for Study 2.	17
Table 5: The respondents in the Katrineholm project.	19
Table 6: The respondents included in the BanaVäg Motala-Mjölby project.	20
Table 7: Time periods for the data collection.	21
Table 8: Studies that were used to answer the research questions. "X" indicates a large contribution, while "x" indicates a smaller contribution.	22
Table 9: Measures taken to ensure the quality of the research.	25
Table 10: Names and definitions for business models based on performance.	32
Table 11: Expenditures and number of projects for rail and road infrastructure in Sweden during 2013.	51
Table 12: The table presents the contribution of each paper 1-5 to the research questions 1-4. A large X indicates a major contribution to the research question, while a small x shows a medium to minor contribution.	56
Table 13: Reviewed contracts for rail infrastructure.	57
Table 14: Reviewed contracts for road infrastructure.	57
Table 15: The three projects and their specifications.	72

1.

INTRODUCTION

In this chapter a brief explanation of the current situation for rail and road infrastructure is presented, followed by an introduction to key concepts of the thesis. Thereafter, the aim of the research and the research questions are presented and motivated, followed by the limitations of the research.

1.1 Introduction to the rail and road infrastructure industry

Rail and road infrastructure have long lifetimes, around 40-60 years, and during these decades regular maintenance and reconstruction is needed to keep the function of the infrastructure. For certain products it is the initial stages of the life-cycle, i.e. the resource extraction as well as the processing and refining of raw material, that have the largest environmental impact (Clift and Wright, 2000). This is the case for the rail and road infrastructure, where the construction of the infrastructure requires large amounts of resources and the overall environmental pressure depends substantially on this (Mroueh et al., 1999; Svensson, 2006).

Furthermore, rail and road infrastructure are large technical systems, meaning capital-intensive infrastructure with many different technical components as well as a variation of actors and institutions involved (Markard and Truffer, 2006). The systems are large in scale, which make them important role for reduction of resource use in society (Jonsson, 2000).

Additionally, the construction industry, where rail and road infrastructure is included, is behind other industries when it comes to efficiency (Bankvall et al., 2010). For large technical systems standards, regulations and norms have co-developed with the physical structure, and this high degree of interdependencies is hindering development of the systems (Markard and Truffer, 2006). Examples of this could be the organization of the infrastructure owner and contractor, the way the infrastructure is used and if public procurement is used.

Considering the amount of products and services procured every year, the public authorities have leverage on the market and can influence suppliers and manufacturers (Commission of the European communities, 2008; Tarantini et al., 2011). In Europe, ten prioritized sectors for public procurement have been identified, and the construction industry is number one on the list based on the basis of e.g. scope of environmental improvement, public cost and impact on suppliers (Commission of the European communities, 2008).

Finally, in large technical systems the availability of the flow is essential and has to be controlled and monitored, since a disruption can affect other parts of the system (Jonsson, 2000). This is true for both rail and road infrastructure; however, disruptions become even more critical for rail infrastructure since there are less alternative routes to take in case of reduced availability. In the road system there are almost always possibilities to take a detour, even though problems on main routes severely affect the availability of the road system as well, but in more contained areas. Every time maintenance is performed or an error corrected, it affects the availability of the tracks and roads to some degree.

1.1.1 Performance-based business models with a life-cycle perspective

Considering the fact that the materials in the construction phase cause a large environmental impact and also a considerable cost, it should be of interest to try to use less material when building infrastructure. Also, it is relevant to build as durable as possible to reduce the reconstruction and the need for maintenance, especially considering the long life-cycles for

rail and road infrastructure. Previous research states that it is in the design phase where materials are selected, and where most of the environmental impacts are locked into the product (Lewis and Gertsakis, 2001). Therefore, business models using a life-cycle perspective where both construction and maintenance of the infrastructure is considered in the design phase could be useful for this industry. Furthermore, there is a need to construct and maintain rail and road infrastructure in such a way that the availability is optimal for the systems, since their aim is to provide possibilities for transportation. For this, business models that are performance-based are relevant, since they imply that the responsible actor has the responsibility to deliver a function, and thereby also has the incentives to optimize material and energy use (Goedkoop et al., 1999; Tukker and Tischner, 2006b). In this way, more durable materials and other designs may prolong the lifetime of the product, and potentially optimize maintenance and operations (White et al., 1999).

1.1.2 Multiple actors involved

For design, construction and maintenance of the infrastructure many different technical components and actors are involved. The different technical disciplines and actors that are involved during the life-cycle of the infrastructure need to be coordinated for a performance-based contract to work. A closer contact between the actors can increase the customization of the offering to better suit the customer (Sundin and Lindahl, 2008; Windahl, 2007), in this case e.g. increased availability for train traffic and resource use. This is because there is often an information asymmetry between actors (van Amstel et al. (2008)), based on their competence and experience. The actor maintaining the infrastructure knows how the construction holds after several years, and if this information was transferred to the actor in charge of designing the infrastructure, modification can be made to e.g. reduce material use or decrease energy use. In this way, transferring information between different phases in the life-cycle has potential to decrease the environmental impact (Cerin, 2006).

1.1.3 Organizational change in a risk-averse industry

For a company to shift to working with performance-based business models including a life-cycle perspective, instead of construction and maintenance separately, requires an organizational change. A traditional mindset and a lack of knowledge regarding life-cycle considerations are examples of this (Mont, 2004). In fact, this change is considered one of the major barriers for the business model, as it leads to changes both within the organization as well as changes in the relationship with other actors (Alonso-Rasgado et al., 2004; Mont, 2002).

Managing the uncertainties for the whole life cycle in the design phase is challenging, and for long-term contracts, risks and uncertainties regarding e.g. performance increase (Erkoyuncu et al., 2011; Meier et al., 2010) and formal risk analysis and management are not used frequently in the construction industry due to lack of knowledge (Akintoye and MacLeod, 1997). However, long-term contracts also reduce unpredictability and variability

by providing a continuous revenue stream to the provider (Brady et al., 2005; Mont, 2004; Mont, 2002). In addition to this, the construction industry is mostly risk-averse (Akintoye and MacLeod, 1997; Lyons and Skitmore, 2004; Uher and Toakley, 1999). This means that actors are willing to sacrifice expected returns to reduce variation in possible outcomes (March and Shapira, 1987), which adds to the organizational obstacles such as the traditional mindset mentioned above.

1.1.4 Introduction to the Swedish case

In Sweden, mismanagement of the rail infrastructure over the past decades has led to a poorly maintained infrastructure and inefficient organization (Alexandersson and Hultén, 2008; Thompson et al., 1998; Tullberg, 2000). The Swedish Agency for Public Management (2009) stated that among construction companies in Sweden, incentives for development, increased efficiency and raised competence are low.

Many infrastructure projects in Sweden exceed their budgets (Nilsson, 2009). Furthermore, the amount of rail and road infrastructure that was produced for the money spent for Swedish rail and road infrastructure has been measured, indicating a decreasing trend (The Swedish National Audit Office, 2011).

The Swedish Transport Administration (STA), the organization that owns and manages the state-owned rail and road infrastructure in Sweden, has thus far not had a life-cycle approach to its work (Svensson, 2006). Furthermore, a problem in the industry is a lack of transferring experience from working with different types of contracts (The Swedish National Audit Office, 2012). Recently, the STA has started to use longer contracts as well as more performance-based contracts, but this development is still in its infancy.

The empirical part of this research focuses on Sweden and its infrastructure, e.g. tracks, switches and asphalt; traffic, trains and motor vehicles are not included. In Chapter 4 the Swedish rail and road infrastructure is further explained, as well as international experiences.

1.2 Aim and research questions

The aim of this research is to *explore and propose a more effective management of rail and road infrastructure and the possibility of a more resource-efficient road and rail infrastructure by applying business models based on performance and a life-cycle perspective.*

In this research, **efficiency** is defined as “doing things right” (Hill, 2000). Given the resources available for rail and road infrastructure, how well are they used? Could it have been done differently? This leads to another interesting way of evaluating by using effectiveness, meaning “doing the right things” (Hill, 2000). This implies that rail and road infrastructure could be built and maintained in an efficient way related to the type of business model used. However, is the best model used? Is the infrastructure managed in an effective way? It has

been indicated in previous studies that the traditional models used provide incentives for the contractors not to realize measures to increase efficiency (Nilsson, 2009).

The starting point and main focus for this research is on the rail infrastructure, since this is where the most critical problems are considering failures, aggregated maintenance and availability. The road infrastructure is used to support and complement the research, since the two types of infrastructure have similarities as described in Section 1.1 and further explained in Section 4. Therefore, developments made for roads can be of help in the development of rail infrastructure. The management of the infrastructure, that is design, construction and maintenance, will be investigated to see what possibilities there are to make it more effective. By focusing on the right things, the process of management will become more effective, and the already scarce budget will be used in a good way. The end-of-life is not included in this research; see Limitations in Section 1.3.

The second part of the aim is the resource efficiency of the actual infrastructure, and if it can be improved. When the infrastructure is constructed and the maintenance phase starts, how can it be as efficient as possible and provide the maximum availability?

To answer the research aim, four research questions (RQs) have been formulated that need answers. They are formulated in a general way but the empirical findings all derive from the Swedish context. Before asking questions regarding what can be done to improve the infrastructure and its management, one must understand the current situation of rail and road infrastructure. For this, RQ1 has been formulated.

RQ1: What are the current primary challenges regarding the management of rail and road infrastructure concerning design, construction and maintenance?

Rail and road infrastructure face similar challenges but the main focus is on rail infrastructure, since the availability problems are more severe there due to interconnection of the rail infrastructure system. Also, rail infrastructure is more regulated, posing problems with changes in general.

This question involves several different aspects; the focus, however, is on organizational issues, resource use and contracts. It is also of importance to understand under what conditions the rail and road industry operates. The regulations of public procurement¹ affect the market, but the mechanism behind this will not be discussed in this thesis. It is assumed that the research is realized within the laws and regulations of public procurement. Instead, the focus is on contracts used and the relationship and interaction between the actors in the industry.

¹ Public procurement is regulated by the Public Procurement Act, with the aim to use the public funds in the best possible way (Swedish Competition Authority, 2012. The Swedish Public Procurement Act – an introduction. Swedish Competition Authority (Konkurrensverket), Stockholm, Sweden.).

The research question will provide a description and analysis of the current situation for rail and road infrastructure management, investigating both advantages and disadvantages. The question has a Swedish focus, but comparisons will be made with other countries with similar conditions. The way information and knowledge is managed as well as the relationship between the actors are investigated and discussed related to the contracting forms used. This information is needed to understand the context for further investigation in RQ2-RQ4.

In Section 1.1.1 the importance of making decisions early in design process was discussed. This research seeks to explore whether a life-cycle perspective could contribute to a more resource-efficient infrastructure, which is the purpose of RQ2.

RQ2: In what ways could a life-cycle perspective affect the resource efficiency of rail and road infrastructure?

Can the infrastructure be built in a more durable way, and are there other priorities when also including the maintenance phase in the contracts? These are the types of questions that RQ2 aims to discuss, both by constructed scenarios and through already realized projects, to gain knowledge of actual outcomes of contracts with a longer perspective than traditionally found in this industry. Since the development for road infrastructure is ahead of rail infrastructure, it is important not only to investigate these projects for future road projects, but also to clarify what can be extrapolated to rail.

The role of information has been emphasized in the literature for many reasons. The need for feedback of accurate information from the use phase to the design phase to be able to improve the product and service is one reason. Also, the information asymmetry between the actors could be a reason to change the business model to make sure that the actor with information has the possibility to use this knowledge to improve the infrastructure. This provides the motivation for RQ3.

RQ3: How can information and knowledge sharing between actors contribute to more resource-efficient solutions and more effective management for rail and road infrastructure?

The multiple actors involved and the many different technical disciplines call for collaboration and coordination between them, as described in Section 1.1.2. Performance-based long-term business models provide incentives for increasing information and knowledge transfer; see e.g. Meier et al. (2010), Sundin and Bras (2005), Sundin and Lindahl (2008) and Windahl (2007). The use and improvement of information and knowledge transfer, in combination with long-term business models, is therefore interesting to explore.

Going from traditional short-term contracts with content and processes specified in detail to long-term performance-based contracts implies uncertainties and changes in risk for the involved actors. What are these uncertainties and risks, and how should the risks be

managed and by whom? Furthermore, the fact that the actors within this industry are risk-averse makes the focus on risk and uncertainties even more important. This is because their attitudes towards risk can hinder them in developing new solutions and working procedures. All these questions are included in RQ4.

RQ4: What are the uncertainties and risks from the actors' perspective when using business models based on performance and a life-cycle perspective for rail and road infrastructure, and how can they be managed?

In this research the actors in focus are the buyer and the contractor, since they are the two contracting parties. However, the design consultant is also important for the design and life-cycle focus of the research, and is therefore also included. There are many more actors involved in a rail and road infrastructure project, such as the sub-contractors, but they are not included here.

1.3 Limitations

The scope of this thesis is to explore effectiveness and efficiency in a qualitative way, and not to quantify these aspects. The focus is on the interaction between the actors and the processes used to design, construct and maintain the infrastructure. The end-of-life for the infrastructure is not included, however, since the focus is on the contracts and interaction between the actors and the end-of-life is not part of the contracts at the moment. Also, the long life-time of the infrastructure suggests that design, construction, maintenance and end-of-life activities would not be included in the same contract. For rail and road infrastructure the construction requires large amounts of resources and the overall environmental pressure depends substantially on this and less on the later phases (Mroueh et al., 1999; Svensson, 2006). Furthermore, tracks, which make up 77 % of the total energy use in the construction phase, are used on the main line for 20-60 years are later reused on regional lines for another 140 years before reaching their end-of-life (Svensson et al., 2006). This provides motivation for the focus on the earlier life-cycle phases in this research.

Rail and road infrastructure face similar challenges, but the main focus is on rail infrastructure since the availability problems are more severe there due to interconnection of the rail system. Also, rail infrastructure is more regulated, posing problems with changes in general. This means that road infrastructure is used to support and complement the research. The research is limited to state-owned rail and road infrastructure, which constitutes the majority of the infrastructure in Sweden.

The rail and road infrastructure industry is regulated by the Swedish Public Procurement Act, which affects the market. However, the mechanism behind this will not be discussed in this thesis. Instead, the focus is on contracts used and the relationship and interaction between the actors in the industry. Furthermore, how the infrastructure projects are financed

is not included, e.g. Public Private Partnership. This research does not focus on the source of the funding for infrastructure projects, but rather on the management of them.

2.

METHODOLOGY

This chapter presents the overall research design and the research process, followed by sections describing each included study. Thereafter, the methods for data collection are presented, as well as the research design for each research question. The last section describes how the quality of the research has been managed.

2.1 Overall Research Design

This research starts from the view that a life-cycle perspective in design has the possibility to improve a large technical system. Adding to this, it was suggested in the Chapter 1 that a performance-based business model creates incentives for resource efficiency. Based on this, the aim of the research is as follows: *explore and propose a more effective management of rail and road infrastructure and the possibility of a more resource-efficient road and rail infrastructure by applying business models based on performance and a life-cycle perspective.*

This aim is of an exploratory nature, since it provides fundamental knowledge and understanding about an area of interest, as well as input to better narrow down the research for further investigation (Yin, 2009). Not much has been done before in the area of IPSOs for large technical systems such as rail and road infrastructure. RQ1 and RQ2 are questions asking “what” are the current challenges, and in “what” way could a life-cycle perspective affect the infrastructure. Typically, questions using “what” as an interrogative are exploratory (Yin, 2009). However, the research also has explanatory features which depend on the characteristics of the research questions that were derived from the overall aim. RQ3 and RQ4 have explanatory features asking “how” information and knowledge can affect the infrastructure and “how” uncertainties and risks can be managed, with “how” being an explanatory question used for explaining operational links (Yin, 2009).

The research primarily has a qualitative approach, but some elements of quantitative methods were introduced as well to further establish the quality of the results.

2.1.1 Unit of Analysis

This research focuses on management of rail and road infrastructure projects. When determining the unit of analysis, one should think about what it is that they want to deliver at the end of the research (Patton, 2002). The main focus is how the infrastructure can be designed, constructed and maintained in a more resource-efficient and effective way. This means that the unit of analysis for this research is rail and road infrastructure projects. The unit of analysis affects the choice of sampling and how the sampling is done (Patton, 2002). This is why it has been important to have a clear picture of the unit of analysis when Studies 1 - 3 were planned and realized.

2.1.2 Approach

This research has an industrial issue in focus, the management of rail and road infrastructure, where from observation it has been made clear that there is a need for improvement (The Swedish National Audit Office, 2010, 2011). Also, previous research within the area of IPSOs has concluded that this concept has great benefits, and is especially interesting to apply to e.g. products with long life-cycles, considerable cost if not working properly and high maintenance costs (Tukker and Tischner, 2006a). These characteristics all apply to rail and road infrastructure. The parallel start in both theory and an empirical setting made inductive and deductive approaches a non-fit for this research. Instead, the

research has an abductive approach (Dubois and Gadde, 2002). In this approach, the intertwined nature of the different activities in the research process and the need to go back and forth between framework, data sources and analysis is key.

The theoretical foundation in IPSOs does not include much about this business model adapted to or tested for large technical systems. Therefore, not all the theory was known from the start of the research. However, general themes for IPSOs in other contexts were known, and these were used as a guide. Furthermore, the results from the data collection in this research led to changes in the theoretical framework, making the research process non-linear, which is a characteristic of an abductive approach (Dubois and Gadde, 2002).

This research not only tries to suggest improvements for the rail and road infrastructure management, but also attempts to draw theoretical conclusions, thus adding to the IPSO research area. As for an abductive approach described by Gadde and Dubois (2002), the aim is not to invent new theories but rather to refine existing ones.

2.2 Research process

In this section, the research process is explained through the different studies and papers, which are summarized in Table 1. This research started with a funding possibility from the STA to investigate the possible use of the IPSO concept for rail infrastructure. This first part lasted almost three years, up to the author's Licentiate thesis, and includes Study 1. Paper 1 was developed from the initial literature; when the literature review was completed, the empirical data collection phase started.

Table 1: Presentation of the papers, conferences and journals included in this research.

Paper	Presented at conference	Status
Paper 1	3rd CIRP International Conference on IPS ² , Braunschweig, Germany, 2011	Peer reviewed. Included in conference proceedings, Springer.
Paper 2	Greening of Industry Network, Linköping, Sweden, 2012	Accepted for Journal of Cleaner Production
Paper 3	The 6th CIRP Conference on IPS ² , Windsor, Canada, 2014	Peer reviewed. Included in proceedings of Procedia CIRP, Elsevier.
Paper 4	Not presented	Draft. To be decided
Paper 5	Not presented.	Accepted for Through-life Engineering Services: Motivation, Theory and Practice. Springer

The data collection consisted mostly of interviews, and it took a long time to find the right people to include in the study, even though the respondents themselves helped with the snowball sampling. From this work, Papers 2 and 5 were developed. The time leading up to the Licentiate thesis also included two conference papers and a book chapter.

After the Licentiate, the plan was to perform a quantitative analysis using scenarios. This is where Study 2 began, but the original idea was not feasible without the funding and support needed from the STA. The empirical part of Paper 3 took almost a year to complete, and ended with only the description of the scenarios since no quantitative data could be collected.

Instead of going deeper into quantifications of environmental impact and life-cycle cost, the decision was made to look deeper and wider into other areas that were indicated in Study 1. This resulted in Study 3, partly included in Paper 4 as well as in the Case report in Appendix I.

2.3 Initial literature study

The research started with an extensive literature review, which was used to help guide the direction of the research and to formulate the research questions, see e.g. Merriam (1994). The aim was to gain knowledge about previously realized IPSO contracts or similar ones, and the results from the literature study are the basis for Paper 1.

The focus was on the long-term aspect, performance aspects and also on larger and complex contracts. Keywords, such as long-term contracts, rail infrastructure, IPSO/PSS contracts, performance contracts, Design-Build contracts, were used to narrow down the search to relevant literature. The study mainly focused on rail and road infrastructure but also included other systems such as aircraft industry since IPSO contracts have been implemented there and availability is, just as for rail infrastructure, a very important factor. Also, since very little has been done in the area of IPSO for rail and road infrastructure, it is of great interest to investigate what other areas have learned in terms of benefits and challenges when implementing IPSO. The study focused on Scandinavia but also included an example from the UK. The search did not only include scientific articles, since the information concerning the use of IPSO contracts for rail and road infrastructure was limited to just a few sources. Therefore, reports, homepages, masters theses as well as doctoral and licentiate theses were included.

2.4 Study 1: IPSOs for Rail Infrastructure

This study focused on rail infrastructure and is the basis for Paper 2 and 6 and the main part of the study is an interview study with 14 respondents, with results validated through a questionnaire with the respondents. A focus group was conducted at the end to take the empirical information one step further and acquire even deeper knowledge. This interview also functioned as a validation of the results from the other interviews. This means that in this interview study, the information was validated through three different data collection methods, and checked from the perspectives of both the STA and the contractors.

Most of the description of the empirical data collection in Study 1 presented in this section is similar, or based on, the Methodology chapter in the author's Licentiate thesis (Lingegård, 2012).

2.4.1 Interviews in Study 1

The main theme for the interviews was IPSO contracts for rail infrastructure, and both the buyer and the contractor sides were included. The aim was to gain knowledge about the actors' perspectives and their interactions. Semi-structured interview guides, one for the buyer and one for the providers, were used based on the initial literature study, as well as an initial clarification interview with a respondent from the STA, who also validated the guide. This type of preliminary interview can be used to pin down the important areas and themes as well as to help make the respondents open up about them (Bell, 1999). Interview guides were used during the interviews to provide support and structure. However, as Bryman and Bell (2011) state, the questions do not have to be asked in a specific order and there is room for flexibility during the interview. The core of the guide was the same for all respondents, but the questions were angled differently, depending on if the respondents were from the STA or were contractors, Appendix II.

Selection of respondents

The STA is the main buyer of rail and road infrastructure in Sweden, making the choice to interview employees from this organization an easy one. It was of importance to include respondents from both the Investment Division and the Traffic Division to have the whole life-cycle of the rail and road infrastructure represented. Furthermore, the choice was made to interview respondents on a managerial level, since an overview of the organization and an understanding of the strategy and market was needed for the interview study. The initial clarification interview provided information not only concerning the research topic, but also regarding potential respondents within the STA that could be of interest. This was a type of snowball sampling that could be used to contact respondents when there is no real sampling frame (Bryman and Bell, 2001). Subsequently, the respondents themselves suggested others as potential respondents during the course of the interview study. This showed that they had understood what information was needed for the study. The interviews were mainly conducted during 2010. The respondents at the STA are presented in Table 2.

Table 2: Respondents within the STA.

STA Divisions	Position	Interview duration (min)	Mode
Procurement	Supply Chain Advisor	63	Phone
Maintenance	Operative Maintenance Control	50	Phone
Maintenance	Procurement Manager	37	Phone
Maintenance	Business Developer	66	Phone
Investments	Operative Procurement	42	Phone
Major Projects	Operative Control and Coordination	62	Face-to-face
Investments	Top Manager	66	Face-to-face

Additionally, the CEO of Arlandabanan Infrastructure AB was interviewed during 60 minutes. This is since the Arlandabanan project is the only IPSO project realized in Sweden for rail infrastructure.

Swedish industry is not that large, which results in only a few larger contractor organizations. The respondents at the STA provided contact information to their contacts within the contractors' organization, another example of snowball sampling. However, some of the contractor respondents were contacted without help from the STA. Two of the contractors were general construction companies, while the rest were specific railway contractors. The respondents worked in managerial positions, and a few respondents worked in the maintenance area. This contributed to the total picture of the contractors' perspective concerning the operations and strategies within their own companies, as well as information regarding the relationship and interaction with the STA. The respondents within the organization of the contractors are presented in Table 3.

