Investigating the development and delivery of integrated product-service systems

By

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Engineering Doctorate Thesis

Submitted in partial fulfilment of the requirements for the award of Doctor of Engineering of Loughborough University

November 2011

CERTIFICATE OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this thesis, that the original work is my own except as specified in acknowledgments or in footnotes, and that neither the thesis nor the original work contained therein has been submitted to this or any other institution for a degree.

…….. (Signed)

…….. (Date)

Acknowledgements

As my Engineering Doctorate journey comes to an end, I look back at the last four years with a great sense of achievement, satisfaction and relief that it is over. Looking back, I find that the journey has shaped me greatly, in terms of my thinking and the way that I perceive the world around me. I would like to express my sincere thanks to all of those who have made this possible.

Firstly, I would like to acknowledge the contribution of my academic supervisors, Prof. Chris Backhouse and Dr Samir Dani, without whose guidance I would have been lost. I would also like to thank my industrial supervisor, Jeremy Lovell, for his continuous support, encouragement and enthusiasm throughout the whole of my research. Additionally, my thanks go to Dr Michael Provost who initially sponsored the research project and brought me into Bombardier Transportation.

Special words of thanks also go out to two other people who have been pillars of support throughout this research project. Firstly, thanks go to my fellow Engineering Doctorate student William Rowell without whose patience, questioning and willingness to be on the other end of a phone this thesis would not have been completed. Second, thanks go to my friend, Bjorn Claes, for the time, support and advice he has given in helping me to strengthen my research.

I would also like to thank Prof. Roger Goodall, Dr Roger Dixon, Sharon Henson and Karen Holmes from the Systems Engineering Doctorate Centre at Loughborough University. Through the structured provision of the core training modules and tireless organisation of yearly conferences and integration events, I have developed skills and gained knowledge that have undoubtedly helped with my research.

Words of thanks also go to all of my colleagues at Bombardier Transportation for their continuing support in helping me to gain a greater understanding of their business. Special thanks go to those who participated in interviews and to the other organisations who gave me an invaluable insight into their businesses.

Finally, I would like to thank the people who have supported me more than they know. To Lisa and my family, you have listened intently and provided me with the determination to progress through this sometimes painful journey. To them I offer my sincere thanks and gratitude.

Abstract

Driven by the highly cyclical nature of their increasingly commoditised product offerings, many capital goods manufacturers are seeing the benefits of delivering services integrated with their core product offerings. Whilst existing research is almost unanimous in advocating the value of a servitization strategy, understanding how these product-service systems (PSSs) can be developed and delivered remains a significant challenge. The closely related PSS field, which has its heritage in the environmental and social science disciplines, is more mature in this area and a number of models have been proposed. The research reported within this thesis contributes to knowledge by investigating whether the approaches to PSS development, reported within the PSS literature, reflects the PSS development practice of servitized manufacturers. More specifically, soft systems methodology was used to explore the delivery of PSSs within the UK railway industry in order to gain an understanding of the implications for developing new PSSs. With this understanding, the existing approaches to PSS development were evaluated with respect to one servitized manufacturer through an in-depth single case study. The findings highlighted a number of significant differences between the practice of the servitized manufacturer and the literature. A survey was used to investigate whether the differences were generalisable to a larger sample of servitized manufacturers. The findings point towards the simplification of the reported phases within PSS development and the inclusion of a number of previously unreported processes and activities. Based on these results a new model of PSS development is proposed to better reflect the practice of servitized manufacturers. The model, consisting of four phases and seventeen processes, was operationalised in the form of a workbook and tested through application. Applying the workbook resulted in the successful creation of a number of new PSS concepts.

Keywords:

Servitization; product-service system (PSS); PSS development; new product development; service design; soft systems methodology (SSM)

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Glossary of terms

BPMN	Business process modelling notation
BT	Bombardier Transportation
BTMLN	Bombardier Transportation, Mainline manufacturing division
BTS	Bombardier Transportation, Services division
CAD	Computer aided design
CATWOE	Customers, actors, transformation, weltanschauung (worldview), owners, environment
DfT	Department for Transport
EngD	Engineering Doctorate
IDEF	Integrated definition methods
OPRAF	Office of Passenger Rail Franchising
ORR	Office of Rail Regulation
PESTLE	Political, economic, social, technology, legislation and environment
PSS	Product-service system
ROSCO	Rolling stock company
SDL	Service-dominant logic
Service CAD	Service computer aided design
SIC	Standard industrial classification
SIPOCR	Suppliers, inputs, process, outputs, customers and regulation
SRA	Strategic Rail Authority
SSM	Soft systems methodology
SSME	Service science, management and engineering
SysML	Systems modelling language
UK	United Kingdom
UML	Unified modelling language
US	United States

1 Introduction

In today's global economic system, manufacturers in developed economies are facing increasing competition from lower wage economies (Neely 2008). Data suggests that US manufacturers have to reduce their costs by 30% to compete with Chinese producers (Wu *et al.* 2006). Sainsbury (2007) reports that in 1980 less than one-tenth of manufacturing exports came from the developing world. Today it is one-third and in 20 years time it is likely to be one-half. In the same report, Sainsbury suggests that one of the best ways for the UK to make the most of globalisation opportunities is through the re-structuring of companies into high-value goods and service industries in what he terms a "race to the top".

This global competition has amplified and accelerated the rate of commoditisation of products. To reduce the risk of commoditisation and mitigate some of the threat from lower wage economies, various authors and studies agree that manufacturing in high wage economies has to change in order to stay competitive (Flanagan *et al.* 2003, Manufuture High Level Group 2004). There is a consensus that this change will involve moving towards high-value, knowledge-intensive goods and services (Wise & Baumgartner 1999, Flanagan *et al.* 2003). For manufacturing organisations, literature argues that this means emphasising the provision of integrated product-service offerings rather than the production of products alone (Wise & Baumgartner 1999, Neely 2007, Baines *et al.* 2009a).

The concept of manufacturers providing services is not new (Schmenner 2009). Indeed, Levitt (1972) proposed that "everybody is in service" (p.42). In reality, the majority of manufacturers have always provided some form of service with their product (e.g. warranty, maintenance and spares provision), but these services have traditionally been seen as add-ons (Neely 2008). More recently, literature reports that some capital goods manufacturers have begun viewing services more strategically, developing and delivering integrated product-service systems (PSSs) (Davies *et al.* 2006, Johnstone *et al.* 2008, Baines *et al.* 2009b, Kapletia & Probert 2009). Literature argues that this shift from product to product-service can offer significant economic, competitive and strategic advantages for manufacturers (Neely 2008).

<u>Economic</u>

Services generally have higher margins than products and service revenue is often smoother and more continuous compared to product revenue which is more susceptible to economic cycles (Brady *et al.* 2005). Additionally, substantial revenues can be generated from a large installed base (Olivia & Kallenberg 2003). For example, Wise & Baumgartner (1999) have identified an installed-base-to-new-unit ratio of 13 to 1 in the automobile industry, 22 to 1 in the railway industry, 30 to 1 in the tractor industry and 150 to 1 in the civil aerospace industry. This is pushing economic value downstream, away from manufacturing towards providing services to operate and maintain products.

Competitive

Services increase the degree of customer lock-in by giving customers performance that only the manufacturer's capabilities and processes can deliver. For example, one manager at Air Liquide stated, "the more we enter into a customer's business, the more the customer forgets how things are done" (Reinartz & Ulaga 2008, p.96). Additionally, services are more difficult to imitate than products (Olivia & Kallenberg 2003), increasing the barriers to competition (Vandermerwe & Rada 1988) and driving up the quality level throughout the supply chain (Goedkoop *et al.* 1996).

Strategic

Services tend to smooth the cycles of product demand with the customer's continuous demand for support (Wise & Baumgartner 1999, Olivia & Kallenberg 2003)

The transition towards providing PSSs is known as servitization (Vandermerwe & Rada 1988) with (Baines *et al.* 2009b) defining it as "the innovation of an organisations capabilities and processes to better create mutual value through a shift from selling product to selling PSS" (p.555). Although the term 'PSS' emerged from the environmental and social sciences disciplines (e.g. Mont 2000, Mont 2001, Manzini & Vezzoli 2003), recent research has begun to merge the servitization and PSS literatures (e.g. Baines *et al.* 2007, Neely 2007, Neely 2008, Baines *et al.* 2009b, Spring & Araujo 2009, Martinez *et al.* 2010).

PSSs are defined as competitive propositions that deliver customer satisfaction and economic viability (Baines *et al.* 2007) consisting of "a marketable set of products and services capable of jointly fulfilling a user's need" (Goedkoop *et al.* 1996, p.18). In their review of the PSS literature, Baines *et al.* (2007) identify three distinct types of PSS: product-oriented, use-oriented and result-oriented. Neely (2008) expands this by adding integration-oriented and service-oriented PSS (Table 1-1).

Although each type of PSS contains a different mix of products and service elements and different product ownership structures, the emphasis in all types is on 'sale of use' rather than 'sale of product' (Baines & Lightfoot 2009). The integration- and product-oriented PSSs can be seen as product plus services where the product is generally sold separately and services are offered that sustain the functionality that the product provides throughout its life. The service-oriented PSS can be seen as products and services where services are incorporated into the product – i.e. the product is sold with a service package which may be enabled by onboard equipment. The use- and result-oriented PSSs can be seen as services plus product where the focus is on the service element. Typically the use-oriented PSS focuses on selling the functionality through providing access to a serviced product (e.g. Streetcar's pay-as-you-go car club) whereas the result-oriented PSSs focus on providing a capability (e.g. Rolls-Royce's Power-By-The-Hour™ contracts provide thrust rather than an engine and BAE System's Typhoon Availability Service).

Table 1-1: Categories of PSSs

Type of PSS	Definition
Integration-oriented	Going downstream, adding services through vertical integration. Ownership is transferred to the customer, but the supplier seeks vertical integration (e.g. by moving into: retail and distribution; financial services; consulting services; property and real estate services; or transportation services). Integration-oriented PSS can be conceptualised as offering a product plus a range of associated services (Neely 2008)
Product-oriented	Ownership of the tangible product is transferred to the customer, whilst included in the original act of sale are additional services (e.g. design and development services; installation and implementation services; maintenance and support services; consulting services; outsourcing and operating services; or procurement services) (Baines *et al.* 2007)
Service-oriented	Incorporate services into the product itself. Ownership of the tangible product is transferred to the customer, but additional value added services are offered as an integral part of the offering (e.g. health usage monitoring systems or intelligent vehicle health management services). Service-oriented PSS can be conceptualised as offering products and services which are enabled by additional technology (Neely 2008)
Use-oriented	Ownership of the tangible product is retained by the service provider. Functions of the product are sold via modified distribution and payment systems (e.g. through sharing, leasing or pooling) (Neely 2008)
Result-oriented	Selling the result or capability instead of a product (e.g. web information replacing directories). Companies offer a customised mix of services where the producer maintains ownership of the product and the customer pays only for the provision of agreed results (Baines *et al.* 2007)

Within the context of this research, the PSSs provided by capital goods manufacturers contain a physical core product which is supplemented by specific services (Aurich *et al.* 2009). Here, ownership of the physical product can reside with either the manufacturer or customer, but the sustainment of functional behaviour is emphasised (Vasantha *et al.* 2011).

Despite the advantages of servitization, a paradox has been reported that suggests that the benefits from a servitization strategy may be difficult to realise (Brax 2005, Gebauer *et al.* 2005). Neely (2008) provides empirical evidence for this paradox, highlighting that although servitized manufacturers generally report higher revenues, their profitability is lower than pure manufacturing organisations. This suggests that servitized manufacturers face a number of challenges which may hinder their ability to successfully deliver PSSs. Whilst literature reports a number of challenges

faced by manufacturers (Martinez *et al.* 2010), these have been classified as challenges relating to shifting mindsets, timescales or business models (Neely 2008).

The challenges of shifting mindsets

For marketers, servitization involves a shift from transactional to relational marketing (Gebauer *et al.* 2006). As long-term contracts are entered into to deliver sustained functional performance, products are no longer simply sold. Hence, the nature of what is being sold and the length the relationship between customer and supplier changes (Neely 2008). In relational marketing, the emphasis is on developing long-term relationships with customers to retain business rather than focusing on one-off sales transactions (Grönroos 1998). Traditionally sales personnel place great emphasis on the sale of the physical product (Gebauer *et al.* 2005). The sale of PSSs, however, requires manufacturers to emphasise the service elements (Vandermerwe & Rada 1988). It is reported that this is often difficult to achieve with Olivia & Kallenberg (2003) quoting from an interviewee in their study, "it is difficult for an engineer who has designed a multi-million dollar piece of equipment to get excited about a contract worth $10,000 for cleaning it" (p.161). Additionally, for manufacturers to successfully servitize and provide sustained functional performance through PSSs, customers have to accept that having a need met is more important than owning a product (Goedkoop *et al.* 1996, Mont 2000).

The challenges of timescale

For complex engineered services, organisations engage in multi-year partnerships (Neely 2007). In these long-term partnerships, significant challenges have been identified in: managing and controlling risks and exposure; and modelling and understanding the costs and profitability implications (Neely 2008). Many of the factors that influence profitability (e.g. fluctuations in oil prices, currency rates or access to credit) are beyond a servitized organisation's control, but they may have a significant impact upon the viability of a long-term service offering. For servitized manufacturers to sustain profitability, understanding how such factors are likely to shift over time and how the associated risks can be mitigated is essential.

The challenges of business models

The marketing literature suggests that there is a need to understand what value customers derive from using the PSSs (value-in-use), rather than define value from the producer's perspective. Whilst a number of service development methodologies have been proposed that focus on developing and delivering mass services (e.g. financial services) (e.g. Scheuing & Johnson 1989, Bowers 1993, Tax & Stuart 1997, Johnson *et al.* 2000), few research studies have sought to investigate integrated product-service development in manufacturing firms (Neely 2008, Baines *et al.* 2009b). However, research within the service domain has reported that "it seems to be worthwhile to explicitly organize the process of developing new services" (De Jong & Vermeulen 2003, p.844) with the most successful firms being those that have formal processes (de Brentani 1991, Kelly & Storey 2000). Furthermore, recent research has highlighted that servitized

manufacturers typically retain capabilities in design (Baines *et al.* 2011a, Baines *et al.* 2011b). This suggests that the creation of formal approaches to the development of PSSs should prove worthwhile for servitized manufacturers.

Although limited research has been conducted within the servitization field proposing formal approaches for developing PSSs, a number have been proposed within the product and service development literatures. However, traditional approaches to product development such as the 'V' model (Royce 1970) or the stage-gate model (Cooper 1986) have generally focused on the development of products separately from services. Similarly within the service development literature, processes such as the normative model of new service development (Scheuing & Johnson 1989) and the new service development process cycle (Johnson *et al.* 2000) have focused on service development separately from products. Whilst research has been conducted that attempts to combine the two paradigms (Bitran & Pedrosa 1998), when products and services are tightly coupled as in PSSs, products and services must be designed concurrently (Alonso-Rasgado *et al.* 2004, Kimita *et al.* 2009).

The PSS literature is more mature in this area and a number of approaches have been proposed (e.g. Brezet *et al.* 2001, Luiten *et al.* 2001, Engelhardt *et al.* 2003, van Halen *et al.* 2005). However, these approaches principally focus on developing PSSs that are optimised to decrease the environmental impact of products and services. Limited research has been conducted to investigate whether they can be applied by servitized manufacturers to develop competitive PSSs. This represents a knowledge gap within the servitization literature. This research contributes to knowledge by: (1) investigating whether the PSS development approaches reported within the PSS literature reflect the PSS development practice of servitized manufacturers; and (2) proposing and testing a new model of PSS development that better reflects the PSS development practice of servitized manufacturers.

1.1 The context of the industrial sponsor

Bombardier Transportation (BT) is a global leader in rolling stock manufacturing and servicing with an installed base of over 100,000 railcars and locomotives worldwide (Bombardier 2011). BT's business is structured around six divisions, focusing on four market segments (Table 1-2).

Table 1-2: The market segment of BT's divisions

Division	**Market segment**
Locomotives, Light Rail and Equipment	Rolling stock manufacturing
North America	Rolling stock manufacturing; Services
Mainline and Metros	Rolling stock manufacturing
Rail Control Solutions	Signalling
Services	Services
Systems	Turnkey transportation systems

Rolling stock manufacturing and sales represent the greatest proportion of BT's revenue, with services representing 15% (year end 2011) (Figure 1-1). This service revenue is primarily driven by three activities:

- Fleet maintenance – maintenance services for rail operators
- Refurbishment and overhauls – modernisation, re-engineering and overhaul of rail vehicles and components
- Material solutions – supply chain management, spare parts inventory management and technical support services for rail operators

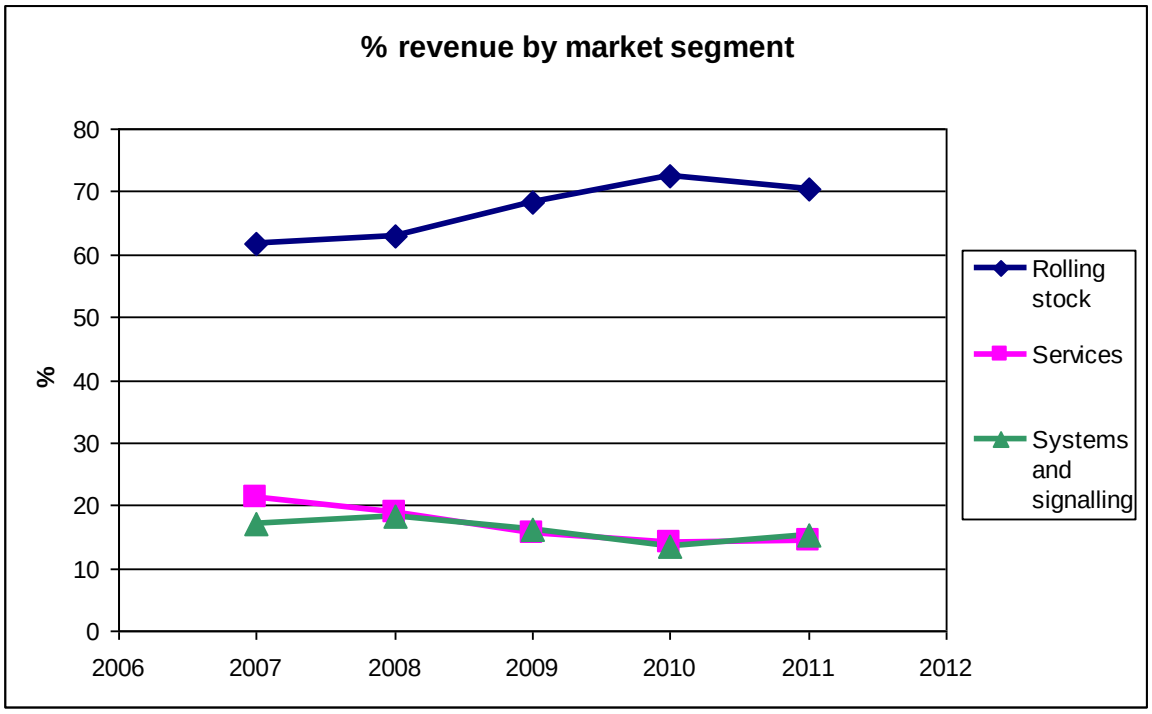

Figure 1-1: BT revenue by market segment (Bombardier 2011)

Although BT provides integrated PSSs through its Systems division (e.g. light rail turnkey transportation systems), its mainline divisions provide products and services separately. The 2007 '*Rail Technical Strategy*' (Department for Transport 2007b) which accompanied the '*Delivering a Sustainable Railway*' white paper (Department for Transport 2007a), outlined the UK government's aim to have "world-class reliability of both infrastructure and rolling stock" (Department for Transport 2007b, p.5). In order to achieve this, the '*Rail Technical Strategy*' highlighted the need for "government and industry [to work] together taking a whole-life, whole-system cost approach in exploiting opportunities" (Department for Transport 2007b, p.6). This has recently been re-iterated by McNulty (2011) who identified that one of the reasons for the UK railway industry's significantly higher costs, when compared to European rail operations, is its failure to take a whole-system approach.

Within this environment, the Department for Transport (DfT) is increasingly seeking to procure the capability to move people at a specified level of performance (i.e. result-oriented PSSs). For example, recent tender requests by the DfT are seeking to procure a "fully financed package for the manufacture, entry into service and maintenance support of a new fleet of rolling stock" (Department for Transport 2008, p.18). These tenders are encouraging rolling stock manufacturers to provide greater levels of service provision as part of their core product offerings, but significant challenges exist in understanding how these PSSs could be delivered and developed by traditionally product-focused manufacturers.