Table 3: Respondents among the contractors.

Contractors	Position of the respondent	Interview duration (min)	Mode
Contractor A	Regional Business Manager	60	Face-to-face
Contractor B	Marketing Manager	41	Phone
Contractor C	Marketing Manager	54	Face-to-face
Contractor D	Business Area Manager, Maintenance	37	Phone
Contractor E	Business Area Manager, Maintenance	52	Phone
Contractor F	Project Manager	52	Phone
Contractor G	Marketing Manager	63	Face-to-face

The interview study was concluded when the results indicated that further interviews would not contribute with new information; that is, theoretical saturation had been reached (Eisenhardt, 1989). Interviews with additional respondents from different divisions of the STA could have provided additional, but not necessarily useful, information. Interviewing those in more operative positions would have provided more detailed information about operations and implementation, but at this stage this was not the type of information preferred. What was really needed was more in-depth information; this is why the decision to gather a focus group was made.

Analysis of the interviews

The interviews were recorded, which made it possible to transcribe them afterwards. This was not done literally; rather, the content of the interviews was condensed into summaries focusing on the essence of the information. Some quotes, however, were written down word for word to be used later in the results. The data from the interviews was sent to the respondents as a validation check. In this way, the credibility of the study was improved by respondent validation (Bryman and Bell, 2011).

The transcribed information was compiled for each interview and structured in the different topics of interest using the concentration approach. This means that the information is formulated into shorter, more concise sentences (Kvale, 1997). Benefits and challenges for the current contracts, as well as for IPSO contracts, were derived and compared. The comparison was made both within the group of contractors and within the respondents from the STA, as well as between the contractors and the STA. Benefits and challenges were concretized from the transcriptions along with the motivation behind them. The different benefits and challenges were listed, and depending on how many of the respondents mentioned a specific benefit/challenge, they were seen as more or less essential. If the benefit/challenge were indicated by at least two of the respondents, it was later used in a survey study to further validate the results.

2.4.2 Survey in Study 1

The aim of the survey was not so much to retrieve new information, but more to validate the results from the interview study and to try and make the respondents narrow down the most important factors in the questionnaire that was sent out to them. The criteria for respondents were that they had participated in the interviews.

The survey was constructed using the Survey Monkey web tool and sent out to the respondents by email. The survey consisted of seven questions and took the respondents approximately five minutes to complete.

There are several different types of questions to use in a survey; in this case, closed questions, open-ended questions and scale questions were used (see e.g. Bell (1993)). The survey began with closed questions, where the respondents were asked to state their name, organization and position. This means that the respondents were not anonymous, and that it was possible to connect the survey results with the interview results. The majority of the questions, however, were scale questions, where the respondents were asked to grade the answer on a scale from 1-5, where 1 = strongly disagree and 5 = strongly agree. The respondents were asked to rank statements derived from the interviews on this scale. The statements represented challenges for the current practice, as well as benefits and challenges for PSS contracts. Information sought for benefits for the current practice was gathered using an open-ended question, since not enough information concerning this had been retrieved from the interview results.

Analysis of the survey

Six out of seven contractors answered the survey, while five out of seven STA respondents answered all the questions and two respondents answered parts of the survey. The results were used to validate the information from the interviews. This was realized by determining that the information was correctly understood, and that the factors identified were in fact important factors. Furthermore, the ranking of the factors was used as an indication of their in-group relationship.

2.4.3 Focus group in Study 1

The purpose of the focus group was to trigger a discussion between experts in the area regarding IPSOs for rail infrastructure. The value of this method is that, as a result of the group dynamic, discussions and aspects are generated that would not appear during individual interviews (Bryman and Bell, 2011). The interaction between the respondents, when for instance they start making comment beyond their original answer after hearing each other's answers, enhances the quality of the data (Patton, 2002). The focus group was unstructured in the way that it only had a few set questions to discuss, but the topic was narrow and focused. Besides being focused on a narrow topic, the focus group also has the advantage that views and perspectives are assessed by the others during the interview (Patton, 2002).

Three respondents from the previous individual interviews participated: the Business Developer for maintenance contracts and the Procurement Manager for maintenance contracts from the Traffic Division, and a top manager from the Investment Division. They were chosen because they represented important areas within the STA, i.e. both the construction and the maintenance perspectives. They had also shown interest in the topic and were open with their ideas and beliefs during the interviews.

The group interview was a recorded discussion lasting five hours, but the topic was continuously discussed during coffee breaks and over lunch. Besides the respondents, three from the research team also participated, mainly as moderators.

Analysis of the focus group

The focus group was recorded and notes were taken at times where important information was discussed. Having the three respondents present at the same time made this group interview different from the other interviews, since the respondents' intergroup discussion brought the topic to a deeper level where arguments that had not previously been raised were presented. The respondents' intergroup dynamic contributed to enriching the information already collected, adding another dimension to the discussion. Additionally, the focus group was a way to validate the information and address remaining questions from previous interviews.

One can argue that the selection of the respondents partially based on their interest in the topic could lead to a bias. However, the respondents were interested in discussing new ways of building and maintaining infrastructure but in no way believed it would be a smooth process to do so. That is, both benefits and challenges for IPSOs were discussed.

2.5 Study 2: Scenarios for railway infrastructure

This study focused on technical changes when introducing a life-cycle perspective for rail infrastructure. The study corresponds directly to Paper 3. The focus was on rail infrastructure in general in Sweden, and interviews were made with respondents from the STA organization. The interviews were of an unstructured character and based on previous

knowledge from Study 1. During these interviews the respondents answered freely while the researcher followed up on relevant topics (Bryman and Bell (2011)). In this study, the respondents were asked to think outside their current practice and describe what improvements could be made to lower the total cost and increase the lifetime for the infrastructure, see interview guide in Appendix II. The respondents were asked: “Consider the possibility of the contractor having the responsibility to design, build and maintain the infrastructure for a longer period of time; what would you do differently in terms of technical solutions?” The reason to use more open questions was to see what areas the respondents focused on and avoid steering the answers. This is the main purpose of this type of interview: to provide maximum flexibility in the way the respondent steers the interview (Patton, 2002).

The respondents were chosen because they have competence about the technical solutions currently used in the projects since they work close to the sites. The snowball sampling explained for Study 2 was used in this study as well, starting with two respondents participating in Study 1. Table 4 presents the respondents. Invitations to participate in the study were sent out to the respondents from the contractors’ organization from Study 1, but no one answered. Therefore, this study lacks the contractor perspective; on the other hand, the STA is an actor that has long-term experience with managing rail infrastructure. However, the new innovative solutions that might be in the minds of the contractors are missing in this study.

Table 4: The respondents for Study 2.

Role at STA	Interview duration [Min]	Mode
Project Leader, Investment	120	Face-to-face
Head of Division, Technology and Environment, Investment	90	Face-to-face
Maintenance Analysis, Traffic	58	Phone
Maintenance Analysis, Traffic	31	Phone
Head of Group, Technology and Environment, Investment	60	Face-to-face
Project Leader, Cost effectiveness	32	Phone
Geotechnical Expert, Investment	15+15	Phone
Supply Chain Advisor	31	Phone
Business Developer, Traffic	36	Phone
Operating Control of Large projects, Investment	42	Phone

Complementing information has also been retrieved from various scientific papers and reports. In some scenarios, additional information about price has been retrieved from a material catalogue published on the STA’s homepage (The Swedish Transport Administration, 2013b).

Analysis of the interviews

Scenarios can be constructed in different ways and can be a catalyst for creative thinking and analysis (Anderberg et al., 2000). This study used a scenario approach, meaning that scenarios were used to describe possible changes when adding a life-cycle perspective.

In Paper 3 the assumptions for the scenarios, such as background information and geological preconditions, are presented. It is important to provide information about assumptions made, sufficient detail for the specific study where the scenario is used, and to be concrete enough to analyze in practical terms (Anderberg, 1989). During the interviews several respondents had a difficult time to think outside of the current procedures applied within the STA. Instead, information from several respondents had to be used to create some scenarios. However, some of the respondents could provide very concrete information concerning technical changes and the consequences for them. Five scenarios were constructed based on the interviews. The scenarios consist of the standard technology solution used today in Sweden, compared with a solution the respondents thought would be used if they had to think from a life-cycle perspective. For some scenarios information from other sources was gathered as well, e.g. for slab track, since this is an established solution in other countries. These scenarios served as a foundation for a discussion concerning resource efficiency in this study.

2.6 Study 3: Three realized projects

This section describes Study 3 which includes three realized projects, two road projects and one rail project. They were chosen since they represent new ways for contracting used in Sweden.

2.6.1 The Katrineholm project: collaboration and partnering

The road project in this study used a type of partnering between the public buyer, the STA, and the contractor that has not been seen before in this industry. The way it was organized and how information and knowledge was handled provides insight into how the industry could improve as a whole. This project is the focus of Paper 4.

The data was collected using semi-structured interviews with eight project participants, Table 5. The respondents included the buyer, the contractor and the design consultant to grasp the whole picture as well as to triangulate the information received.

The study included both participants with managerial positions and participants that were experts in their fields, such as paving experts. This was done not only to get the top-down view, but also the perspective from a specific technology group within the project. Also, at the beginning of the study it was indicated by the respondents that a different type of technical solution for paving the road had been used, which made it natural to include the pavement experts. However, the skilled workers performing the actual construction work were not included, since the aim of the study was on a more general project level.

Table 5: The respondents in the Katrineholm project.

Role in the project	Party	Interview duration [Min]	Mode
Project Leader	Buyer	76	Face-to-face
Assistant Project Leader	Buyer	86	Face-to-face
Project Leader	Contractor	85	Face-to-face
Quality, Environment and Work Environment	Buyer	68	Face-to-face
Head of Production, Road	Contractor	64	Phone
Pavement Expert	Buyer, Consultant	65	Face-to-face
Pavement Expert	Contractor	54	Phone
Head of Design	Design Consultant	45	Phone

The interviews were semi-structured, as some information was known before from reports about the project. The interview guide used can be found in Appendix II. While some interviews were made face-to-face and others were conducted over the phone, all the interviews were recorded.

Analysis of the interviews

The data from the interviews was summarized and briefly discussed in a report that was sent to the respondents in order to validate the study. The report also included a map illustrating the interaction between the actors and the information flows within the project, which was later used in Paper 4 as well.

The data from the interviews was synthesized into different parts using the validated report as a basis. First, the collaboration and partnering in the project was analyzed to be able to understand how information and knowledge was transferred in the project and if it was the partnering that contributed to this. It was further investigated if the increased information flow and knowledge integration in the project resulted in any gains in effectiveness and efficiency. This was discussed from a qualitative point of view based on the respondents' description of the projects as well as the actual outcome. Also, the choice of technical solutions was discussed from both the resource efficiency and life-cycle perspectives, along with its implications for the infrastructure. This study served as a direct input to Paper 4 and contributes to the discussion of the research questions in this thesis.

2.6.2 Road and rail projects with new perspectives

The second project, called BanaVäg Motala-Mjölby, was large and included one road and one railway part. The data from this study can be found in the Case report, Appendix I. The road project will be described first.

Three road projects, using the approach of including construction and a longer maintenance period in the same project, have been realized in Sweden so far. One of these projects, Riksväg 50 (Case I), was included to be investigated in this study since it includes this rare

life-cycle perspective. The construction phase of this project is completed and the project has now entered its 20-year-long maintenance phase.

A major input for this project was a "theme day" organized by the STA in February 2014 where both the buyer, the STA, and the contractor, the NCC, presented their reflections about the project. This day was then complimented with semi-structured interviews, using an interview guide, Appendix II. For this project, the contractor is in charge and has the responsibility which is why it made sense to interview the Project leader for the contractor. However, it is also of importance to learn the perspective of the buyer, which is why the buyer's Project leader has also been included in the study. The respondents are presented in Table 6.

Table 6: The respondents included in the BanaVäg Motala-Mjölby project.

Role in the project	Party	Interview duration [Min]	Mode
Project Leader, Road	Contractor	43	Phone
Project Responsible, Road/Rail	Buyer	91	Face-to-face
Project Leader, Rail	Contractor	47	Phone

The rail project, Bana Motala-Mjölby (Case II), used a Design-Build approach and was one of the first larger rail projects to do so. The rail project was realized at the same geographical location as the road project, but has not received as much attention as the road project. The reason for this, which was revealed during the interviews, was related to the outcome of the project. The buyer's Project Leader was the same for both projects, providing an overview as well as the buyer's perspective. The Project Leader at the contractor, Balfour Beatty Rail, was interviewed to include the provider perspective. The interview guide, Appendix II, was almost the same as for the road contractor, with only a few words changed.

Analysis of the interviews

The road project was investigated to get the perspective of the buyer and contractor working in what for them was a new constellation, where the contractor is in charge and also has a long-term maintenance responsibility. The interviews were conducted on the managerial level of the project and the data collected was on a general project level, even though the respondents had an understanding of how the operative processes worked.

The rail project studied also contributed with a unique perspective of being one of the first to use a Design-Build approach. The empirical data focuses on the things that worked as well as improvement potentials for this type of contract for rail infrastructure.

The information from the two projects was then synthesized and categorized in a Case report, Appendix I. The analysis from this study serves a direct input to all of the research questions in this thesis, and complements the information from the more extensive interview studies.

2.7 Methods for data collection

The research process consisted of several steps and different data collection methods. This section starts with an introduction to how the research questions and data collection methods are connected. Section 2.7.1 explains how the literature reviews were made, while 2.7.2 describes in a general way how the interviews were made. Table 7 presents when the data was collected.

Table 7: Time periods for the data collection.

Data collection	Time period
Initial Literature Review	November 2009 – March 2010
Empirical Study 1	March - November 2010 + May 2011
Empirical Study 2	September 2012 – February 2013
Empirical Study 3	September - December 2013 & February-April 2014

2.7.1 Literature reviews

During the course of this research, several literature reviews were performed for different purposes. The research started with an extensive literature review, which is described in Section 2.3. While this literature study helped guiding the direction of the research, the main purpose of the other literature reviews was to find literature to compare and contrast the empirical results; see e.g. Creswell (2009). Also, the literature reviews were used to develop the theoretical framework which has been evolving throughout the research and has been inspired by the empirical findings, as suggested by Gadde and Dubois (2002). The reviews were performed within the process of writing the appended papers, and thus focused on the specific scope of the paper. That made the scopes more narrow and the reviews less extensive. Examples of scopes are risk allocation and partnering. However, the reviews were conducted in a similar way using keywords and the reference list in the articles as stepping stones to more references.

Throughout the process, the information has been read in a critical way to understand what audience it was written for and with what purpose in mind; see e.g. Yin (2009). The articles chosen were first of all relevant for the content and context, but when it was possible the number of citations was counted in, since that is an indication of how important the articles are in their specific research topic. This is according to established criteria stated by Merriam (1994) for conducting a literature review. When the same references started to show up in the search the literature review was stopped (Merriam, 1994).

2.7.2 Interview studies

In this research, interviews were the primary method of collecting empirical data. In this case, no other method could provide the type of information needed since it is based on the experience and opinions of the respondents, and therefore could not be found for example in

archives. The interviews give descriptions of the context within the respondents’ work environment and their interpretation of it. This is an example of descriptions that can only be provided by asking the respondents, and then interviews are the only way to do so (Merriam, 1994).

The interviews in Studies 1 and 3 were semi-structured, a type of interview style used to obtain a description of a phenomenon from the perspective of the respondent (Kvale, 1997). Also, in Study 1 a focus group was conducted to gain even more in-depth knowledge. However, the interviews for Study 2 had more of an open character. Three interview studies were performed during this research, and Table 7 presents when they were performed. Interview guides developed for each study can be found in Appendix II.

The interviews conducted for this research were made face-to-face or by phone. Occasionally, some complementary questions were sent with email. All verbal interviews were recorded and later transcribed to ensure quality, dependability and repeatability as well as to reduce the possibility of interpretations from the researcher.

2.8 Research Design for each Research Question

This section briefly explains the research design for each research question. The aim was too complex to investigate without specifying more detailed research questions. However, the empirical data for the research is overlapping for the research questions, meaning that more than one of the Studies 1-3 correspond to each research question. This is natural, since an interview study concerning one specific project includes the whole project, as the project as an item is the most important and the different parts are interlinked and cannot be treated as completely separate items. This is also why the research questions are interlinked, and why e.g. trust is an area discussed for both information and knowledge sharing in RQ3, as for risk allocation in RQ 4. Table 8 illustrates how each paper contributes to the research questions.

Table 8: Studies that were used to answer the research questions. "X" indicates a large contribution, while "x" indicates a smaller contribution.

	Initial Literature Review	Empirical Study 1	Empirical Study 2	Empirical Study 3
RQ1	X	X	x	x
RQ2	x	X	X	X
RQ3		X		X
RQ4		X		x

2.8.1 RQ1: What are the current primary challenges regarding the management of rail and road infrastructure concerning design, construction and maintenance?

The introduction to this research indicates that there are problems with the management of rail and road infrastructure in Sweden. This has also been concluded in reports from the

Swedish Audit Office (2011, 2012). Therefore, the research questions in this study assume that there are challenges, and the aim is to investigate what they are. This question provides the foundation for the coming research questions, since the current state has to be known to be able to suggest changes.

The contracting types used today are mainly found in publications from the STA and different Swedish agencies and institutes. However, to be able to investigate how they work and how they affect the management of the infrastructure, interviews with actors have been made. This was the main purpose with Study 1. The interviews were semi-structured and included both the perspective of the STA and the contractors. The initial interview with a respondent from the STA, and an extensive literature study focusing on different type of contracts for rail and road infrastructure, were used to develop the interview guides. Additionally, the results from the interviews were validated in a survey sent to the respondents.

This question is not only descriptive but explanatory, especially when investigating the actors and their involvement in the contracts. This information is needed to understand the context for further investigation in RQ2-RQ4.

2.8.2 RQ2: In what ways could a life-cycle perspective affect the resource efficiency of rail and road infrastructure?

As stated earlier, the overall aim of this research has an inherent assumption that a life-cycle perspective could improve the management of rail and road infrastructure. In Study 1 the actors indicated general benefits with a life-cycle perspective, but no concrete suggestions were made. Therefore, a new interview study was realized, Study 2, where respondents from the STA were asked for concrete examples of changes if introducing a life-cycle perspective for rail infrastructure. The respondents were asked to think outside the current practice, which turned out to be difficult, and the current practice was clearly hindering them to think in a different way. Employees from the contractor organizations, the providers, were asked to participate but never responded to the request. Study 2 resulted in scenarios for different options for technical solutions as well as indicated the importance of parameters such as availability of the tracks.

Road infrastructure management has come further in developing its contracting forms and has already started to include a clear life-cycle perspective in certain projects. Therefore, Study 3, focusing on projects with different contracting forms, is used to answer this research question. Only the Riksväg 50 project has an outspoken life-cycle perspective. For the other two projects, the Katrineholm project and the Bana Motala-Mjölby project, life-cycle considerations and potential were investigated, making a contribution to this research question. Apart from interviews with the actors in the projects, different types of documentation were used to collect data.

2.8.3 RQ3: How can information and knowledge sharing between actors contribute to more resource-efficient solutions and more effective management for rail and road infrastructure?

The role of information has been emphasized in the literature for many reasons. This question investigates the role of information and knowledge sharing/transfer such as feedback of information within the projects, information and knowledge transfer between actors, how the information is managed etc. In Study 3, interviews with actors in realized projects described for RQ2 were made since new ways of collaborating were used and the actors shared more information and knowledge than in a traditional project. In the rail and road projects for BanaVäg Motala-Mjölby the contractor was in charge, but the STA was present as an active buyer throughout the project. For the Katrineholm project, a unique type of collaboration or partnering was used for a road project.

Furthermore, a literature review focusing on collaboration and partnering was realized to compare with other types of partnering projects and to add a theoretical foundation for the discussion. Additionally, the management of these projects has been compared to traditional use of information and knowledge in rail and road projects to be able to say something about the development.

2.8.4 RQ4: What are the uncertainties and risks from the actors' perspective when using business models based on performance and a life-cycle perspective for rail and road infrastructure, and how can they be managed?

All projects have related risks and uncertainties, but a long-term contract adds more uncertainty since everything cannot be predicted. Also, the fact that the contractor takes more responsibility means that the risk allocation is changed. It has been evident from the beginning that risk is a key parameter for the discussion, partly due to the inherent risk in long-term contracts but also since the interview respondents early indicated risks as a focus area for the industry as a whole. This is why the research question asks "what risk aspects". However, the second part of the question has an explanative focus, asking "how" the risks can be managed.

In Study 1 the respondents were asked about the potential risk factors that would be relevant regarding IPSO contracts for rail infrastructure. Risk has also been present in the investigated road contracts, where it has been allocated in different ways depending on the contracting form. In the Katrineholm project and the rail project for Bana Motala-Mjölby the risk allocation was mostly in focus, while the long-term risks were in focus for the road project Riksväg 50. Therefore, empirical data from Study 3 was also used to answer to RQ4.

2.9 Overall research quality

The research quality has already been partly covered for each of the studies, but an overall discussion is presented in this section. Patton (2002) lists three different methods to ensure the quality of the research: method triangulation, analyst triangulation and theory

triangulation. These three methods will be discussed in this section, and Table 9 presents an overview. In general, triangulation is used to ensure that it is not just one researcher using one single source and one method to derive the result presented (Merriam, 1994; Patton, 2002). Additionally, the transferability or internal validity will be discussed at the end of the section, as this issue has only been touched upon earlier in this chapter and needs more focus.

Table 9: Measures taken to ensure the quality of the research.

Quality strategies	Measures
Methods triangulation	At least two empirical studies and/or an initial literature study for each research question.
	Different sources for data collection used <ul style="list-style-type: none"> • Literature reviews • Interview studies • Focus group • Survey
	Perspectives from different actors include <ul style="list-style-type: none"> • Buyer • Contractors • Design Consultants
Analyst triangulation	Co-authors have validated the process
	Respondents' validation of the interviews
	The interviews were recorded
	Presentations and validation at research conferences, industry fairs and seminars
	Papers 1-3 and 5 have gone through review processes
	Review of Licentiate thesis by opponent
	Review of PhD thesis draft by external researcher
Theory triangulation	Different theories and areas are included
	Literature for both buyer and supplier perspectives
	Benefits and challenges are included

2.9.1 Methods triangulation

This type of triangulation checks the consistency of the findings by using more than one method for the research problem (Patton, 2002). Interviews were the main data source for this study, but literature reviews have also had a major contribution. Below follows a brief summary of the data collection methods for the different studies.

- The initial literature study included a literature search covering a wide range of sources, from scientific articles to project reports.
- Study 1 included interviews and a survey involving both the buyer and contractor, a focus group with the buyer and secondary data.
- Study 2 included interviews with respondents within different divisions of the STA and secondary data.

- Study 3 included interviews with the actors and documents from three realized projects.

The individual literature review and the empirical studies did not employ multiple methods for data collection, except for Study 1. Studies 2 and 3 were mostly based on interviews with actors in the industry as well as on documentation. However, this research is based around the research questions presented in the introduction, and all four research questions are based on at least two of the empirical studies and/or the initial literature review. This means that several different methods and studies are the foundation for the data used to answer the research questions. Overall, there is a consistency in the data, meaning that the different studies provide a coherent picture of the industry. Sometimes the respondents have different opinions about things such as risk allocation, but this is normal in a competitive market. If an overall consistency in the data is found or if reasonable explanations for differences are given, this significantly adds to the overall credibility of the findings (Patton, 2002).

2.9.2 Analyst triangulation

This type of triangulation deals with the bias from the researcher and how the data has been analyzed. The inner validity is assessing whether or not the results correspond well to reality (Merriam, 1994). The research in this thesis is based on the work of its author, but the co-authors of the papers have contributed with guidance and support throughout the process. This is a way to ensure the quality, assumptions and logical connections made are relevant and just. Multiple observers and analysts can help increase the objectivity of the research (Patton, 2002).

To check the accuracy of the data participant validation can be used, where the respondents can react to the descriptions and conclusions (Patton, 2002). This is a way to check if the research corresponds to reality (Bell, 1993). For Study 1, the data summary was sent out to the respondents and the data was validated by a group interview and a survey. In Study 2, the data was not sent out to the respondents but instead checked during the interviews to ensure that the suggestions from one respondent were relevant to the next. For the investigation of the Katrineholm project in Study 3, a report including descriptions as well as discussion and conclusions was sent out to the respondents to validate. The confirmability of the study, that is to what extent the findings are objective (Bryman and Bell, 2011), has thereby been assessed by recording and transcribing the interview and sending the summaries back to the respondents.

Furthermore, the research has been presented in scientific conferences, industry fairs and seminars and thereby has been subject to scrutiny. This is also true for the papers published in journal and book chapters since they all have been under review. This type of audience review increases the credibility of the research (Patton, 2002). The research has also been assessed by experts such as the opponent for the Licentiate thesis and the discussant for the pre-seminar before the actual PhD dissertation.

2.9.3 Theory triangulation

Theory triangulation focuses on having different theoretical perspectives for the same data (Patton, 2002). This research starts with the assumption that a life-cycle perspective can improve the rail and road infrastructure. Also, the IPSO concept is chosen as a way to discuss this life-cycle perspective from the view of a business model and contracting form. However, to be able to discuss the research questions other theory areas are included such as knowledge transfer, resource efficiency, buyer-supplier relationships and partnering. The area of buyer-supplier relationships is e.g. matched with partnering when analyzing the actors' relations with each other.

Furthermore, the difficulties and challenges with IPSOs are not overlooked, but instead investigated further using theories from areas such as risk management, trust and pricing. These three areas are all interconnected, and the price depends very much on the risk and how the risk is allocated. Also, trust depends of the buyer-supplier relationship and how much information and knowledge a party is willing to share. In this way, different theoretical areas were used to address the different aspects of the empirical findings.

Patton (2002) also states the importance of examining the data from different stakeholders' perspectives. This research tries to include both the buyer and contractor perspectives, both empirical and from the literature point of view. In some cases, the design consultants' views are included as well. As stated in the section about methods triangulation in Section 2.9.1, the different actors sometimes disagreed about certain issues. This is a common occurrence and needs to be included to provide the whole picture (Patton, 2002).

2.9.4 Transferability

Transferability deals with external validity and when the results from the studies are useful in other settings (Bryman and Bell, 2011). The rail infrastructure studies are not focusing on a specific project, making the results valid for any type of rail infrastructure project in Sweden and also abroad if the conditions are somewhat similar. Also, as long as the results are not rail infrastructure-specific, e.g. technical solutions regarding shifters, the results are valid for road infrastructure as well. The road studies in Study 3 use specific projects to investigate certain areas of interest, namely collaboration aspects and life-cycle thinking. The conclusions regarding these areas are valid for other road projects as well since they can be discussed on a general level. A further discussion about transferability, how this research can be generalized and its limitations can be found in the conclusion in Chapter 7.

3.

FRAME OF REFERENCE

In this chapter the different theories needed to discuss the aim and research questions of this research are presented. First, a key theory for this research, namely the life-cycle perspective, is presented as well as related theories such as eco-design. Subsequently, Integrated Product Service Offerings are introduced and explained, followed by organizational changes needed for implementation of this business model. The buyer-provider relationship is also explained including the topics of trust and power, followed by a more formalized relationship, partnering. Finally, relevant risk and uncertainties are explained.

3.1 Life-cycle perspective

Flows of material and energy cause a large degree of the environmental pressure on society (Ayers, 1994). The life-cycle perspective is an approach to products, processes and services and acknowledges that all life-cycle phases have environmental and economic impacts (Fava and Weston, 1997). The phases include design/development, resource extraction, production of materials, manufacturing, usage and end-of-life activities (Rebitzer et al., 2004).

Rail and road infrastructure have long lifetimes, around 40-60 years, and during these decades require regular maintenance and reconstruction, as seen in Figure 1. In this research the life-cycle phases included are design, construction and maintenance, as explained in Chapter 1. For certain products it is the initial stages of the life-cycle, i.e. the resource extraction as well as the processing and refining of raw material, that have the largest environmental impact (Clift and Wright, 2000). This is the case for the products within rail and road infrastructure, where the resource extraction and construction of the infrastructure requires large amounts of resources and the overall environmental pressure depends substantially on this (Mroueh et al., 1999; Svensson, 2006). Svensson (2006), noted a case where rail infrastructure included 569 different products ranging from small screws to rails. This variation of different products is one of the characteristics for a large technical system (Markard and Truffer, 2006).

Figure 1: Graph illustrating the cost profile for rail and road infrastructure. Modified from Nilsson (2009).

Dematerialization is one way to achieve more efficient use of resources by reducing the amount of material used without reducing the function of the product, something which can be achieved by cooperation, a focus on functions, reduction of material and energy use, and a value focus (Dobers and Wolff, 1999). This implies a holistic view where products or systems cannot be regarded in isolation to their surroundings, i.e. industrial ecology (Graedel and Allenby, 2003). For this a life-cycle perspective is a key feature, as well as designs to

minimize the environmental impact for the use phase of products (Ehrenfeld, 1997; Graedel and Allenby, 2003).

The effects of a decision at one point in the life-cycle can cause environmental impacts at other stages (Graedel and Allenby, 2003). The importance of making decisions early in the product development process, when there is still freedom to make changes, is illustrated in Figure 2. The further along one travels in the life-cycle process the more the modifications cost, due to the difficulty in making the changes, see e.g. (Boothroyd and Alting, 1992).

Figure 2: The relation between “Freedom of action”, “Product knowledge” and “Modification cost” known as the design paradox (Lindahl and Tingström, 2000).

If compared to Figure 1, this means that for the use phase of the rail and road infrastructure the level of maintenance cost and the reinvestments needed are already determined in the design and construction phases during the first years of the life-cycle. Within the infrastructure industry the earlier in the planning process the provider is involved, the better the opportunities are to adapt the content and the realization of the project to its specific conditions and requirements (Nilsson, 2009).

The design phase has the largest part in the influence on the environmental performance of the product (Lewis and Gertsakis, 2001). By integrating environmental considerations into the different life-cycle phases both environmental and economic benefits can be achieved, e.g. by identifying the material and energy use in the products (Fava and Weston, 1997).

Eco-design is a research area that focuses on design and development which aims to reduce environmental impacts as well as to continuously improve the environmental performance of the products throughout their life cycle (ISO 14006, 2011). This could be done through different strategies such as reducing the material used, using cleaner techniques, reducing

environmental impact from the use phase and optimizing the product life (Roy, 2000). However, there are limitations to eco-design techniques, such as lack of service focus and customer value (Sakao and Shimomura, 2007). Furthermore, most eco-design methods have an emphasized focus on the operational level rather than the strategic level (Maxwell and van der Vorst, 2003).

3.2 Integrated Product Service Offerings

Previous research has suggested a business model including a life-cycle perspective is a way towards dematerialization (Ayers and van den Bergh, 2005). Using more durable materials and other designs may prolong the lifetime of the product and potentially optimize maintenance and operations (White et al., 1999). Furthermore, shifting the focus from product sales to selling the function of the product will affect environmental soundness since it would be worth designing for durability (Lelah et al., 2011; Lindahl et al., 2014; Mont, 2008).

Many different definitions and names exist for contracts or business models based on performance or function (Ng and Yip, 2009; Ng et al., 2009; Nilsson et al., 2006a; Sakao and Shimomura, 2007; Zietlow, 2004). Further developments of these models are the ones including a systems approach, where the life-cycle of the product and service are included (Alonso- Rasgado et al., 2004; Brady et al., 2005; Goedkoop et al., 1999), as seen in Table 10. Additionally, some business models take the life-cycle approach one step further and emphasize the integrated development of the product and the service for the offering (Lindahl et al., 2009; Meier et al., 2010; Meier et al., 2005).

Table 10: Names and definitions for business models based on performance.

Name	Definition/description	Reference
Outcome-based contracting	"...a contracting mechanism that allows the customer to pay only when the firm has delivered outcomes, rather than merely activities and tasks."	(Ng et al., 2009, p. 1)
Performance-contracting	"The contract terms are based on that future users are given access to some specific services, not on the contractor fulfilling technical specifications: it is the performance of the asset over the contracting period that matters."	(Nilsson et al., 2006a, p. 7)
Performance-based contracts	"...are about contracting on performance, rather than tasks or outputs by the service provider."	(Ng and Yip, 2009, p. 207)
Performance contracts	"Performance Contracts are defining a product and it is up to the contractor how to achieve this. Therefore, work selection, design and delivery are all his responsibility."	(Zietlow, 2004, p. 3)
Solutions projects	"...solutions projects usually include the responsibility for the provider to manage, resource, support and improve the delivery of the solution through the life of the product or system in use."	(Brady et al., 2005, p. 364)
Functional sales	"The customer purchases a function and the hardware plus service includes the totality of activities that enable the	(Alonso-Rasgado et al.,

Name	Definition/description	Reference
	customer to benefit from a total functional provision.”	2004, p. 515)
Product service system, PSS	“a system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact than traditional business models”	(Mont, 2002, p. 239)
Industrial Product Service System, IPS ²	“...is characterized by the integrated and mutually determined planning, development, provision and use of product and service shares including its immanent software components in Business-to-Business applications and represents a knowledge-intensive socio-technical system.”	(Meier et al., 2010, p. 608), originally in (Meier et al., 2005)
Integrated Product Service Offering, IPSO	“...from a lifecycle perspective, to offer and optimise a solution with a combination of products and services that satisfies an identified customer needs”	(Lindahl et al., 2006, p. 1-2)

In this research the Integrated Product Service Offering business model, or IPSO, will be used, as the importance of a life-cycle perspective has been pointed out as well as the performance of a product instead of the product itself. Furthermore, the choices made in the design phase affect the whole life-cycle, and Figure 2 points out the importance of making those choices from a cost perspective as early as possible. For rail and road infrastructure, this means that the choices made early in the life-cycle will affect the infrastructure for several decades, showing the importance of an integrated business model such as the IPSO.

The IPSO has a life-cycle perspective and includes large parts of the value chain in an integrated offering that instead of selling physical products provides functions, service and performance (Sundin et al., 2006). In this thesis, performance-based IPSOs, where the provider delivers an agreed upon result but how they achieve it is not regulated (Tukker, 2004), are discussed.

In previous research the following characteristics are mentioned as well-suited conditions for a long-term business model based on performance (Tukker and Tischner, 2006a):

1. Products with high cost of operation and maintenance.
2. Products which require special competences in the design and use phase of the life-cycle
3. Products with significant consequences or/cost if not used in a proper way
4. Products with long lives

3.2.1 Drivers for IPSOs

The IPSO gives the provider a possibility to increase the value of the solution for the customer by integrating components to work together in new ways (Brady et al., 2005), and thereby serves as a driver for the development of technical solutions (Lindahl et al., 2006). New technical solutions can also be drivers for new IPSOs. Furthermore, the provider needs to be competitive, which requires a minimum use of resources for a maximum utilization of the element in the offering (Meier et al., 2010). This focus on dematerialization is in line with

the key aspects of industrial ecology (Ehrenfeld, 1997). This means that the provider will try to achieve the most cost-efficient way to design and deliver a system (Tukker, 2004). The product and service are required to work as an optimal offering by e.g. minimizing downtime on products by making them easy to maintain (Kindström and Kowalkowski, 2009). Consequently, there are incentives for the provider to realize improved economic and environmental development when considering the whole life-cycle (Lindahl et al., 2006; Lindahl et al., 2014).

The IPSO could be initiated by the provider to generate growth or a continuous revenue stream throughout the whole life cycle of the product (Brady et al., 2005; Mont, 2002). Other internal drivers for the provider are resource management and environmental improvements (Mont, 2004). The external drivers vary depending on the industry sector. In a mature market such as for the rail and road infrastructure industries it can be difficult for providers to differentiate. This is due to standardized technology, which makes the competition focused on price and subsequently results in low profit margins (Mont, 2004).

3.2.2 Industry examples of IPSO implementation

In this section, examples of implemented IPSOs are presented. The examples, representing different industry sectors, were collected from different research groups in Europe.

BT Industries

BT Industries is a global forklift manufacturer owned by the Toyota Material Handling Group. The company provides forklifts on a long-term rental basis with the aim to provide customers with a forklift function at the lowest price (Sundin E. and Bras B., 2005). The rental solution includes forklifts, maintenance, spare parts and driver training and can be complemented with back-up trucks during peak seasons (Kowalkowski, 2008). Information is gathered, by maintenance personnel or software solutions, from products in use at the customer site to better control the fleet of rental forklifts (Östlin et al., 2008). After use, the product returns to the seller and a remanufacturing operation is realized (Östlin et al., 2008). The idea behind the solutions is that the customers should focus on their core business and let BT Industries take responsibility for the material handling (Sundin E. and Bras B., 2005). By doing so, customers know the cost of their material handling in advance and avoid having capital tied up in forklifts (Kowalkowski, 2008). For the customer, this implies less risk as well as more flexibility (Sundin E. and Bras B., 2005).

Danfoss

The description of the IPSO provided by Danfoss has been collected from a case description in a PhD thesis (Matzen, 2009). The company is a Danish manufacturer of refrigeration, heating, and motion control products for a global market, and has traditionally sold controls and refrigeration components to refrigeration equipment manufacturers and contractors. A new service offering called RETAIL-CARE was developed targeting food retail companies with hundreds of stores. The remote monitoring and control functionality of electronic

refrigeration control systems for their offerings range from remote monitoring to project management contracts. Customer training and technical support are examples of services that existed before the IPSO contracts, but they are now a revenue-generating activity instead of a sales support function.

ITT Flygt

Submersible pumps are the most common products provided by ITT Flygt, a leading supplier in this area. The description in this section has been collected from earlier research in the industrial service area (Kowalkowski, 2008). The company has an ambition to offer its customers trouble-free operations and the lowest possible maintenance and energy cost by using advanced monitoring and control systems. The company has related an after-market ladder for the development of service offerings. The ladder starts with part distribution and traditional maintenance and repair, and ends with long-term service contracts such as condition monitoring and operation agreements where the customer pays a fixed price per volume of liquid. In 2008, all the different types of offerings were in place except the last mentioned above. The aim of the service contracts is to create value for customers in the form of reliability, extended product life, cost control, etc. A fixed predictable income and a better position in the replacement business are benefits for the provider, ITT Flygt.

Rolls-Royce

Rolls-Royce, a global manufacturer of gas turbines, provides integrated power systems and services for several different markets for use on land, at sea and in the air (Rolls-Royce, 2011). Instead of selling the engine to the customer, Rolls-Royce leases out “power-by-the-hour” in a Total-Care Package (Baines et al., 2007). The company gets paid based on availability, meaning the number of hours the engine is in use (Erkoyuncu et al., 2011). The company has direct access to the products and can collect data to enable improvements such as increased efficiency and maintenance schedules. This reduces cost and environmental impact (Baines et al., 2007). To achieve this, Rolls-Royce works with a supply chain with 20 worldwide storage locations to be able to optimize support and avoid disruption within its customers' operations (Rolls-Royce, 2011).

3.3 Organizational change

The construction industry is lagging behind in efficiency and incentives for development (Bankvall et al., 2010; The Swedish Agency for Public Management, 2009). The specific characteristics of the construction industry, e.g. regulations, organizational features, lack of long-term relationships, lack of integration in the supply chain and the involvement of many different actors, affect development (Bygballe and Ingemansson, 2014). Intensive interaction during projects can lead to development but project success, learning and innovation are influenced by knowledge-integration capability, i.e. the project organization's ability to turn knowledge into action (Dietrich et al., 2010). Furthermore, there is a challenge in how to connect the specific project with the organization and spread new solutions; it is here that

there is significant improvement potential in the construction industry (Bygballe and Ingemansson, 2014).

3.3.1 The providing organization

For a company to shift to IPSOs instead of selling products and services separately requires an organizational change. The new conditions require that operational and organizational structures for the provider need to be adapted (Meier et al., 2010). For instance, a cross-functional way of working to design an IPSO is a necessity, meaning that representatives from different areas and departments in the provider organization need to be involved (Brady et al., 2005). In fact, this change is considered one of the major barriers for the business model, as it leads to changes both within the organization and in the relationships with other actors (Mont, 2002). Learning and culture can lead to inefficiency if the employees are not willing to explore new ways of doing things, since this could cause them to lose their positions of control and power (Ahmed and Shepard, 2010). Not only do physical elements need to be changed but also existing skills, behavior patterns and work practices, and this raises the barriers for development (Perkins, 2003).

In contrast to traditional product sales the provider does not necessarily transfer the control of the product to the buyer. Instead, in many cases of IPSOs the responsibility of the physical product is retained by the provider (Kowalkowski, 2008). Knowledge of how products are repaired across the entire customer base makes it possible for the provider to optimize maintenance routines and thereby minimize cost, increase availability and reduce product failures (Alonso-Rasgado and Thompson, 2006; Toffel, 2008). This knowledge is not easily accessible for other actors, since it is distinctive to the firm and includes the individual way in which the technology is applied (Trott, 2012). Feedback from the maintenance phase is an important resource of information about the performance of the product and can be used to improve the offering (Goh and McMahon, 2009). In this way the IPSO provider affords a specialization to optimize the processes, and this could lead to an increased eco-efficiency for the company (Manzini and Vezzoli, 2002). However, the feedback from maintenance is often unstructured, unreliable and delayed making it difficult for collection and analysis (Busby, 1998; Goh and McMahon, 2009).

3.3.2 The buying organization

Earlier research has pointed out the difficulties associated with a traditional mindset among buyers (Alonso-Rasgado et al., 2004). This means that buyers focus on the initial product price instead of, in the case of the IPSO, the price for the whole life-cycle, and these two cannot be directly compared. The buyer needs to learn about the cost structure of the offerings; otherwise, this lack of knowledge could serve as a barrier (Mont, 2004; Mont, 2002). There is, therefore, a need for models and tools that can illustrate in a simple way the financial benefits of the offerings (Berggren and Björkman, 2002). Additionally, buyer acceptance of the offering as well as trust between the actors is of importance (Mont, 2002).

3.4 Provider-buyer relationships

Rail and road infrastructure are project-based industries. This means that it is problematic for management relationships due to e.g. the discontinuity of demand and the complexity of the project due to the number of actors involved (Skaates et al., 2002). The short-term interactions and the focus on individual projects make it important to constantly work on the business relationships between projects as well (Skaates et al., 2002). Generally, the providers move from project to project and thereby also from customer to customer, creating a need to start from scratch each time in terms of understanding the customer need (Bygballe and Ingemansson, 2014).

3.4.1 Collaboration between actors

There is great potential for productivity improvements in the construction industry, and collaboration is one way to move forward (Fulford and Standing, 2014). Even though extensive inter-firm collaboration is needed for the construction industry, however, it is not easy to achieve (Dietrich et al., 2010). An IPSO often creates close contact between the provider and customer, resulting in for example customized and improved offerings to better suit the customer (Sundin and Lindahl, 2008; Tuli et al., 2007; Windahl, 2007). The IPSO also implies a longer business relationship that needs to be strong for long-term performance (Meier et al., 2010). However, one of the great challenges with IPSOs is to manage the actors involved (Meier et al., 2010; Mont, 2004). The actors, for example, could be sub-contractors for the provider. Conflicts of interest between the different actors can be one problem (Mont, 2002); uncertainties regarding skill requirements for the actors is another (Meier et al., 2010).

Other barriers are inadequate information sharing, fear of loss of control and a lack of understanding the buyer (Benton and Maloni, 2005). Focusing on teamwork and group efforts rather than rewards and individual effort should result in improved project efficiency, better organizational performance and stronger partnerships (Fulford and Standing, 2014). However, to achieve collaboration quality Dietrich et al. (2010) present five points. Communication, as in a working information exchange between the actors, and coordination, meaning a shared understanding of goals, activities and contributions, are important. Dietrich et al. (2010) also identify the importance of mutual support, i.e. willingness to help each other and be flexible, as well as aligned efforts and contributions. Finally, cohesion and the existence of collaborative spirit are important for collaboration quality. These are similar to the requirements for successful partnering, which are described in Section 3.5.2.

3.4.2 Trust

Collaboration quality is also enhanced by trust among actors (Dietrich et al., 2010). Trust can be defined as:

“the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party” (Mayer et al., 1995 p. 712).

When trust is presented, in a relationship people can achieve constructive interaction without wondering whether the other party has a hidden agenda or for risks of revealing information (Kadefors, 2004).

Evidence from the Canadian construction industry states that the level of trust in general is low between the parties, which indicates the level of existing mistrust (Zaghloul and Hartman, 2003). Research from the UK construction industry shows that relationship quality is mainly driven by interpersonal trust between the provider and buyer (Jiang et al., 2011). The same research also states that confidence and effective exchange are increased by a high level of trust, meaning e.g. that the buyer may share confidential information. To openly share information, e.g. economic transparency with open books, is a way to develop trust (Kadefors, 2004).

The ability to save significant costs in construction is affected by the level of trust in the buyer-contractor relationships (Zaghloul and Hartman, 2003). In Swedish construction projects, however, there are several things that hinder development of efficient relationships based on trust (Kadefors, 2004); detailed specifications and close monitoring of the contractors hinder the development of trust, creating vicious circles of distrust instead.

According to Zaghloul and Hartman (2003), in a high-trust relationship in the construction industry contractors tend to add a lower margin for risk, while a higher margin is used in a low-trust relationship with the buyer. They therefore state that risk allocation is mainly a function of trust or mistrust in the buyer-contractor relationship. Risk and risk allocation are further discussed in Section 3.6.

3.4.3 Power

There are two ways for the buyer to influence a provider; by creating inter-organizational trust, as described above, and through different forms of power (Mayer et al., 1995). Power can be defined as:

“the ability of one individual or group to control or influence the behavior of another” (Hunt and Nevin, 1974 p. 186).

The more power an organization has, the more can it determine its interactions and inter-organizational exchange (Cook, 1977). According to Cook (1977), when the resources mediated by an organization increase, so does its power, and often buyers have power over providers (Kähkönen and Lintukangas, 2010).

Power balanced between the actors supports collaboration, but if there is a dominant actor, it may not be willing to commit (Kähkönen and Lintukangas, 2010). Exploitation of a powerful party can lead to underperformance and disputes, while a good relationship enhances the performance, since uncertainty and vulnerability for the weaker party is lowered (Maloni and Benton, 2000; Nyaga et al., 2013).

3.5 Partnering in the construction industry – a formalized relationship

There are informal relationships on Swedish construction sites between e.g. the site managers of the parties. However, according to Kadefors (2004) the focus for these relationships is on finding compromises and the needs for the production, not on the overall goals and searching for innovative solutions. Previous research shows that in Sweden, the efficiency of the process in the construction industry is perceived as low, as well as the level of formal conflict, and therefore the industry could greatly benefit from partnering (Kadefors, 2004).

Bygballe et al. (2010) conclude that although there is not a single definitive definition for partnering, much of the literature in the area refers to it as:

“a long-term commitment between two or more organizations for the purpose of achieving specific business objectives by maximizing the effectiveness of each participant’s resources. This requires changing traditional relationships to a shared culture without regard to organizational boundaries. The relationship is based upon trust, dedication to common goals, and an understanding of each other’s individual expectations and values. Expected benefits include improved efficiency and cost effectiveness, increased opportunity for innovation, and the continuous improvement of quality products and services” (Construction Industry Institute, 1991 p. 4).