Whilst BT uses a formal, documented approach to developing products (termed the *'Product Planning Process Directive*' (Carton 2006)), no such methodology exists for developing services simultaneously with products: "*…we know there is a need for [PSS example 1], [PSS example 2], etc and we are struggling…we are not using them, we are not integrating them and do not have a proper process to develop them*" (Vice President). During interviews conducted as part of the research, one respondent stated:

I guess the most successful service offering we currently have…is actually our bread-and-butter maintenance offering where we've been able, because of the experience, to deliver something that we know works and can deliver with respect to what the customer wants (Director)

This suggests that without a formal, documented process BT is capable of developing traditional products and maintenance services separately because of the experience its employees have gained in delivering these over a number of years. However, BT is seeking to complement its traditional offerings through the provision of integrated PSSs (e.g. providing optimised availability and reliability enabled by onboard condition monitoring). Developing integrated product-service offerings will enable BT to fulfil the UK government's requirements whilst simultaneously providing an opportunity to deliver integrated PSSs to existing contracts, increasing their value. Literature suggests, however, that it is unlikely that BT will be able to deliver superior service if the PSSs are being conceived and developed in an ad hoc, non-repeatable fashion (De Jong & Vermeulen 2003, Reinoso *et al.* 2009).

The research reported within this thesis was motivated by a desire to fill this need of the industrial sponsor. This research contributes to BT by providing it with a rigorously defined model of how it could develop its future PSSs.

1.2 Aim and objectives

1.2.1 Aim

The aim of the research reported within this thesis was to investigate existing approaches to developing and delivering PSSs, creating a new model to aid servitized manufacturers develop PSSs.

1.2.2 Objectives

Given that BT currently delivers its product and service offerings separately, the first stage of research focused on exploring how PSSs could be delivered within the railway industry. Having gained an understanding of the implications of delivering PSSs, the models of PSS development reported within the PSS literature were evaluated and a new model proposed to better reflect the practice of servitized manufacturers. The new model of PSS development was then operationalised, in the form of a workbook, and applied to the development of a PSS. Three objectives were identified for the research:

1. Exploring how PSSs could be delivered in the UK railway industry
    a. Review existing literature, identifying the types of PSS that are typically offered by capital goods manufacturers and their implications for the railway industry
    b. Explore how the traditional, separated product and service operations are delivered
    c. Develop an understanding of how these might be integrated
    d. Create a model describing how PSSs could be delivered in the UK railway industry

2. Investigating PSS development
    a. Review and synthesise literature, identifying and analysing the approaches proposed for developing PSSs
    b. Using a single case study, evaluate whether the model of PSS development, synthesised from literature, reflects the practice of one servitized manufacturer
    c. Using a survey, evaluate whether the findings from the case study reflect the practice of a larger sample of servitized manufacturers
    d. Based on the findings from the case study and survey, propose a new model of PSS development to better reflect the practice of servitized manufacturers

3. Operationalising the proposed model of PSS development
    a. Review the existing literature to select an approach to modelling the proposed new model of PSS development in a workbook
    b. Create the workbook
    c. Apply the workbook
    d. Based on the application, identify any implications for the new model of PSS development and broader theory

1.3 Motivation for applying systems engineering techniques

1.3.1 What is systems engineering?

Systems engineering is aimed at managing the complexity in the design and development of new systems and is defined as “an interdisciplinary approach and means to enable the realization of successful systems” (Haskins *et al.* 2011, p.6). A system is defined as “a combination of interacting elements organized to achieve one or more stated purposes” (Haskins *et al.* 2011, p.5). Systems engineers use systems thinking to gain a unique perspective on reality – one that considers wholes and how parts within these wholes interrelate. Systems thinkers know how systems fit together in the context of day-to-day life, how they behave and how to manage them. Systems engineering techniques, tools and methods are used by systems engineers to support their systems thinking activities.

Traditionally, systems engineering principally focused on the management, design and development of systems with purely technical components (Hughes 2000). These systems are purposive – designed to reach the goal specified by engineers (Jackson 2003). Over time, systems engineering has been applied to a number of social systems (e.g. Checkland 1981) where systems are said to be purposeful – parts of the system (e.g. human beings) can generate their own purposes from inside the system and these might not correspond to any purposes prescribed by engineers (Jackson 2003). More recently, systems engineering has focused on the management, design and development of socio-technical systems consisting of both technical and organisational components (Hughes 2000).

1.3.2 Applying systems engineering to PSS development and delivery

PSSs, consisting of both technical and organisational elements, can be considered socio-technical systems (Meier *et al.* 2010). The PSSs delivered by capital goods manufacturers consist of both complex products (e.g. aircraft, rolling stock, broadband networks, business information networks, offshore drilling rigs, etc (Davies & Brady 1998)) and complex service systems composed of individuals, firms, government agencies or any organisation of people and technology (Spohrer *et al.* 2007). As such, developing and delivering products and services simultaneously requires an interdisciplinary approach to manage the complexity associated with the product elements, the service system and the interactions between them. The PSS development literature reports that PSSs have to be regarded as a whole to ensure guaranteed results for customers (Maussang *et al.* 2009). As such, they are considered system-level innovations (Brezet *et al.* 2001, van Halen *et al.* 2005).

Although similarities have been identified between PSSs and the problems tackled by systems engineering (complexity, interdisciplinary approach and holism), few research studies have sought to view the development and delivery of PSSs from a systems perspective. Two notable exceptions to this are Morelli (2003) and Kar (2004). Kar (2004) applies a systems perspective to

the development of mobile information services, suggesting three elements that should be considered in parallel: the service formula – the differentiating value proposition demanded by customers; the value network – the configuration of activities between organisations, their relationships and cost and revenue structures; and enabling technology – the service architecture providing the necessary technical functions to realise the service. Although Kar uses a systems perspective to aid in the creation of her methodology, no systems engineering tools, techniques or methods are used by Kar to aid development teams use the methodology to create PSSs. In contrast, Morelli (2003) does propose the use of a systems engineering technique (i.e. use cases) that development teams can use to provide an indication of the main requirements for the PSS. However, the application of use cases is limited to one phase within PSS development. This suggests that use cases were chosen as a means of representation rather than as a tool to support systems thinking activities.

Given these limitations, it is the author's belief that through applying systems engineering a more holistic understanding of how PSSs can be developed and delivered can be attained.

1.4 Scope

The research reported within this thesis focused on the development and delivery of PSSs. Reflecting this, the domain of the research work contained is bounded by the five main considerations:

Choice of manufacturers

Given that the research was conducted mainly within BT and to ensure greater comparison with the majority of the previous research within the servitization domain (e.g. Kerr & Ivey 2001, Olivia & Kallenberg 2003, Kumar & Kumar 2004, Brax 2005, Davies *et al.* 2006, Johnstone *et al.* 2008, Neely 2008), the focus of the research work was the development and delivery of PSSs within capital goods manufacturers. Within the context of this research, capital goods manufacturers sell products and services in business-to-business environments. Whilst some research has investigated servitization and PSSs within consumer markets (e.g. Rexfelt & Ornas 2009 and Parry *et al.* 2011), these are not considered within this work.

Type of PSS

PSSs have been categorised in a number of different ways. Within the context of this research, the PSSs provided by capital goods manufacturers contain a physical core product which is supplemented by specific services related to the product. Whilst ownership of the physical product can be either retained by the servitized manufacturer or transferred to customers, the emphasis within this thesis is on PSSs that deliver sustained functional performance through products and services.

Servitization strategy

A number of servitization strategies have been reported within the literature - e.g. basic services, professional services, maintenance services and operational services (Olivia & Kallenberg 2003). Given that the definition of PSSs focuses upon delivering sustained functional behaviour through products and services, only servitization strategies that include maintenance and operational services are considered within this thesis (e.g. Rolls-Royce's Power by the Hour™ and BAE Systems ATTAC™). Other strategies, such as professional services (e.g. IBM's transition to business solutions provider) were not considered within this work.

PSS development triggers

Literature reports that the need to develop PSSs can be triggered by: an organisation proactively seeking to offer PSSs; customers demanding PSSs; the imitation of competitors who already deliver PSS; or pressure to increase the perceived value of an offering (Neely 2008). Although BT is developing PSSs in response to customer requests (i.e. responding to tenders for the delivery of full packages of manufacture and servicing for new rolling stock), there is an increasing emphasis on developing new products and services that customers have not explicitly requested but will deliver significant financial and performance improvements (e.g. BT's ECO4™ energy saving technologies were developed to help customers reduce the environmental impact of running train services and not in response to specific tenders). Whilst the PSS development approach pursued by an organisation is likely to be different depending on what triggers the need for development, within the context of this thesis, PSS development is assumed to be proactive – i.e. the servitized manufacturer seeks to develop PSSs to fulfil unexpressed needs that are not currently being fulfilled by competitors' PSSs.

PSS development

Within this thesis, the development of PSSs is defined as an approach to creating products and services that, when integrated, are capable of fulfilling customers' needs by delivering sustained functional performance. Reflecting the systems engineering nature of the engineering doctorate, the model of PSS development is consistent with the structure proposed in ISO 15288 (2002). As such, within the context of this research, the model of PSS development consists of phases that describe the state of the PSS at any point during its development. Phases are made up of a number of processes that are executed throughout the phases in order to develop the PSS.

1.5 Synopsis of research papers

During the course of the research, a number of research papers were published. Table 1-3 provides a summary of the related published papers.

Table 1-3: Synopsis of research papers

ID	Title	Journal / Conference	Status	Description	Location
1	Generating value from whole-life solutions – A new opportunity for the UK rail industry	Production and Operations Management Society (POMS) 20th Annual Conference 2008	Published	A literature review of servitization; exploring the implications for the UK railway industry	Appendix III, Paper 1
2	Applying systems engineering to optimise the operation and maintenance of railway vehicles throughout the value chain	7th Annual Conference on Systems Engineering Research (CSER) 2009	Published	Summarises the use of soft systems methodology to explore how BT can deliver PSSs with the UK railway industry	Appendix III, Paper 2
3	Evaluating existing approaches to product-service system design: A comparison with industrial practice	Journal of Manufacturing Technology Management	Published	Synthesises a model of the phases within PSS development from literature and compares it to the practice of one servitized manufacturer	Appendix III, Paper 3
4	Comparing existing approaches to product-service system development with the practice of servitized manufacturers	International Journal of Production Economics	Submitted	Synthesises a model of the phases and processes within PSS development from the literature and compares it to the practice of servitized manufacturers through a single case study and survey	Appendix III, Paper 4

ID	Title	Journal / Conference	Status	Description	Location
5	A process model for developing integrated product-service offerings	18th International Annual European Operations Management Association (EurOMA) Conference 2011	Published	Presents the findings from the application of the PSS workbook	Appendix III, Paper 5

1.6 Thesis structure

The remainder of this thesis is structured as follows:

Chapter 2 presents a review of the literature associated with PSS development. First, the research associated with servitization is discussed before PSS development is defined. Phases and processes are synthesised from the existing approaches reported in the literature. A synthesised model of PSS development is created and the research question is posed.

Chapter 3 details the research design that was adopted to answer the research question. Consistent with the researcher's post-positivist paradigm, the mixed methods strategy adopted throughout the research is presented.

Chapter 4 describes the findings from the first stage of research which sought to explore how PSSs could be delivered within the UK railway industry. Implications for developing new PSSs were identified.

Chapter 5 presents the findings from the second stage of research that investigated PSS development. Specifically, the findings from a single case study and survey are presented which sought to determine the extent to which the model of PSS development, synthesised from the literature, reflected industrial practice. Based on these findings, a new model of PSS development is proposed.

Chapter 6 details the research conducted to operationalise the new model of PSS development in the form of a workbook that servitized manufacturers can follow to develop PSSs. The workbook was tested through its application to one PSS development project.

Chapter 7 concludes this thesis, presenting the principal findings from the research and summarising the original contribution of the research to knowledge and industry. The limitations of the research are discussed before areas for future work are presented.

Appendix I provides examples of the interviews conducted as part of the research and their analysis.

Appendix II gives greater detail on the structure of the UK railway industry.

Appendix III contains the peer-reviewed papers produced as part of the research programme.

Appendix IV contains the PSS Development Workbook which operationalises the proposed new model of PSS development.

2 Literature review

This chapter builds on the background information provided in chapter 1, exploring in more detail the concepts of servitization and PSS development. In section 2.1 previous research associated with servitization is presented. The term 'PSS development' is defined in section 2.2 with reference to the extant product, service and product-service literatures. Following this a number of existing approaches to PSS development are identified and analysed in section 2.3. Common phases and processes are identified before a synthesised model of PSS development is presented in section 2.4. An assessment of the application of the existing PSS development approaches is made before the research question is identified and a summary of this chapter is provided in section 2.5.

2.1 Research associated with servitization

The concept of servitization has been the focus of numerous studies that have sought to understand the implications of service-led competitive strategies and the methods used by servitized manufacturers to enact these strategies (Wise & Baumgartner 1999, Olivia & Kallenberg 2003, Baines *et al.* 2009a). At the same time there has been a similar growth in research on related topics – e.g. PSSs (Goedkoop *et al.* 1996, Mont 2000), services marketing (Palmer & Cole 1995, Vargo & Lusch 2004), service operations/engineering (Johnson 1999, Bullinger *et al.* 2003, Baines *et al.* 2009, Sakao *et al.* 2009) and services science (Spohrer & Maglio 2008)[1].

2.1.1 Product-service systems

The PSS concept originated in Northern Europe in the late 1990s (Goedkoop *et al.* 1996). Most contributions have been made by researchers from the environmental and social sciences (e.g. Mont 2000, Mont 2001, Manzini & Vezzoli 2003) principally publishing in the *Journal of Cleaner Production*, *the Journal of Design Research* and the *EcoDesign Journal* (Baines *et al.* 2007). Whilst the literature reports a range of PSS examples, most tend to emphasise significant environmental and social gains rather than economic success (Baines *et al.* 2009a). Within the PSS literature, PSSs are seen as having the potential for decoupling environmental pressure from economic growth by focusing on asset utilisation rather than asset ownership - a process termed 'dematerialisation' (Mont 2000). Mont (2001) identifies a significant barrier to the adaptation of PSSs in that consumers may not be enthusiastic about ownerless consumption.

Within the literature a number of approaches have been proposed for developing PSSs (e.g. Brezet *et al.* 2001, Luiten *et al.* 2001, Engelhardt *et al.* 2003, van Halen *et al.* 2005); however, Baines *et al.* (2009a) report that they "tend to lack the pedigree that is formed through careful evaluation in practice" (p.497). These approaches also reflect the broader PSS literature, emphasising environmental and social gains rather than the economic effects of delivering new PSSs.

[1] In addition to these, research within the project management literature has investigated design-build-operate-maintain contracts as part of Public Private Partnerships/Private Finance Initiatives. These can be seen as specific examples of organisations delivering integrated PSSs.

2.1.2 Services marketing

Much of the initial research into marketing focused upon the exchange and distribution of commodities (Baines *et al.* 2009a). Over time, the emphasis shifted from economic exchange to marketing management which emphasised the need to satisfy customers (Vargo & Lusch 2004). In 1960 the marketing mix model (or the four Ps – product, price, place and promotion) was proposed as a tool to assist in the defining of marketing strategy (McCarthy 1981). Marketers use the model to gain an understanding of what factors can be adjusted independently of market factors to satisfy customers. In the 1970s, Shostack (1977) reported that the marketing of services was different from products. Further, Levitt (1983) reported that products and services are often inseparable and that the sale of a product can lead to a relationship where services can be sold over an extended period of time. This shifted the focus of marketing from emphasising the transactional exchange towards a relational exchange.

The work of Shostack (1977) and Levitt (1983) acted as forerunners to two new streams within marketing literature – services marketing and relationship marketing. Whilst services marketing researchers have argued that the marketing of services is different from products because they are intangible, heterogeneous, inseparable and perishable (Spring & Araujo 2009), the relationship marketing literature is based on the premise that competition is between firms and that the exchange between actors has a temporal, relational dimension (Grönroos 2000). Recently, these two fields have converged to inform the 'service-dominant logic' (SDL) (Vargo & Lusch 2004). In the SDL the customer acts as a co-creator of value with the firm through an ongoing relationship and products act as vehicles for the delivery of services (Vargo *et al.* 2008).

2.1.3 Service operations

Prior to 1980, the academic literature was primarily concerned with the production, marketing and management of physical goods despite the fact that services represented the significant percentage of the gross domestic product in most developed economies (Johnston 1999). The 1970s saw an emerging recognition within the operations management field of service with the publication of the first to texts to place some emphasis on service (Johnson *et al.* 1972, Buffa 1976). A major breakthrough came in the operations management literature with Sasser's 1976 publication which sought to investigate what makes service industries distinct from manufacturing and what strategies are available to service managers. Later, Chase (1978) challenged operations managers to consider two types of operations: the back office factory and the customer-facing front office. These, and other publications of this period, reflected a growing awareness within the operations management field of service, customer operations and customer contact, but the nature of these academic works were largely descriptive and focused on the difference between goods and services (Johnston 1999).

Between 1980 and 1985 it became accepted that services were different from products (Brown *et al.* 1994) and much of the academic research conducted was conceptual in nature, characterised

by the development of frameworks to help understand the characteristics of service and service management (e.g. Grönroos 1984, Bowen and Schneider 1985, Parasuraman *et al.* 1985). Whilst this research sought to challenge existing operations management paradigms through the concept of customer operations (Johnston 1999), there was a significant focus on applying manufacturing operations concepts to the management of service operations (Davis & Heineke 2005).

The period 1985 to 1995 is seen as the era of service management and predominantly focused on the empirical testing of ideas and frameworks, resulting in tested models (e.g. Parasuraman *et al.* 1988, Bitner *et al.* 1990, Collier 1991). Of particularly importance in this period is the "service factory" concept (Chase & Garvin 1989) that calls for the inclusion of customer service as an integral part of a manufacturer's product specifications. Additional research focused on the development of service processes, service quality, service failure, service design and service technology with a view that service could contribute to manufacturing (Johnston 1999).

Whilst much of service operations literature is descriptive, a number of studies within the operations management literature have sought to be more prescriptive (Johnston 1999). For example, Baines *et al.* (2009) propose and test a framework to help manufacturing firms configure their internal production and support operations, enabling the effective and efficient delivery of products and their closely associated services. Similarly, Bitran & Pedrosa (1998) review the literature on product development from a services perspective, proposing a model for the development of service-products.

More recently, service engineering has emerged as a discipline that seeks to enhance the service design models emerging from the service operations literature with models, methods and tools emerging from the engineering design discipline. Service engineering has been defined as "a technical discipline concerned with the systematic development and design of services using suitable models, methods and tools" (Bullinger *et al.* 2003, p.276). The proponents of service engineering argue that it adopts a more technical-methodological approach to new service development when compared with marketing-oriented approaches.

Within service engineering, significant emphasis has been placed on the development of methods and tools to aid organisations design services, but these predominantly focus on activities that are conducted within the traditional 'concept design' or 'detailed design' phases of a product's development lifecycle. For example, service CAD aims to link articulated customer needs into a functional service design in a software tool (Arai & Shimomura 2004, Shimomura *et al.* 2009). Recent research has been conducted to extend the models within service engineering to encompass the execution and evaluation phases of new service development (Shimomura *et al.* 2011), but these models remain underdeveloped.

2.1.4 Service science

Originating in the IT sector, service science is an interdisciplinary concept for service and is defined as the "study of service systems, aiming to create systematic service innovation" (Maglio & Spohrer 2008, p.18). Service science seeks to integrate people, technology and business to lead to systematic service innovation (Spohrer & Maglio 2008). Services science draws on ideas from many existing disciplines (e.g. computer science, engineering, cognitive science, economics, organisational behaviour, human resource management, marketing and operations research) and aims to integrate them into a coherent science of service (Chesborough & Spohrer 2006).

Maglio & Spohrer (2008) identify that the service system is the basic unit of analysis of a service. Service systems are "value co-creation configurations of people, technology, value propositions connecting internal and external service systems, and shared information (language, laws, measures and methods)" (p.19). Entities within service systems exchange competences along four dimensions: information sharing, work sharing, risk sharing and goods sharing. For example, Maglio & Spohrer (2008) identify that information sharing dominates in business consulting, work sharing dominates in outsourcing, risk sharing dominates in insurance and goods sharing dominates in renting.

Service science builds upon the SDL reported within the services marketing literature, proposing SDL as a theoretical foundation for the development of service science and the study of service systems (Maglio *et al.* 2009). Consequently, within service science, service is conceptualised as a process that represents the basis of social and economic exchange with goods perceived as conduits for service provision (Vargo & Akaka 2009). Co-creation goes beyond inviting customers to participate in production and design processes, suggesting that there can be no value without customers incorporating the firm's offering into their own lives (Vargo & Akaka 2009). SDL as a theoretical foundation for service science thus defines service in terms of benefit for both manufacturer and customer. This and its relational, co-creative perspective on value creation expands the role of management and engineering in order to understand how manufacturers' resources can be integrated with customers' resources to offer new service systems.

The interaction between service science, management and engineering and the expansion of the traditional management and engineering disciplines dictated by SDL has led some authors to suggest that service science is not broad enough. Recently, there has been a call for a broader approach - S*ervice Science, Management and Engineering* (SSME) (Spohrer & Maglio 2008). SSME is defined as "the application of scientific, management, and engineering disciplines to tasks that one person, organization, or system beneficially performs for another person, organization, or system" (Spohrer & Maglio 2008, p.224). This expanded name indicates directly the need for an integrated approach to investigate service systems, spanning traditional academic disciplines and organisations. Thus SSME looks to integrate traditionally separate fields associated with service

(e.g. integrating service engineering and service operations with the SDL proposed within the service marketing field) to gain new insights.