In the construction industry, public procurement is often used and there is praxis for rewarding the lowest bid, which is therefore not necessarily based on the collaboration skills of the contractor. However, Kadefors et al. (2007) discuss the importance of selecting partners that can contribute to the collaboration. The lack of flexibility to develop optimal solutions and the short-term collaboration that public procurement provides are other arguments against partnering in the construction industry (Larson, 1995). The regulations for public procurement and the procedures of tendering are seen as the main contributors to short-term and adversarial traditional contracts (Bygballe et al., 2010). Nevertheless, Larsson (1995) concludes that for the success of the partnering efforts, the choice of a low-bid basis is not important.

3.5.1 Different types of partnering

There are typically two types of partnering: strategic and project. Strategic partnering implies long-term commitment over several projects, while project partnering includes maximizing the outcome from specific projects (Bygballe et al., 2010; Construction Industry Institute, 1991). Partnering can also be divided into different categories, depending on the characteristics of the relationship. Larsson (1995) suggests four different types of partnering:

- Adversarial: the parties focus on their own interests at the other party’s expense, and a lack of trust is present. Legal protection requires considerable time and energy, and superiors resolve conflicts on a win/lose basis.

- Guarded adversarial: there is a lack of trust between the parties, and superiors handle disputes in relation to formal obligations. The parties cooperate within the frame of the contract, which is managed in a formal way.
- Informal partners: individual success is dependent on cooperation, which both parties realize. Cooperation goes beyond the frame of the contract, and disputes are solved by compromises.
- Project partners: the parties work as a team with common goals and have routines for collaborative problem solving in a mutually satisfying way.

Larsson (1995) concludes that superior results in controlling costs, achieving technical performance and satisfying customer needs were realized in partnering projects compared to traditional and more informal partnering. This is supported by Bresnen and Marshall (2000), who state that collaboration can be hindered if there is a lack of a systematic approach to partnering such as supporting systems for training staff.

3.5.2 Successful partnering

Controlling costs, meeting deadlines, technical performance, avoiding litigation and customer satisfaction are all factors used to measure success for partnering (Larson, 1995). Partnering projects have been shown to result in substantial savings; it is not always clear, however, how the benchmarking was done, or if similar savings could have been achieved using traditional contracting (Naoum, 2003).

To achieve successful partnering, Naoum (2003) discusses four requirements: mutually agreed objectives and goals, inter-organizational trust, a mechanism for problem resolution and continuous improvement related to benchmarking. Goal alignment and trust were also two of the points stated by Dietrich et al. (2010) for achieving quality in collaboration.

Economic incentives have the power to motivate in a strong way, but they do not replace the means for motivation and mutual trust (Kadefors, 2004). In line with this, variations in the incentive systems only have a smaller effect on performance, suggesting there are limitations to using incentives (Bresnen and Marshall, 2000). According to Kadefors (2004), previous research studies emphasize mutual goals and soft goals for cooperation before economic incentives. The impact of incentive systems relies on the context, and the effect can be the reinforcing of trust, but not if the intentions of the other party are unclear (Bresnen and Marshall, 2000).

3.5.3 Challenges in partnering

Partnering is however not a universal solution for all infrastructure projects, as stated by several authors (Alderman and Ivory, 2007; Chan et al., 2006; and Gadde and Dubois, 2010). There are several barriers and challenges to achieving successful partnering, and for a project with a public buyer, most of the problems are related to the attitude change needed from the stakeholders (Ng et al., 2002). Larger bureaucratic organizations hinder the implementation and effectiveness of partnering if they are not flexible enough, or if their procedures are too

rigorous (Chan et al., 2006). This is in line with Ng et al. (2002), who state that a lack of flexibility in design modifications as well as unnecessary administrative requirements are major issues in partnering with public clients. Furthermore, the public procurement process is in need of change (Alderman and Ivory, 2007; Black et al., 2000). A lowest-bid procurement process and partnering often coexist, causing an organizational paradox with both a relationship focus and an individual focus on reducing operational costs (Alderman and Ivory, 2007). Ng et al. (2002) discuss how this type of procurement results in low margins, which can divert focus from the partnering arrangement to profit protection. This is because a traditional attitude contradicts the partnering concept.

Black et al. (2000) state that in general the potential benefits of partnering outweigh the challenges, but point out the importance of dealing with cost problems together and therefore having mechanisms for adjusting the price. If not, these issues can result in the parties going back to traditional thinking. This is in line with Ng et al. (2002), who note that public clients can have an inflexible and dominating organizational culture, causing an unwillingness to ease contractors' tight financial situations due to low-margin bids.

Chan et al. (2006) describe partnering as a way for the involved parties to communicate better and avoid misunderstandings. This is a view shared by Alderman and Ivory (2007), but who also state that partnering can be used as a smokescreen to motivate contractors to work harder, while in reality it is still business as usual. Furthermore, partnering can hide the inequalities of power between the stakeholders (Alderman and Ivory, 2007).

3.6 Risk and uncertainty

Uncertainty implies the deviation from the ideal outcome and the actual outcome (Walker et al., 2003) and an inability to plan, but can also be seen in terms of trade-offs between risk and reward (Eisenhardt, 1989). Uncertainties can cause risks if not handled properly, with risk defined as:

“uncertain future events which if they happen will cause significant extra cost or delay”
(Barnes, 1983 p. 24).

There are three types of risk, related to time, cost and performance (Barnes, 1983; Erkoyuncu et al., 2009). Risk in construction is in general the activities that affect the cost, time and quality of a project, and formal risk analysis and management are not used frequently due to a lack of knowledge (Akintoye and MacLeod, 1997).

3.6.1 Risk attitude in the construction industry

Previous research has shown that there is little incentive in the construction industry to make changes in the existing combination of resources, since this is in general deemed to be risky and unpredictable (Bygballe and Ingemansson, 2014). The risk tolerance is different for different stakeholders, and the size of the risk and the return period of the event determine how willing an actor is to accept a specific risk (Cha and Ellingwood, 2012).

The construction industry is mostly risk-averse (Akintoye and MacLeod, 1997; Lyons and Skitmore, 2004; Uher and Toakley, 1999), meaning that actors are willing to sacrifice expected returns to reduce variation in possible outcomes (March and Shapira, 1987). Furthermore, risk-averse decision makers have a tendency to overestimate possible losses (Cha and Ellingwood, 2012). The parties' attitude toward risk has to be considered when setting up the principles for risk allocation (Barnes, 1983).

3.6.2 Long-term contracts and uncertainty

Implementing the IPSO as a business model is not without its challenges; as for any change in the business model, the risks change as well (Nystén-Haarala et al., 2010). An IPSO implies taking over some of the customer's processes, which is a major risk for the provider (Meier et al., 2010). On the other hand, the IPSO also reduces unpredictability and variability of demand during the contract time, which makes risk reduction a driver for the business model (Mont, 2004).

Managing the uncertainties for the whole life cycle at the bidding stage is challenging; the major inputs to calculate the cost are e.g. historical data, supplier inputs and user requirements (Meier et al., 2010). For a new construction project, the design phase is the most important since the final cost is significantly impacted by the decisions made there (Uher and Toakley, 1999). The importance of decisions early in the design phase was also highlighted in Section 3.1. Assumptions concerning equipment failure have to be made as well as a prediction of maintenance activities (Datta and Roy, 2010). Another problem with long-term contracts is the risk of obsolescence, with e.g. a technology or component no longer in use and unable to be purchased (Romero Rojo and Roy, 2009).

3.6.3 Risk allocation between contracting parties

The actor that carries the risk has the incentive to minimize the impact; therefore, it is important that some of the risks related to cost and time are allocated to the contractor (Barnes, 1983). This is supported by (Akintoye and MacLeod, 1997), who discuss how contractors have to carry some risk for there to be innovation initiatives within the construction industry. However, external risks should not be allocated to the contractor since a high-risk premium, i.e. margin, would be used (Barnes, 1983). In general, the risk should be allocated to the party that is in the best position to handle it (Akintoye and MacLeod, 1997), and that assesses it to be the least amount of risk (Barnes, 1983).

The premium an actor charges for taking a risk reflects their willingness to take on a risk, and this depends on several aspects as stated by (Ward et al., 1991). For a contractor to evaluate and price a risk there needs to be enough information to do so. Generally, there is a lack of information about project uncertainties and lack of time to prepare the tender (Ward et al., 1991). Although access and gathering information is important, Mitchell (1995) emphasizes that it is the way the information is used that can reduce the risk. There needs to be a clear understanding of risks, i.e. how to manage and allocate them, before starting the

project (Zaghloul and Hartman, 2003). A contractor should for instance not have to price risks that cannot be quantified to a certain level of certainty due to the small profit margins in the industry (Ward et al., 1991). The risk carried by the contractor should be below the tolerable threshold, since this would ensure a serious contractor and not a gambler submitting a low tender (Barnes, 1983). In general, a trust relationship between the parties should exist for a better risk allocation process (Zaghloul and Hartman, 2003).

4.

RAIL AND ROAD INFRASTRUCTURE – AN OVERVIEW

This section presents a background to Swedish rail and road infrastructure. First, a brief historical overview of rail and road infrastructure in Sweden is presented, followed by the current situation regarding contracts used and the status of rail and road infrastructure in Sweden today. Then, the environmental impact of the infrastructure in Sweden is briefly presented, and examples of rail and road infrastructure projects abroad are described.

4.1 An historical review of the rail infrastructure in Sweden

The history of the Swedish State Railways (Statens Järnvägar), SJ, starts in the middle of the 19th century, when the railroad came to Sweden and was from the start a topic for discussion concerning financing (Tullberg, 2000). In 1939, the Swedish Government decided that the entire rail infrastructure should be state-owned and the tracks should be privatized. The history continues into the 1950s, when the market for the railroad totally changed with the use of private cars, and when SJ began to prioritize important tracks while cancelling others (Tullberg, 2000). When a line started to show losses, the investments in the infrastructure were normally halted (Alexandersson and Hultén, 2008).

During the 1980s, rail traffic increased again due to environmental thinking related to the oil crisis. However, SJ could not handle this increase, and the result was higher costs for the organization. This led to questions about the organization's finances and efficiency, and it was considered unwieldy, reluctant and incapable of change (Tullberg, 2000). In 1988, SJ was divided into two parts: the Swedish Rail Administration, responsible for infrastructure, and a reorganized SJ, in charge of train traffic (The Swedish National Audit Office, 2005). The driving force behind this was SJ's recurring problems (Alexandersson and Hultén, 2008). The organization now had stand-alone business units within the divisions that had their own profit centers, and internal service markets were created (Kopicki and Thompson, 1995).

The split between the rail infrastructure and train traffic functions, as well as increased competition, may have resulted in sub-optimization of the system and loss of economies of scale (Alexandersson and Hultén, 2008). On the other hand, the reorganization was needed for several reasons, e.g. to change the managerial focus from production to customer service (Kopicki and Thompson, 1995). The reorganization of the railways and of the tender system also put focus on operational cost efficiency (Alexandersson and Hultén, 2008).

Since 1995, train traffic in Sweden has been open to competition (Tullberg, 2000). Prior to 2001, the construction and maintenance of the infrastructure were only realized by a single internal organization, Banverket Produktion at the Swedish Rail Administration, but since then are now procured in competition. Infranord (formerly Banverket Produktion) is still the dominant actor in the market (Banverket, 2008).

4.2 An historical review of the road infrastructure in Sweden

The history of the Swedish Road Administration began in 1841, when the Royal Road and Water Administration was trusted with the construction and maintenance of state roads (Graedel and Allenby, 2003).

In 1944 the maintenance of the roads was neglected, and it was decided to include the maintenance of the rural roads as well, as stated in a report by the former Swedish Road Administration (Boehm and Thomas, 2013). The report further explains that the resources increased in the 1950s and many new roads were constructed; there was, however, no long-

term strategy regarding the road infrastructure. In 1967 a new organization took over, Statens vägverk, which focused only on roads, but the organization was difficult to maneuver due to many different administration centers around the country. This led to a new organization to reform this being launched in the 1990s and the different divisions were created, namely construction and design, as a first step in procuring in competition (Boehm and Thomas, 2013). In 2009 the construction was transferred into a company of its own, Svevia, and the design division was incorporated in a new company called Vectura, together with the corresponding part of the Rail Administration's organization.

4.3 The rail and road infrastructure in Sweden today

Since 2010, the organization managing the majority of the rail and road infrastructure in Sweden is called the Swedish Transport Administration (The Swedish Transport Administration, 2010). Additionally, there is another organization, the Swedish Transport Agency, that carries the overall responsibility to write up regulations and ensure that authorities, companies, and citizens follow them (The Swedish Transport Administration, 2013b). This organization is not included further in this research.

There are 98,500 km of state-owned roads and 42,000 km of municipal roads in Sweden, and 16,500 km of railway, whereof 14,700 km are managed by the state (The Swedish Transport Administration, 2014). That means that the STA owns 70% of the road infrastructure and 89% of the rail infrastructure, making it the dominant actor for managing and procuring rail and road infrastructure in Sweden. Figure 3 illustrates the rail and road infrastructure in Sweden.

4.3.1 The procurement process

The STA is divided into two divisions, where the Investment Division participates in the design and construction phase, while the Traffic Division is involved in maintenance phase. Public procurement is used to purchase the management of the infrastructure. The term public procurement means "the measures taken by a contracting authority with the aim of awarding a contract or concluding a framework agreement regarding products, services or works" (Swedish Competition Authority, 2012 p. 4). The act, 2007:1091 – LOU, is largely based on an EU Directive regarding public procurement (Swedish Competition Authority, 2012). Construction and maintenance are traditionally realized in separate contracts that are procured by public procurement, where the lowest cost bid normally wins. The contractors formulate tenders based on requirements and specifications provided by the STA. The STA uses design consultants for the design of the infrastructure, requirements and specifications. The procurement of the construction and the subsequent operations and maintenance are done independently. When a maintenance contract ends, a new procurement process is initiated for a new maintenance contract until a reinvestment is needed to improve the standard of the facility. There is no continuation between building and maintaining, since

these are separate contracts and there could also be separate contractors who win the contracts.

Figure 3: Rail and road infrastructure in Sweden, a) showing the state-owned roads while b) illustrating the state-owned railway (The Swedish Transport Administration, 2014).

4.3.2 The contracts used

The three contract types that are the most common in Sweden are presented here: Design-Bid-Build, Design-Build and maintenance contracts. Figure 4 illustrates the progression of contracts according to the vision of the STA, while Figure 5 shows the construction and maintenance phases for the contracts.

Figure 4: The progress in contract types according to the vision of the STA. Figure based on Sjöstrand (2014) and Finnra (2003).

Figure 5: Illustration of traditional Design-Bid-Build contracts as well as two cycles of maintenance contracts for the infrastructure. For Design-Build contracts the responsibility for the construction phase is shared by the STA and the contractor.

Design-Bid-Build contracts, where the procurer specifies what, how and how much, are the most common contracts within the infrastructure construction industry in Sweden (Nilsson and Pyddoke, 2007; Nilsson et al., 2006b). Typically, the scope of the projects and the detailed design specifications are realized by consultants on behalf of the STA, and the contractor is obliged to realize the project within the set time, price and standard level (Pakkala, 2002).

The choice of tender is mainly based on the lowest price (Hedström et al., 2005). These contracts imply that the procurer carries all the risk, and a maximum roof for the price is set which does not create any incentives for the contractors to make the processes more efficient; instead, they benefit from reaching the maximum sum (Nilsson et al., 2005).

A newer type of contracting for building rail infrastructure is the **Design-Build contract**, where the contractor is responsible for both the more detailed design phase as well as the construction phase (Nilsson, 2009). This provides an opportunity for the contractor to influence the construction. In Sweden, Design-Build contracts have only been used for a few years, and during 2010 only 13% of the building contracts for railway were Design-Build contracts (Olander et al., 2010). However, the STA has a set a goal that 50% of the contracts over 25 million SEK for rail and road infrastructure should be procured using Design-Build contracts (The Swedish Transport Administration, 2012a). The STA has the overall responsibility until the construction phase, where it is shared with the contractor in charge of the detailed design. The overall design has already been determined by the STA with the help of design consultants, and performance requirements are set for the technical standards, but the way in which these requirements are met is the contractor's choice.

Maintenance contracts have used performance requirements since 2005, meaning that the STA procures a set functionality of the track and the contractor decides appropriate measures to take while still considering maintenance regulations (Banverket Produktion, 2009; Riksrevisionen, 2010). The maintenance contracts are 5-7 years and different contractors can win the subsequent contracts. The contractor is responsible for parts of the detailed design, as seen in Figure 5. The function, however, is set on a detailed level. Examples of functional requirements include (Banverket, 2009):

- “The snow depth at the railway yards (...) is not to exceed 200 mm over the top edge of the sleepers.”
- “Clearing of snow around gears (...) on the railway yards is to be executed regardless of snow depth so that full function can be achieved.”

Recently, contracts including **Design-Build-Operate-Maintain** (see the contract type at the top step in Figure 4) have been realized for road projects. One of these projects, Riksväg 50, is presented in the Case report, Appendix I. In this project the contractor has the responsibility for the design, construction and 20 years of maintenance for 28 km of highway and 37 bridges, including a large one crossing Lake Vättern. For this large bridge there will be a fee for travelers as a way to finance the project. The construction phase of the project was finished in 2013, ahead of schedule and within budget.

When it comes to rail infrastructure in Sweden only one project thus far has used a Design-Build-Operate-Maintain contract, and this project also included financing. The shuttle between Stockholm and Arlanda consists of 20 km of tracks, a tunnel and an underground station (Arlandabanan Infrastructure AB, 2010). The construction was finished in 1999 and the contractor consortium receives traveler fees as a way to finance the project. The

companies taking part in the construction sold their shares in the project when the building phase was completed, and new companies are now maintaining the infrastructure. This means that the construction and the maintenance parts are two separate parts lacking continuity. More about this project can be found in Paper 1.

4.3.3 The status of the infrastructure

Rail and road infrastructure have long lifetimes, around 40-60 years and during these decades regular maintenance and reconstruction is needed to maintain the function of the infrastructure. In Sweden, there is an aggregated need for maintenance for the rail infrastructure system. The Swedish Transport Administration (2013a) has concluded that a key factor to a robust system is proactive and planned maintenance. However, it is the corrective maintenance, i.e. handling errors and malfunctions, that is increasing (Government Offices of Sweden, 2010). During the period of 2002-2009 the maintenance cost per track meter for rail infrastructure increased, making the maintenance less efficient (The Swedish National Audit Office, 2011). Furthermore, reinvestments are not conducted to a sufficient extent, and this combined with an increased traffic volume is a major problem (The Swedish Transport Administration, 2011). The expenditure of investments, reinvestments and maintenance of state-owned rail and road infrastructure in Sweden during 2013 was 28.6 billion SEK (3.1 billion €) (The Swedish Transport Administration, 2013c), as seen in Table 11. The number of projects realized during 2013 is also presented in Table 11, showing that a larger number of road infrastructure projects are realized during a year than for rail infrastructure.

Table 11: Expenditures and number of projects for rail and road infrastructure in Sweden during 2013.

	Rail infrastructure	Road infrastructure
2013 Expenditures (investments, re-investments and maintenance)	10.8 billion SEK	17.8 billion SEK
Number of projects (approx.) during 2013 over 1 million SEK	Investments: 207 Reinvestments: 116	Investments: 590 Reinvestments: 0

Every time maintenance is performed or an error corrected, it affects the availability of the tracks to some degree. The parts of the rail infrastructure system that cause most of the delay hours, 60%, are contact wires, shifters, signal control, tracks and positioning systems (The Swedish Transport Administration, 2012b). Mismanagement of the rail infrastructure in Sweden over the past decades has led to a poorly maintained infrastructure and an inefficient organization (Alexandersson and Hultén, 2008; Thompson et al., 1998; Tullberg, 2000).

Considering the large quantities of material used and the importance of availability of the tracks as well as the roads make the rail infrastructure system an interesting candidate for a performance-based business model using a life-cycle approach.

4.4 The environmental impact from the infrastructure

For certain products, such as infrastructure, it is the initial stages of the life-cycle, i.e. the resource extraction as well as the processing and refining of raw material, that have the largest environmental impact (Clift and Wright, 2000). For rail and road infrastructure the construction requires large amounts of resources; the overall environmental pressure depends substantially on this, and less on the maintenance phase (Mroueh et al., 1999) (Svensson, 2006).

For rail infrastructure it is the upstream production stages that are significant, and it is mainly steel, concrete and crushed rocks that contribute to this (Svensson and Eklund, 2007). Rail and road infrastructure have similar foundational construction and crushed rocks are also a major part of the construction of roads. Road infrastructure also consists to a large extent of asphalt layers or concrete and stone materials.

4.5 Rail and road infrastructure abroad

In this section a brief summary of the management of rail and road infrastructure outside Sweden is presented, focusing on a few concrete examples as a comparison to the Swedish case. More projects using integrated approaches for managing rail and road infrastructure is described in Paper 1.

According to Pakkala et al. (2007) the challenges of constructing and maintaining infrastructure is something that many countries are struggling with. Design-Build contracts have been used since the 1990s for road projects, and have become the model preferred for most large and medium-sized projects (Pakkala et al., 2007). Furthermore, Pakkala et al. conclude that the Design-Bid-Build model, where the lowest price is used as criteria for winning tenders, is used in most countries.

4.5.1 Road infrastructure in Finland

In Finland in 2001 it was realized that the infrastructure industry had not developed as well as other industries, due its own game rules and a lack of incorporating life-cycle costs, lowering costs, reducing environmental impact and promoting product development (Finnish Road Administration, 2003). This started the development of procurement methods, reforming the Finnish National Road Administration, and the opening up of competition during the transition period of 2001-2004 (Finnish Road Administration, 2003). Finland has since then further developed its contracts and implemented several road projects using the Design-Build-Operate-Maintain approach, as seen in Figure 4. More about these projects can be found in the literature study in Paper 1.

4.5.2 Road infrastructure in the Netherlands

When Lenferink et al. (2013) describe the situation for road infrastructure management in the Netherlands in the late 1990s it sounds very similar to traditional contracting in Sweden:

separate contracts for construction and maintenance, as well as detailed specifications projects where the lowest price bid was granted the project. Planning processes were slow and completed projects had shortcomings in cost, time and quality (Lenferink et al., 2013).

The development started when contracts for maintenance used performance levels instead of specified products and processes, and the contractors were allowed more freedom to optimize their work (Lenferink et al., 2013). The next step was Design-Build contracts, and nowadays several contracts integrating design, construction and maintenance have been realized. Additionally, in these contracts they use a financing form where the contractor finances parts of the project. In this thesis, the financing parts are not in focus and thus will not be further elaborated on. However, they state that a linkage between construction and maintenance is still uncommon in the Netherlands when planning infrastructure.

Lenferink et al. (2013) further describe the contracts as availability-based and spanning 15-30 years. Context-sensitive criteria are used in the procuring for increased attention between the project and the surroundings, as well as to give more flexibility to the contractors in choosing solutions. On the other hand, the authors state that the construction phase is similar to traditional contracts, with the public authority supervising the process. They also describe that the construction and maintenance parts in the contract are handled separately in the consortia and distributed to the parties in charge, making the life-cycle optimizations limited after the design phase. Finally, Lenferink et al. (2013) conclude that improvements to the infrastructure have been made using these integrated contracts but that there are still considerable improvement possibilities.