2.2 Defining PSS development

Within the literature several terms are used to describe related ideas about how organisations create new products and/or services. The terms 'design' and 'development' are often used synonymously to define the overall approach to creating products and/or services or to define discrete stages within an overall approach (ISO 9000 2005).

Within the product literature, engineering design was conceived as a stand-alone process (Pahl *et al.* 2007), but due to increasing competition a broader perspective was required from traditional product design (Motte *et al.* 2011). In this broader perspective, it is necessary to prioritise market needs and establish a well defined development strategy. As a result product design progressed towards product development, where design is included as an activity within a broad development process. This is reflected in the service literature where service development is defined as the "overall process of developing new service offerings" (Johnson *et al.* 2000, p.5). Within the context of this thesis, 'development' refers to the overall approach to creating PSS offerings.

Given that PSSs are defined as "a marketable set of products and services capable of jointly fulfilling a user's need" (Goedkoop *et al.* 1996, p.18), emphasising the 'sale of use' rather than the 'sale of product' (Baines *et al.* 2009b), within the context of this research PSS development is defined as:

An overall approach to creating products and services that, when integrated, are capable of fulfilling customers' needs and delivering sustained functional performance

The term 'product' is often defined as "a tangible commodity manufactured to be sold" (Goedkoop *et al.* 1996, p.17), but this fails to recognise intangible products. For example, software development results in a product that is intangible (computer code) but the output can be inventoried and sold (Sampson & Froehle 2006). Thus, within the context of this research, 'product' is defined as a tangible or intangible commodity produced to be sold. Although there is significant debate within the literature on the definition of the term 'service' (e.g. Sampson & Froehle present a number of definitions), Spring & Araujo (2009) suggest that there are three distinct types of service:

- the "request for intervention" such as a car repair or a hair cut
- the "right to use a capacity" such as the temporary right to use a technical system – e.g. the right to use the telephone network to make a phone call
- "performance" such as that which takes place in a theatre – effectively the use of human capacity

Encompassing these service types, within the context of this research 'service' is defined as "any purchase […] by an economic agent B (whether an individual or organization) […] from organization A of the right to use, generally for a specified period, a technical and human capacity owned or controlled by A in order to produce useful effects on agent B or on goods C owned by agent B or for which he or she is responsible" (Gadrey 2000, p.382-3).

2.3 Existing PSS development approaches

Whilst limited research has been conducted within the servitization field proposing approaches for developing PSSs (Baines *et al.* 2009b), a number have been proposed within the related PSS and service engineering fields. The approaches within the service engineering field, however, emphasise activities within the traditional 'concept design' or 'detailed design' phases of product development and not the whole development process as reported within the PSS literature. Given this, existing approaches were considered principally from the PSS field.

From 2002 to 2004 the SusProNet project (an EU Fifth Framework Programme), which aimed to develop and exchange expertise on the creation of PSSs for sustainable competitive growth, identified thirteen separate approaches (Tukker & Tischner 2004). The majority of these, however, focus on specific phases within the development process – e.g. the INNOPSE (Innovation studio and exemplary developments for Product Service Engineering) project focused primarily on the idea generation process and the application of TRIZ techniques (Abdalla *et al.* 2005). Additionally, other approaches also focus on a subset of the whole PSS development process – e.g. James (2001) and Tukker & van Halen (2003) both report processes for requirements elicitation and idea generation and selection whilst Morelli (2009) identifies a series of techniques for service design structured around design as a collective decision making process: identification of problems, development of solutions and selection of policies. Whilst these approaches have their merit, due to their incompleteness they do not provide enough information to describe all of the phases within PSS development. Of the approaches identified within the SusProNet project, four cover all phases within PSS development: designing eco-efficient services (Brezet *et al.* 2001), the Austrian eco-efficient PSS project[2] (Engelhardt *et al.* 2003), the methodology for product-service system innovation (van Halen *et al.* 2005) and the Kathalys method (Luiten *et al.* 2001) (Table 2-1).

In addition to the approaches developed within the SusProNet project, but still emerging from the PSS literature, Mont (2000) proposes creating PSSs in an incremental fashion based on the Deming plan-do-check-act cycle. This approach is essentially sequential, incorporating a feedback loop to ensure continuous improvement of the PSS once it is being delivered.

[2] This publication is only available in German

Table 2-1: Phases within the existing PSS development approaches

	Brezet *et al.* (2001)	**Luiten *et al.* (2001)**	**Engelhardt *et al.* (2003)**	**van Halen *et al.* (2005)**
Phases	Exploration	Future exploration	A new perspective	Strategic analysis
	Policy formulation	Systems design	Creativity and innovation for my product	Exploring opportunities
	Idea finding	Product-service specification	The evaluation of the PSS	PSS idea development
	Strict development	Draw in detail	Marketing roadmap for new PSS idea	PSS development
		Implementation	Implementation	Implementation
			Process evaluation	

Goedkoop *et al.* (1996) offer a four-axis model for auditing PSSs (ecology, economy, identity/strategy and client acceptance axes), but they provide little evidence of the phases describing the states of PSS development. Maxwell & Vorst (2003) report on the creation of the sustainable product and services development method, but it predominately advises the designer of the important criteria when optimising for sustainability in products and services – it provides little advice to organisations developing PSSs.

Differing from these approaches, Morelli (2003) uses a design exploration process to investigate how technology, organisation and culture impact upon the design profession when creating PSSs (Figure 2-1). Whilst this approach provides information to describe all of the phases within PSS development, it is aimed at supporting the design profession to think about PSSs and not at supporting organisations to develop new product-service offerings. Given that Morelli (2003) reports its successful use in developing a PSS, it is considered within the context of this research.

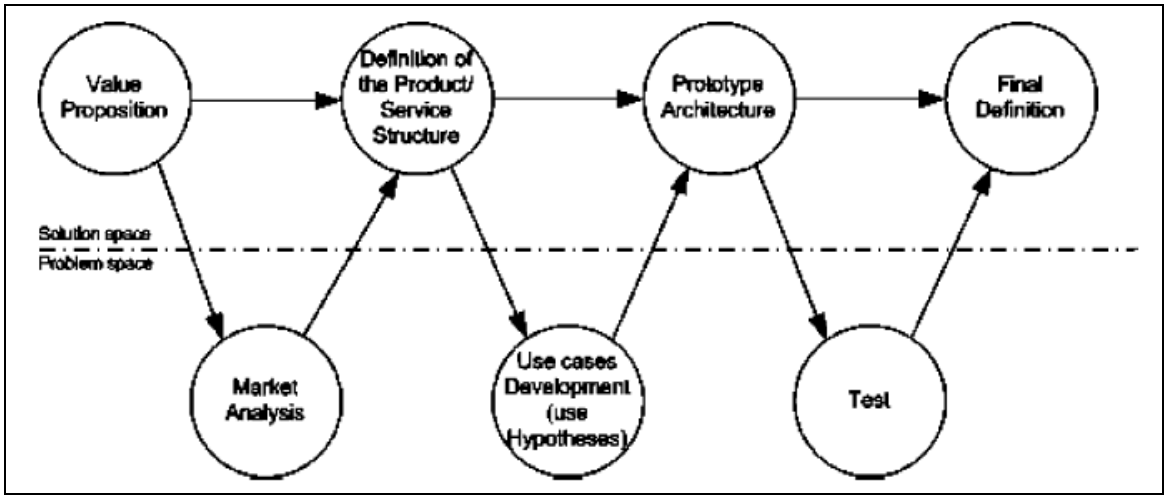

Figure 2-1: The design exploration process used by Morelli (2003)

Outside the PSS literature, a small number of approaches have been proposed that seek to integrate product and service development. For example, Aurich *et al.* (2006) proposes an approach for technical service development that has been modified from the product development approach proposed by Wheelwright & Clark (1992) (Figure 2-2). Here, the technical service development process consists of six phases. Each phase is made up of a number of processes. Aurich *et al.* (2006) proposes that integrated PSS can be developed by combining different processes from the product and technical service development approaches.

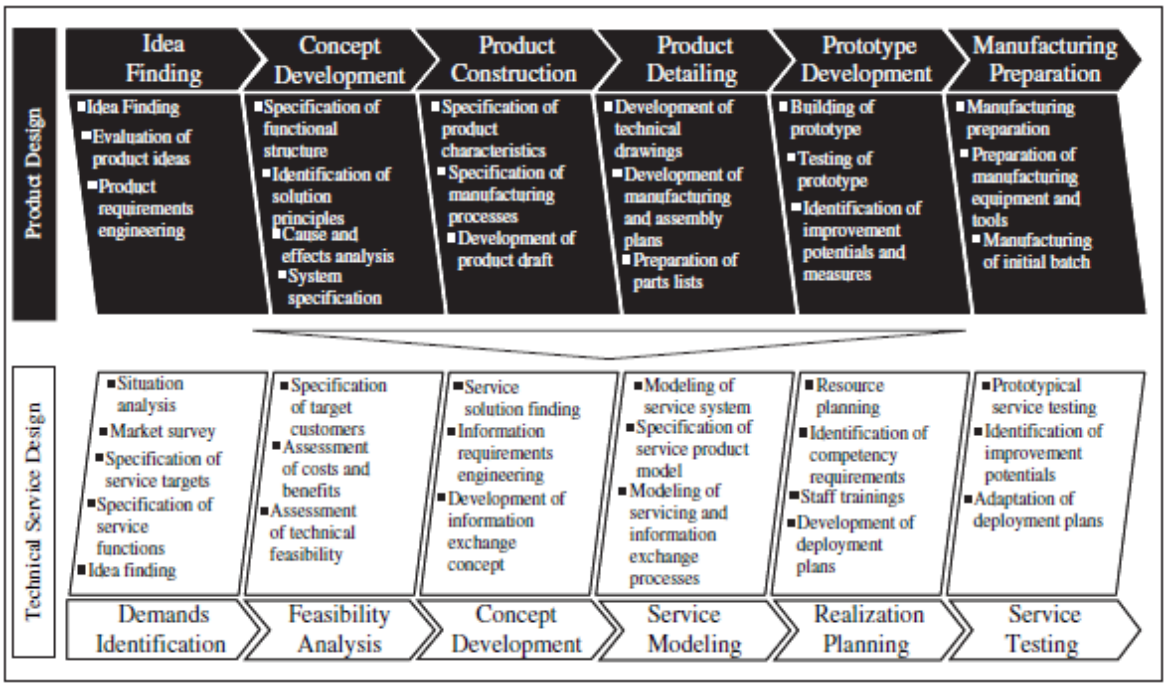

Figure 2-2: Product and technical service development processes (Aurich *et al.* 2006)

Additionally, modified from the service development literature, Kindström & Kowalkowski (2009) and Kar (2004) propose approaches to industrial service and information service developments respectively. Kindström & Kowalkowski (2009) propose a cyclic framework consisting of four phases: market sensing, development, sales and delivery. In contrast, Kar (2004) proposes a linear approach to developing PSSs consisting of five phases: analysis, preparation, synthesis, implementation and test. Although created specifically for information services, Kar's methodology is described as a service system design approach, suggesting that it may be applicable more generically. Consequently, Kar's model of information service development is considered within this research. Similarly, although outside the PSS development literature, Kindström & Kowalkowski's model relates directly to developing services within manufacturing organisations and is considered within this research.

Whilst eight approaches to PSS development have been identified from the existing literature, each represents the structure of the elements within their models differently (Table 2-2). For example, van Halen *et al.* (2005) structure their model of PSS development in terms of phases, steps and

process where phases are the highest level of the model, steps are the sequential building blocks of the phases and processes are action-oriented descriptions of the activities that need to be executed. In contrast, Luiten *et al.* (2001) structure their model in terms of five tracks (the product/service system, sustainability, organisation, the user and the economical feasibility) that are all worked upon concurrently throughout five project phases. Whilst Luiten *et al.* give an indication of the outputs per phase per track they do not provide a definition of what constitutes a track or a phase. This is similar to the models proposed by Brezet *et al.* (2001), Engelhardt *et al.* (2003), Morelli (2003) and Kindström & Kowalkowski (2009) who all indicate a hierarchical structure within their models of PSS development, but they do not provide definitions of what constitutes the elements at the different hierarchical levels.

Table 2-2: Structure of the eight models of PSS development

PSS development models	Structure within the models	Define elements?
Brezet et al. (2001)	Phase/Step → Action	
Luiten *et al.* (2001)	Phase → Track	
Engelhardt *et al.* (2003)	Workshop → Agenda points	
Morelli (2003)	Phase	
Kar (2004)	Phase → Element → Activity	✓
van Halen *et al.* (2005)	Phase → Step → Process → Action	✓
Aurich *et al.* (2006)	Phase → Process → Activity	✓
Kindström & Kowalkowski (2009)	Stage	

Given the differences reported in the structures of, and elements used within, the existing models of PSS development, a consistent hierarchical structure with defined elements is needed to ensure greater levels of comparison between the existing approaches and wider practice. To this end, the hierarchical structure and elements defined within ISO 15288 (2002) are used. Throughout the remainder of this thesis and reflecting ISO 15288, phases are made up of processes, which are executed in each phase. Processes, in turn, are made up of activities. Phases are defined as "a period within the [development] life cycle of a [product-service] system that relates to the state of the [product-service] system" (ISO 15288 2002, p.4). Processes are defined as a "set of interrelated or interacting activities which transforms inputs into outputs" (ISO 15288 2002, p.4). Activities are defined as "a set of actions that consume time and resources and whose performance is necessary to achieve, or contribute to, the realization of one or more outcomes" (ISO 15288 2002, p.3).

2.3.1 Identification of the common phases

Synthesis of the approaches that consider all phases within PSS development led to the identification of seven phases: project initiation, analysis, idea generation and selection, detailed design, prototype the service, implementation and evaluation (Table 2-3).

Table 2-3: Common phases of PSS development

Synthesised phase	Brezet *et al.* (2001)	Luiten *et al.* (2001)	Engelhardt *et al.* (2003)	Morelli (2003)	Kar (2004)	van Halen *et al.* (2005)	Aurich *et al.* (2006)	Kindström & Kowalkowski (2009)
Project initiation	✓		✓		✓			
Analysis	✓	✓	✓	✓	✓	✓	✓	✓
Idea generation & selection	✓		✓			✓	✓	
Detailed design	✓	✓	✓	✓	✓	✓	✓	✓
Prototype the service	✓	✓		✓	✓			
Implementation	✓	✓	✓		✓	✓		✓
Evaluation	✓		✓		✓		✓	

✓ Indicates agreement with the synthesised phase

2.3.2 Identification of common processes

Although the existing PSS development approaches are consistent in reporting phases, current literature is inconsistent in reporting further levels of detail. For example, van Halen *et al.* (2005) report that phases consist of steps, which are made up of processes in which activities are executed, whilst Luiten *et al.* (2001) and Morelli (2003) do not report at the process or activity level.

Given this inconsistency, processes were synthesised by identifying the interrelated and interacting activities reported in the PSS and wider literature. Activities were considered as specific actions that seek to operationalise processes. Where no activities were reported, processes were used. If processes were not reported (e.g. Luiten *et al.* 2001), this source was not used to synthesise common processes. For example, literature reports that some of the following activities are performed during the analysis phase:

- Customer analysis - build an understanding of customers' latent needs and how these may evolve over time (van Halen *et al.* 2005, Kindström & Kowalkowski 2009)
- Competitor analysis - identification of potential rivals for meeting the customers' needs (Bergen & Peteraf 2002)
- Identify new technology - develop an understanding of how new technologies might be used to assist customers' practices (Neely 2008)
- Identify strategic partners - identify potential partners to aid in the development and delivery of PSSs (Brezet *et al.* 2001, Kar 2004)

These activities are interrelated – they all refer to performing analysis on different aspects of the servitized organisation's business and market to identify opportunities to offer PSSs. Given the high level of interaction between these activities, they were combined into one process – market research. A total of 39 separate activities where identified as terms that operationalise fourteen processes (Table 2-4).

2.4 Synthesised model of PSS development

Given the common phases and processes identified from within the PSS development literature, PSS development can be said to be made up of seven distinct phases and fourteen processes (Figure 2-3).

In the synthesised model of PSS development, project initiation is reported as being the first phase within the development process. Project initiation begins when "one person, company or institute gets the idea for a function or system level innovation and makes sustainability part of this innovation" (Brezet *et al.* 2001, p.13). This differs from the models of PSS development proposed by Aurich *et al.* (2006) and van Halen *et al.* (2005) where project initiation occurs prior to the start of PSS development, but is similar to Engelhardt *et al.* (2003) and Kar (2004) where the first phase is concerned with gaining authorisation to begin a PSS development project and assembling the necessary team and resources. Reflecting the majority of the existing approaches, the synthesised model of PSS development (Figure 2-3) represents project initiation as the first phase.

Consistent with the traditional approaches to product development, the majority of the existing PSS development approaches report separate prototype the service and implementation phases. This suggests that PSS development is similar to product development in that it is be possible to create a version of the PSS that can be tested on a small customer sample before being implemented with a larger population of customers. This differs from the service development literature which suggests that because of the inseparability characteristic of services (production and consumption occurs simultaneously) (Spring & Araujo 2009), it is not possible to prototype a service without it being co-delivered by service provider and customer. For example, if the purpose of a PSS is to secure an airspace, whilst it may be possible to test the physical components (e.g. military aircraft, anti-aircraft weapons, surveillance equipment, IT infrastructure, etc), it is not possible to test whether the service provider can successful secure an airspace until it is securing that airspace. Nevertheless, given that the majority of the PSS development literature reports the prototype the service and implementation phases are occurring separately, the synthesised model of PSS development (Figure 2-3) presents them as separate phases.

Table 2-4: Common processes within PSS development

Process	Phase executed in	Definition	Activities used to operationalise the process	Sample reference
Capture requirements	Analysis	Requirements are defined that describe the functionality that the PSS should deliver	Define requirements	Brezet *et al.* (2001), Kar (2004) and van Halen *et al.* (2005)
Concept development	Idea generation & selection	Identifies: the total benefits that customers are likely to receive from the PSS and estimates what this might be worth to customers; and identifies the form of the service and the characteristics of the products required to enable the service to be delivered	Define value of offering; design the service and product characteristics	Brezet *et al.* (2001) and van Halen *et al.* (2005)
Customer involvement	Analysis; idea generation & selection; detailed design; prototype the service; implementation	Customers are involved in dialogue to identify their needs and co-design and co-produce the PSS	Generate an understanding of the objectives; selection of engagement method; involve customer; integrate insights	van Halen *et al.* (2005)
Customisation	Prototype the service; implementation	The tailoring of the product and/or service elements to specific customers' businesses	Describe main elements; propose variations	van Halen *et al.* (2005)

Process	Phase executed in	Definition	Activities used to operationalise the process	Sample reference
Deliver	Prototype the service; implementation	Both manufacturer's and customers' staff are executing the agreed work procedures/service process	Provide resources; execute agreed work procedures (co-production)	Kindström & Kowalkowski (2009)
Delivery planning	Detailed design	Providing guidelines for delivering the PSS, identifying potential obstacles and specifying tools and technologies that might aid in delivery	Identify delivery issues; identify delivery tools and instruments	Aurich *et al.* (2006)
Evaluation	Evaluation	Assessment of the market response, environmental impact and financial effects of the PSS	Define evaluation criteria; monitor customers' response and usage; measure the value provided; evaluate the PSS; write evaluation report	Brezet *et al.* (2001) and Aurich *et al.* (2006)
Idea generation	Idea generation & selection	Generating, evaluating and screening potential PSS ideas that will fulfil the identified customer needs	Generate ideas; select ideas; evaluate ideas	Brezet *et al.* (2001)
Market communications	Detailed design	Creating and implementing a strategy to communicate the value of the PSS to existing and potential customers	Quantify value of the PSS; communicate	Kindström & Kowalkowski (2009)
Market research	Analysis	An ongoing process to identify customer needs as well as the monitoring of competitive activities, staying on top of industry events, analysing new business opportunities and searching out strategic alliance partners	Customer analysis; competitor analysis; identify strategic partners; identify new technology	Kar (2004) and van Halen *et al.* (2005)

Process	Phase executed in	Definition	Activities used to operationalise the process	Sample reference
Product design	Detailed design	Identification, selection and specification of the technical components required to enable the PSS to be delivered	Specification of technical components; identification of technical components; selection of technical components	Kar (2004) and Aurich *et al.* (2006)
Project initiation	Project initiation	Authorisation to begin a PSS development project is given and the resulting goals and plans are documented	Project authorisation; define goals; create team; create project plan	Kar (2004) and van Halen *et al.* (2005)
Service design	Detailed design	The co-design of the service process and service system between manufacturer and customer	Specify the service process (activities); specify the service system (resources)	Aurich *et al.* (2006)
Systems analysis	Analysis	Gaining an understanding of the use of current products and services to identify opportunities for new PSSs	Understand usage profile of existing products and services; gain customer feedback; identify products	van Halen *et al.* (2005)

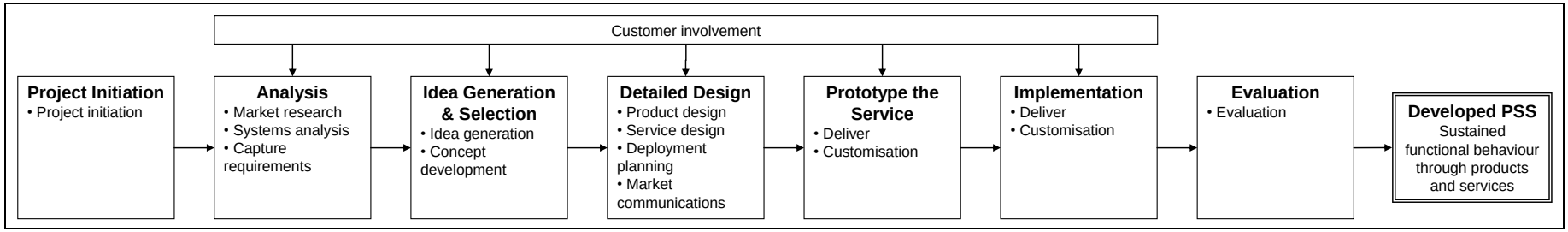

Figure 2-3: Model of PSS development synthesised from literature

Whilst a number of the existing approaches to PSS development identify the need to include customers (Brezet *et al.* 2001, Kar 2004, van Halen *et al.* 2005 and Kindström & Kowalkowski 2009), only van Halen *et al.* (2005) report specific processes and activities for including customers within PSS development. The model proposed by van Halen *et al.* includes customer involvement in PSS idea development (concept design) and PSS development (development) phases, but research in the wider service design literature reports that customer's should be involved in all phases of service development (Alam & Perry 2002). In fact, Alam & Perry go further and identify that one of the crucial success factors in service development is the level of customer involvement in all of the phases. Given that customer involvement is identified in the PSS development literature and to better reflect the findings from the service design literature, customer involvement is proposed as a process that is executed in the analysis, idea generation & selection, detailed design, prototype the service and implementation phases of the synthesised model of PSS development (Figure 2-3).