4.5.3 Rail infrastructure in the Netherlands

In the Netherlands, a rail infrastructure projects has been realized using a 40 million Euro Design-Build contract including 5 km of double track, a station and a few smaller installations (Laan et al., 2011). The building site was situated in a city center making it a high risk project and therefore a project partnering form was used. The public part and the contractor shared goals and also split the risks 50/50, as well as the of budget leftovers due to design optimizations (Laan et al., 2011). This was beneficial for developing trust between the actors, which led to better problem solving and improved project outcome. Laan et al. (2011) concluded that using partnering provided better alignment of incentives compare to traditional contracts or Design-Build contracts, by increasing the trust between the actors.

4.5.4 The case of the rail infrastructure in the UK

British Rail was privatized in 1997, and its train operations were split into over 90 separate contracts (Shaw, 2001). The railway infrastructure, including track, signaling and stations, was however transferred to one company called Railtrack (McCartney and Stittle, 2010). In 2000 a major accident occurred caused by train tracks that had been broken for months (Shaoul 2006). Railtrack went bankrupt soon after the accident, after trying to fix all the problems with the infrastructure. A new company was established called Network Rail, and

during the first year of its operation expenditures increased 137% compared to the average during the four years before the accident ((National Audit Office, 2011). This indicates that there was a backlog of work to do on the infrastructure. While Railtrack had subcontractors performing all the maintenance and reinvestments, Network Rail has brought this work back in-house (Shaoul 2006).

The Office of Rail Regulation in the UK regulates the finances and safety of the rail industry, while Network Rail is responsible for operation, maintenance, renewal and reliability of the national rail network (National Audit Office, 2011). According to the National Audit Office (2011) the contract is outcome-based to let the company find the most cost-efficient operation. However, the National Audit Office also acknowledges that there is a monopoly situation, resulting in weaker incentives for efficiency. Furthermore, Network Rail is financed by debt guaranteed by the Government and has no shareholders, resulting in a lack of incentives that drive efficiency savings (National Audit Office, 2011). The Government has no formal control over Network Rail and its loans, and so far privatizing the railway system in the UK has been very expensive (Shaoul 2006).

5.

APPENDED PAPERS AND CASE REPORT

This section briefly summarizes each of the appended Papers 1-5, as well as a Case report. Table 12 shows which papers contributed to each of the four research questions.

Table 12: The table presents the contribution of each paper 1-5 to the research questions 1-4. A large X indicates a major contribution to the research question, while a small x shows a medium to minor contribution

	Paper 1	Paper 2	Paper 3	Paper 4	Paper 5	Case report
RQ1	X	X	x	x	X	x
RQ2	x	x	X	X	x	X
RQ3		X		X	x	X
RQ4		x		x	X	x

5.1 Paper 1 – PSS contracts for rail and road infrastructure

Lingegård S., Lindahl, M., Svensson, N., 2011. PSS for Rail and Road Infrastructure, in: Hesselbach, J., Herrmann, C. (Eds.), *Functional Thinking for Value Creation, Proceedings of the 3rd CIRP International Conference on IPS²*. Springer, Braunschweig.

The author of this dissertation conducted the literature study and wrote the paper. Guidance and support was provided by the co-authors.

5.1.1 Aim and method

This paper aims to investigate what types of contracts are used for rail and road infrastructure, to what extent Product Service Systems² are used for rail and road infrastructure, and how these examples are documented. The paper is based on a literature study and focuses on Scandinavia, but also includes an example from the UK.

5.1.2 Main contributions

The paper provides examples of rail and road infrastructure projects where contracts with IPSOs or similar types of contracts have been used, describing two rail infrastructure projects, found in Table 13, and three road infrastructure projects, listed in Table 14.

The paper concludes that currently, Design-Bid-Build contracts, or construction contracts are the most common way to procure rail and road infrastructure in Sweden, while for maintenance contracts more performance-based contracts are used.

All the contracts reviewed in Table 13 and 14, have a life-cycle perspective, and thereby a combination of construction and maintenance is included. However, both the length of the infrastructures and contracts vary. Some contracts also include a finance part, where the private actor finances the whole or part of the construction; this part of the contracts is not further discussed in this thesis. Furthermore, even though the contracts are performance-based there are still detailed requirements from the buyer. For the two rail infrastructure projects the operation of the train is included in the contract, while for the road projects, one of the variable indexes is the variation in traffic volume on the roads.

² Product Service Systems in this paper is equivalent to Integrated Product Service Offerings.

The paper concludes that little has been done, and consequently documented, in the area of PSS contracts for road and rail infrastructure. This is especially true for the rail infrastructure, where few projects have been realized. The lack of publications, in combination with interest from the industry in the field, implies that there is a gap in the area where research is needed—both to facilitate the use of the contracts and to move the research forward.

Table 13: Reviewed contracts for rail infrastructure.

Project	Content	Length	Payment
Arlanda-banan, 20 km (SWE)	Finance, build, operate and maintain.	45 years	Contractor built the tracks and is now leasing them. Ticket revenues.
The Northern Line, 50 stations (UK)	Design, manufacture and service.	30 years	Leasing contract based on a guaranteed number of trains and performance improvement.

Table 14: Reviewed contracts for road infrastructure.

Project	Content	Length	Payment
Norrorts-leden, 7 km (SWE)	Design, construct and maintain.	15 years	Fixed yearly sum based on index Special payment model for tunnels.
E18, 51 km (FIN)	Finance, design, construct, and maintain.	21 years	Initial investment and service fee to contractor depending on availability and service level of the road. Adjusted for change in traffic.
E39, 27 km (NOR)	Finance, design, construct, and maintain.	25 years	Payment depending on availability and standard of the road. Toll system for procurer.

5.2 Paper 2 – Integrated Product Service Offerings for Rail Infrastructure – Benefits and Challenges Regarding Knowledge Transfer and Cultural Change in a Swedish Case

Lingegård, S., Lindahl, M., 2014b. *Integrated Product Service Offerings for Rail Infrastructure – Benefits and Challenges Regarding Knowledge Transfer and Cultural Change in a Swedish Case. Journal of Cleaner Production Special Issue. Accepted.*

The author of this dissertation conducted the data collection and wrote the paper. Guidance and support was provided by the co-author.

5.2.1 Aim and method

The aim of this paper is to investigate potential benefits and challenges regarding knowledge transfer and cultural change from the provider and buyer perspectives when using IPSOs for rail infrastructure. Research areas such as product development, knowledge transfer and networks, as well as literature focusing on the IPSO, are used to discuss the empirical

findings. The empirical part, focusing on the rail infrastructure industry in Sweden, has been collected using individual interviews and a group interview approach. Representatives from the providers, the contractors, and the buyer, The Swedish Transport Administration, have been interviewed.

5.2.2 Main contributions

Traditional construction contracts, Design-Bid-Build, have their advantages, such as being a familiar business model that is straightforward to calculate for contractors. However, the current procurement practice is seen as resource-demanding and inefficient by both buyer and contractors. Examples of this are designs not adapted to the construction causing delays in the process, and lack of information regarding the status of the infrastructure. One reason for this is that contractors have no incentives to provide data from their operations, implying an information asymmetry, or even knowledge asymmetry, between the contractors, the STA and the design consultants. This information could be used to improve the design.

In this paper IPSO contracts for rail or road infrastructure are described, Figure 6. The buyer, the STA, procures performance such as: “build a railway from A to B with capacity C and maintain it for X years. After the contract period the railway should have required capacity Y.” Here, the design of the construction and the maintenance is the responsibility of the contractor.

Figure 6: Schematic figure illustrating an IPSO contract for rail infrastructure (Lingegård, 2012).

An increased contractor responsibility would start a thinking process making use of the knowledge within the contractor organization. In addition, the buyer believes that the contractor would build more durably if they knew they were to maintain the infrastructure for a longer period as well.

However, there are several challenges with a potential implementation of IPSOs for rail infrastructure, which can be divided three categories. First, there are contractual challenges including length of the contract, evaluation and requirement needed, and risk allocation. Second, there are market-related challenges such as the size of the contracts and the need for collaboration. Third, there are organizational challenges to include design competence,

continuity, corporate culture, competence and trust. Some of these challenges are further elaborated on below.

The organization and the culture of the buyer are not adapted to managing infrastructure from a life-cycle perspective. The divisions managing construction and maintenance do not cooperate or communicate much, suggesting sub-optimizations. The buyer and providers see themselves as parties with opposing interests, and this becomes clear when responsibility and risks are discussed with the respondents.

The lack of information and knowledge transfer between the actors and the conservative business culture of the buyer are hindering the management of the infrastructure. Since IPSO contracts imply integration of construction and maintenance, improved information transfer is likely to take place between these phases. By involving the contractors in the design phase their knowledge could be used in a better way, creating a feedback loop from practice to design.

5.3 Paper 3 – Scenarios for Resource-Efficient Rail Infrastructure – Applying Integrated Product Service Offerings

Lingegård, S., Svensson, N., 2014. Scenarios for resource-efficient rail infrastructure – applying Integrated Product Service Offerings, The 6th CIRP Conference on Industrial Product-Service Systems. Elsevier, Windsor, Canada.

The author of this dissertation conducted the data collection and wrote the paper. Guidance and support was provided by the co-author.

5.3.1 Aim and methods

This paper discusses scenarios for increased resource efficiency and more value for the money spent by applying an IPSO perspective to rail infrastructure. The scenarios were developed based on interviews with eight employees at the STA. The scenarios were used to describe possible changes that can be made in building and maintaining rail infrastructure by adding an IPSO perspective.

5.3.2 Main contributions

Five scenarios were developed and discussed, and included choices in technical solutions: track type, number of tracks, steel quality, space between tracks and shape of embankments. “Track type” and “Number of tracks” illustrate how the scenarios are presented in the paper, as seen in Figure 7. For “Track type”, the choices can be made between ballast-free or ballast track types, and thereafter between premium or normal steel quality. The choices affect the need for maintenance and reinvestments in different ways, as well as the availability of the track. For “Number of tracks” there is a choice between double or single track, implying different consequences for maintenance and availability.

The best option of each scenario very much depends on the conditions at the construction site and how critical the availability of the track is. Additionally, there are regulations that hinder the development of the infrastructure, such as land use.

It is important to add that the profitability of the different options in the scenarios depends on which lifetime that is used for calculating the life-cycle cost. Expensive investments normally take a substantial time period to recoup, but this depends on the value that is set for availability of the tracks. However, it can be concluded that no matter how long the calculated lifetime is set for, it is important to actually take it into account and adopt a life-cycle perspective in the design and construction phases.

All of the scenarios have options where the maintenance could be decreased, cutting cost and environmental impact from material and energy use. However, these options add to the construction costs, and given the way the management of the infrastructure is handled today, it is not an option. A life-cycle perspective is needed to see the positive influence on material and energy use as well as availability.

Figure 7: Illustration of two scenarios for rail infrastructure: a) Choice of track type, b) Choice of number of tracks.

5.4 Paper 4 – Partnering – a Way to Reach Resource- Efficient and Effective Road Infrastructure Projects through Increased Information and Knowledge Transfer?

Lingegård, S. 2014. *Partnering – a way to reach resource-effective and efficient road infrastructure projects through increased information and knowledge transfer?* Draft.

The author of this dissertation conducted the data collection and wrote the paper.

5.4.1 Aim and method

The aim of this paper is to investigate implications of partnering as a way to reach more resource-efficient and effective road infrastructure projects through increased information and knowledge transfer. The empirical data was collected using interviews with participants in a partnering project for constructing road infrastructure including buyer, contractor and design consultant.

5.4.2 Main contributions

This was one of the first major road projects in Sweden using partnering, and the project was realized using less time than estimated as well as achieving a lower total cost than budgeted. The buyer and contractor were in a partnering agreement, and there was an outspoken aim to develop the organization into one team with shared goals and an open atmosphere. Open books were used, and there was a high level of trust between the actors. The gains and risk were shared 60/40 between the buyer and the contractor, meaning that the buyer had the power to decide regarding the technical solutions used. Despite this, there was a feeling of equity and all respondents were satisfied with the collaboration.

Representatives from the buyer, contractor and design consultant were co-located, and they all felt this was a good forum to openly and unconditionally discuss the benefits and drawbacks of different technologies and solutions. Active design was used, meaning an iterative process between construction and design, making it possible to be flexible depending on the site conditions. One such change was the use of clay instead of plastic in the ditches, since the quality of the clay at the site was good. This also facilitated future maintenance as well as reduced environmental impact. Maintenance was not included in the contract, but the respondents stated that they would have built some things differently if it had been.

The co-location and the close collaboration led to increased information transfer. Figure 8 illustrates the information and communication flows between the actors in the project. A table describing each flow can be found in Paper 4. Since all actors were part of both the design and construction phases, this improved the process. An example of this is that the design consultants received immediate feedback on the design and could see which solutions would work. According to the design consultant, this type of feedback had never been provided before.

The partnering project was realized with a lower total cost and lower environmental impact than projects using a traditional contracting type. As a bonus, several new resource-efficient technical solutions were implemented. A key factor in the success of the project was the totally different approach to how to organize the network of actors involved, as well as to promote knowledge sharing. This approach added value to the road infrastructure as well as to the actors and organizations that participated.

Figure 8: Information and communication flows between the actors in the project. The striped shapes in orange to the right in the figure are part of the contractor's organization, while the green shapes represents the buyer. The oval boxes represent the respondents.

5.5 Paper 5 – Identification of Risks related to Integrated Product Service Offerings of Rail Infrastructure – A Swedish Case

Lingegård, S., Lindahl, M., 2014. *Identification of Risks related to Integrated Product Service Offerings of Rail Infrastructure – A Swedish Case. Through-life Engineering Services: Motivation, Theory and Practice*, Springer.

The author of this dissertation conducted the data collection and wrote the paper. Guidance and support were provided by the co-author.

5.5.1 Aim and method

This paper aims to identify if IPSO contracts could improve the management of rail infrastructure, and to determine potential risks for both the provider and buyer perspectives. The empirical data is based on interviews with actors in the industry, both buyers and contractors.

5.5.2 Main contributions

The actors in the rail infrastructure industry are generally risk-averse, meaning they overestimate possible losses and want to reduce the variation of the outcomes. This may explain why in the contracts the requirements are specified in detailed, since the buyer knows exactly what will be delivered.

IPSO contracts for rail infrastructure shift the responsibility from the buyer to the contractor, which also implies that the contractor would have to carry more of the risk. An IPSO contract would entail much more risk for the contractor, an uncertainty that seems to frighten them. Considering the fact that the contractors believe there is a risk that the STA will transfer all the risk to them indicates a lack of trust between the parties.

Construction risks are in general activities that affect the cost, time and quality of a project; IPSO contracts also add uncertainty in regard to the long duration of the contract. The risk carried by the contractor has to be reasonable, and most risks that arise externally should be carried by the buyer, since contractors would charge too much to bear them due to their risk-averse attitude. In this case, such risks could be concerning ground conditions that cannot be properly investigated. On the other hand, some of the risks associated with cost and time should be carried by the contractor, since risk and incentives go together, and because the actor who bears the risks has reason to minimize the impact. Both parties have indicated that the evaluation, both during the contract and afterwards, will be difficult. Operationalization of the functional result of the contracts is therefore of importance, as well as to determine precise parameters for evaluation.

The lack of information about the status of the existing rail infrastructure in Sweden affects the choice of appropriate IPSO projects. Reinvestment projects are for instance less suitable since there are many unknowns about the condition of the infrastructure, thus increasing the uncertainty for the projects. This will force the contractors to add high risk premiums to the project cost. The size of the projects also matters; they must be large enough that the contractors could invest in a maintenance organization for the specific contract, and could justify the administrative cost due to regulations, etc.

Furthermore, the price is an important factor for the actors and the buyer prefers a fixed price, while the contractors believe a flexible price is better. In any case, renegotiations are needed to make adjustments e.g. with changes in traffic volume.

To conclude, most of the risks and uncertainties identified by the actors are due to their lack of experience as well as the working procedures used today. In fact, it is only the uncertainty connected to the time dimension of a long-term contract that will always be an inherent uncertainty factor. It seems like the actors lack sufficient knowledge about how to plan and calculate the risk, implying that implementation of an IPSO contract must occur gradually.

An increased level of trust between buyer and contractors could make the process more effective, since less detailed specifications and control of the process would be needed. The

actors have to either embrace the fact that more uncertainties are involved and develop the necessary skills and competence needed to identify and handle these and the potential subsequent risk in a strategic manner, or take the problems as they come in more of an ad hoc way. Most of all, it seems like the obstacle to change lies more in the business culture and attitude of the actors than in technical complications.

5.6 Case report

In this report the empirical data from two cases is presented: the road infrastructure project Riksväg 50 (Case I) and the rail infrastructure project Bana Motala-Mjölby (Case II). The aim of the report is to explore the use of two types of contracts used for rail and road infrastructure. Interviews with the contractors' Project Managers as well as with the buyer's Project Manager were conducted to collect the empirical data.

5.6.1 Case I: Riksväg 50 – a type of IPSO contract

Riksväg 50 was a Design-Build-Operate-Maintain project, meaning that the contractor is responsible for design, construction and maintenance. The project did however have an outspoken ambition to be characterized more by cooperation versus that found a traditional project. The buyer's good relationships with other authorities eased the process, according to the contractor.

The buyer was located a few kilometers away from the site, and the contractor wished for co-location to be able to communicate more. The buyer, however, believed distance to be a good thing to avoid being too involved, and thereby having to share the responsibility. The design consultant working for the contractor was located at the site, and having direct control of the design consultants and getting immediate feedback on the solutions from construction were great benefits, according to the contractor. Also, bringing people from the production in the design phase was important, since they have many ideas. The contractor's Project Leader wished that the construction staff had been more engaged in this process.

The contractor had to use several different design consultants to get enough capacity, resulting in a split of the project into smaller parts. The synching later needed between the parts cost the contractor both time and money. Also, the contractor's organization was similar to one for a Design-Build contract, since according to the contractor the maintenance part was not really represented. This is something that could have been improved upon, and would have facilitated the choice of technical solutions. Examples of solutions chosen with a life-cycle cost perspective are described in the case report.

In general, the contractor believed that the project was excessively steered by a fixed overall design set from the beginning; it would have been better, they felt, if the overall frames were set and then the rest was decided on in cooperation with the buyer. Further description of potential improvements for this type of contract is addressed in the case report.

5.6.2 Case II: Bana Motala-Mjölby: Design-Build contract

Bana Motala-Mjölby was a Design-Build project, where the contractor was responsible for the design and construction of the infrastructure.

For rail infrastructure there are many regulations hindering the flexibility of the contractor. Basically, according to the contractor, the only freedom they had was in what order to build the different parts. Both the contractor and the buyer stated that the outcome of this project was no different than if a traditional contract would have been used.

From the beginning, the design and construction phases were supposed to run in parallel, but due to delays this was not possible and the potential interactions in between were lost. The whole process was ineffective and inefficient, according to the buyer. The contractor used a design consultant that did not have enough capacity, causing a general sense of a lack of control over the overall design from the contractor's side. Also, the design responsibility within the contractor's organization was on the site manager, who was also in charge of the ongoing construction. This turned out to be too much to handle for one person. Inexperience or lack of resources could be why the contractor chose to handle the design in this way, according to the buyer.

6.

DISCUSSION

In this chapter the four research questions are addressed and discussed, one by one. The discussion includes results from the appended papers to some extent, since this is a compilation thesis. However, a new, more general discussion is included as well for each research question.

6.1 Introduction to IPSOs for rail and road infrastructure

Before discussing the research questions it is important to emphasize that IPSOs are not an updated version of the old in-house monopoly that the former Swedish Administration's responsible party for rail and road previously had on the Swedish infrastructure market, as described in Chapter 4. The principal of IPSOs is that one provider has the overall responsibility for the design, construction and maintenance (Lindahl et al., 2006). For example, even though Swedish State Railways (Statens Järnvägar) had the overall responsibility before the rail market was exposed to competition this was not a form of IPSO. This is because the divisions were structured as their own profit centers and an internal market was created (Kopicki and Thompson, 1995). The different parts of the organization cared more about their internal finances than the overall project, which created sub-optimization. Additionally, this internal market was a monopoly situation since there was only one part that constructed the infrastructure and one that maintained it. Thus, without competition there was possibly less incentive for quality improvement or innovation.

The rail and road infrastructure market operates in Sweden within the laws and regulations of public procurement, which adds certain conditions and a different context to the buyer-provider perspective of IPSOs. Hence, the provider in this case cannot change the business model and initiate an IPSO in a way that generates growth and continuous revenue streams; see e.g. Brady et al. (2005) and Mont (2002). Instead, the possibility to change the market lies mainly with the government, and subsequently with the STA. Considering that the STA owns a large part of the rail and road infrastructure in Sweden the organization has leverage in the development. Previous research has concluded that regulatory policies are important drivers for environmental innovations, and that governments have a key position in spreading successful IPSO concepts (Mont and Lindhqvist, 2003). A more durable rail and road infrastructure for a lower life-cycle cost would imply an increased value for the STA, and thereby for society.

Tukker and Tischner (2006a) have listed characteristics for products that are well-suited for a long-term business model based on performance, as discussed in Section 3.2. All these conditions apply to rail and road infrastructure. In a large technical system such as rail and road infrastructure, availability is essential since a disruption can affect other parts of the system; see e.g. Jonsson (2000). This is especially true for the rail infrastructure, where disruptions become even more critical since there are fewer ways to avoid the problem areas than for road infrastructure. The rail and road infrastructure is capital-intensive, with many different technical components as well as various actors and institutions involved, which are characteristics for large technical systems (Markard and Truffer, 2006). The life-cycle of rail and road infrastructure lasts decades and there is a continuous need for maintenance, but at a high cost.

Increased customer value is one of the main benefits for the IPSO business model (Brady et al., 2005). The costs for the rail infrastructure are increasing, and the STA has an outspoken

strategy to improve cost efficiency (Banverket Produktion, 2009; Trafikverket, 2011). The contractors interviewed in Paper 2 hope that IPSOs would make the STA focus less on the initial purchasing price, as they do today, and more on quality and the best solution for the facility by adopting a life-cycle perspective when evaluating the price.

6.2 Current challenges for Swedish rail and road infrastructure

This first section addresses the first research question, RQ1, which asks *“What are the current primary challenges regarding the management of rail and road infrastructure regarding design, construction and maintenance?”*

This research has identified several different challenges for rail and road infrastructure in Sweden. Since the main buyer, the STA, is the same for both types and since the contractors and design consultants are basically the same, the challenges are similar between rail and road. Different types of business models and contracts were presented in Chapter 4 as well as in Paper 1. In this section the different types of contracts used are discussed, including the role of the different actors. Also, the organizational issues are discussed since they clearly affect the way the rail and road infrastructure is managed.

6.2.1 The use of traditional contracts

Traditional construction contracts or Design-Bid-Build contracts have been used to a large extent in Sweden, for both rail and road infrastructure. As explained in Paper 2, the STA argues that one of the advantages with Design-Bid-Build contracts is that they know exactly what will be built. For the contractor it is straightforward to calculate and leave a tender. On the other hand, the STA does not get more than asked for since the contractor only is paid to follow the specifications. Detailed specifications provide no incentives for innovation, since innovation typically comes through the contractor or supplier network (Pakkala, 2002). Instead, the focus is on costs and the winning bids are often the ones with the lowest price. The focus in the standardization phase of a technology cycle should also be on efficiency (Schilling and Esmundo, 2009). Nevertheless, in this case both the respondents in Paper 2, both from the STA and the contractors, claim that the traditional contracting form as well as the way the work is realized is inefficient and time-consuming.

However, for road infrastructure there has recently been a shift to using Design-Build contracts, where the contractor has the responsibility for the design and the construction, providing them with a bit more flexibility. For these contracts the distinct roles for the actors have been an issue and the STA has interfered more than what was initially decided, as explained in Chapter 4. This has sometimes made the Design-Build contracts similar to the construction contracts. So far, only one such contract has been implemented for railway (Case II). In Paper 1, the use of business models such as the IPSO or similar are discussed, with the conclusion that very few of them have been implemented, especially in Sweden. Recently, two road projects, including Riksväg 50 (Case I), have used IPSOs, including

design, construction and a longer period of maintenance. This indicates that the STA is starting to use a new type of business model with a long-term contract.

The situation in Sweden for road infrastructure is similar to those of e.g. Finland and the Netherlands. Finland has had a similar lack of life-cycle perspective for their infrastructure. Nonetheless, in Finland a development of new management techniques of the infrastructure have emerged (Finnish Road Administration, 2003). Additionally, Lenferink et al. (2013) describe the situation for road infrastructure management in the Netherlands in the late 1990s; which is similar to the traditional contracting in Sweden. The Netherlands have since started to reform and use contract integrating design, construction and maintenance (Lenferink et al., 2013). These two examples indicate similar problems as in Sweden but also that reformation of the management of at least road infrastructure are being adopted.

6.2.2 Lack of information and knowledge transfer

The STA has the overall view of and responsibility for the infrastructure when using traditional contracts. This organization should therefore hold information regarding the condition of the infrastructure. However, as explained in Paper 2, this information is not complete; one reason is that the contractors have no incentives to provide data from their operation. This means that information and knowledge gained is not transferred back to the STA and the design consultants when they design the infrastructure. Thereby there exists an information asymmetry, see e.g. van Amstel et al. (2008), or even a knowledge asymmetry, between the contractors, the STA and the consultants. The contractor is the actor that obtains this information, but it is still the STA that decides on the detailed specifications. This means that the improvement potential is not utilized, since the information is not transferred to the party that makes the decisions.

Nor is the information transferred back to the design consultants that create the solutions for the STA. This has been exemplified by the fact that the solutions suggested by the design consultants are not always feasible to build, as described in Paper 2. The contractors realize this in the construction phase, since they have more operative knowledge about the technology than the consultants do. This knowledge is not easily accessible for other actors, since it is distinctive to the firm and includes the individual way in which the technology is applied (Trott, 2012).

The construction process then has to be stopped while the design is reworked, losing time and money while the project is delayed. This is an example of the cost overruns that are usual for this type of contracting (Pakkala, 2002). Design and performance of a system can be improved by using knowledge about the system performance (Geyer and Davies, 2000), but in this case this feedback loop is lacking. In this way, the existing structures, such as behavior patterns and work practice, are enabling and reinforcing the existing technology as explained by Perkins (2003). How the information and knowledge can be used in a better way is discussed in Section 6.4.

6.2.3 Corporate culture

The rail and road industry in Sweden is characterized by one dominant buyer and a few contractors, as explained in Chapter 4. There are two ways for the buyer to influence providers: through different forms of power and by creating inter-organizational trust (Mayer et al., 1995). As it is now, the STA uses its power to set the rules for the market. Power plays an important role in the relationship, and exploitation of a powerful party can lead to underperformance and disputes, while a good relationship enhances the performance (Maloni and Benton, 2000). The actors, both buyer and contractors, have indicated that they see themselves as parties with contradictory interests to some extent (Paper 2). This is in line with the general view of the construction industry, with a low level of trust between the buyer and contractor (Zaghloul and Hartman, 2003). Trust, and the effect of trust on the relationship, are further discussed in Section 6.5.

The organization has a conservative culture where the willingness to change is sometimes low, which in itself can lead to inefficiency (Ahmed and Shepard, 2010). This is in line with Kähkönen and Lintukangas (2010), who state that a dominant actor might not be willing to commit to change. Paper 2 describes how the organization within the STA, with separate divisions for construction and maintenance, are not cooperating or communicating. This indicates a sub-optimization when managing the infrastructure, due to a lack of overall responsibility.

An important aspect of the rail and road infrastructure industry is that it is generally risk-averse, which is the case for the construction industry as well; see e.g. Akintoye and McLeod (1997), Lyons and Skitmore (2004) and Uher and Toakley (1999). This means that an actor wants to reduce variation in possible outcomes and is willing to sacrifice expected returns to do so (March and Shapira, 1987). This could explain the reason for the traditional business model, where the technical solutions as well as the processes are specified in detail. In this way, the buyer will get exactly what is asked for without any surprises. Risk-averse decision makers have a tendency to overestimate possible losses (Cha and Ellingwood, 2012), which could be a reason for the specified contracts and tardiness in reforming the industry. Also, even though the contractors in Paper 2 are critical to this business model, there are benefits for them such as it being easy to calculate. Furthermore, the buyer carries all the risk and with a maximum ceiling for the cost, the contractors benefit from reaching the maximum sum (Nilsson et al., 2005). This is supported by the contractor in the Katrineholm project (Paper 4), who states that the contractor sometimes put unnecessary emphasis on some parts, which can happen sometimes since the contractor wants to make money.

6.3 Exploring a life-cycle perspective for resource efficiency

This section aims to answer the second research question, RQ2, which addresses *“In what ways could a life-cycle perspective affect the resource efficiency for rail and road infrastructure?”*

A life-cycle perspective is one of the key aspects of an IPSO business model (Sundin et al., 2006). Paper 1 describes projects that use IPSOs or similar models, but in Sweden only one rail and three road projects have been realized using IPSOs. These include Riksväg 50 (Case I) as well as the Arlandabanan project (Paper 1 and in Chapter 4).

6.3.1 Analysis of realized projects

Three road projects with different scope are discussed in this chapter, Table 15. The contractor for Riksväg 50 (Case I) maintenance only had a limited focus, even though it is the longest phase of the life-cycle. The construction was the main focus for the contractor's project leader, and he admits that it would have been good to include the maintenance section more to achieve even more resource-efficient solutions. Still, the results from Riksväg 50 show that other choices in material and solutions were chosen compared to a traditional contract. The contractor weighted the construction and maintenance costs and took the thinking one step further than normal, e.g. when choosing more energy-efficient lights along the road. The contractor believed that more could have been done with increased flexibility, but in this case much of the overall design was locked from the start. This shows that even though the STA is willing to try new business models, the contracts are still highly regulated and the full potential of the business model is not achieved. Changing a business model requires a changed mindset (Alonso-Rasgado et al., 2004; Sundin et al., 2009), and the STA is clearly still stuck in old routines. The lack of trust between the actors can also be a reason the STA is not going the distance with the IPSOs; see e.g. (Mont, 2002).

Table 15: The three projects and their specifications.

	Type of project	Design	Construction	Maintenance	Responsible party
Riksväg 50	Design-Build-Operate-Maintain/ IPSO	Included (limitations)	Included	Included	Contractor
Bana Motala-Mjölby	Design-Build	Included	Included	Not included	Contractor
Katrineholm	Design-Build with partnering	Included	Included	Not included	Buyer/Contractor

The Katrineholm project (Paper 4) did not include maintenance in the contract, but still some considerations were made. This could be because of the increased cooperation and discussion that took place on-site during this project due to the partnering. Achieving improved technical performance is a key result from partnering according to (Larson, 1995). For example, clay was chosen to protect the sides of the road instead of plastic, facilitating the maintenance but also reducing the environmental impact. This cut the cost of the construction, which was the main objective for the project, but it also had benefits from the maintenance perspective. If maintenance would have been included more durable asphalt would have been used, costing more initially but less in the maintenance phase, according to

some of the respondents in Paper 4. For the Katrineholm project, the general conclusion from the respondents was that that responsible people from maintenance could have been more included to improve the process. This means that with or without a life-cycle perspective in the project, increased involvement the maintenance section would be beneficial when the design is completed. In that way, the design choices made in the beginning of the life-cycle would get input from the later parts of the life-cycle, creating a feedback loop (Goh and McMahon, 2009; Meier et al., 2010; Sundin and Bras, 2005). This is further discussed in Section 6.4.

In the Bana Motala-Mjölby (Case II) Design-Build project for rail infrastructure a life-cycle perspective was not on the agenda. Instead, this project had difficulties integrating the first two parts of a potential IPSO, namely design and construction. According to the contractor almost everything was regulated, and it was only the order in which to build the different parts that was flexible. For example, all the material was set from the beginning. This means that the performance requirements were set on a detailed level, resulting in very little actual flexibility for the contractor to make any choices. The contractor believed in the end that the infrastructure looked the same as it would have if using a traditional Design-Bid-Build contract. Again, this is an example of the buyer, the STA, not adapting the contract to the new business model, as was the case for the Riksväg 50 project. These two projects were actually realized in parallel at the same site, and by the same Project Leader from the buyer's side. The Project Leader stated that there were many things that should have been done differently for the rail project. An example is that the design responsibility was carried by the Site Manager of the contractor, resulting in an excessive workload, especially considering the contractor's inexperience with Design-Build contracts for rail infrastructure. This can be compared to the Katrineholm project, where the contractor had people especially dedicated to the design. The contractor meant that for Design-Build contracts to work for rail, more flexibility is needed, which has been adjusted for the road infrastructure.

6.3.2 A life-cycle perspective for continuity

For rail infrastructure, the Arlandabanan project is the only contract resembling to IPSO in Sweden. However, as described in Chapter 4, since the actor maintaining it is not the same as that who constructed the infrastructure, the life-cycle perspective can be questioned. If the constructing contractors did not plan to maintain the infrastructure there would not have been any real incentives to think about the overall cost and use of resources. The contractors in the Katrineholm project (Paper 4), as well as contractors interviewed for potential implementation of IPSOs for rail infrastructure (Paper 3), stated that knowing that they were going to maintain the infrastructure themselves would result in a more durable infrastructure. This is because they have the possibility to balance the construction cost with the maintenance cost, which is in line with previous research on infrastructure projects ((Pakkala, 2002; White et al., 1999). This can be related to the design paradox in Figure 2 (Chapter 3), emphasizing the importance of making decisions early in the life-cycle, since this

is where the environmental impact is locked into the product (Lewis and Gertsakis, 2001). The focus of both the buyer and contractors is on cost reduction and process efficiency, but this indirectly results in a focus on reduction of environmental impact as well. Low-energy lights, for example, were chosen for Riksväg 50, and clay was used instead of plastic in the Katrineholm project. This indicates that the contractors using the IPSO business model would make sure that the facility is as durable as possible to reduce maintenance and changing of spare parts, which implies less use of resources such as material and energy.

6.3.3 Scenarios for future life-cycle projects

The results from the interviews concerning rail infrastructure, found in Papers 2, 3 and 5, indicate that a contract including both construction and maintenance provides incentives for new solutions that are more resource-efficient. The scenarios for rail infrastructure developed in Paper 3 show that availability and resource efficiency are connected to the choices made when building rail infrastructure. The changes illustrated in the scenarios all affect the materials that contribute the most to the environmental impact from the rail infrastructure; see e.g. Svensson and Eklund (2007). This makes the scenarios relevant for resource efficiency discussions, and shows how to change the current practice and thereby achieve more value for the money spent on the infrastructure by applying a life-cycle perspective. In this way, a minimum input of resources would be used for a maximum utilization of the elements in the offering, as explained by Meier et al. (2010). The contractors will try to have the most efficient and durable product on the market. Phenomena like planned obsolescence then become unwanted (Sherif and Rice, 1986). Applying this to IPSOs means that the contractors within the contract period would build as durable as possible. Instead of hourly payments for the maintenance they would have incentives to reduce the need for maintenance. This is due to the fact that they would be paid for performance, e.g. availability on the track. This is true for infrastructure where the availability is critical such as on high-trafficked tracks, that is where the traffic is intense compared to the capacity of the infrastructure. However, a contractor could choose to perform regular maintenance more often if the availability is less critical, as long as the total life-cycle cost is within the budget. This is because the contractor has to pay for every hour the track or road is not available for traffic in an IPSO.

6.3.4 The size and length of the IPSOs

When discussing a life-cycle perspective, one has to consider that the lifetime for rail and road infrastructure is normally around 40 years; as shown in Figure 1 (Nilsson, 2009), Chapter 3. The length of the life-cycle is very much dependent on the products (e.g. tracks, asphalt, etc.) used for the construction, as well as which products are determined to be the ones steering the length of the contract. Also, even though the construction part could be a rather large project, the maintenance part for the same infrastructure might not, which is discussed in Papers 2 and 5. This means it could be difficult for the contractor to achieve

efficient maintenance if the contract does not include enough volume, that is a large enough infrastructure in terms of kilometers and included parts.

The benefits for a contractor winning a long-term contract, such as reduced unpredictability and variability and a continuous revenue stream (Brady et al., 2005; Mont, 2004; Mont, 2002), have to be balanced with the fact that uncertainties increase the longer the contract length (Erkoyuncu et al., 2011; Meier et al., 2010). Furthermore, what contractor will still be around after 40 years? Therefore, IPSO contracts spanning the whole life-cycle of the infrastructure might impose too many uncertainties regarding the survival of the contractor, as well as sub-contractors. However, the contracts have to be long enough for the contractor to recuperate its investments, and to create incentives for efficiency in the use of resources. In the literature study (Paper 1) the long-term projects ranged from 10-45 years, which is supported by Lenferink et al. (2013), who state that 15-30 years is the norm for availability-based contracts in the Netherlands.

In addition, Paper 5 discusses the fact that every project requires administration e.g. related to the regulations in the industry, and if the projects were not large enough the cost for the administration compared to the project volume would not be justified. The current legal framework for rail infrastructure in particular is so resource-demanding that, according to the contractors in Paper 5, a large overhead cost is required to match it. This is why the packaging of the project is very important, both in terms of contract length and volume.

6.3.5 Organizational change

A change in mindset

Only changing the business model and contracts would be insufficient, since the relational issues are required and determined by the business needs (Thompson et al., 1998). One challenge is related to the change of mindset within the organization and the need for marketing the business model internally (Sundin et al., 2009). For the STA, this would imply that those responsible for the construction recognize the importance of maintenance-adapted construction. Also, those responsible for maintenance have to show interest in the construction projects and participate in them to make sure the infrastructure is as maintenance-friendly as possible. Both in the Katrineholm project (Paper 4) and the Riksväg 50 project (Case I) the lack of maintenance perspective was highlighted. This is in line with Lenferink et al. (2013) stating that even though contracts with integrated construction and maintenance parts are used, the parts are handled separately in the contract; sometimes even by different actors. This implies that the potential optimizations from a life-cycle perspective are limited after the design phase.

However, one of the respondents in the Katrineholm project felt that the maintenance section had more to gain from being involved in the construction process than the other way around. This indicates a lack of understanding for the life-cycle perspective and a problem

with rising above traditional thinking, an identified barrier for business models with a life-cycle perspective (Mont, 2004).

Incentives for incorporating the life-cycle perspective have to be provided by the buyer, since it is likely that the contractors do not have incentives to optimize anything but their profit. This can be compared to the problems for the UK rail infrastructure where the private part in charge had not kept up the quality of the infrastructure and accidents were caused due to a backlog of maintenance (National Audit Office, 2011; Shaoul 2006). This implies that the processes and the work procedures have not been the right ones and thereby not effective.

The buyer in Sweden is the owner of the infrastructure, and even though the contracts do not all involve a life-cycle perspective, the business model of the buyer has to, since it is in the beginning of the life-cycle where there is still freedom to make changes; see e.g. Boothroyd and Alting (1992), Lewis and Gertsakis (2001), and Lindahl and Tingström (2000). It is not effective management or efficient use of resources to only think of one life-cycle phase at the time, since the environmental impact of the following life-cycle stages are already determined, and the further along in the process the more modifications cost due to the difficulty in making the changes (Lewis and Gertsakis, 2001).

The mindset on the road side has begun to change with the use of new contracting forms resulting in more flexibility and responsibility for the contractor, as described above. There is however still improvements to be made. For the Riksväg 50 project (Case I), the performance criteria were more focused on how to solve the technical issues rather than on the overall performance.

For the rail infrastructure there are small changes made for the mindsets and contracts. For the Bana Mjölby-Motala project (Case II), one of the first rail projects using a Design-Build contract, according to the buyer's Project Leader no changes were made to adapt to the new contracting form. No new solutions were used since the project was excessively steered by regulations, according to the contractor. The contractor stated that for there to be a future for this type of contract within the rail sector, the STA has to increase the freedom to make changes for the contractor. The buyer's Project Leader claimed that regulations are one part of the problem, but also the lack of experience in Design-Build contracts from the contractor's side, especially in the way the design process was handled. According to the buyer's Project Leader, the contractor misjudged the resources needed for the design phase, and the contractor stated that the lack of capacity of the Design Consultant resulted in the use of several consultants, and thereby a loss of the overall picture. Instead, according to the contractor, different parts of the infrastructure were designed separately and later had to be adjusted to each other, costing both time and money. The contractor had not fully grasped the magnitude of the increased responsibility of a Design-Build contract, and did not succeed in integrating design and construction, as was also discussed in Section 6.2.1. The contractor had not fully adapted to the contract type, but a new set of conditions requires adaptation of operational and organizational structures (Meier et al., 2010).

Possible organizational synergies

The fact that the STA has one division for construction and one for maintenance creates a high risk for sub-optimization, since each division works within its budget constraints. Furthermore, there are potential synergies to be made between rail and road infrastructure as well, since the STA is in charge of both in Sweden. This means that the construction and maintenance of both rail and road infrastructure falls within the same organization. This implies a possibility for synergies internally, and a possibility to learn from each other. In this case, the rail side can benefit from the fact that the road sector is ahead in the development. Furthermore, there are more kilometers of road than rail in Sweden, and more projects realized every year for road infrastructure (The Swedish Transport Administration, 2014). This indicates that new processes could be implemented faster for road projects, resulting in a faster learning curve. This could be a reason the road infrastructure side has developed and used new contracting forms and technical solutions to a higher degree than rail infrastructure. Other reasons could be the higher degree of regulations and security measures needed for rail, the fact that it is a more complex technical system and that availability is more critical.

The contractors' organizations often mimic the organization of the STA, since this facilitates the process. For a business model based on a life-cycle perspective, changes have to be made. The conservative culture at the STA causes internal resistance, as discussed in Paper 2. This has been described in previous research as preventing the change needed to develop new product-service mixes (Cooper and Evans, 2000). A multi-skilled and cross-functional team is needed to produce the offering (Brady et al., 2005). The organization in the Katrineholm project (Paper 4) formed a unique team with the buyer, contractor and design consultant working together as one organization, Figure 8 in Section 5.4, but the maintenance perspective was lacking. The contractors in Paper 2 could identify potential synergies within their own organizations as a result of a life-cycle perspective and the cross-functional approach for rail infrastructure. The construction and maintenance phases would benefit from the fact that all information and knowledge would be in the same organization, and solutions could be discussed from a life-cycle perspective.

6.4 Information and knowledge sharing

The third research question, RQ3, addresses *“How can information and knowledge sharing between actors contribute to more resource-efficient solutions and effective management for rail and infrastructure?”* and will be discussed in this section.

There is a lack of trust between the parties in the industry as well as a lack of information and knowledge transfer between them, as discussed in Section 6.2. Also, the organization at the STA is divided into two parts, with little collaboration and communication. This all contributes to a lack of effectiveness and efficiency in the industry. Including a life-cycle

perspective and more responsibility for the contractors, as discussed in Section 6.3, requires new arrangements and processes.

6.4.1 Information asymmetry between the actors

The contractors are the executors in all types of contracts and they have the best knowledge about the infrastructure, such as solutions for different site conditions and how to execute the maintenance. This information asymmetry gives them an information advantage, and if they were responsible for an IPSO they could use this information to improve the offering; see e.g. Meier et al.(2010) and Goh and McMahon (2009) . The contractors seem to have that knowledge now but typically, especially for rail infrastructure, they are not using it since they in general follow detailed specifications. Currently, the STA sets the agenda most of the time and without a functioning feedback loop from maintenance to design; this information will not come to use, as discussed in Paper 2. Also, the information has to be transferred to the design consultants since they are in charge of the design. This was one of the key points from the Katrineholm project (Paper 4), where the design consultant was also involved during the construction phase and could see which solutions worked. According to the design consultant, this type of feedback had never been provided before.

There is a learning curve for how to optimize new contracts, which is why more IPSOs need to get to the market while the people who worked with the few IPSO contracts that have been realized still have the knowledge fresh in their minds. If not, there is a risk that this competence will be lost. In general, with knowledge of how the equipment is repaired across its entire customer base, the provider can optimize maintenance routines and thereby minimize cost as well as increase availability and reduce product failures (Alonso-Rasgado and Thompson, 2006; Toffel, 2008). For the rail and road infrastructure there is mainly one dominant buyer, but there are many projects that can serve as a source for obtaining knowledge. The more IPSO contracts a contractor has realized the more knowledge about how to optimize them will be gained, increasing the effectiveness and efficiency for the infrastructure. One issue, however, is how to spread the development achieved in projects to other projects in the industry (Bygballe and Ingemansson, 2014).

6.4.2 Improved information transfer

A key point from the Katrineholm project (Paper 2) was the significantly improved information and knowledge transfer that took place. The actors were co-located and the partnering contract increased the trust level, which is a key aspect of partnering (Construction Industry Institute, 1991). According to the respondents, the increased trust helped the actors to share more information. This project was finished earlier and with a lower total cost than estimated for a traditional contract. This is in line with Figure 2 (Chapter 3), the design paradox, and with Lewis and Gertsakis (2001), who state that information and knowledge could potentially result in efficiency gains and technical development, since it is in the design phase where most of the major decisions are made.

For both the Katrineholm project (Paper 4) and the Riksväg 50 project (Case I) the design was integrated with the construction, making it possible to adjust and change solutions when necessary. This was an iterative feedback loop between construction and design that seemed to be an efficient way of adjusting for the conditions at the sites. This integrated process was also planned for the rail project, Bana Motala-Mjölby (Case II). However, due to delays this was not possible and the design was done in a traditional way before construction. Also, the design process was not optimal and the contractor (Case II) stated that this could have been better coordinated, since the overview was lost due to a lack of information transfer between the parts causing unnecessary synching issues. This means that the project lacked feedback loops between the design and construction, and also between the different parts of construction. This was the total opposite of the Katrineholm project, where partnering increased the interaction between the actors and active design created an iterative working process between design and construction. Using active design meant that the design was not finished before the construction started, and that changes could be made depending on the site conditions. This is further discussed in Paper 4.

Feedback from maintenance back to design is required to be able to make necessary updates and adjustments (Goh and McMahon, 2009; Meier et al., 2010). The processes for maintenance can be developed during the contract using the knowledge and experience gained during the maintenance phase of IPSOs (Meier et al., 2010). IPSO contracts would also provide incentives for documentation, since the contractor has to demonstrate the value of the facility at the end of the contract as well as have measures for evaluation during the contracts. In this way, it would be easier to use IPSOs for reinvestments as well, and not only for new infrastructure. The problem today, as discussed in Paper 5 and Section 6.2, is that information e.g. concerning the status of the facilities lacks detail; this is especially a problem when using IPSOs for reinvestments where uncertainties are great. This lack of information causes unpredictability and uncertainties (Ng and Nudurupati, 2009), which the contractors are reluctant to deal with. For previous implementation of IPSOs in other industries, information, e.g. visualization, has been a key factor in the realization of the offerings (Baines et al., 2007; Kowalkowski, 2008; Matzen, 2009; Östlin et al., 2008). Therefore, even though these loops are not yet in place for all infrastructure projects, and especially not for rail infrastructure, this might be improved by using IPSOs, where information between the different phases is essential.

6.4.3 Synthesized information flows for contracts

Several different projects have been discussed in Chapter 6 thus far. Figure 9 illustrates the interaction, information and knowledge flows between the three main actors, i.e. the buyer, contractor and design consultant. The flows are numbered corresponding to the contract types stated below. The thickness of the arrows corresponds to the level of interaction, while the direction of the arrows corresponds to the direction of the flows. However, the flows are not exact and only indicate the level of interaction.