A number of approaches include an evaluation phase to assess the performance of the PSS once it is being delivered (Brezet *et al.* 2001, Kar 2004, Aurich *et al.* 2006), but Engelhardt *et al.* (2003) propose a process evaluation phase which is not reported in the alternative approaches. The process evaluation phase acts as a feedback loop, allowing for the re-design of the PSS development approach based on experience from its application. Consistent with this type of evaluation being conducted once the whole development process has been executed and reflecting the evaluation of the on-going delivery of the PSS, the synthesised model of PSS development (Figure 2-3) presents evaluation as occurring as the final phase.

Currently, research within the PSS field reports the use of the existing approaches to develop numerous PSSs that emphasise producing products with lower environmental impacts. Of the PSS development approaches considered within this thesis, no research has been identified that seeks to apply them to help servitized manufacturers develop competitive PSSs (Table 2-5). Existing research does, however, report high levels of synergy between the PSS and servitization literature (Baines *et al.* 2009b) with many identical concepts (Tukker & Tischner 2004). Given these reported similarities, a knowledge gap has been identified in understanding whether the models proposed within the PSS field can be used to aid servitized manufacturers develop competitive PSS. Consequently, the research reported within this thesis seeks to answer the question:

To what extent does the model of PSS development, synthesised from the PSS literature, reflect the PSS development practice of servitized manufacturers?

Table 2-5: Reported applications of PSS development approaches

Brezet *et al.* (2001)	**Luiten *et al.* (2001)**	**Engelhardt *et al.* (2003)**	**Morelli (2003)**	**Kar (2004)**	**van Halen *et al.* (2005)**	**Aurich *et al.* (2006)**	**Kindström & Kowalkowski (2009)**
Car sharing	Individual transport over short distances	*None reported*	Telecentre	Mobile information and entertainment service	Production of natural paint solutions	Optimisation of the service network for a manufacturer of heavy road construction machines	*None reported*
Individual transport over short distances					Exploring the environmental advantages of integrated lighting solutions		
Upgradeable oven							
Outsourcing of clothing care					The supply of electricity and advice to reduce consumption		
Office furnishing							

2.5 Summary

This chapter has presented a review of the published work associated with servitization and the field of PSS development. The chapter began by reviewing the literature associated with developing service-led competitive strategies. Following this the term 'PSS development' was defined, before a number of relevant approaches reported within the PSS field were identified. Analysis of these approaches led to the identification of seven common phases and fourteen common processes. The phases and processes were synthesised to create a model of PSS development. Whilst existing research has sought to apply PSS development to a number of applications, these have typically excluded PSS development within servitized manufacturers. Overcoming this knowledge gap represents the aim of the research reported within this thesis. To this end, the following research question was posed:

To what extent does the model of PSS development, synthesised from the PSS literature, reflect the PSS development practice of servitized manufacturers?

The following chapter presents the approach used to answer the research question through the adoption of an appropriate research design.

3 Research design

This chapter describes how the research presented within this thesis has been designed in order to answer the research question. Given that "methodology is not detachable from the philosophy/theory" (Jackson 2003, p.43), section 3.1 provides a discussion of research philosophy, leading to a description of the worldview adopted during this research project. Consistent with the worldview, the research methodology is presented in section 3.2 before a discussion of potential research methods are presented in section 3.3. Section 3.4 provides a summary of the research methods adopted in the different stages of the research before this chapter is summarised in section 3.5.

3.1 Research philosophy

Before a researcher can claim to have created new knowledge, they must first define what knowledge is. This means that research must be based on a philosophy of knowledge (Lee & Lings 2008). This philosophy constitutes the researcher's worldview (or paradigm). Guba & Lincoln (2005) present five alternative paradigms to which Cresswell (2003) proposes the addition of a sixth (Table 3-1). Each paradigm consists of four perspectives:

- Ontology refers to the belief about the nature of reality
- Epistemology reflects the types of knowledge that can be generated from an ontology
- Axiology refers to the goal of particular worldviews
- Methodology refers to the rules governing the research enquiry

These perspectives are often held implicitly and the governing structures that guide research are not always explicitly discussed or reflected upon by researchers (Lee & Lings 2008).

An ontological and epistemological approach was not defined at the beginning of this research. Instead post-positivism was naturally assumed. This is reflected in the nature of the research question in that it seeks to explain PSS development, investigating whether existing approaches reflect the practice of servitized manufacturers before proposing a new model of PSS development.

3.2 Research methodology

The critical realism of post-positivism suggests that whilst a generic model of PSS development exists in reality, it is imperfectly apprehensible – i.e. any model of PSS development is only probably true. To increase the probability of reporting an accurate model of PSS development, a mixed methods strategy was adopted (Cresswell 2007, Cresswell & Plano Clark 2007). Three main arguments are presented in favour of mixed methods approaches:

Table 3-1: Basic beliefs of alternative paradigms (Guba & Lincoln 2005)

	Positivism	**Post-positivism**	**Critical Theory**	**Constructivism**	**Participatory**	**Pragmatism**[3]
Ontology	Naïve realism – 'real' reality but apprehensible	Critical realism – 'real' reality but only imperfectly and probabilistically apprehensible	Historical realism – virtual reality shaped by social, political, cultural, economic, ethnic and gender values; crystallised over time	Relativism – local and specific constructed realities	Participative reality – subjective-objective reality, co-created by mind and given cosmos	Not committed to any theory of reality
Epistemology	Dualist / objectivist; findings are true	Modified dualist / objectivist; critical tradition / community; findings probably true	Transactional / subjectivist; value-mediated findings	Transactional / subjectivist; created findings	Critical subjectivity in participatory transactions with cosmos; extended epistemology of experiential, propositional and practical knowing; co-created findings	Truth is what works at the time and arises out of action, situations and consequences

[3] Entries in this column are based upon Cresswell (2003, p.11-12)

	Positivism	Post-positivism	Critical Theory	Constructivism	Participatory	Pragmatism[3]
Methodology	Experimental / manipulative; verification of hypotheses; chiefly quantitative methods	Modified experimental / manipulative; critical multiplism; falsification of hypotheses; may include qualitative methods	Dialogic / dialectical	Hermeneutical / dialectical	Political participation in collaborative action inquiry; primacy of the practical; use of language grounded in shared experiential context	Mixed methodologies that best meet a researcher's needs and purposes
Axiology	Explanation: prediction and control	Explanation: prediction and control	Critique and transformation; restitution and emancipation	Understanding and reconstruction; aiming for consensus	Understanding and reconstruction; acknowledging that people are disenfranchised by power and authority	Application; finding the solution to problems

- Real world problem situations are multi-dimensional (Boyer & Swink 2008)
- Different approaches are suitable at different stages of research intervention (Cresswell 2003)
- Using mixed methods can provide triangulation, validating the results (Jick 1979)

Mixed methods strategies are gaining popularity in the operations management literature (Boyer & Swink 2008), providing an opportunity to develop a holistic understanding of real world problem situations – something that is often missed when adopting a single approach (Mingers & Gill 1997).

Within the context of this research, mixed methods research is defined as "the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g. use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breath and depth of understanding and corroborations" (Johnson *et al.* 2007, p.123).

Cresswell (2003) reports three general strategies for mixed methods research: sequential, concurrent and transformative (Table 3-2). Within the context of this research, a sequential mixed methods research strategy was adopted.

Whilst mixed methods strategies have advantages over single approaches (Mingers & Gill 1997), critics have raised concerns about the philosophical and conceptual problems associated with combining methods from different paradigms. However, Lee & Lings (2008) argue that qualitative and quantitative methods can be successfully combined provided that the researcher is careful in the knowledge claims they are making.

3.3 Research methods

Research methods are specific techniques used to conduct research into the research phenomenon and are broadly categorised into two groups:

- Qualitative – gather an in-depth understanding of, and the factors that govern, human behaviour. Qualitative research focuses on answering 'how' and 'why' questions as theories emerge from data (Easterby-Smith *et al.* 1991)
- Quantitative – the investigation of phenomena via statistical techniques. Quantitative research focuses on developing mathematical models to test theories and/or hypotheses (Easterby-Smith *et al.* 1991)

Table 3-2: General strategies for mixed methods research (Cresswell 2003)

Mixed methods strategies	Description	Advantages	Disadvantages
Sequential	The researcher seeks to expand or elaborate on the findings of one method with another	1. Two-phase structure makes it simple to implement by a single researcher 2. The design lends itself to multi-phase investigations	1. Lengthy to implement the design 2. The researcher must decide whether to use the same or different individuals for each phase
Concurrent	The researcher converges or merges qualitative and quantitative data	1. Both types of data are collected during one phase 2. Each data type can be collected and analysed separately and independently	1. Much effort and expertise is required and may best be addressed by a research team 2. Researchers may face the question of what to do if the quantitative and qualitative data do not agree
Transformative	The researcher uses a theoretical lens as an overarching perspective within a design that contains both qualitative and quantitative data	1. Can be used by a researcher whose projects are time constrained 2. May be more manageable because one method requires less data than the other method	1. It can be difficult to integrate the results 2. Researchers must specify the purpose of collecting qualitative (or quantitative) data as part of a larger quantitative (or qualitative) study

In determining which are the most appropriate research methods, Yin (2003) categorised a number of potential methods by: the form of the research question; whether the researcher has control over the events under consideration; and whether the focus of the research is on phenomena in a modern-day context (Table 3-3).

Table 3-3: Relevant situations for different research strategies (Yin 2003)

Strategy	Form of research question	Researcher has control over events under consideration?	Contemporary context?
Experiment	How, why?	Yes	Yes
Survey	Who, what, where, how many, how much?	No	Yes
Archival analysis	Who, what, where, how many, how much?	No	Yes / No
History	How, why?	No	No
Case study	How, why?	No	Yes

Of the methods reported by Yin, both experimental analysis and surveys can be considered examples of quantitative research approaches (Cresswell 2003). Experimental analysis can take a number of forms. For example the behaviour of a system can be investigated by altering one variable at a time whilst keeping the others fixed. In this way, knowledge of the relationships between variables can be achieved. Alternately, experimental analysis could be used to determine whether one course of action (e.g. one approach to PSS development) is better than another by scoring how two groups using one course of action each score against a specified outcome. Surveys, on the other hand, are a collection of related questions on a specific topic and enable the researcher to gather numeric data on trends, attitudes or opinions of a population by studying a sample of that population. Surveys have been used in a number of new product/service development studies (e.g. Edgett 1994, Kelly & Storey 2000, Storey & Hull 2010), but respondent apathy has been identified as a significant concern (Janes 2001). These can emerge as low response rates resulting in incorrect conclusions being drawn. More recent delivery techniques (e.g. the internet) may help combat these issues by providing a global reach, low administration costs, increased speed and timeliness of responses (Evans & Mathur 2005).

Archival analysis, history and case studies can be considered as examples of qualitative research approaches (Cresswell 2003). Archival analysis requires that the researcher has access to detailed documented records which can then be used to explore a research phenomenon. Care must be taken as some records, which may be quantified, may be inaccurate. Similar to archival analysis, historical research strategies review situations that have occurred in the past. This strategy is particularly useful when there is no control or access to the behaviour of the research data. Case studies are a strategy of enquiry in which the researcher explores a programme, event, activity, process or one or more individuals in-depth (Cresswell 2003). Case studies are particularly useful when the boundaries between the phenomena and context are not clearly defined (Yin 2003). Although there is some resistance to validity and generalisability of the findings from case study (Yin 2003), it is generally accepted that case study research can be applied with sufficient scientific rigour to lead to significant advances in knowledge (Eisenhardt 1989).

3.4 Adopted research approach

Within the context of this research, and reflecting the objectives, the research was conducted in three distinct stages (Table 3-4). Stage one focused on conducting research to explore how PSSs could be delivered within the UK railway industry. Based on the findings describing what a PSS might look like within the UK railway industry, stage two focused on evaluating the synthesised model of PSS development. This evaluation took two forms: a single exploratory case study to evaluate in-depth the approach used by one organisation and a survey to investigate PSS development within a larger sample of servitized manufacturers. Based on these findings a new model of PSS development was proposed. Stage three involved testing the proposed new model of PSS development through application. The following sub-sections describe the adopted research method within each stage of the research.

Table 3-4: Summary of adopted research approach

Research stage	Research Objectives	Adopted research methods	Research output
1	**Exploring how PSSs could be delivered in the UK railway industry**		
	a. Review existing literature, identifying the types of PSS that are typically offered by capital goods manufacturers and their implications for the railway industry	Literature review	Appendix III, Paper 1
	b. Explore how the traditional, separated product and service operations are delivered	Soft systems methodology	Appendix III, Paper 2
	c. Develop an understanding of how these might be integrated		
	d. Create a model describing how PSSs could be delivered in the UK railway industry		
2	**Investigating PSS development**		
	a. Review and synthesise literature, identifying and analysing the approaches proposed for developing PSSs	Literature review	Appendix III, Paper 3
	b. Using a single case study, evaluate whether the model of PSS development, synthesised from literature, reflects the practice of one servitized manufacturer	Case study	
	c. Using a survey, evaluate whether the findings from the case study reflects the practice of a larger sample of servitized manufacturers	Survey	Appendix III, Paper 4
	d. Propose a new model of PSS development to better reflect the practice of servitized manufacturers		
3	**Operationalising the proposed model of PSS development**		
	a. Review the existing literature to select an approach to modelling the new model of PSS development in a workbook	Literature review	Appendix III, Paper 5
	b. Create the workbook	Action research	
	c. Apply the workbook		
	d. Identify any implications for the new model of PSS development and broader theory		

3.4.1 Stage 1: Exploring how PSSs could be delivered in the UK railway industry

The dynamic complexity associated with transforming an organisation from delivering products and services separately to delivering them as a PSS, and the fact that PSSs consist of people, processes and tools all working concurrently to manufacture, operate and maintain products requires a systemic process of inquiry. Checkland's soft systems methodology (SSM) (Checkland 1981, Checkland & Scholes 1990) has been applied within the aerospace and defence sectors to explore how PSSs can be delivered (Morcos & Henshaw 2009, Dogan & Henshaw 2010). SSM was adopted to explore the delivery of BT's existing add-on maintenance services and understand how integrated PSSs could be delivered. Within the context of this research, the 'two-strands' representation of SSM was used (Figure 3-1).

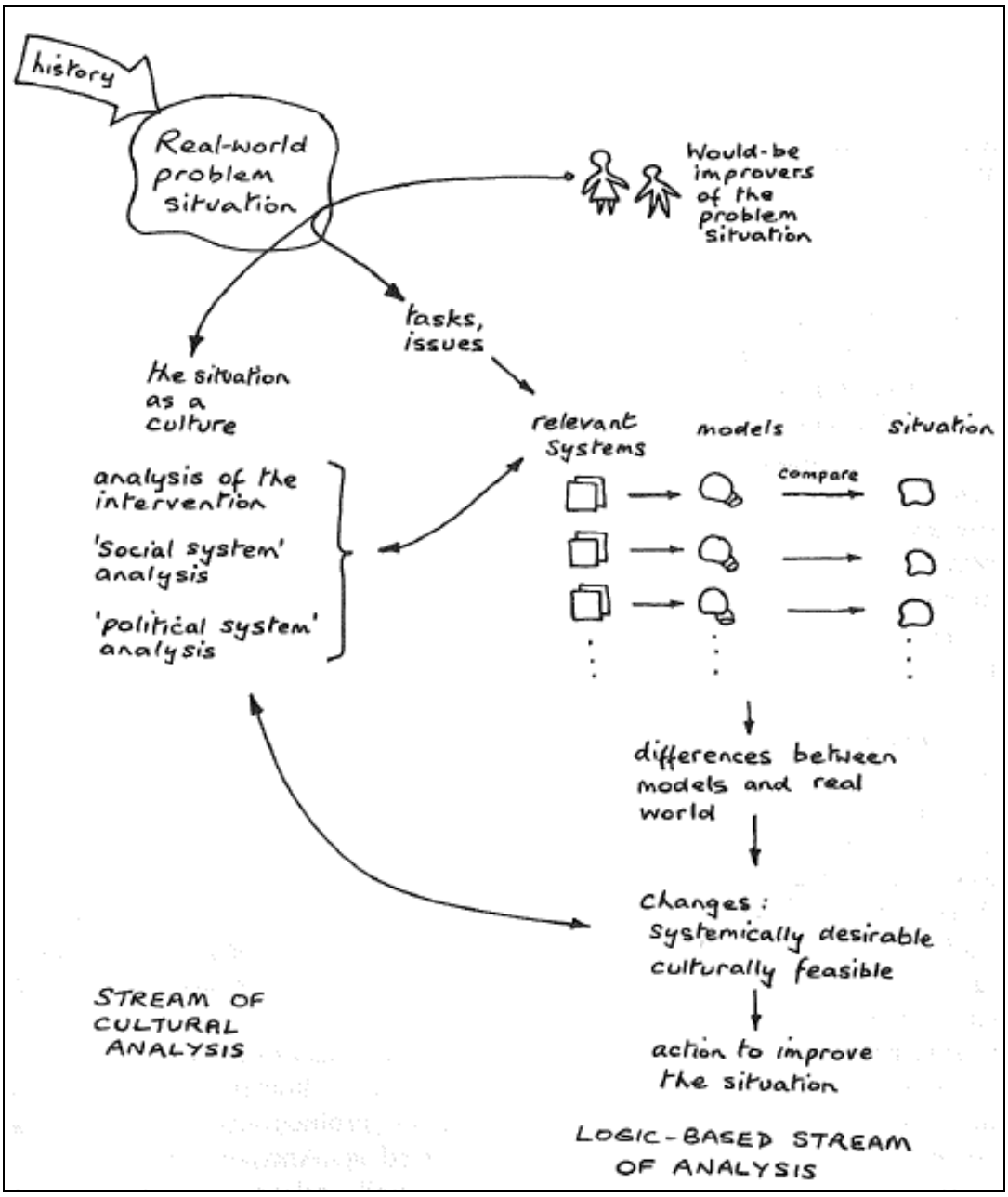

Figure 3-1: The 'two-strands' representation of SSM (Checkland & Scholes 1990)

The ‘two-strands’ model recognises four essential activities (Checkland 1999):

1. Finding out about the problem situation, including culturally and politically
2. Formulating some relevant purposeful activity models
3. Debating the situation, using the models, seeking from the debate:
    a. Changes which could improve the situation and are regarded as both desirable and culturally feasible
    b. An accommodation between conflicting interests which will enable action-to-improve to be taken
4. Take action to bring about the improvement

Consistent with the first stage of SSM, data was collected to explore the delivery of existing products and service. To ensure the dynamic complexity was fully understood, eighteen semi-structured interviews were conducted with respondents from different functional areas. Interviews were carried out on a one-to-one basis, lasting for approximately 90 minutes each. Some interviewees were approached on more than one occasion to better understand some of the contextual and situational factors involved (Table 3-5).

Table 3-5: Interview respondents for stage one of the research

Position	**Functional area**
Customer Account Director A[4]	Commercial
Customer Account Director B	Commercial
Director of Material Solutions and Fleet Spares	Materials and spares
Director of Predictive Asset Management	Engineering
Director of Strategic Programmes	Commercial
Fleet Delivery Manager	Operations
Fleet Director	Operations
Fleet Material Planner	Operations
Head of Central Material Stores	Materials and spares
Head of Product Development	Engineering
Inventory Specialist	Materials and spares
Logistics Manager	Materials and spares
Material Buyer	Materials and spares
Material Forecaster	Materials and spares
Material Planning Manager	Materials and spares
Project Engineer	Operations
Vice President of Strategy, Marketing and Product Planning	Commercial
Vice President, Services UK	*N/A*

[4] Letters (A, B, C, etc) were used to distinguish between different interview respondents who have the same job title

To help structure an exploration of the existing situation and understand the transition required to deliver integrated PSSs, the rich pictures and interview notes were analysed to identify purposeful activities. Rich pictures are the expression of the problem situation, in a diagrammatic format, compiled by a researcher to examine elements of structure, elements of process and the situation climate (Checkland 1981). The purposeful activities reflected interviewees' perspectives of the purpose of maintenance services and helped explore the transition required to provide maintenance services as a part of an integrated PSS. For each purposeful activity, the researcher created a root definition consistent with the CATWOE (customers, actors, transformation, weltanschuuang (worldview), owners and environment) mnemonic (Checkland 1981). A root definition is a concise, tightly constructed description of a human activity system which states what the system is (Checkland 1981). Once defined, conceptual models were created which represented the perceived minimum number of activities required to achieve the transformation enshrined in the definitions (i.e. conceptual models elaborated on what the system does). Interviewees were interactively involved in the analysis of the conceptual models, identifying the changes that would be required to transition the existing delivery of separate products and services towards the delivery of integrated PSSs. Based on these identified changes, rich pictures were created representing how integrated PSSs could be delivered. Interviewees were asked to analyse the rich pictures to determine whether they represented the changes identified.

3.4.2 Stage 2 - Investigating PSS development

Appreciating that the researcher has little control over the events under investigation and that the phenomenon exists in a contemporary context, Yin's framework (Table 3-3) suggests that case study is an appropriate method to adopt. Case studies have been reported as being popular in the operations management literature (Voss *et al.* 2002) with Baines *et al.* (2009b) reporting that they are the dominant research method adopted within the servitization field. Within this stage of research, case study was adopted as the primary research method.

3.4.2.1 Case study

Case selection

One of the first steps in case study research is to identify whether a single or multiple cases should be researched (Yin 2003). Eisenhardt (1989) suggests that whilst there is no ideal number of cases, a number between four and ten is desirable for generating theory. From a review of case studies, Voss *et al.* (2002) have reported that between one and sixteen cases have been used for exploration and theory building. Moreover, Handfield & Melnyk (1998) suggest that a "few focused case studies" (p.324) are required to identify key variables and their relationships. Dyer & Wilkins (1991) report that a number of important studies have advanced the knowledge of organisations and social systems based on single or low quantity case studies. Although the literature does not agree on the ideal number of cases, there is general agreement that single case studies permit for greater depth (Dyer & Wilkins 1991) but limitations on the generalisability of conclusions have been reported (Voss *et al.* 2002). Given that the development of PSSs is a complex phenomenon, and

to ensure that industry practice was understood in sufficient detail, the adoption of a single case study is appropriate as it permits for a deep research enquiry and comes as close as possible to the research phenomenon (Dyer & Wilkins 1991). Given the limits on generalisability caused by the use of a single case study and consistent with a mixed methods research methodology, a survey was used as a secondary research method to increase the validity of the research findings.

Selection of focal organisation

Following from the decision to perform research based on a single case study and to gain sufficient understanding of industrial practice, the research sought to investigate a manufacturer that has made significant gains in transitioning to being a product-service provider. Applying the definition of the term 'case' presented by Miles & Huberman (1994) as "a phenomenon of some sort occurring in a bounded context" (p.25), the case selection criterion was set as:

- A contemporary manufacturing organisation that supplies products and services in the business-to-business environment that, when integrated, fulfil customers' needs and deliver sustained functional behaviour

Complying with these selection criteria, BT is an original equipment manufacturer that designs, manufactures and services high-value capital equipment for the railway sector. Although BT provides mainline products and services separately, given the trend within the UK to procure full packages for the manufacturing and servicing of rolling stock, BT's UK divisions have made significant advances in recent years towards developing integrated PSSs. Due to the sponsorship for the research being provided by BT's UK Services division (BTS), this organisation provides the focus of the research.

Within the UK divisions, BT generates approximately 50% of its revenues from services. Although the majority of this service revenue is generated from providing maintenance services that are sold as add-ons to rolling stock that have been manufactured and sold by BT's mainline and metros manufacturing division (BTMLN), BTS also provides a number of (service-oriented) PSSs (e.g. energy management and data provision services enabled by onboard sensing and monitoring technology).

Data collection protocol

During the course of data collection it became clear that BTS does not follow a documented process for developing its PSSs. This was confirmed by a number of respondents who described the process as "informal": *"Is there a process? I don't think there is today. As far as I am aware there certainly isn't a formalised process"* (#3)[5]. To ensure that the undocumented (and informal)

[5] Quotes are provided that have been taken directly from the interview transcripts. To ensure anonymity, the quotes are followed by a reference indicating the interview number from which the extract was taken (e.g. #3 indicates that the quote was taken from the third interview). The order in which the interviews were conducted is not the same as that presented in Table 3-6.

process was fully understood, 32 interviews were conducted with respondents from different functional areas (Table 3-6) and ten company documents were analysed.

Table 3-6: Interview profile for stage two of the research

Interview Aim	Position	Functional area
Understanding servitization and PSS	Director of Strategic Programmes	Strategy
	Director of BTMLN Sales	Commercial
	Director, Head of UK Spares	Spares
	Director of Predictive Asset Management	Engineering
	Director of Predictive Services Engineering	Engineering
	Fleet Director A	Operations
	Head of Business Process Improvement	Spares
	Head of Performance Management	Engineering
	Vice President, Marketing, Product Planning and Strategy	Commercial / Strategy
Exploring PSS development	Bid Director*	Commercial
	Customer Account Director A*	Commercial
	Customer Account Director B*	Commercial
	Customer Account Director C*	Commercial
	Director of Strategic Programmes*	Strategy
	Fleet Director B*	Operations
	Head of Systems Engineering*	Engineering
	Product Manager – Innovation*	Engineering
	QHSE Director*	Operations
	Sales Proposals Manager*	Commercial
	Vice President, International Sales and Marketing*	Commercial
	Vice President, Head of Services UK*	*N/A*
Validating model of PSS development	Commercial Director	Commercial
	Director of Strategic Programmes	Strategy
	Director, Head of Engineering	Engineering
	Director, Predictive Asset Management	Engineering
	Engineering Manager	Engineering
	Fleet Project Manager	Operations
	Head of Business Process Improvement	Spares
	Product Manager – Innovation	Engineering
	Sales Proposals Manager	Commercial
	Vice President, Marketing, Product Planning and Strategy	Commercial / Strategy
	Vice President, Head of Services UK	*N/A*

* Indicates interviews that were recorded and subsequently transcribed verbatim

The purpose of the initial interviews was to gain an understanding of respondent's perspective of servitization and PSSs within BTS. Extensive notes were taken during each interview and analysis of these identified that BTS does not follow a documented process of developing its PSS. An example of the notes taken in one of these interviews is provided in Appendix I.

The second set of interviews, which were recorded and subsequently transcribed verbatim, focused on exploring how BTS develops its existing PSSs and any lessons learnt from this application. Given that the existing literature reports the phases and activities of PSS development (from which processes were synthesised), the interview design sought to identify the phases and activities to enable greater comparison with existing literature. Similar to the analysis conducted in the literature review, activities reported by interviewees were synthesised to identify BTS's PSS development processes. The approach to data collection meant that specific questions changed between interviews, but common topic areas were covered, including:

- The interviewee's perspective of PSS development (e.g. "What I would like to do is try to understand how currently BTS designs new PSS offerings and I'd like to get your perspective on how that happens. I suppose the first question would be: is there a process?")
- The phases used to describe the progress of PSS development projects (e.g. "If we had to draw a diagram of what that process looked like, the different phases, what would that look like?")
- The activities that are performed within PSS development projects (e.g. "When [the PSS development team] are developing the offering, how do they do that? What are the things they think about?" […] "What are the steps that [BTS] go through?" […] "When [BTS] are doing market analysis, how do [they] do that?")
- The tools, methods and techniques used within PSS development (e.g. "Do [the development team] use any tools or methodologies?" […] "Are there any specific tools or techniques or methods [BTS] use[s] within the informal process?")
- Examples of unsuccessful projects and why the interviewee believed weaknesses in development made the projects unsuccessful (e.g. "Can you think of any examples where [BTS] have gone through the process and have come up with what [they] think is a decent offering, [they] have been successful in selling that to the customer and it doesn't quite work as planned?" […] "What do you thing went wrong in the design process of that [BTS PSS offering]?" […] "Can you think of any product-service that [BTS] currently deliver[s] that doesn't behave as expect and why, when they were designed, they don't?")
- Examples of successful projects and why the interviewee believed strengths in development made the projects successful (e.g. "What about a contract that was or is successful. What happens in the design process there?")

Based on the analysis of the interview transcripts and company documents, a model of BTS's PSS development practice was created.

The third set of interviews focused on validating whether the model of BTS's PSS development practice accurately represented the views of the second set of interview participants and a larger sample of BTS's personnel. Extensive notes were taken during each interview. Analysis of these notes helped validate the model created to represent BTS's PSS development practice. An example of the notes of one of these interviews is provided in Appendix I alongside the results of the analysis.

Data analysis

The aim of data analysis was to interpret the data collected from interviews and company documents in a manner that provided insights into PSS development. To achieve this, it was important to reduce the data into categories through a process of coding (Glaser & Strauss 1967, Miles & Huberman 1994). Open coding was used to identify the phases within BTS's PSS development practice. Given that the majority of respondents did not explicitly state the phases within their descriptions of BTS's PSS development practice, phases were identified by interpreting the data collected in line with the definition of phase provided in ISO 15288. This meant that the range of possible phases was not set before coding, but emerged from the coding process. This ensured that BTS's PSS development practice was investigated without trying to fit existing models. Based on the results of the open coding, a simplified model of PSS development was created. Next, phrases relating to the activities executed during BTS's PSS development were extracted. The model of BTS's PSS development practice was compared with the model synthesised from literature. Based on the findings, five hypotheses were proposed.

3.4.2.2 Survey

Given the limitations of using a single case study, it is not possible to claim that the findings from the case study are generalisable, representing the PSS development practice of servitized manufacturers. Consistent with a mixed methods research methodology, a survey was used to test the hypotheses proposed from the case study findings. The survey research comprised four stages: survey design and pre-testing; definition of the population of interest and identification of respondents; application of the survey; and processing the collected data.

Survey design and pre-testing

To collect data from the target population, a survey instrument was developed following the suggestions and experiences in Dillman (2007). The survey consisted of six sections. The first section sought background information about the respondents (i.e. their job title, how many years experience they have developing PSS, the number of PSS development project they have been involved with and examples of PSSs that they have been involved in developing). Sections two to six presented respondents with a series of statements and, using a five-point Likert scale (strongly

disagree, disagree, neither agree nor disagree, agree, strongly agree), respondents were asked whether each statement was always conducted in the PSS development projects that they have been involved in. The initial survey instrument was pre-tested using representatives from the target population. Respondents' experiences regarding the ease of filling out the survey (in terms of time and complexity) and the nature of the questions were evaluated. As a result, changes were made to approximately 10% of questions and the survey was shortened by around 20%. A copy of the final survey instrument has been included in the appendix of Paper 4 (Appendix III).

Definition of population and identification of respondents

To obtain results from the survey that were comparable with the results from the case study, the same criterion for selecting focal organisations was used. For clarification, this is repeated below:

- A contemporary manufacturing organisation that supplies products and services in the business-to-business environment that, when integrated, fulfil customers' needs and deliver sustained functional behaviour

To identify this target population, companies were identified from Bureau van Dijks's FAME database of UK and Irish companies. After Neely (2008), initially firms with SIC codes in the range 10 to 39 were extracted. This resulted in 119,990 companies. The second step involved adding a control for company size. Only firms with over 100 employees were included. This resulted in 5,933 companies. Finally the 'trade description' field (a text based description of the company) was searched for the term "service". This resulted in 129 companies. A review of the descriptions of these firms highlighted that a number were not servitized manufacturing firms (e.g. Counterline Limited who manufacture food service counters and displays). These organisations were removed, resulting in a sample population of 109 companies.

To increase the quality and reliability of the answers, where possible the survey was targeted at specific individuals within the target population. These individuals had to have some experience of being involved in developing PSSs within their organisations and typically occupied job roles such as: Business Development Manager, Service Development Manager, Head of Engineering, etc.

Application of the survey instrument

Whilst Dillman *et al.* (2009) report that self-administered surveys generally result in a lower response rate than oral surveys, oral surveys increase the risk of respondents providing answers that would please the researcher. Given that this survey sought to investigate respondents' perceptions of PSS development within their organisations, a self-administered survey was adopted to increase the reporting of negative information and attitudes. As such, respondents were asked to complete a document based questionnaire in isolation from the researcher. To further encourage respondents to answer questions fully and frankly, the survey did not seek

information regarding the respondents' identities or organisations. The survey population was requested to complete the questionnaire through an online survey tool - SurveyMonkey™.

The data collection took place between July and September 2011 and yielded 31 fully filled out responses, providing a response rate of 28.4%.

Processing the survey data

The analysis of the survey data was conducted in SPSS 18 and took place in three stages. First, to identify whether the survey data reflected the processes reported by literature and the case study, factor analysis (principal component analysis) was conducted. To ensure that a set of measures referred to a single process, the first eigenvalue had to be greater than one and no subsequent eigenvalue could be greater than or equal to one (Norusis 2005). Given that a number of measures were used to operationalise each process, the reliability of all measures in the form of internal consistency was tested using the Cronbach's alpha coefficient (Cronbach 1951). Whilst a Cronbach's alpha coefficient of 0.7 is often reported being the minimum coefficient for acceptable reliability (Nunnally 1978), for identifying new constructs a coefficient of 0.6 is sufficient (Robinson *et al.* 1991). Based on these results, the hypotheses generated from the case study findings were updated to reflect any changes to the processes suggested from the survey data.

The second stage of analysis sought to test the first hypothesis which predicted a sequential relationship between the phases within PSS development. This was tested using an ordinary least squares regression analysis.

The third stage of analysis sought to test hypotheses two to five which predicted the allocation of processes within the phases. This was tested using an ordinary least squares regression analysis.

The results from the case study and survey were synthesised and a new model of PSS development proposed to better reflect the practice of servitized manufacturers.

3.4.3 Stage 3 - Operationalising the proposed model of PSS development

The purpose of this stage was to test the proposed new model of PSS development in practice. The testing focused on assessing the proposed model of PSS development and not any resulting PSS – i.e. "does following the model enable servitized manufacturers to develop PSSs?" rather than "does the servitized manufacturer obtain significant financial returns from the delivery of the new PSS?" The reason for this approach was to remove as many extraneous effects as possible. If efforts were made to relate the use of the proposed new model to the financial returns from delivering the resulting PSS, significant questions would arise concerning whether these returns were due to the following the model. For example, changes in the economic climate or actions of competitors would significantly influence the financial returns from the PSS. To overcome these limitations, testing would require large sample sizes and extensive use of statistical analysis to

understand the impact of all of the variables. This would, however, only indicate correlation, not causation. Within the context of this research, the aim of testing was to develop a deeper understanding which could be used to further refine the proposed new model of PSS development.

Given that the testing prescribes a different approach to developing PSSs from what organisations would normally use, action research is an appropriate method (Platts *et al.* 1998). In action research, the researcher not only participates in the study, but actively seeks to direct and influence the way in which action is conducted (Coghlan & Brannick 2010). However, the adoption of action research raises some significant issues. Foremost is the perceived lack of controls and repeatability (Stringer 2007). For example, the 'tester' is not independent of the test and the processes executed within the proposed new model of PSS development may vary significantly depending upon who is involved in testing.

Given that the research aimed to contribute towards improving BT's existing approach to PSS development, action research was employed to investigate whether pursuing the proposed model could lead to the development of a PSS. Having adopted an action research approach, the testing fell into four stages: process model design, process model development, process model testing and reflection.

During process model design, the requirements for the workbook which sought to operationalise the new model of PSS development were elicited. Based on these, the PSS Development Workbook was created in process model development. During process model testing the PSS Development Workbook was applied within BT to identify possible product-service offerings that could create a step change in its performance. Twenty participants were involved during the testing (ranging from senior directors to mid-level managers). Testing was undertaken over the course of six full day and nine half-day workshops. Given that previous research has identified that during testing there is a danger of the facilitators achieving success by means of their experience in developing the process to be followed (Platts *et al.* 1998), facilitation was conducted by individuals new to the PSS Development Workbook. Within the context of this research, two external consultants were recruited to facilitate the workshops and implement the PSS Development Workbook. The researcher was involved in all workshops and meetings and was able to observe the application of the workbook and, through reflection, identify any improvements needed to the workbook and any implications for the proposed new model of PSS development.

3.5 Summary

This chapter has described the strategy adopted to conduct the research reported within this thesis. First, an overview of research philosophy was provided before the researcher's own post-positive paradigm was discussed. Consistent with the critical realism ontology associated with post-positivism, the mixed methods strategy adopted during the research was discussed. To meet the research objectives, the research was separated into three stages. The first stage focused on

applying Checkland's SSM to explore how PSSs could be delivered within the UK railway industry. The second stage of research focused on investigating the extent to which the model of PSS development, synthesised from the literature, reflected the industrial practice of a single servitized manufacturer. Based on the findings, a survey was conducted to determine whether the phases and processes reported within the literature and case study are valid in a larger sample of servitized manufacturers. Synthesising the findings from the case study and survey, a new model of PSS development was proposed. Finally, stage three sought to test the proposed new model of PSS development through action research.

The following chapter presents the findings from the first stage of the research, exploring how PSSs could be delivered within the UK railway industry.

4 Exploring how PSSs could be delivered in the UK railway industry

Whilst significant research has been conducted to investigate the delivery of PSSs within a number of industries, this has principally excluded the railway industry. The aim of this chapter is to investigate how existing, separate product and service operations within the UK railway industry might be integrated to deliver a PSS. Soft systems methodology (SSM) was applied to gain an understanding of the existing situation and identify changes that might be required to deliver PSSs. Section 4.1 summarises the use of rich pictures to gain an understanding of the existing situation. The purposeful activity models that were created are summarised section 4.2 and their use to stimulate debate on the changes required to deliver integrated PSSs reported in section 4.3. Section 4.4 presents the results from the debate in the form of rich pictures describing how PSSs could be delivered before a summary of this chapter is presented in section 4.5.

4.1 Rich picture of the current situation

Within the current UK railway industry (represented in detail in Appendix II), a tender is traditionally issued for the design, construction, delivery and warranty of a new fleet of rolling stock. Railway vehicle manufacturers (e.g. BTMLN) will bid for the tender, with the lowest cost offering usually winning the contact to manufacture rolling stock. The finance to procure a new fleet is provided by a Rolling Stock Company (ROSCO), which becomes the asset owner. ROSCOs generate value by leasing the vehicles to train operators for the length of a franchise (approximately five to seven years). Once the franchise has expired, the ROSCO will look to lease the vehicles to another operator. This process is repeated until the vehicles reach the end of their useful lives (approximately 30 years). Once the fleet is about to enter service, the operator/ROSCO will tender a contract for the maintenance of their vehicles for the life of the franchise. Service providers (e.g. BTS) will then bid for this contract, with the operator/ROSCO awarding the contract to the lowest bidder (Figure 4-1).

In the traditional environment, organisations try to maximise revenue generation for themselves by managing their interactions with other stakeholders. For example, operators will try to maximise the number (and price) of fares whilst simultaneously trying to minimise the amount they pay for light and heavy maintenance. The perception of interviewees is that this has lead to very transactional and confrontational relationships. Additionally, Figure 4-1 highlights a disconnect between rolling stock manufacturing and servicing – service contracts are awarded immediately prior to a fleet entering service and follow a separate bidding process from that of buying the fleet. One manifestation of this is in the interaction with suppliers. During the new build phase where the rolling stock is initially manufactured after a tender has been won, procurement teams working for rolling stock manufacturers seek inexpensive suppliers and discounts to provide a high volume of particular components. This enables rolling stock manufacturers to reduce the cost of trains,

increasing their competitiveness and likelihood of winning bids. During maintenance, service providers are often locked into the suppliers chosen by new build manufacturers.