Figure 9: Illustration of the flows of information and knowledge as well as the interaction between the actors. The numbers in the figure denote the following: 1) Traditional contracts in general; 2) Maintenance contracts 3) Design-Build for rail project; 4) Partnering for road construction project; 5) IPSO for road project; and 6) Theoretical IPSO.

1. **Traditional construction contracts** (Design-Bid-Build) are managed by the buyer using detailed specifications drawn up by the design consultant. The design is later executed by the contractor.
2. For **maintenance** contracts, a bit more flexibility is introduced compared to the construction contracts. This is due to the fact that performance requirements are used, though the requirements are on a detailed level. The actual flows have not been empirically investigated and the flows in Figure 9 are only indicators.
3. **Design-Build** contracts integrate the design and construction phases and the contractor has the responsibility. In the Bana Motala-Mjölby contract, this did not work as planned since several different design consultants were involved and the overall perspective of the construction was lost.

4. In the case of **partnering** for constructing in the Katrineholm project, the consultant and the STA worked as one organization where the design consultant was involved as well. The information flows were present for different levels between the different actors.
5. For the Riksväg 50 project an **IPSO** was used but not fully implemented. The design consultant worked for the contractor. The buyer was only involved in some of the discussions as well as approving the suggested solutions. However, the maintenance perspective was not incorporated more than for a Design-Build contract.
6. These flows illustrate how an **IPSO** would look if design, construction and maintenance were all fully included, compared to the case of IPSO for Riksväg 50 described above. The design consultant closely interacts with the contractor, while the buyer is not actively involved in the project, but communication and coordination exists between the construction and maintenance divisions within the buyer's organization.

In Figure 9 it becomes evident that partnering increases the interaction between the parties compared to all the other options. The buying organization's role is also changing. In traditional contracts the buyer decides everything, while for an IPSO contract the buyer would have a more passive approach. However, the buyer has to be involved to some extent, due to the regulations and the need to approve new technical solutions no matter what type of contract is used.

6.5 Risk aspects and risk management

This section addresses the fourth research question, RQ4, which asks *"What are the uncertainties and risks from the actors' perspective when using business models based on performance and a life-cycle perspective for rail and road infrastructure, and how can they be managed?"*

6.5.1 Contract length and uncertainties

Construction risks are in general activities that affect the cost, time and quality of a project, and formal risk analysis and management are not used frequently in the construction industry due to lack of knowledge (Akintoye and MacLeod, 1997). The long-term aspect of an IPSO contract is connected to the risk assessment possibilities for both the contractor and buyer perspectives (Alonso-Rasgado and Thompson, 2006). The contractors in Sweden do not have any experience with calculating long-term contracts for rail, and only a few have experience from road projects. This is in line with previous research by Erkoyunco et al. (2011), where contractors in the defense industry are concerned about the possibility to estimate the costs for a long-term contract, which is something that has to be done in the bidding stage. For the road project Riksväg 50 (Case I), according to the buyer's Project Leader the maintenance contract is set for 20 years as a way to ensure that the contractor cannot gamble with the quality. Everything contractors build lasts for at least five years, but with longer contracts they would be more thorough, stated a contractor in Paper 2. This

shows how important the length of the contract is for the quality. The respondents in Paper 2 did not have a common opinion about the time span for IPSO contracts for rail infrastructure, but the interval of 10-45 years was mentioned. This was further discussed in Section 6.3.4. The contractors acknowledge that the longer the contract, the longer payback on machines, etc. On the other hand, a longer contract implies higher uncertainty and risk.

Pricing structure of the contracts

The Katrineholm project had a fixed price with incentives to lower the total cost, while the Riksväg 50 project had both a fixed and an adjustable part, with incentive to finish ahead of plan. Concerning rail infrastructure project, the contractors preferred a fixed and an adjustable part of the price to reduce the risk, as stated in Paper 5. The buyer, on the other hand, is of the opinion that if a contractor has the overall responsibility for the project, the price should be as fixed as possible. In general, the contractor does not want to be responsible for risks such as changes in the traffic volume, which affect the maintenance need. This is in line with (Barnes, 1983), who states that external risks should not be allocated to the contractor since a high risk premium would be used. The premium an actor charges for taking a risk reflects the willingness to take on a risk (Ward et al., 1991), and considering the risk-averse nature of the construction industry discussed in Section 6.2, it would not be cheap. This premium would increase the cost for the STA and thereby societal costs as well. This would, therefore, not be an adequate way to allocate the risks, and ineffective way to change the business model. However, other industries have managed the uncertainties with long-term contracting by adding flexibility to the contract using soft elements such as renegotiation (Nystén-Haarala et al., 2010). An adjustable part of the price or re-negotiations as a way to decrease risk-taking would be appropriate if including e.g. changes in traffic volume.

6.5.2 Performance requirements and evaluation

Other precautions for risk are performance requirements (Nystén-Haarala et al., 2010). Both the STA and the contractors have indicated that the evaluation, both during the contract and afterwards, will be difficult. Operationalization of the performance of the contracts needs extra attention; one important part of the contracts is to specify precise parameters so that it can be determined whether the IPSO is satisfactory delivered (Alonso-Rasgado and Thompson, 2006; Tukker and Tischner, 2006b). However, it is important that the buyer does not specify too much, as was the case e.g. in the Riksväg 50 project (Case I) and in Design-Build projects in general, as described in Chapter 4. Due to the length of the contract, it will take time before the entire project can be evaluated, and a residual value has to be determined so that the two parties can work towards the same goal. Challenges for the contractors are e.g. assumptions concerning equipment failure, prediction of maintenance routines and communication problems with the buyer (Datta and Roy, 2010). This is all interconnected to the information and knowledge issues discussed in Section 6.4. Risk of unpredictable costs can be reduced by access to resources, and the trust in a relationship can

be helped by sharing information (Ng and Nudurupati, 2009). Trust in relationships is further discussed in Section 6.5.4.

6.5.3 Risk allocation

For rail infrastructure the contractors are concerned about their increased responsibility, including a large part of the life-cycle for the infrastructure. According to the contractors in Paper 2 and 5, this increased responsibility equals increased risk. On the other hand, the contractors would have a large long-term project resulting in predictable income. This possibility to reduce unpredictability and variability of demand during the contract time has been described as a driver for long-term contracts (Mont, 2004; Oliva and Kallenberg, 2003). The contractors want more flexibility in the contracts on one hand, but are on the other hand reluctant to take more responsibility needed to achieve this due to the increased risk. This risk-averse attitude is discussed in Paper 5, along with how most of the risks and uncertainties identified by the actors are due to lack of sufficient knowledge about how to plan and calculate risk, implying that an implementation of IPSOs must come gradually for rail infrastructure. This reasoning is supported in Case II, which describes a Design-Build contract for rail infrastructure where an integration of design and construction was already too much to handle for the contractor.

The reason for exploring IPSOs for the rail and road infrastructure industry would be to make the most efficient and durable infrastructure possible, by a minimum input of resources for a maximum utilization; see e.g. Meier et al. (2010) and Sherif and Rice (1986). It is important, therefore, to allocate and manage the risks so that this is realized. The contractors need to have incentives to minimize the risks related to time and cost for there to be innovation initiatives (Akintoye and MacLeod, 1997; Barnes, 1983). In the Katrineholm project (Paper 4) and the Riksväg project (Case I), the risk related to the execution of the projects was always carried by the contractor. This makes sense, since it is the contractor that was in charge of the operations. However, for the Katrineholm project the risks for choice of technical solution were allocated to the buyer. According to the buyer, this was done to ensure a better infrastructure, since the contractor would have been more careful and conservative if they had split the risks. This also meant that the buyer could turn down suggested solutions since they carried the risk for them. According to the contractor, this could have affected the cooperation negatively, since this scenario was not clearly defined in the contract. In general, from the interviews from the Katrineholm project it seems that the contractors' respondents were a bit confused about the responsibilities and risk allocation in the project. If there had been a conflict, according to these respondents it was unclear how it would have been handled, even though they had defined steps to follow. Without clear mechanisms for problem solving the parties might go back to traditional thinking when problems arise (Black et al., 2000). This never happened in the Katrineholm project, but several respondents raised the question.

Lack of information

Coming back to the lack of information and knowledge transfer in the industry discussed in Section 6.4, this can serve as an obstacle for the contractor to evaluate and price risk. If the preconditions are not clear in a new project, or if the status of the infrastructure is not adequately documented for a reinvestment, the risk premium will be high. It could even be the case that serious contractors do not leave a tender (Barnes, 1983). Therefore, as the contractors in Paper 5 emphasize, calculable risks are important due to the small profit margins in the industry, which is also supported by Ward et al. (1991). Lack of information about e.g. ground conditions, in combination with lack of time to prepare the tender, affect the contractors' ability to evaluate the risks (Ward et al., 1991). In the Katrineholm project, several issues at the construction site resulted in changes in the design, and these were possible to make since they used an iterative process between construction and design. Nevertheless, the design consultant stated that more time should have been dedicated to the design phase, and if it so they would have constructed an even better infrastructure.

6.5.4 Collaboration as a mean to increase trust

The STA and contractors see themselves as parties with opposing interests. This could also mean that they have competing goals, which is opposite to what is recommended for mutual gains; see e.g. Emden et al. (2006). This is normally the case, according to one of the contractor's respondents in Paper 4. The objective of the contractor is to perform tasks that generate income, but in the Katrineholm project the objective was instead to reduce everything unnecessary and cut costs. The partnering and extensive cooperation between the parties was successful, since the total cost and the environmental impact decreased and the project was finished ahead of time. This is supported by Dietrich et al. (2010), who state that trust among actors increased collaboration quality, and that collaboration in projects increases knowledge integration. It can, however, not be evaluated from a maintenance standpoint, since this phase started in 2013 and has yet to be evaluated. For the Katrineholm projects, all five elements for quality in collaboration presented by Dietrich et al. (2010) were fulfilled, namely communication, coordination, mutual support, aligned efforts and cohesion. In this partnering project the buyer was the dominating party with the power to make decisions regarding the technical solutions. Despite this, there was a feeling of equity and the Project Leaders put a lot of energy into forming one united organization for the project. The contractor was satisfied with the collaboration, which shows that no matter how the power in a relationship is distributed a successful collaboration is still possible; see e.g. Benton and Maloni (2005; 2000). This can be compared to traditional Design-Bid contracts where the buyer makes all the decisions, leaving no flexibility for the contractor, as described in Chapter 4. For rail infrastructure the relationships between buyer and contractors are characterized by distrust (Paper 5), and there are quality problems in the rail infrastructure. Benton and Maloni (2005) state that a bad relationship can lead to underperformance and disputes, while a good relationship enhances the performance, something which is evident in the rail infrastructure case.

Partnering for increased collaboration

It has also been stated by Lockett et al. (2011) that a formal relationship is not enough for an IPSO contract, and for the partnership to be successful there is a need to align the profit incentives between them. This implies that both parties benefit from the same overall objectives, which is the aim of project partnering (Larson, 1995). The success of the Katrineholm project suggests that partnering could be a way forward for road as well as for rail infrastructure. The contractor for this project stated that there were risks regarding choices of technical solutions that they would not have taken without the partnering agreement. The solutions chosen were a good match for the conditions at the site and more standard solutions would have been chosen with traditional contracting. Instead of spending time on re-making poorly-adapted designs, the partnering parties' time could be spent on other things, making the process more effective as well.

The Katrineholm project is a type of project partnering, and the parties acted as project partners with common goals and routines for collaborative problem solving; see e.g. Bygballe et al. (2010) and Larson (1995). The aim was to build with good quality but to cut costs compared to traditional projects, that is maximizing the output. This is in line with previous research stating that superior results in costs, technical performance and satisfying customer needs can be achieved with partnering compared to traditional contracting (Bresnen and Marshall, 2000; Larson, 1995).

The actors in the Katrineholm project all had a clear perspective to cut costs, but previous research by Kadefors (2004) states that economic incentives have the power to motivate in a strong way, although they do not replace the means for motivation and mutual trust. The fact that open books were used indicates a high level of trust to be implemented (Johnsen et al., 2009). Therefore, it can be said that the Katrineholm project had a partnering organization characterized by trust and openness, something also stated by the respondents.

The Riksväg 50 project (Case I) also used a type of collaboration between the actors, but much less extensive and formal than for the Katrineholm project. The actors had a common goal, trusted each other and had a positive attitude towards cooperation. However, the full responsibility was on the contractor and the buyer only participated by discussing and approving the solutions. The buyer did not make any decisions, and the buyer's Project Leader stated that this was a clear strategy to avoid responsibility for the solutions. Using the definitions of Larson (1995), this partnering was a mix between guarded adversarial and informal partners. There was not one team organization; instead, the actors had their own organizations but collaborated since the individual success was dependent on cooperation. The design consultant worked together with the contractor on-site creating the feedback loop discussed in Section 6.4, which is important for improvement of the offering (Goh and McMahon, 2009; Meier et al., 2010). The project can be said to be efficient and effective since it was finished ahead of schedule, within budget and used solutions that were right for the site. However, the contractor wished for more freedom to choose the solutions since the buyer still controlled the overall design (Paper 4). This means that the project had potential

to improve e.g. by involving the maintenance perspective more, making the project more effective and efficient from a life-cycle perspective.

7.

CONCLUSIONS, CONTRIBUTIONS AND FUTURE RESEARCH

This chapter presents the conclusions drawn regarding the research questions (Sections 7.1-7.4) explored in a Swedish context. Subsequently, the transferability of the conclusions is described. The theoretical contributions are then discussed, followed by the practical implications of the research. Finally, suggestions for future research are presented. .

7.1 Current primary challenges regarding the management of rail and road infrastructure concerning design, construction and maintenance

This research has identified several challenges for rail and road infrastructure in Sweden. One of the main challenges is the lack of information and knowledge transfer between different projects and actors. The overall information regarding the status of the infrastructure, especially rail, is incomplete due to a lack of information transfer from e.g. the contractors. Because of this, the information is not used to improve designs since it is not transferred to the party that makes the decisions, the STA. In this way, the management of the infrastructure is not realized in an effective way.

Another challenge is that traditional contracts, where the buyer specifies the content and the process in detail, are used to a large extent, especially for rail infrastructure. These contracts split the life-cycle of the infrastructure into several small contracts, and this probably adds to the lack of overall information. Also, the designs for the infrastructure often have to be reworked, since they are not feasible to build due to lack of knowledge transfer between the contractors and design consultant. While the design is reworked, time and money are lost in the delay. This is also connected to the lack of information transfer from construction to design. The contracting form as well as the way the work is realized is inefficient and time-consuming, and therefore a major challenge.

The conservative cooperate culture within the buyer organization, and the fact that the buyer is the dominant actor on the market and sets the game rules, are also identified challenges. Separate divisions for construction and maintenance are not cooperating nor communicating. This indicates a sub-optimization when managing the infrastructure due to a lack of overall responsibility. Furthermore, the actors within the industry are in general risk-averse, and this in combination with a general feeling of distrust between the actors could explain the use of contracts with detailed specifications to avoid any surprises.

7.2 Ways a life-cycle perspective could affect the resource efficiency for rail and road infrastructure

Applying life-cycle based contracting forms such as the IPSO could provide a holistic view of the management of the infrastructure that is lacking today, and may improve the availability of the infrastructure, which in some cases is very critical.

In general, an IPSO contract would imply a more durable infrastructure since the contractors have to balance construction and maintenance costs. Even though the focus would be on cost reductions in technical solutions and process efficiency, this would indirectly result in a reduction of environmental impact, since less material and energy are likely to be used. Scenarios for rail infrastructure show that availability and resource efficiency are inter-related to the choices made when building rail infrastructure. The reason for this is that contractor is forced to consider the most efficient way of handling the resources.

In the contracts included in this research the buyer has in some cases tried to incorporate a life-cycle perspective, but often this thinking has not been fully implemented. This is partly due to the control of the buyer and the difficulties for the buyer to let go of the control, and partly because the contractor had not fully embraced the life-cycle concept. However, maintenance aspects of the infrastructure have been taken more into consideration in the contracts with a life-cycle perspective.

7.3 How information and knowledge sharing between actors can contribute to more resource-efficient solutions and more effective management for rail and road infrastructure

The contractors, in comparison with the buyers, have the best knowledge about the infrastructure such as solutions for different site conditions and how to execute the maintenance. This information asymmetry suggests that contractors should be involved in the design, compared to traditional contracts. An iterative information and knowledge transfer between construction and design seems to be an efficient way of adjusting the design for the conditions at the sites. In this way, the processes become more effective since the design fits the site and the technical solutions are more adapted to the conditions.

The information asymmetry also provides the contractors with a useful advantage for IPSOs since they could use this information to improve the offering. IPSOs would include more responsibility for the contractors and require new arrangements and processes, and there is a learning curve for how to optimize this. IPSOs would also provide incentives for documentation, since the contractor has to demonstrate the value of the facility at the end of the contract, as well as to have measures for evaluation during the contracts. In this way, it would be easier to use IPSOs for reinvestments as well, and not only for new infrastructure.

Furthermore, increased collaboration, e.g. through partnering, seems to be a promising way to increase the information and knowledge transfer between actors. The interaction as well as the trust between the actors increases, which favors more information sharing between them. Additionally, co-location facilitates informal communication and thereby increases the interaction between actors and different parts of the project, thus benefiting a holistic perspective.

7.4 Uncertainties and risks from the actors' perspective when using business models based on performance and a life-cycle perspective for rail and road infrastructure, and how these can be managed

There are inherent risks in IPSOs for rail and road infrastructure, particularly due to the length of the contracts that create uncertainties. The actors have limited experience in calculating long-term contracts, and even though they ask for more flexibility they are reluctant to take the responsibility needed to achieve this due to the increased risk. It may be

that the risk-averse attitude is an obstacle in the development of new contract forms such as IPSOs. It also implies that if implementing more IPSOs, this has to be done gradually in the industry. A longer contract implies higher uncertainty and risk, but on the other hand also longer payback on e.g. machines and a predictable income. Contractors state that infrastructure lasts for at least five years, but with longer contracts they would be more thorough, providing incentives for more durable infrastructure.

Risk allocation between the actors is paramount for effective management as well as trust between the actors. In general, external risks such as traffic volume should not be included in the contract without the possibility for renegotiations, since this would be too uncertain and the risk premium would increase. Also, operationalization of the performance is important to avoid the risk of misunderstandings and to facilitate evaluation. However, there still has to be flexibility and freedom in the contract for the contractor to choose solutions and processes. One way to do this is to increase collaboration, such as through partnering, and to mutually discuss possible solutions without being opposing parties in the project. In this way, the regulations could be more flexible since the buyer is actively participating in the project and can trust the solutions chosen.

7.5 Overall conclusions

To recall, the aim of this research is *to explore and propose a more effective management of rail and road infrastructure and the possibility for a more resource-efficient road and rail infrastructure by applying business models based on performance and a life-cycle perspective.*

Rail and road infrastructure have characteristics that are well-suited for the use of IPSOs. However, a public procurement situation and one dominant buyer affect the applicability. The contractors cannot take initiative themselves to start providing IPSOs, as is the case in many other industries. If the buyer decides to use IPSOs then these offerings will have leverage on the market, due to the sheer volume of the buyer's procurement.

There are potential synergies to be made between rail and road infrastructure as well, since the construction and maintenance of both falls within the same organization in Sweden. This implies the possibility for more effective management and a prospect to learn from each other. Large amounts of resources are dedicated to the management of rail and road infrastructure, and there is potential for improved resource efficiency by introducing a life-cycle perspective and performance-based business models.

7.6 Transferability of the conclusions

The Swedish setting for this research does not limit the relevance for its results in other geographical areas. This is because the discussion is mostly on a managerial level, and does not specifically look into certain geotechnical or climate conditions. Instead, themes in focus are long-term contracts, risk allocation, collaboration and incentives for a life-cycle

perspective, all which can be discussed on a general level. However, the research is done within a public procurement setting and the case of one dominant buyer and few contractors, which sets the game rules for the market. This provides an important contextual setting that has to be considered when reflecting on the results. Other sectors with characteristics such as public procurement, long-term contracts and availability importance are e.g. district heating and water supply systems. Therefore, the conclusions in this research could be relevant for these industry areas as well.

7.7 Theoretical contributions

This research contributes to several different areas of research, and the contributions are presented below.

7.7.1 Integrated Product Service System / Product Service System

Contributions are made in the area of Integrated Product Service Offerings, IPSOs, as well as in the wider area of Product Service Systems, PSSs. The area of design and management of these business models is important but insufficiently researched; see e.g. Boons and Lüdeke-Freund (2013).

The research also contributes with both a buyer and a provider perspective for IPSOs. The focus is on the buyer-contractor relationship, and concludes that the lack of trust and the uncertainties in some of the technical solutions make partnering an interesting form for collaboration. This could be more effective since the right decisions are made when sharing the risk. The right decision in this case seems to include a life-cycle perspective in the design, resulting in more efficient solutions.

This research also includes another actor apart from the buyer and contractor, namely the design consultant. This is a topic of interest for the PSS community, since the involvement of different stakeholders in the design process of PSS needs to be further investigated (Beuren et al., 2013). This research also discusses the inexperience of both buyer and contractor when it comes to providing service, and concludes that the culture and organization of the buyer is an obstacle for effective management.

The PSS field calls for more concretized results since there are many vague examples of the concept (Boehm and Thomas, 2013). This research contributes with scenarios for rail infrastructure when applying a life-cycle perspective and a performance-based business model where availability is essential. Also, a road infrastructure project using an IPSO contract is explored to understand the buyer-contractor relationship and how the technical solutions were chosen. Furthermore, two additional projects are used to illustrate different ways of collaborate and to integrate different parts of the life-cycle in a contract. In this way this research provides an extensive empirical contribution. This is needed in the PSS field to understand the transition from traditional business models to PSS (Beuren et al., 2013; Boehm and Thomas, 2013).

7.7.2 Eco-design

This research also contributes to eco-design by proposing a business model for rail and road infrastructure that emphasizes the importance of the design phase to reduce material use and optimize infrastructure lifetime.

The research explores projects where two or more life-cycle phases have been integrated; design, construction and maintenance. In this way, a management structure is adopted, and this research proposes a more effective one as a result of this holistic view.

7.7.3 Contributions to other related research fields

Contributions are also made to the development of the area of large technical systems by providing insight into how these systems can be managed in a more effective way, and how resources can be more efficiently used. This is in line with Jonsson (2000), who states that large technical systems play an important role for the reduction of resource use in society.

Other contributions are to the field of service marketing, where the perspective of the buyer as well as other actors outside the buyer-provider relationship needs further attention (Biggemann et al., 2013; Kowalkowski, 2008). In this thesis there are three actors in focus, the buyer, the contractor and the design consultant, thereby widening the scope from only buyer-provider perspectives. This research also contributes to the transition from product to function focus. This is a challenge acknowledged within the IPSO literature, as well as for the service marketing field (Baron et al., 2014).

7.8 Practical implications

The main practical implications for this research are presented below.

7.8.1 Organizational synergies and learning potential

In Sweden, the state-owned rail and road rail infrastructure is managed by the same actor and there are potential synergies to be made between rail and road, as well as between the construction and maintenance areas. This implies a possibility to learn from each other; the rail infrastructure can benefit in particular from the fact that the road infrastructure is ahead in its development, and has a faster learning curve due to more projects every year. More performance-based contracts including a life-cycle perspective are needed to improve the learning curve.

7.8.2 Embrace the life-cycle perspective

The full potential of the life-cycle contracts employed has not been reached, and there needs to be incentives to actually include the maintenance part in a more integrated way. This could be done for example by using better-adapted incentives for life-cycle cost in the contracts, as well as having a better understanding of the life-cycle perspective for both contractor and buyer. The performance requirement set by the buyer steers the outcome of

the contract, and therefore must be carefully thought through. This is a new way of thinking, and the buyer needs to develop competence in this area.