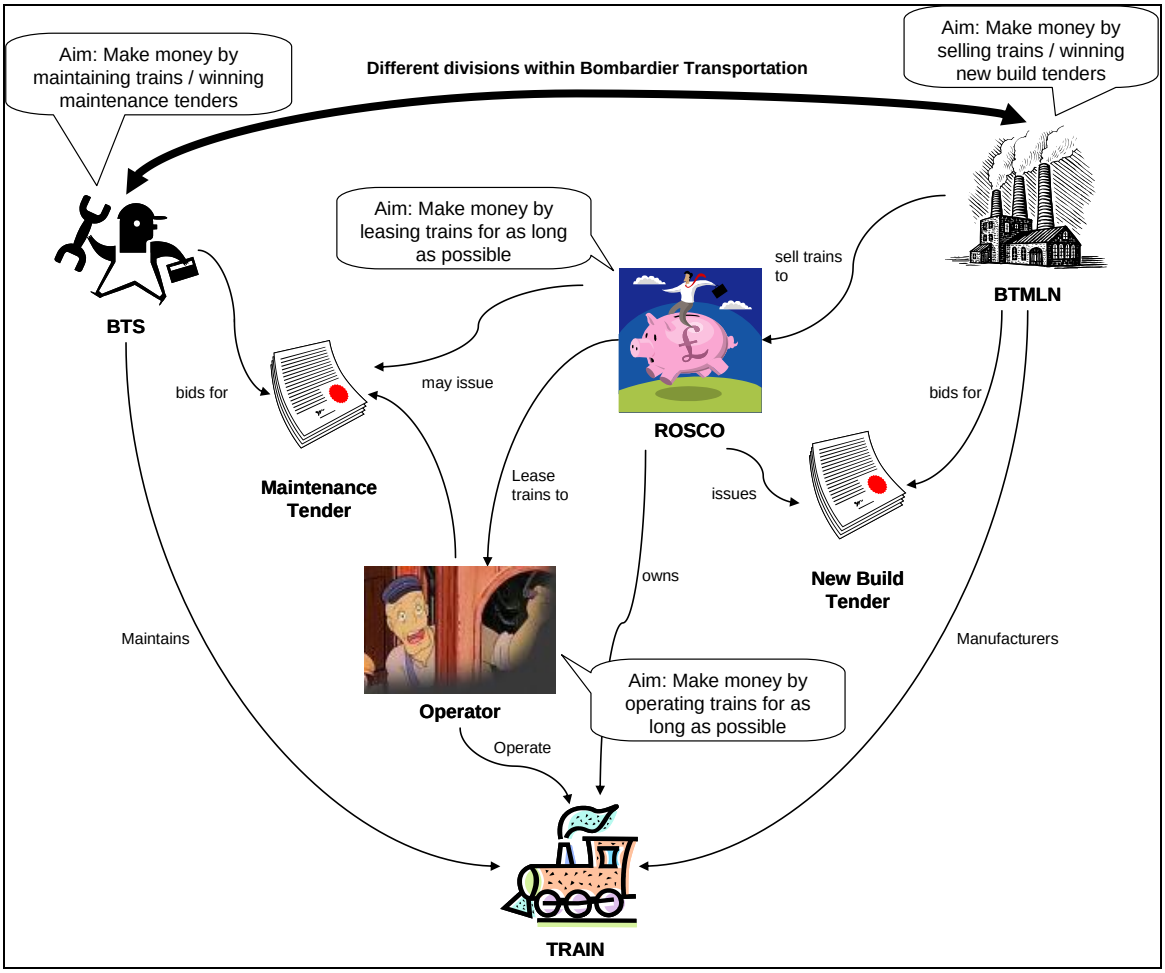

Figure 4-1: Rich picture of UK rolling stock new build and maintenance market

Procurement teams have difficulty negotiating discounts (suppliers are seeking to re-coup potential losses made in selling to rolling stock manufacturers), especially given that a lower volume of parts may be required. This results in higher maintenance costs and potentially lower reliability (Figure 4-2).

During maintenance, BTS operates a number of depots where rolling stock is maintained. In an attempt to reduce much of the additional cost caused by procuring relatively small volumes of parts over short-term time horizons, plans and forecasts are created. These aim to minimise risks to the supply network, and costs to BTS, by giving an indication of future parts availability requirements (Figure 4-3).

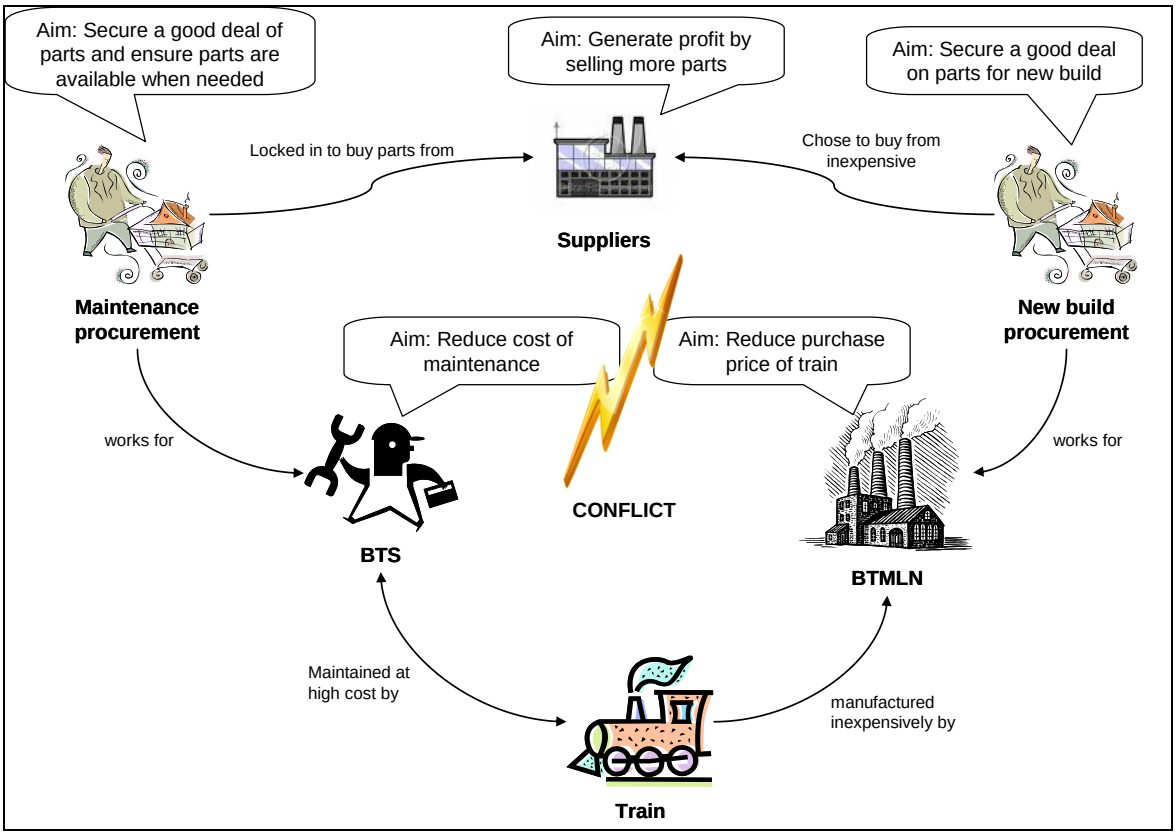

Figure 4-2: Rich picture of the impact of parts supply in the traditional environment

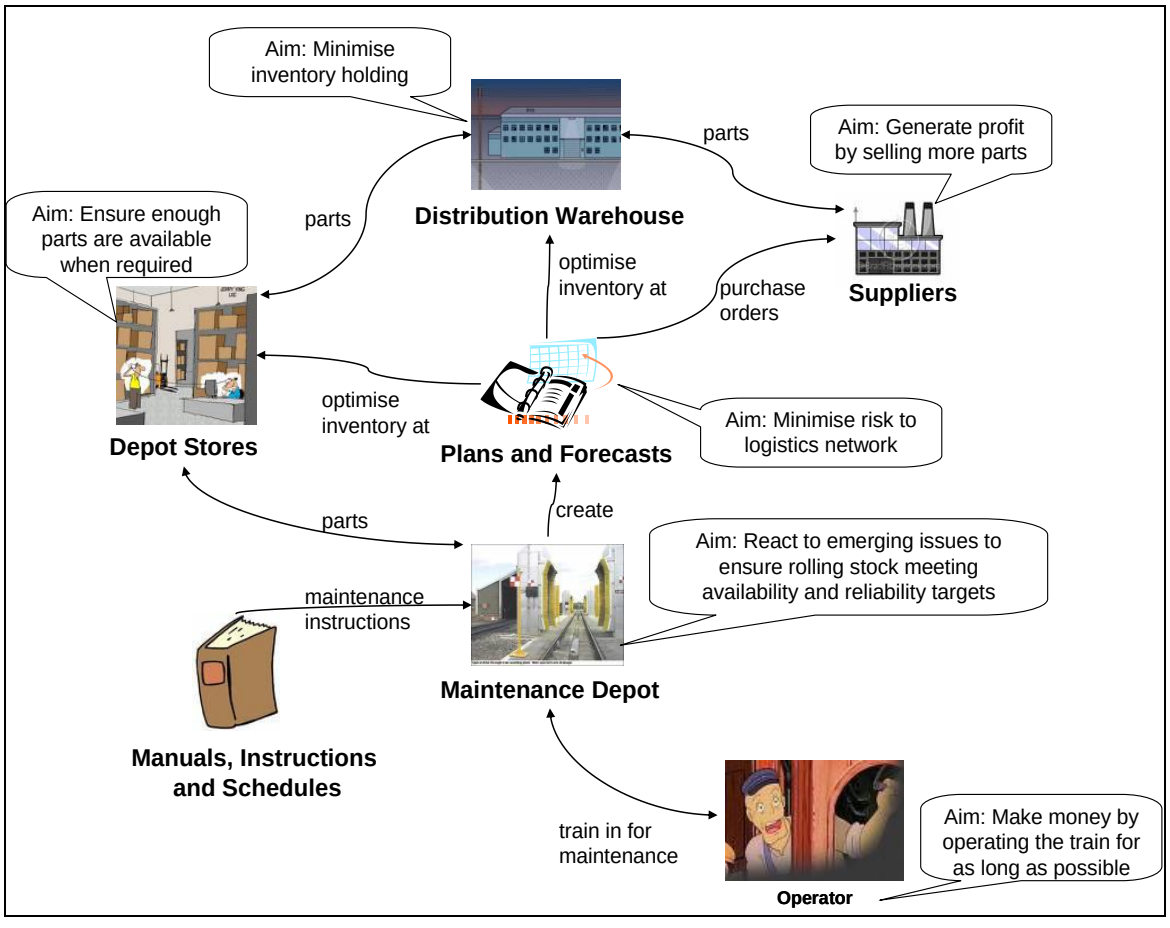

Figure 4-3: Rich picture of BTS's full maintenance provision

Analysis of the rich pictures (presented in Figure 4-1, Figure 4-2 and Figure 4-3) highlighted a number of issues that must be overcome in order to transition to delivering integrated PSSs:

- There is a lack of understanding of the dependencies that exist between rolling stock manufacturing and servicing
- Cost accounting rules stipulating projects/functions should always be in profit often artificially increase costs (margin-on-margin effects when procuring internally)
- There is an emphasis on local initiatives (e.g. new build procurement negotiating discounts to provide parts to the production line and not seeking long-term supply agreements)
- Emphasis on cost reduction in manufacturing and service divisions separately often leads to a higher total cost of ownership

4.2 Purposeful activity models

The purposeful activities represent the different purposes, identified from the interviews, of the product-service delivery system from the perspective of the multiple stakeholders involved in product-service delivery. For example, from a maintenance technician's perspective the aim of the product-service delivery system is to maintain a train, but from the Head of BT's perspective the aim of the product-service delivery system is to generate a profit. In total, twelve purposeful activities were identified:

- Create and provide information to all relevant parties
- Maintain good relationships with suppliers
- Provide a sufficient float of materials
- Maintain a train
- Generate a profit for BT
- Provide sufficient employment for skilled and unskilled labour
- Retain technical railway capabilities within the UK
- Prevent in-service failures
- Test and make use of supplied components and whole systems, providing feedback to design
- Extending railway vehicles' lives
- Utilise BT's experience of a vehicle (from build) to generate further revenue streams
- Maintain good relationships with customers

Root definitions were created for each purposeful activity. These expressed each purposeful activity model as a transformation process. For example, the root definition created for the 'create and provide information to all relevant parties' purposeful activity was given as:

A BTS and BTMLN owned and operated system which ensures that the right information exists, and that it is provided to the right people, ensuring that maintenance can take place with the right people, in the right place, equipped with adequate tools and material

To make the model more meaningful, each of the purposeful activity models were elaborated by defining the other elements which make up the mnemonic CATWOE (Checkland 1981):

Customers: *Shift managers, material planners, maintenance planners, material forecasters, material managers, stores managers, team leaders, procurers and suppliers*

Actors: *BTS and BTMLN*

Transformation: *A need for information → that need met*

Weltanschauung (worldview): *Information is the key driver for whole-life service provision*

Owners: *BTS, BTMLN, shift managers, material planners, maintenance planners, material forecasters, material managers, stores managers, team leaders, procurers and suppliers*

Environment: *Information is available in some form; information can be passed between all stakeholders*

Once root definitions were elaborated for each purposeful activity model, conceptual models were created (Figure 4-4). The twelve purposeful activity models do not purport to be representations of existing product-service offerings or potential ways in which PSSs can be delivered. Instead, they are accounts of concepts of purposeful activity, based on declared worldviews, which were used to stimulate questions and debate about what changes would be required to deliver PSSs.

4.3 Debating the situation

Once completed, the purposeful activities models were used to stimulate a debate with interview participants to identify the changes required to deliver integrated PSSs. This was done by using the models as a source of questions to ask what will require changing from delivering traditional offerings to PSSs. For example, the following questions were created based on the 'create and provide information to all relevant parties' conceptual model:

- What changes may be required in the way that information is used?
- Why is information required?
- What types of information may be required?
- How will information need to be created?
- How and what information will need collating?

- How will information be analysed?
- How will information be communicated to where it is needed?

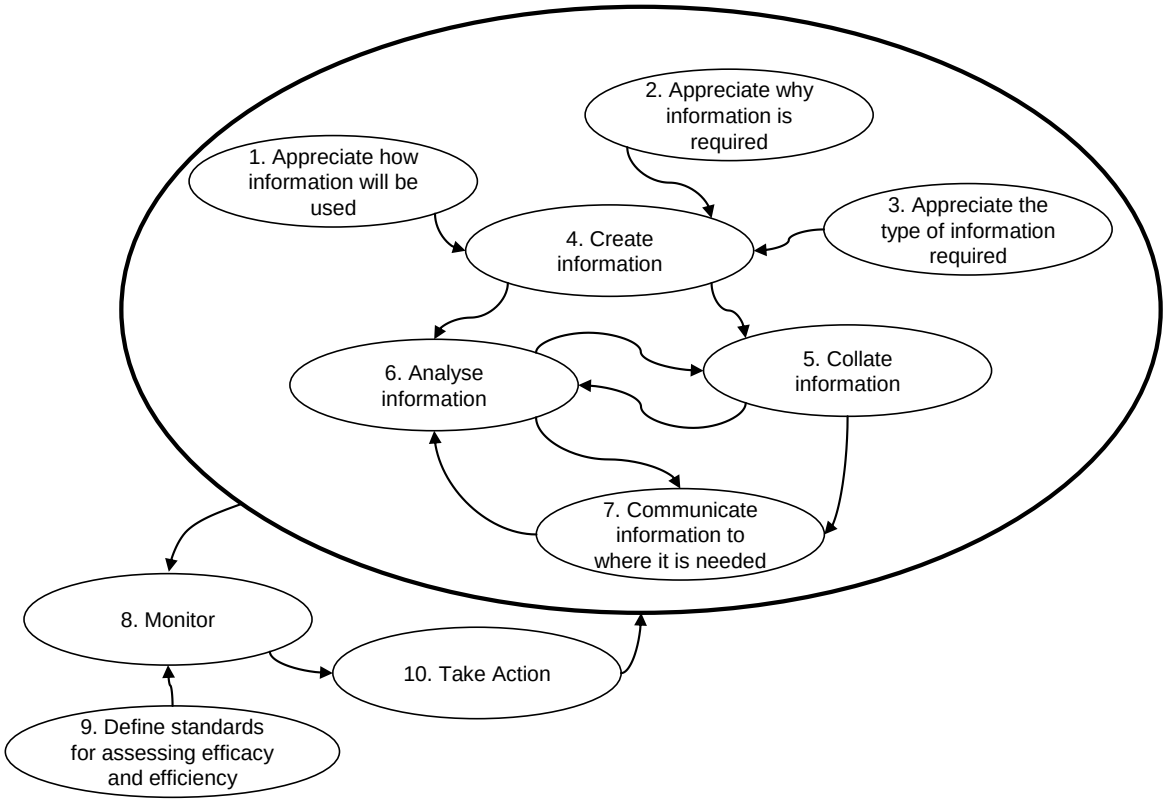

Figure 4-4: 'Create and provide information to all relevant parties' conceptual model

Focusing on information relating to the health of on-board systems, interview respondents reported that this information will be required to diagnose and predict component failures and assess the impact of these on service provision. Within new build design, BTMLN need to have an understanding of the decisions that BTS will need to make to sustain the operation of trains, and any analyses they conduct, before specifying sensors to gather particular data. The information gathered can also be fed back and used by BTMLN and suppliers to improve the reliability of the systems they design. In order to gather health information, data from on-board sensors will need to be collected. BTS must understand how frequently it will need the data to make informed decisions (e.g. real-time or once a day) before BTMLN design the communication systems. Going further, BTS has to understand how health data captured from trains will be analysed and how the results of these analyses will be provided to maintainers. For example, is data analysed manually or automatically? If automatically, what rules are needed to analyse the data? Once analysed, are work orders automatically created to specify the required maintenance actions? Additionally, other stakeholders may require information on the health of their trains in order to calculate the train's residual value (e.g. ROSCOs).

4.4 Taking action

Within the context of this stage of the research, it was not practical to transition BT into an integrated PSS provider. Instead, rich pictures were created representing how BT could deliver one type of PSS, namely the result-oriented PSS where train operators would procure the capability to move people. Interview participants felt that the result-oriented PSS will enable BT to be better able to meet the UK government's aspiration to procure fully financed packages of rolling stock manufacturing and maintenance support.

In the result-oriented PSS, BTS, BTMLN and ROSCOs could form strategic alliances to deliver bundled solutions which include the design, build, maintenance and finance of new rolling stock. Here, operators or the Department for Transport (for large programmes) issue a tender for the capability to move people. Within the strategic alliance, ROSCOs provide the funding to manufacture, and purchase, the new rolling stock; BTMLN designs and manufactures the rolling stock, optimising for total cost of ownership and not necessarily lowest first cost; and BTS provides through-life maintenance services. From the operators' perspective, they are paying the strategic alliance for a maintained train (Figure 4-5).

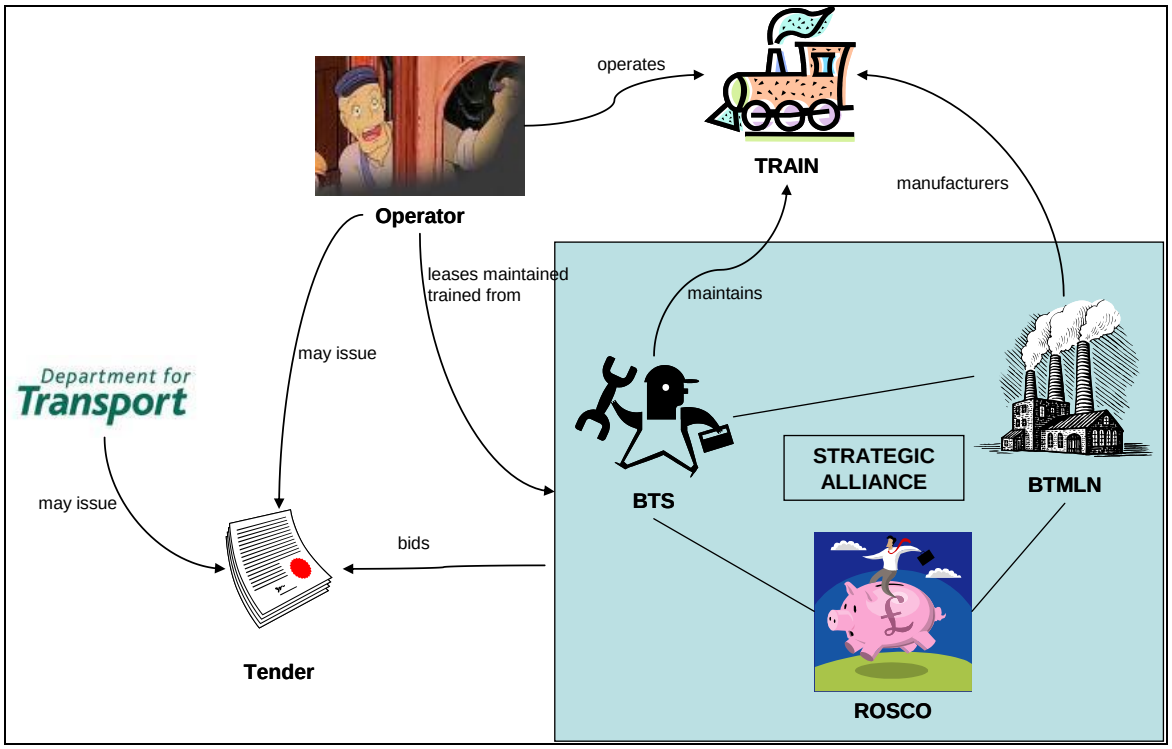

Figure 4-5: Rich picture of how the result-oriented PSS could be delivered

In contrast to the traditional approach, there is no disconnect between rolling stock manufacturing and servicing. Here, the aim of all strategic partners is to reduce total cost of ownership. One manifestation of this is in the interaction with suppliers. Instead of two procurement teams (one focusing on new build and one on services) with conflicting aims, delivering PSSs should encourage long-term supply agreements. In this environment, one procurement team could be

created that focuses on purchasing components with the lowest whole-life cost (e.g. expensive parts to purchase but very reliable parts requiring little maintenance) (Figure 4-6).