7.8.3 Collaboration possibilities

The possibilities for more collaboration in the industry should be further investigated since there are positive experiences from collaboration in different projects. The life-cycle perspective and using performance requirements are new to the rail and road infrastructure industry, and by collaborating it could be easier for the buyer to loosen up some of the strict requirements that are currently an obstacle for IPSO contracts. The performance requirements currently used are sometimes too detailed, which is a remnant from the traditional contract.

7.9 Suggestions for future research

This research has had IPSOs for rail and road infrastructure as the main focal point. For this performance-based business model it is important to set appropriate performance criteria to actually achieve the quality and resource efficiency potential. Therefore, further investigation and analysis of these requirements, e.g. the appropriate level of detail and adequate measurements, are needed in the contracts. The requirements have to be on a level where they sustain the quality but do not hinder the contractor's flexibility in choosing e.g. technical solutions.

The life-cycle perspective discussed in this research did not include the end-of-life phase. The contracts do not include this phase, but the owner of the infrastructure will have to deal with this phase nonetheless; a suggestion for future research is to include this phase as well when exploring possible contract boundaries.

A next suggested step in this research topic is to evaluate the contracts discussed in a quantitative way, both from a cost and an environmental perspective, using life-cycle cost analysis and life-cycle assessment. Furthermore, the overall business model from the buyer's perspective needs to be quantitatively assessed, e.g. if societal cost and overall environmental performance are changed when using IPSOs. This quantitative assessment is in line with Boehm and Thomas (2013), who state that more quantitative research is needed in the field to validate the theories and models.

8.

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A black and white photograph of a railway track. The tracks run diagonally from the bottom left towards the center right. Above the tracks, there is a complex system of overhead power lines and support structures. On the right side, a signal post with two circular lights is visible. The background shows some industrial or construction-related structures and a hazy sky. The overall scene is industrial and somewhat desolate.

APPENDIX I PAPERS AND CASE REPORT

Appended Papers

The articles associated with this thesis have been removed for copyright reasons. For more details about these see:

<http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-110015>

CASE REPORT

Description of Case I and II

CASE REPORT: CASE I AND II

1 INTRODUCTION AND METHODOLOGY

The aim of the report is to explore the use of two types of contracts used for rail and road infrastructure. In this report, the empirical data from two cases is presented: a road infrastructure project Riksväg 50 (Case I) and a rail infrastructure project Bana Motala-Mjölby (Case II). These two projects were part of a larger project called BanaVäg Motala-Mjölby, which was completed in 2013. Riksväg 50 was a Design-Build-Operate-Maintain project, meaning that the contractor is responsible for design, construction and maintenance, as described in Table 1. Bana Motala-Mjölby was a Design-Build project, where the contractor is responsible for the design and construction of the infrastructure, also shown in Table 1. The buyer was the Swedish Transport Administration (STA), and the contractors were NCC (Case I) and Balfour Beatty Rail (Case II).

Table 1: Characteristics for Cases I and II.

Project	Type of project	Design	Construction	Maintenance	Responsible party
Riksväg 50 (Case 1)	Design-Build-Operate-Maintain	Included	Included	Included, 20 years	Contractor
Bana Motala-Mjölby (Case 2)	Design-Build	Included	Included	Not included	Contractor

A starting point in the data collection for Case I was a theme day, organized by the STA in February 2014, where both the buyer, the STA, and the contractor, the NCC, presented their reflections about the project. This day was then complimented with semi-structured interviews, which was also a way to collect the empirical information for Case II, as shown in Table 2. The interview guide used for both projects can be found in Appendix II. the projects had the same buyer and the Project Manager was interviewed from the buyer’s perspective. For the contractors’ perspective, the Project Manager from each of the contractors was interviewed.

Table 2: The respondents included in the BanaVäg Motala-Mjölby project including interview duration.

Respondent	Role in the project	Party	Interview duration [Min]	Mode
A	Project Leader, Road	Contractor	43	Phone
B	Project Manager, Road/Rail	Buyer	91	Face-to-face
C	Project Leader, Rail	Contractor	47	Phone

2 CASE 1: RIKSVÄG 50

2.1 Introduction to the project

The project used a Design-Build-Operate-Maintain contract or a Design-Build contract with 20 years of operations and maintenance, as the actors described it. A bonus of 2 million SEK per week (max. 20 million SEK) was set for an earlier finish of the construction phase than planned for. Also, 0.5 million SEK was set as a traffic safety bonus during the maintenance phase. If no penalties were used during the maintenance phase, 25 million SEK was granted in bonus each year.

Short facts:

- 28 kilometers between Motala and Mjölby
- 8 interchanges, 37 bridges, 620m bridge over Lake Vättern
- Cost: 1.5 billion SEK
- Finalized 10 weeks ahead of schedule, duration of 3 years
- Funding:
 - Bridge tolls over Lake Vättern
 - Public funds, state and regional

2.2 Project organization

All decisions regarding the project were taken in Motala, close to the site, to achieve effective and efficient organization. The contractor had preferred being co-located with the buyer to be able to have an information dialogue (A). Now, there were a few kilometers between them. However, the full responsibility was with the contractor, and the buyer only participated by discussing and approving the solutions. The buyer did not make any decisions, and the buyer's Project Manager (B) stated that this was a clear strategy to avoid responsibility for the technical solutions. In general, contractors are more creative than the buyer and are more open for new solutions (A).

There was an outspoken ambition to have more cooperation than in a traditional project, and group dynamics exercises were realized to facilitate the processes in the project. This cooperation was only to facilitate individual interaction and avoid "us and them" attitudes, and not a form of partnering. A goal document for the project was established, and there the responsibilities were clearly defined. According to the contractor the parties trusted each other, and the buyer's good relationships with other authorities eased the process (Lidberg, 2014). However, the collaboration for different projects depends on the involved individuals (B).

The contractor followed a payment plan and the buyer had no insights on the finances of the contractor; i.e., the difference between the offering and the actual cost was not known to the buyer. The project had both a fixed and an adjustable part, with incentive to finish ahead of plan. The organizations of the buyer and contractor were established to match each other, and if more resources were needed in one part of the project, there was flexibility to facilitate this.

The design consultant was also located at the site which implied fast processes, and the close presence of the buyer made the review process easier (Lidberg, 2014). Compared to a traditional contract where the buyer is in charge, the design consultants had a busier schedule, according to the contractor. However, the contractor's organization was similar to one for a Design-Build contract, since the maintenance part was not really represented (A). This is something that could have been improved and would have facilitated the choice of the technical solutions (A).

2.3 Design

The contractor had to use several different design consultants to get enough capacity, resulting in a split of the project into smaller parts. The synching later needed between the parts costs the contractor both time and money. The contractor wanted to be creative and find new solutions, but the creativity of the different consultants varied. It is important to bring people from the production into the design phase since they have many ideas, but they have to be more committed to the process than they were (A). To be able to directly control the design consultants and get immediate feedback on the solutions from construction were great benefits (Lidberg, 2014).

Also, the buyer did not have time to review all the suggestions for new technical solutions, and therefore a longer design phase was needed (A). The buyer also felt that a longer design phase would have been good to really work through the solutions, but on the other hand the time pressure was identified as positive for the project (B). It was, however, very good that the design and construction phases were run in parallel.

For the project, the maintenance contract was set for 20 years as a way to ensure that the contractor could not gamble with the quality, according to the buyer's Project Manager (B). The contractor believed that they could have provided a better infrastructure if the buyer would have loosened up the control a bit more. The overall design was set and steered the technical solutions possible to use to a large degree (A). According to the contractor (A) it would have been better if the overall frames were set, and then the rest were determined in cooperation with the buyer. The buyer stated that some regulations are needed, especially in cities and along highways (B). The city council had requirements for the number of trees along the road, and this could not be changed.

The risks related to the execution of the project were carried by the contractor, but the pre-set solutions were the responsibility of the buyer. However, if changes were made to the pre-set solutions the contractors took over the risk. None of the solutions were jointly developed, and the buyer only checked that the performance requirements were fulfilled. The buyer was very careful not to make decisions. This was difficult, however, and a change of mindset is needed for this to really sink in (B).

2.3.1 Technical solutions chosen

The integration of design and construction increases the possibilities for new innovation and the use of life-cycle cost (Lidberg, 2014). Examples of life-cycle cost thinking are more energy-efficient lights along the road, bars and refuges designed to facilitate maintenance, and bridge insulation lasting longer, according to the contractor (A). The design of the interchanges was remade as well as the profile of the road to improve the run-off of water. The contractor also chose pressing down the ground as a technical solution for the stabilization of the ground. According to the contractor (A), the buyer had previously chosen excavation as a method since there was no time to evaluate other solutions. The city council chose a certain number of trees along the road, and the contractor would have chosen to use fewer trees since these require maintenance (A). If the contractor was to re-do the project today, the focus would be on fewer changes in the original design and weighing the amount of work to the actual consequences before starting to work with many changes right away.

2.4 Final remarks

The contractor believes that this type of contract does not fit all types of projects. Uncomplicated projects do not have any room for changes to the technical solutions, and then a traditional Design-Bid-Build contract would be a better match (A). Also, the maintenance part can become too small and not profitable, which makes the size of the project important as well (Lidberg, 2014).

The functional requirements were sometimes difficult to interpret, which is why good communication with the buyer is necessary (Lidberg, 2014). Therefore, partnering would be an interesting next step to investigate (Lidberg, 2014). The buyer thought that the collaboration made the project process smoother, and this is something to strive for in future projects. Finally, the contractor also believes that for this type of thinking to work, more of these contracts have to be implemented to create continuity.

3 CASE II: BANA MOTALA-MJÖLBY

3.1 Introduction to the project

The rail project, Bana Motala-Mjölby, used a Design-Build contract, including design and construction, and was one of the first larger rail projects to do so. The rail project was realized at the same geographical location as the road project, but has not received as much attention. The reasons for this are related to the outcome of the project and less interest in general for changes within road infrastructure (B).

Short facts

- 26 kilometers of double tracks between Motala and Mjölby
- A new station in Motala
- Bridges, 3 over canals
- 200 million SEK
- Project duration: 5 years

3.2 Project organization

In general, it was difficult to keep the deadlines in the project due to delayed permissions and archeological issues that had to be solved along the way (B). Therefore, the buyer's Project Manager (B) felt like he had to focus on solving these issues since they were the buyer's responsibility, instead of developing new processes for the project.

The whole process was ineffective and inefficient, according to the buyer (B). The overall project meeting was used as a discussion forum and an information meeting instead of a decision-making meeting. The buyer's Project Manager came late into the project due to organizational changes, and he felt like he could not change this even though he wanted to.

The contractor used a design consultant for both the design and the project management of the design. However, according to the contractor (C) it would have been better to keep the project management in-house. This is because the consultant did not have enough resources to handle this, and there was a general sense of a lack of control from the contractor's side. Also, the design responsibility within the contractor organization was on the site manager, who was also in charge of the ongoing construction. This turned out to be too much to handle for one person, according to both the contractor (C) and the buyer's Project Manager (B). Inexperience or lack of resources could be why the contractor chose to handle the design in this way, according to the buyer (B).

In general, the contractor believes the construction process could be improved by more coordination. Several potential synergies could be made, and one example is all the cables

that need to be laid down. It does not matter if this work is executed by a person from the electricity or signal field, since the cables are very similar.

3.3 Design

The functional requirements are different for rail than for road infrastructure, according to the contractor (C). Many areas are regulated and cannot be changed such as how to build the track, how to build the signal towers, and how to connect it all. This means that the freedom to make choices is limited to the building process and in which steps everything is realized (C). Therefore the end product, the infrastructure, would not have looked any different with another type of contract, according to the contractor. This is in line with the buyer's perspective that the contractor made no changes to adapt to the new contract type (B).

For rail infrastructure, 80% of the material is determined in advance and bought from the buyer, which limits the freedom of the contractor. Also, signal towers and signal systems have to be bought from a specific supplier, Bombardier. This means that the material choices are very regulated, but the contractor (C) believes that there is a possibility to clear out some of the regulations without sacrificing the safety level needed. The contractor also stated that you cannot follow all the regulations, saying "if you follow one you will probably break another, it is impossible to follow them all". It is the responsibility of the contractor to make sure all regulations are followed, even though it is impossible to keep track of them all (C).

The plan was to work with design and construction in parallel, but the project was appealed and had to be put on hold for one year. During this time the design phase continued, and consequently the design and construction were realized one after the other.

The project was geographically divided into different steps that were designed separately and then connected. This could have been improved, according to the contractor (C), by making an overall design and thereafter breaking down the needs for each step to reach this design. This would have simplified the work and reduced the cost, since less synching between each step would have been needed (C). According to the contractor, if they were to redo the project this is where they could cut down working hours.

Most of the rail infrastructure projects do not include the ground preparation process, and this project was no exception. This part was done by another contractor. Therefore, consortia could be a good way to create more flexibility in the contracts, something that was actually done for the railway yards since synergies between two different contract were identified (C).

3.4 Concluding remarks

For Design-Build contracts to work in a satisfactory way the use of regulations has to be redone to create more freedom and flexibility (C). Furthermore, the level of the functional requirements has to be reconsidered as well to identify the potential cost savers (B). A large

part of the overall cost is in the material, and if the choice of material could be more flexible this could make a huge difference for the overall cost (C).

The content of the contract is also important, and the contractor believes that more has to be involved, such as the ground preparation process, to be able to make real changes. Taking this one step further and including maintenance in the contract as well would require more free use of material, according to the contractor (C). Also, the size of the contract is critical; at least 300 kilometers is needed (C). An obstacle is the fact that the maintenance today is very regulated.

The contractor (C) sees a possibility for a Design-Build-Operate-Maintain contract for new larger rail infrastructure project such as Ostlänken¹. On the other hand, he believes it will take time before such a contract is realized due to the mindset in the industry. The different technical areas are very much set, and more flexibility is required to find synergies. Also, the different divisions within the buyer's organization need to collaborate more for this to work (C).

REFERENCES

Lidberg, T., 2014. Vägen till framgång Rv 50, Industry conference: Design Build contracts [Temadag totalentreprenader med funktionskrav]. NCC Construction Sverige, Arlanda, Sweden.

¹ Ostlänken is a planned fast speed train for south of Sweden.

A black and white photograph of a railway track. The tracks run diagonally from the bottom left towards the upper right. Above the tracks, there is a complex system of overhead power lines and support structures. On the right side, there are several signal lights. The background shows some trees and a hazy sky. The text "APPENDIX II" and "INTERVIEW GUIDES" is overlaid in the center of the image.

APPENDIX II

INTERVIEW GUIDES

INTERVIEW GUIDES, STUDY 1

Interview guide for the Swedish Rail Administration

Respondent:

Date:

Position:

The term functional contract (funktionsentreprenad med helhetsåtagande) was used for IPSO contracts during the interview.

Introduction

1. What types of contracts are used in the current situation for "train-related" procurement i.e. track, maintenance, etc?
2. What is your definition of a functional contract with overall commitment?
3. What obstacles and challenges are there in the current situation when it comes to procurement contracts? For each type of contract?
4. What obstacles and challenges are associated with the functional contracts?
5. What advantages would there be with the functional contract?
6. How would functional contracts affect the use of technology?
7. What problems with the current construction would a change solve?
8. Do you see the function of procurement as a future scenario?
9. What would be required for the Swedish Rail Administration to start with function contracts with overall commitment (design, construction, maintenance)?

Contracts

10. How long are the contracts today?
11. How long should the contract be for the functional contract?
12. Are there regulations on contract length with regards to public procurement?
13. Do you see any problems with the length of this type of contract? What?
14. Do you think the tendering process will take a longer or shorter period of time?
15. In some contracts in the UK, renegotiation of some parts at regular intervals (5 years) was introduced; is this something that you think might be necessary? How long should the intervals be? What would need to be renegotiated?
16. Are there risks associated with the contract length? For the contractor / client?
17. What are the advantages and disadvantages of using such long contracts?

Cost, reimbursement and risks

18. How does the funding look today?
19. What should the funding look like?
20. How are reimbursement costs for offers (contracts) in use calculated (should be calculated) ? What are the difficulties in this?
21. Are there regulations for compensation etc. by public procurement? (how compensation is calculated, etc.)
22. How does the contractor set a fixed price that covers the risks, but at the same time is competitive?
23. What degree of transparency would be needed to assess offers on price etc?
24. How should interest rates and profits be handled?
25. Where should the line be drawn between client and contractor? Risks, responsibilities, etc?
26. What is needed to determine risks and compensation?

Organization

27. What functions or parts of the organization are involved in procurement work today?
28. What organizational changes will be required at the Swedish Rail Administration?
 - Which parts of the organization will need to change? How?
 - What is the interplay between the involved parts today? Will the interaction between the parts change?
 - Will new skills be required in the organization to implement functional contracts? Which ones?
29. Are there routines in place to preserve knowledge within the organization?
30. The Swedish Rail Administration's organization will have less detail control over the functional contracts. Will this create any problems in the corporate culture?
31. Does the Swedish Rail Administration's have the organization necessary to implement functional contracts?

Contractors

32. What will be required of suppliers, contractors and subcontractors, as opposed to today?
33. Do the contractors have the organization necessary to implement the functional contracts?
34. What organizational changes will be required of the contractor?
35. What requirements must be placed on the contractor's organization in the tender?
36. Will the relationship between client and contractor change?
 - How? What are the challenges?
37. How do functional contracts potentially affect the contractor market?
38. How many contractors are there today in Sweden and abroad who could perform a functional contract?
 - Number of contractors who are capable of a functional contracts?

Contracts

39. Do you have any contact with other employees within the Swedish Rail Administration's that I could contact to get their perspective on the functional contracts?
40. Do you have any contacts with contractors who I could contact to get their perspective on the functional contracts?

Interview guide: Contractors

Respondent:

Date:

Position:

The term functional contract (funktionsentreprenad med helhetsåtagande) was used for IPSO contracts during the interview.

Introduction

1. What types of contracts are used in the current situation for "train-related" procurement, i.e. track, maintenance, etc?
 - Functional contracts? With overall commitment?
2. Has Company X performed any type of functional contract yet?
3. What is your definition of a functional contract with overall commitment?
4. What obstacles and challenges are there in the current situation when it comes to procurement contracts? For each type of procurement (contract)?
5. What obstacles and challenges are associated with functional contracts?
6. What advantages do you see with the functional contract?
7. How would the functional contract affect the use of technology?
8. Have there been problems in the past that have been solved with the help of changes in the contract form?
9. What type of contracts in the future? What problems with the current construction would a change solve?
10. Do you see the function contracts as a future scenario?
11. What would be required for the Swedish Rail Administration to start with functional contracts with overall commitment (design, construction and maintenance)?

Contracts

12. How long are the contracts today?
13. What would the business model look like for a functional contract with overall commitment?
14. How long should the functional contract be?
15. Are there regulations on contract length with regards to public procurement?
16. Do you see any problems with the length of this type of contract? What?
17. Do you think the tendering process will take a longer or shorter period of time?
18. In some contracts in the UK, renegotiation of some parts at regular intervals (5 years) was introduced; is this something that you think might be necessary? How long should the intervals be? What would need to be renegotiated?
19. Are there risks associated with the contract length? For the contractor / client?

Cost and compensation

20. How does the funding look today?
21. What should the funding look like?
22. How are reimbursement costs for offerings (contracts) in use calculated (should be calculated)? What are the difficulties in this?
23. Are there regulations for compensation etc. by public procurement? (how compensation is calculated, etc.)
24. How does the contractor set a fixed price that covers the risks, but at the same time is competitive?
25. What degree of transparency would be needed to assess offers on price etc?

26. How should interest rates and profits be handled?
27. Where should the line be drawn between client and contractor? Risks, responsibilities, etc?
28. What is needed to determine risks and compensation?
29. What are the advantages and disadvantages of using such long contracts?

Organization

30. How does the organization work today? What functions or parts of the organization are involved in offers at the Swedish Rail Administration?
31. Would changes in the organization be required?
32. Will new skills be required in the organization to implement this type of overall commitment? Which ones?
33. Are there routines in place to preserve knowledge so that it remains within the organization?
34. Could it require cooperation with other contractors to offer overall commitment?
35. Does the Swedish Rail Administration have the organization necessary to implement functional contracts?
36. What requirements must be placed on the contractor's organization in tender?
37. Will the relationship between client and contractor change?
 - How? What are the challenges?

Contractor market

38. How does the function of contractors potentially influence the contractor market?
39. How many contractors are there today in Sweden and abroad who could perform functional contracts?
 - Number of contractors who are capable of a functional contract? Minimum number that is acceptable for competition?
40. Problems with having multiple subcontractor companies that are dependent during the entire life-cycle? If a vendor retires / goes bankrupt etc?

INTERVIEW GUIDES, STUDY 2

Interview support, Study 2

Respondent:

Date:

Position:

1. What improvements can be made to lower the total cost and increase the life-time of rail infrastructure? (think outside the organization and budget used today)
2. What affects the life-time of the rail infrastructure?
 - a. What factors determine this?
 - b. Which factors are the most important?
3. Could the life-time of the infrastructure be longer if any of these factors were changed?
 - a. In which way would they have to change?
 - b. What would they affect?
 - i. Material
 - ii. Processes and organization
 - iii. Total cost
4. Why haven't these changes already been made?
5. Which are the main cost drivers in the infrastructure?

INTERVIEW GUIDES, STUDY 3

Interview guide Study 3: The Katrineholm project

Respondent:

Date:

Position:

Consequences from choosing the contract form (construction project with partnering)

1. What benefits do you see with this contract form and way to work?
 - a. Lower cost and faster realization were achieved.
 - i. Which were the reasons for this?
 - ii. Which parts of the project were faster than normal and why?
 - iii. For which parts of the project could the costs be cut and why?
2. Which were the challenge and disadvantages with the contract form and the way to work?
 - a. Where there parts of the project that cost more than normal? Why?
 - b. Where there parts of the project that took longer than normal? Why?
3. What would have been done differently if the project were to be re-done today?

Maintenance

4. How were maintenance issue managed within the project?
5. The cost for the construction was lower than expected. What is the prognosis for the maintenance costs?
6. Was the total cost considered?
7. What would have been done differently us maintenance was included in the project?

Responsability and risk management

8. What were the risks and how were the risks managed?
9. Which part was responsible for what within the contract?
10. How did this work? Would this have been done differently if redone today?

Actors and information flows

(Flow sheet was drawn during the interview)

11. Which actors took part in the project?
 - a. For different phases of the project (design, construction)?
 - b. Key individuals?
 - c. What roles did the key individuals have?
12. Who was in contact with each other?
 - d. What type of flows were between them?
 - i. Documentation, information, knowledge, services, products?

- ii. One-way or two-way communication?
- iii. How frequent were the flows?
- e. How did these flows change over time (design, construction)?

Concluding questions

13. Which other people do you recommend I talk to, to complement the information about this project?

Interview guide Study 3: Case I and II

Respondent:

Date:

Position:

Organization

1. How was the project organization set up?
2. How was the design realized?
3. How was active design used?
4. What was done differently now when maintenance was included in the contract, compared with Design-Build projects? (Only for Case I)
 - a. Different technical solutions?
 - b. Different processes?

Benefits/challenges/improvement potentials

5. What are the benefits with this type of contract and this way to work?
6. What are the challenges with this type of contract and this way to work?
7. What would have been done differently if the project was re-done today?

Responsability and risk management

8. What were the risks and how were they managed?
9. Which part was responsible for what? (buyer, contractor)
 - a. How did this responsibility/risk allocation work?
 - b. Would it have been done differently if the project was redone today?