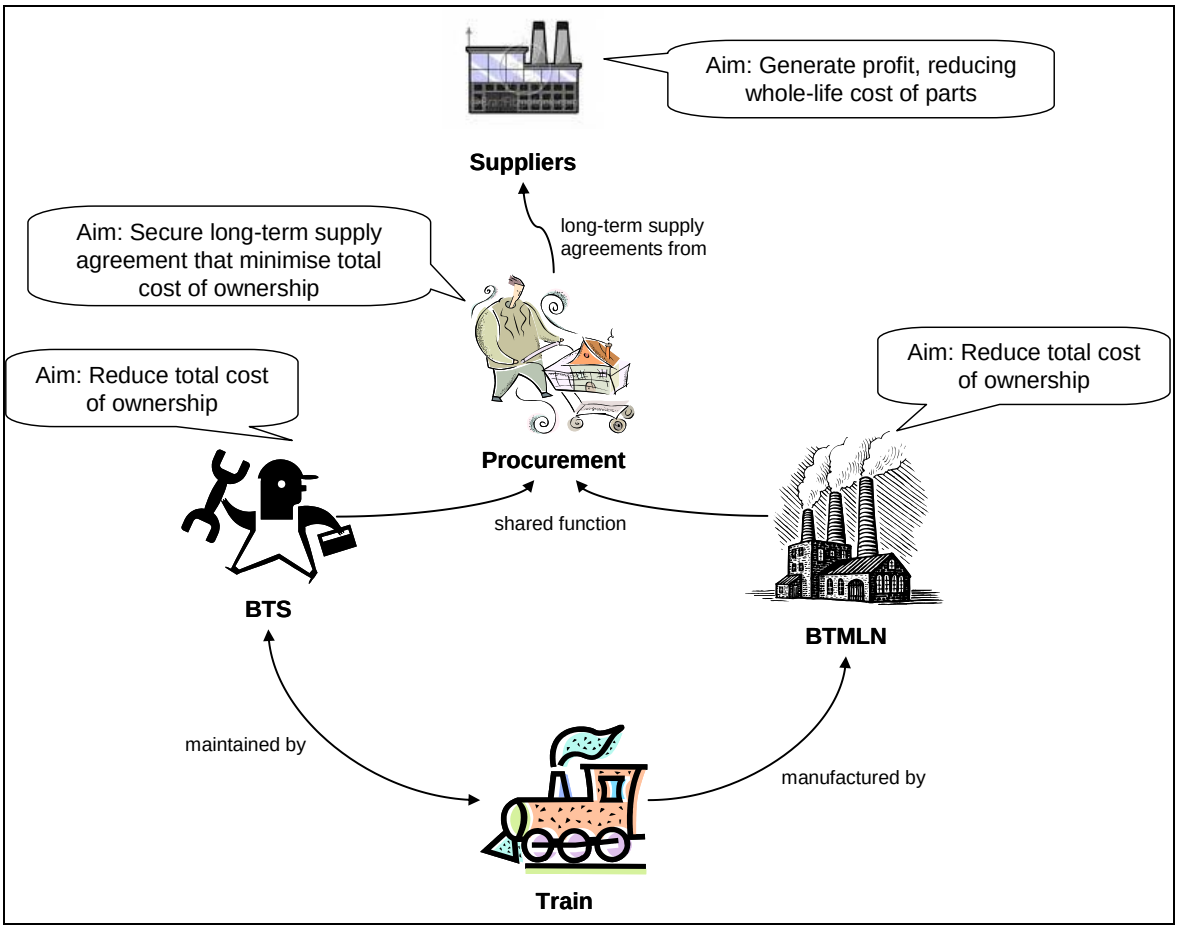

Figure 4-6: Rich picture of the impact of the result-oriented PSS on the supply network

In the environment represented in Figure 4-6, it is likely that BTMLN will be procuring and installing higher quality, more reliable and potentially more expensive components. Given current cost accounting rules stipulating projects/functions should always be in profit, BTMLN's profit margin will be significantly reduced by the procurement of more expensive components. Interview respondents identified a number of potential options to overcome this conflict:

- Senior management within BT recognise that current cost accounting rules are not suitable for delivering result-oriented PSSs and change them
- BTS pays BTMLN to procure and install the more reliable components, gaining a return on their investment through reduced maintenance cost during the rolling stock's life

Whilst this stage of research sought to understand the changes that might be required to deliver integrated PSSs, interviewees reported that a significant challenge existed in developing products and services together so that they could be delivered through an integrated PSS. The knowledge

gained in this stage of research was used to inform further research that sought to investigate how PSSs are developed in servitized manufacturers.

4.5 Summary

During this stage of research, SSM was applied to understand the changes that might be required within BT and the UK railway industry to deliver integrated PSSs. Rich pictures were created to model the current, separate product and service operations. Analysis indicated that the traditional approach has resulted in a disconnect between rolling stock manufacturing and servicing, harming BT's ability to deliver PSSs. Purposeful activity models were used to help structure an exploration into the changes that might be required. Debating these led to the development of rich pictures which sought to represent how one type of PSS could be delivered. Whilst this research sought to understand how existing products and services could be integrated to deliver PSSs, interviewees identified significant challenges in developing new integrated product-services.

The following chapter presents the research conducted to investigate how PSSs are developed.

5 Investigating PSS development

This chapter summarises the findings from the case study and survey to test whether the model of PSS development, synthesised from the literature, reflects the PSS development practice of servitized manufacturers. In section 5.1 a summary of the findings from the single case study are presented. The case study was conducted in two distinct stages. The first stage sought to evaluate whether the phases reported in the synthesised model of PSS development reflected the phases within BTS's PSS development practice. The results from this led to the creation of a simplified model of PSS development. The simplified model of PSS development was further evaluated in the second stage of the case study to determine whether the processes reported within the model reflected BTS's PSS development practice. To validate the findings and determine whether the simplified model of PSS development was generalisable to a larger sample of servitized manufacturers, section 5.2 summarises the results of the survey. Synthesis of the findings from the case study and survey are presented in section 5.3 and a new model of PSS development is proposed to better reflect the practice of servitized manufacturers. A summary of this chapter is presented in section 5.4.

5.1 Case study findings

5.1.1 Investigating the phases within PSS development

The aim of this analysis was to identify whether the phases reported within the synthesised model of PSS development are executed during BTS's practice. The data coding initially identified 31 terms that were used by interviewees and within the company reports to describe the phases within PSS development, ranging from '*articulate value proposition'* to *'selling'*. Where codes had the same meaning (e.g. *'develop offering'* and *'detailed design'*) they were grouped into the same concept. Eight concepts were identified by grouping the codes. Four codes had no similarities with any other code (Table 5-1).

The remaining twelve codes and concepts were considered as the phases executed within BTS's PSS development practice. Respondents and a larger sample of BTS's personnel were asked to verify that these were the phases guiding BTS's PSS development practice (Appendix I).

Once the phases within BTS's PSS development were identified, the interview transcripts and company reports were further analysed in order to identify definitions for each phase. Themes were identified from interviewees' definitions of each phase and what was stated in the company reports. Based on these themes, and synthesising them with those from other interviewees' definitions, common definitions were synthesised for each phase (Table 5-2).

Table 5-1: Synthesis of the codes determined from the interview transcripts

Concept / Phase codes	Create team	Analyse customers	Design	Idea generation	proposition	Prototype	Implementation	Evaluation
Articulate value proposition					✓			
Assess cost					✓			
Assess resource needs*								
Assess worthwhileness								✓
Build team	✓							
Commercialise							✓	
Concept design			✓					
Cost offering					✓			
Create price					✓			
Create project plan*								
Create team	✓							
Demonstrate value						✓		
Detailed design			✓					
Develop delivery mechanism			✓					
Develop offering			✓					
Develop service proposition			✓					
Evaluation								✓
First application						✓		
Gap analysis*								
Generate ideas				✓				
Idea development				✓				
Idea generation				✓				
Identify client pain		✓						
Identify customer needs		✓						
Identify expressed customer needs		✓						
Identify unexpressed needs		✓						
Implementation							✓	
Price Offering					✓			
Prototype						✓		
Production*								

* Codes that have no similarities with the other codes

Table 5-2: Definitions of BTS's PSS development phases

Phase	Definition
Create team	The creation of a project team to perform the PSS development
Analyse customers	The identification of opportunities for the development of a PSS that will fulfil customers' needs
Design	The development of the PSS concept from the most promising ideas and an assessment of how the PSS will be delivered to customers
Idea generation	Identifies possible ideas that the product-service provider could develop into a PSS that fulfils the identified needs
Articulate value proposition	Determine the cost and price of the PSS and identify how the offering will be communicated to customers
Prototype	Is the first application of the PSS in one customer's environment in order to test that the product element functions and that the service is delivered as expected
Implementation	The large scale roll out of the PSS
Evaluation	The assessment of the PSS
Assess resource needs	Identifies the resources needed to deliver the PSS
Create project plan	The creation of a schedule that identifies the activities that need to be completed during PSS development, the major milestones and deliverables
Gap analysis	The identification of differences between existing resources and what are needed to deliver the PSS
Production	The realisation of the product elements within the PSS

Although the phases within PSS development reported by interviewees and the company reports are not the same as those reported by literature, there are similarities. Interviewees identified the analyse customer, idea generation, prototype, implementation and evaluation phases which are consistent with the analysis, idea generation & selection, prototype the PSS, implementation and evaluation phases reported by literature (Table 5-3). Additionally, the outputs from the project initiation phase include: a team with a mission and a project plan. These outputs are the same as those reported from the create team and create project plan phases identified at BTS. As such, BTS's create team and create project plan phases were considered activities executed within the project initiation phase that the literature reports.

Synthesis of the phases reported by literature and interview respondents suggests that PSS development consists of eight phases: project initiation, analysis, idea generation, detailed design, production, articulate value proposition, prototype, implementation and evaluation.

Table 5-3: Comparison of phases between BTS and literature

		Phases synthesised from literature						
		Project Initiation	Analysis	Idea Generation & Selection	Detailed Design	Prototype the PSS	Implementation	Evaluation
Phases reported from BTS	Create team	■						
	Create project plan	■						
	Analyse customers		✓					
	Idea generation			✓				
	Design				✓			
	Assess resource needs				■			
	Gap analysis				■			
	Production	No mapping to literature						
	Articulate value proposition				■			
	Prototype					✓		
	Implementation						✓	
	Evaluation							✓

✓ Phases are the same between BTS and literature

■ BTS phase considered as an activity within a phase reported by literature

Analysis of synthesised phases suggested that a number can be considered processes within broader phases (e.g. prototype and implementation both could be considered to refer to a broader delivery phase where PSSs are co-delivered). Similarly, a number of the 'phases' can be considered activities that operationalise specific processes (e.g. create team is one activity that operationalises the project initiation process). Given this, the phases within PSS development can be simplified to analysis, concept design, development and delivery (Table 5-4).

The allocation of processes to the phases reported in the literature can be represented within the simplified phase structure of PSS development (Figure 5-1).

Table 5-4: Definitions of the simplified phases within PSS development

Phase	Definition
Analysis	Building an understanding of the manufacturing organisation's customers, its installed base, competitors and internal organisation (van Halen *et al.* 2005, Kindström & Kowalkowski 2009) in order to identify a first set of objectives and requirements for the PSS concept (Aurich *et al.* 2006). Analysis is performed continuously (Day 1994) to identify customers' latent needs (i.e. those needs that customers have not articulated but could be fulfilled through PSSs)
Concept design	The generation, evaluation and screening of ideas and development of PSS concepts (Aurich *et al.* 2006) fulfilling the identified customer needs. Projects are initiated to further developed the most feasible and financial viable PSSs
Development	Transforming the PSS concept into a viable, marketable PSS offering (Aurich *et al.* 2006). All product elements of the PSS are developed concurrently with the service elements and preparations are made for delivery.
Delivery	The product elements are produced and all preparations to execute the service elements are made (Brezet *et al.* 2001). The delivery phase can be applied with one customer specifically, principally to test and prototype the PSS, before being delivered to customers in the wider market. Delivery is ongoing, ensuring that functional behaviour is sustained over time

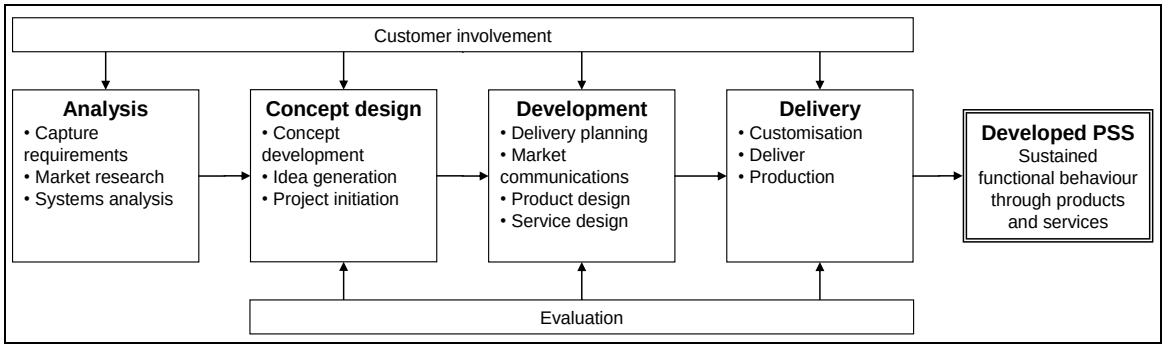

Figure 5-1: Simplified model of PSS development

The processes within the analysis phase of the simplified model of PSS development are consistent with the processes reported within the analysis phase from the literature. Similarly processes within the development phase of the simplified model of PSS development are consistent with the processes reported within the detailed design phase within the literature. The concept design phase is broadly consistent with the idea generation and selection phase reported within the literature. The project initiation process reported within the project initiation phase is also performed within concept design. At BTS, specific projects are initiated once a viable concept has been developed. This has similarities with the project management (Grant 2010) and service design literatures (Froehle & Roth 2007) where projects are initiated after the identification of market demands, business needs or technological advances and after initial service concepts have been evaluated to determine their viability. The delivery phase is consistent with synthesising the

prototype the service and implementation phases reported within the literature. Additionally, the production phase reported by the interview respondents is considered a process within the delivery phase of the simplified model, reflecting Baines *et al.* (2011a, 2011b) who report that servitized manufacturers typically retain capabilities in production. The PSS development literature reports evaluation as a separate phase (Brezet *et al.* 2001), but its definition ("the assessment of the PSS") suggests that it can be considered as a process applied within a number of phases. This has similarities with the stage-gate approach to product and service development where progression between phases is determined by 'gates' (Cooper 1986) and concurs with interview respondents who identified that *"you would continuously need to do feasibility studies about is it worth it, what is the price going to be, what will it save, what are the costs, what can we sell it as and therefore is it sensible?"* (#4).

5.1.2 Investigating the processes within PSS development

The aim of this analysis was to identify whether the processes reported within the simplified model of PSS development are executed during BTS's practice. Closed coding was used to find evidence for the activities presented in Table 2-4. During the closed coding, 181 phrases were extracted from the interview transcripts. These related to the activities identified from the literature that operationalise the processes reported within the synthesised model of PSS development. Table 5-5 presents a summary of the number of phrases extracted from each interview per activity/code.

Of the 181 phrases extracted, two-thirds of them refer to activities performed within just five processes: market research, service design, market communications, concept development and customer involvement. The high proportion of phrases referring to activities within these processes suggests that the majority of the respondents agree that these processes were executed during the PSS development projects they have been involved in.

In contrast, only a small number of the 181 phrases refer to activities executed within the capture requirements, project initiation, deployment planning and production processes. The low proportion of phrases referring to activities conducted within these processes suggests that whilst a small number of respondents agree that these processes were executed during the PSS development projects that they have been involved with, the majority of respondents do not.

Additionally, no phrases were extracted to provide evidence for seven activities: describe main elements, identify delivery tools and instruments, define evaluation criteria, write evaluation report, define goals, create project plan and understand the usage profile of existing products and services. This suggests that the processes to which they belong are executed differently from that described in literature.

Table 5-5: Phrases extracted from transcripts referring to each activity

Process	Activity (code)	Interview										Total
		1	2	3	4	5	6	7	8	9	10	
Capture requirements	Define requirements	2	1	1	0	0	0	0	0	0	0	**4**
Concept development	Define value of offering	0	0	1	1	2	1	0	0	0	3	**8**
	Design the service and product characteristics	2	2	0	3	1	0	0	0	1	0	**9**
Customer involvement	Generate understanding of the objectives	0	0	0	0	1	0	0	0	0	0	**1**
	Selection of engagement method	1	0	0	2	0	0	0	0	0	0	**3**
	Involve customer	3	1	3	2	1	3	1	0	0	1	**15**
	Integrate insights	0	1	0	0	1	0	0	0	0	0	**2**
Customisation	Describe main elements	0	0	0	0	0	0	0	0	0	0	**0**
	Propose variations	0	0	0	1	0	0	1	2	0	3	**7**
Deliver	Provide resources	0	0	0	1	0	0	1	0	1	0	**3**
	Execute agreed work procedures (co-production)	2	0	1	2	0	2	0	0	0	0	**7**
Deployment planning	Identify delivery issues	0	0	2	0	0	1	0	0	0	1	**4**
	Identify delivery tools and instruments	0	0	0	0	0	0	0	0	0	0	**0**
Evaluation	Define evaluation criteria	0	0	0	0	0	0	0	0	0	0	**0**
	Monitor customers' response and usage	0	0	0	0	0	0	0	0	0	1	**1**
	Measure the value provided	0	0	0	0	0	0	0	0	1	0	**1**
	Evaluate the PSS	2	1	3	1	1	1	0	0	1	1	**11**
	Write evaluation report	0	0	0	0	0	0	0	0	0	0	**0**

Process	Activity (code)	Interview										Total
		1	2	3	4	5	6	7	8	9	10	
Idea generation	Generate ideas	1	1	1	2	1	0	0	0	0	0	**6**
	Select ideas	0	0	1	0	0	0	0	0	0	0	**1**
	Evaluate ideas	0	0	1	0	0	1	0	0	0	0	**2**
Market communications	Quantify value	1	1	0	1	3	0	0	0	0	3	**9**
	Communicate	0	0	0	0	3	2	1	1	0	1	**8**
Market research	Customer analysis	2	1	2	3	4	4	4	0	2	2	**24**
	Competitor analysis	0	0	0	0	1	0	3	0	0	0	**4**
	Identify strategic partners	0	0	0	0	0	0	1	0	1	0	**2**
	Identify new technologies	0	0	0	0	1	0	2	0	0	0	**3**
Product design	Specification of technical components	0	2	0	2	0	1	0	0	0	0	**5**
	Identification of technical components	0	1	0	0	0	0	0	0	0	0	**1**
	Selection of technical components	0	1	0	0	0	0	0	0	0	0	**1**
Project initiation	Project authorisation	2	0	1	0	0	0	0	0	0	0	**3**
	Define goals	0	0	0	0	0	0	0	0	0	0	**0**
	Create team	2	0	0	0	0	0	0	0	0	0	**2**
	Create project plan	0	0	0	0	0	0	0	0	0	0	**0**
Service design	Specify the service process (activities)	0	0	0	2	0	4	0	0	0	0	**6**
	Specify the service system (resources)	2	1	2	2	5	8	0	0	1	0	**21**
Systems analysis	Understand the usage profile of existing products and services	0	0	0	0	0	0	0	0	0	0	**0**
	Gain customer feedback	0	0	1	0	0	0	0	0	0	0	**1**
	Identify products	0	1	0	0	1	1	0	0	3	0	**6**

In addition to the phrases relating to the activities reported from the literature, a further 34 phrases were extracted from the interview transcripts which provide evidence for activities not reported in the literature (Appendix III, Paper 4). Grouping phrases with a similar meaning led to the identification of nine codes that represent activities conducted by BTS but not reported in the literature. Table 5-6 presents these activities and the related processes.

Table 5-6: New activities suggested by respondents

Process	**Activities not reported in literature but executed at BTS**
Systems analysis	Resource analysis
Market research	Market trend analysis
Capture requirements	Validate requirements
Concept development	Position offering
Service design	Specify behaviours
Market communications	Create sales strategy
	Determine revenue mechanism
Customisation	Determine level of customer specificity
Customer involvement	Identify engagement customers

Given that the case study focused exclusively on one organisation, there was insufficient evidence to determine whether any of the differences reported between BTS and the simplified model of PSS development reflect more general differences between servitized manufacturers' industrial practice and the extant literature. This suggested that whilst the case study provided an in-depth understanding of one organisation's approach to PSS development, further research was needed to evaluate the simplified model of PSS development on a larger sample of servitized manufacturers.

Based on the findings from the case study, five hypotheses were proposed for testing through the survey:

Hypothesis 1: *There is a sequential relationship between the analysis, concept design, development and delivery phases within PSS development*

Hypothesis 2: *The analysis phase within PSS development is made up of the capture requirements, market research, systems analysis and customer involvement processes*

Hypothesis 3: *The concept design phase within PSS development is made up of the concept development, idea generation, project initiation, customer involvement and evaluation processes*

Hypothesis 4: *The development phase within PSS development is made up of the delivery planning, market communications, product design, service design, customer involvement and evaluation processes*

Hypothesis 5: *The delivery phase within PSS development is made up of the customisation, deliver and production processes*

5.2 Survey findings

A survey was conducted to provide validation of the simplified model of PSS development by testing the five hypotheses proposed from the analysis of the case study findings. Given that no differences in the activities used to operationalise the idea generation and product design processes were reported from case study, these processes were not included in the survey.

5.2.1 Factor and reliability analyses

Given that a number of measures were used within the survey to investigate each process, principal component analysis was initially conducted determine whether the each process, reported in the simplified model of PSS development, sufficiently accounted for the variability in the responses to the measures. For example, existing literature operationalises market research in terms of performing four activities: customer analysis (Slater & Narver 1999, Gronroos 2008), competitor analysis (Bergen & Peteraf 2002), investigating strategic partners (Brezet *et al.* 2001, Kar 2004) and identifying new technologies (Neely 2008). The results from the case study suggest that market research can also be operationalised in terms of a market trend analysis activity. Given that a large number of phrases were extracted from the interview transcripts relating to customer analysis, market research was operationalised through the customer analysis and market trend analysis activities. These were measured by asking respondents to rate on a 5-point likert scale whether they agreed or disagreed with statements that: customers are involved in helping to determine their needs (Q4); dialogue is used with customers to understand their businesses (Q8); techniques are used to engage customers in determining their requirements (Q12); analysis is conducted of current markets to identify opportunities (Q15); analysis is conducted of different markets to identify potential PSSs that could be delivered in respondents' markets (Q20); and analysis is conducted to identify trends in customers' business environments (Q25). Factor analysis performed on these items (using varimax orthogonal rotation) failed to produce a workable construct, suggesting the need to eliminate Q15, Q20 and Q25. The factor analysis performed on the remaining three items demonstrated one factor larger than 1, explaining 60.4% of the variance in the survey responses. The reliability of the three items yielded a Cronbach's alpha of 0.655. This suggests that market research, operationalised in terms of the customer analysis activity, is a valid process within PSS development. In contrast to the case study findings, analysis suggests that the survey respondents do not conduct market trend analysis within the market research process.

Whilst the principal component analysis indicated that the variation in responses can be explained by the majority of processes, analysis indicated that the systems analysis and project initiation processes are not reflected in the PSS development practices of the survey respondents. The principal component analysis indicated that there are two independent factors that explain the variability in the responses to the measures associated with the systems analysis process. The analysis indicated that the first factor consists of Q14 (existing skills are identified to determine their suitability for developing PSSs), Q19 (analysis is conducted to identify if existing personnel could be used to deliver new PSSs) and Q24 (analysis is conducted to identify whether existing resources could be used to deliver new PSSs). Assessment of these measures highlighted that they are concerned with conducting analysis of an organisation's skills and resources – termed resource analysis. This suggests that resource analysis is an independent process, attaining a satisfying 0.847 Cronbach's alpha, explaining 77.5% of the variance. Additionally, the analysis indicated that the variability in the responses to Q13 (analysis is conducted to determine how customers are using existing products and services) and Q18 (analysis is conducted to determine the operating profile of existing products and services) from the systems analysis process and Q15 (analysis is conducted of current markets to identify opportunities) and Q25 (analysis is conducted to identify trends in customers' business environments) from the market trend analysis activity can be explained by one process. Assessment of these measures highlighted that they are concerned within analysing existing products and services before identifying opportunities to deliver new PSSs – termed benchmarking. These were combined and are considered within a benchmarking process, attaining a satisfying 0.765 Cronbach's alpha, explaining 60.2% of the variance.

The principal component analysis indicated that there are two independent factors that explain the variability in the responses to the measures associated within the project initiation process. The analysis indicated that the first factor consists of Q29 (PSS projects are sponsored by senior management), Q34 (formal authorisation is given to begin PSS projects) and Q39 (approval is given to being PSS projects). Assessment of these measures highlighted that they are concerned with gaining senior management's approval to begin PSS projects – termed project authorisation. This points towards a project authorisation process, attaining a satisfying 0.770 Cronbach's alpha, explaining 69.3% of the variance. Additionally, the analysis indicated that the second factor consists of Q30 (goals for the project are defined), Q31 (projects are executed by teams), Q32 (project time schedules were specified), Q36 (formal or informal techniques are used to identify team), Q37 (project milestones are specified), Q40 (the deliverables for the project are specified), Q41 (a team leader is appointed to manage the people involved in the project) and Q42 (projects are managed with the aid of project plans). Assessment of these measures highlighted that they are concerned with creating plans, agreeing goals and creating project teams – termed project planning. This points towards a project planning process, attaining a satisfying 0.893 Cronbach's alpha, explaining 58.3% of the variance.

A full detail of the factor and reliability analyses is provided in Table 5-7.

Table 5-7: Reliability and validity for the PSS development processes

Phase	Process	Cronbach's alpha	# of items	1st Eigenvalue	2nd Eigenvalue	Variance explained
	Customer involvement	0.680	3	1.830	0.693	61.0%
	Evaluation	0.786	6	3.039	0.911	50.6%
Analysis	Benchmarking	0.765	4	2.409	0.734	60.2%
	Resource analysis	0.847	3	2.326	0.400	77.5%
	Capture requirements	0.856	5	3.235	0.746	64.7%
	Market research	0.655	3	1.813	0.737	60.4%
Concept design	Project planning	0.893	8	4.664	0.973	58.3%
	Project authorisation	0.770	3	2.079	0.781	69.3%
Development	Delivery planning	0.633	4	1.908	0.951	47.7%
	Market communications*	0.908	7	4.515	0.733	64.5%
	Service design	0.791	4	2.473	0.797	61.8%
Delivery	Production	0.832	6	3.411	0.809	56.9%
	Customisation	0.666	3	1.804	0.687	60.1%
	Deliver	0.657	2	1.495	0.505	74.8%

* Refers to an enlarged market communications process consisting of Q46, Q47, Q51, Q52, Q56, Q57 and Q69

Based on the results of the principal component analysis, hypotheses 2 and 3 were updated to reflect the changes suggested from the survey data:

Hypothesis 2-updated: *The analysis phase within PSS development is made up of the capture requirements, market research, benchmarking, resource analysis and customer involvement processes*

Hypothesis 3-updated: *The concept design phase within PSS development is made up of the concept development, idea generation, project authorisation, project planning, customer involvement and evaluation processes*

5.2.2 Regression analysis

5.2.2.1 Relationship between the phases

Hypothesis 1 predicts a sequential relationship between the phases within PSS development. This hypothesis was tested by running three linear regression models. In the first model (equation 1) the indicators of the concept design phase (CONDES) were the dependent variable and the indicators of the analysis phase (ANAL) the independent variable. In the second model (equation 2) the indicators of the development phase (DEV) were the dependent variable and the indicators of the concept design phase (CONDES) the independent variable. In the third model (equation 3) the indicators of the delivery phase (DEL) were the dependent variable and the indicators of the development phase (DEV) the independent variable. Complexity of the PSS (CPLX) and respondents' experience in developing PSSs (EXP) were used as control variables in the regression models.

$$CONDES = \beta_0 + \beta_1(ANAL) + \beta_4(CPLX) + \beta_5(EXP) \quad (1)$$

$$DEV = \beta_0 + \beta_2(CONDES) + \beta_4(CPLX) + \beta_5(EXP) \quad (2)$$

$$DEL = \beta_0 + \beta_3(DEV) + \beta_4(CPLX) + \beta_5(EXP) \quad (3)$$

The results of the regression models are presented in Table 5-8.

Table 5-8: Regression results for hypothesis 1

	Model 1			**Model 2**			**Model 3**		
	CONDES			DEV			DEL		
	β	Sig.	SE	β	Sig.	SE	β	Sig.	SE
Constant (β_0)	2.625	0.002	0.768	1.784	0.014	0.682	2.831	0.000	0.538
ANAL (β_1)	0.435	0.035	0.196						
CONDES (β_2)				0.380	0.020	0.153			
DEV (β_3)							0.297	0.057	0.149
CPLX (β_4)	-0.047	0.491	0.017	0.106	0.084	0.059	-0.001	0.951	0.012
EXP (β_5)	-0.018	0.281	0.017	0.010	0.488	0.015	-0.049	0.358	0.052
R^2	0.187			0.238			0.133		
N	31			31			31		

The results confirm a significant relationship (95% confidence level) between the concept design and analysis phases and the development and concept design phases, suggesting agreement with the sequential relationships proposed in the literature. In contrast to what was expected, the

results do not show a statistically significant relationship between the development and delivery phases.

5.2.2.2 Allocation of the processes within the phases

Analysis

Hypothesis 2-updated predicts that the analysis phase is made up of five processes: capture requirements, market research, benchmarking, resource analysis and customer involvement. This hypothesis was tested by running a linear regression model (equation 4). The indicators of the analysis phase (ANAL) were the dependant variable and the benchmarking (A_BEN), resource analysis (A_RES), market research (A_MR), capture requirements (A_CR) and customer involvement (CI) processes as the independent variables. Complexity of the PSS (CPLX) and respondents' experience in developing PSSs (EXP) were used as control variables in the regression model.

$$ANAL = \beta_0 + \beta_1(A\_BEN) + \beta_2(A\_RES) + \beta_3(A\_MR) + \beta_4(A\_CR) + \beta_{13}(CI) + \beta_{15}(CPLX) + \beta_{16}(EXP) \quad (4)$$

The results of the regression model are presented in Table 5-9.

Table 5-9: Regression results for hypothesis 2-updated

	Model 4		
	ANAL		
	β	Sig.	SE
Constant (β_0)	-0.001	0.838	0.004
A_BEN (β_1)	0.265	0.000	0.001
A_RES (β_2)	0.200	0.000	0.001
A_MR (β_3)	0.200	0.000	0.001
A_CR (β_4)	0.334	0.000	0.001
CI (β_{13})	0.001	0.266	0.001
CPLX (β_{15})	0.000	0.489	0.000
EXP (β_{16})	0.000	0.393	0.000
R^2	1.000		
N	31		

Results confirm significant relationships between the benchmarking, resource analysis, market research and capture requirements processes and the analysis phase, suggesting that these processes are executed during analysis. In contrast to what has been reported in the literature and the case study findings, no signification relationship was observed between the analysis phase and the customer involvement process.

Concept design

Hypothesis 3-updated predicts that the concept design phase is made up of concept development, idea generation, project authorisation, project planning, customer involvement and evaluation processes. This hypothesis was tested by running a linear regression model (equation 5). The indicators of the concept design phase (CONDES) were the dependent variable and the project authorisation (CD_PA), project planning (CD_PP), customer involvement (CI) and evaluation (EVAL) processes as the independent variables. Complexity of the PSS (CPLX) and respondents' experience in developing PSSs (EXP) were used as control variables in the regression model. Given that the factor analysis of the concept development process failed to produce a workable construct and no differences were identified between the case study and literature for the idea generation process, these process were not included in the regression analysis.

$$CONDES = \beta_0 + \beta_5(CD\_PA) + \beta_6(CD\_PP) + \beta_{13}(CI) + \beta_{14}(EVAL) + \beta_{15}(CPLX) + \beta_{16}(EXP) \quad (5)$$

The results of the regression model are presented in Table 5-10.

Table 5-10: Regression results for hypothesis 3-updated

	Model 5		
	CONDES		
	B	Sig.	SE
Constant (β_0)	-2.853	0.319	2.806
CD_PA (β_5)	0.919	0.221	0.731
CD_PP (β_6)	0.811	0.000	0.067
CI (β_{13})	-0.69	0.142	0.045
EVAL (β_{14})	0.094	0.174	0.067
CPLX (β_{15})	-0.007	0.747	0.022
EXP (β_{16})	-0.006	0.309	0.006
R^2	0.935		
N	31		

Results confirm significant relationships between the project planning process and the concept design phase, suggesting that this process is executed during concept design. In contrast to what has been reported in the literature and the case study findings, no signification relationship was observed between the concept design phase and the project authorisation, customer involvement and evaluation processes.

Development

Hypothesis 4 predicts that the development phase is made up of delivery planning, market communications, product design, service design, customer involvement and evaluation processes.

This hypothesis was tested by running a linear regression model (equation 6). The indicators of the development phase (DEV) were the dependent variable and the delivery planning (DEV_DP), service design (DEV_SD), market communications (DEV_MC), customer involvement (CI) and evaluation (EVAL) processes as the independent variables. Complexity of the PSS (CPLX) and respondents' experience in developing PSSs (EXP) were used as control variables in the regression model.

$$DEV = \beta_0 + \beta_7(DEV\_DP) + \beta_8(DEV\_SD) + \beta_9(DEV\_MC) + \beta_{13}(CI) + \beta_{14}(EVAL) + \beta_{15}(CPLX) + \beta_{16}(EXP) \quad (6)$$

The results of the regression model are presented in Table 5-11.

Table 5-11: Regression results for hypothesis 4

	Model 6		
	DEV		
	β	Sig.	SE
Constant (β_0)	-0.001	0.826	0.005
DEV_DP (β_7)	0.267	0.000	0.001
DEV_SD (β_8)	0.266	0.000	0.001
DEV_MC (β_9)	0.467	0.000	0.001
CI (β_{13})	0.000	0.972	0.001
EVAL (β_{14})	-0.001	0.681	0.001
CPLX (β_{15})	0.000	0.397	0.000
EXP (β_{16})	0.000	0.693	0.000
R^2	1.000		
N	31		

Results confirm significant relationships between the delivery planning, service design and market communications processes and the development phase, suggesting that these processes are executed during development. In contrast to what has been reported in the literature and the case study findings, no signification relationship was observed between the development phase and the customer involvement and evaluation processes.

Delivery

Hypothesis 5 predicts that the delivery phase is made up of customisation, deliver, production, customer involvement and evaluation processes. This hypothesis was tested by running a linear regression model (equation 7). The indicators of the delivery phase (DEL) were the dependent variable and the production (DEL_PRO), customisation (DEL_CUST), deliver (DEL_DEL), customer involvement (CI) and evaluation (EVAL) processes as the independent variables.

Complexity of the PSS (CPLX) and respondents' experience in developing PSSs (EXP) were used as control variables in the regression model.

$$DEL = \beta_0 + \beta_{10}(DEL\_PRO) + \beta_{11}(DEL\_CUST) + \beta_{12}(DEL\_DEL) + \beta_{13}(CI) + \beta_{14}(EVAL) + \beta_{15}(CPLX) + \beta_{16}(EXP) \quad (7)$$

The results of the regression model are presented in Table 5-12.

Table 5-12: Regression results for hypothesis 5

	Model 7		
	DEL		
	β	Sig.	SE
Constant (β_0)	-0.009	0.140	0.006
DEL_PRO (β_{10})	0.550	0.000	0.001
DEL_CUST (β_{11})	0.180	0.000	0.001
DEL_DEL (β_{12})	0.273	0.000	0.001
CI (β_{13})	0.000	0.573	0.001
EVAL (β_{14})	-0.002	0.099	0.001
CPLX (β_{15})	0.001	0.137	0.000
EXP (β_{16})	0.000	0.718	0.000
R^2	1.000		
N	31		

Results confirm significant relationships between the production, customisation and deliver processes and the delivery phase, suggesting that these processes are executed during delivery. In contrast to what has been reported in the literature and the case study findings, no signification relationship was observed between the delivery phase and the customer involvement and evaluation processes.

5.3 Synthesis of case study and survey findings

5.3.1 Identification of the phases and the processes

Based on the literature review, fourteen processes were identified as being executed during seven phases of PSS development. The findings from the case study indicate that the PSS development practice of servitized manufacturers can better be reflected in terms of four phases: analysis, concept design, development and delivery and that a process not reported in literature – production – is executed. Further, during the processes BTS: (1) executes a number of activities not reported in literature; and (2) does not execute a number of activities which are reported in literature. Whilst some concurrence between the activities executed within BTS's PSS development practice and the

literature was also highlighted, the differences suggest the model of PSS development synthesised from the literature does not accurately reflect the industrial practice of BTS. Analysis of the survey data identified that the systems analysis and project initiation processes do not accurately reflect the PSS development practice of the sampled servitized manufacturers. Analysis of the data suggested the inclusion of benchmarking and resource analysis processes to replace the systems analysis process and project authorisation and project planning processes to replace the project initiation process (Table 5-13).

Table 5-13: Comparison of the processes

Phase	Process	Literature	Case study	Survey
	Customer involvement	✓	✓	✓
	Evaluation[1]	✓	✓	✓
Analysis	Systems analysis	✓	✓	×
	→ Benchmarking[2]	×	✓	✓
	→ Resource analysis[3]	×	✓	✓
	Capture requirements	✓	✓	✓
	Market research	✓	✓	✓
Concept design	Idea generation	✓	✓	*Not included in survey*
	Concept development	✓	✓	×
	Project initiation	✓	✓	×
	→ Project authorisation[4]	✓	✓	✓
	→ Project planning[4]	✓	×	✓
Development	Product design	✓	✓	*Not included in survey*
	Service design	✓	✓	✓
	Delivery planning	✓	✓	✓
	Market communications	✓	✓	✓
Delivery	Production	✓	✓	✓
	Deliver	✓	✓	✓
	Customisation	✓	✓	✓

[1] Although evaluation is reported within each data source, literature reports it as the final phase in the existing PSS development approaches. The second phase of the case study and the survey consider evaluation as a process, conducted throughout numerous PSS development phases

[2] Although benchmarking was not identified from the case study findings, market trend analysis which was synthesised with activities from the systems analysis process was identified

[3] Resource analysis was identified from the case study findings, but it was initially considered as an activity within the systems analysis process and not a process in its own right

[4] Identified as activities from the literature and not distinct processes as reported from analysis of the survey data

Given the findings from the case study and survey, the benchmarking and resource analysis processes are considered as separate processes within PSS development replacing the systems analysis process. Similarly, the project authorisation and project planning processes are considered as separate processes within PSS development replacing the project initiation process. Although limited evidence was found from the survey to validate the concept development process, further investigation of the interview transcripts suggested that the positioning of the offering activity has similarities with the determining of the form and characteristics of the PSS activity: *"…what business are we in - selling the piece of kit, selling and fitting the kit, are we into deriving a value gain share from the benefit of the kit and, if so, to what degree?"* (#8). This points towards a broader activity concerned with determining the form and characteristics of the PSS activity, but further research is needed to investigate whether this is the case.

5.3.2 The relationships between the phases and the processes

Literature reports sequential relationships between the phases of PSS development. Although simplified phases were reported from the case study, findings suggest agreement with the relationships reported in the literature. Analysis of the survey data found statistically significant relationships between the analysis and concept design phases and the concept design and development phases, but no statistically significant relationship between the development and delivery phases was observed. This would seem to disagree with the results from the case study and literature. Further analysis of data indicates a positive relationship between development and delivery, as expected, at a significance level of 0.057. Whilst this is not statistically significant at the 95% confidence level, the relationship is almost statistically significant. Given this and the evidence provided within the existing literature and from the case study findings, a sequential relationship is included between the development and delivery phases within PSS development.

Whilst the case study and literature report project authorisation (as an activity) as occurring within the concept design phase, the results from the analysis of the survey data did not find a statistically significant relationship between project authorisation and concept design. This would seem to disagree with the results from the case study and literature, suggesting project authorisation is not an activity executed during PSS development. Further analysis identified a standard error for this relationship of 2.518, suggesting significant variation in the responses to the questions associated with this process. This would seem to indicate that the measures used to operationalise this process are not precise enough. Given the agreement between the literature (Froehle & Roth 2007) and case study results, project authorisation is provisionally included within the concept design phase, but further research is needed to investigate whether this is the case.

Although significant evidence is presented in the literature (Alam & Perry 2002) and the case study for the execution of customer involvement in a number of phases, the results from the survey data did not find a statistically significant relationship between customer involvement and any phase. A potential explanation for this difference may be seen in the fact that the customer involvement

process was operationalised in terms of an identify engagement customers activity (identified from the case study results and not the literature). This indicates that the identify engagement customers activity reported by respondents at BTS is not reflected in the PSS development practice of the surveyed servitized manufacturers. Future research should seek to operationalise customer involvement in terms of all of the activities reported from the literature and case study, potentially validating the role of customer involvement in all of the phases of PSS development. Given the strong support in the existing literature for involving customers in all phases of PSS development (Alam & Perry 2002) and concurrence with the case study results, customer involvement is included within the model of PSS development.

The results from the survey data did not find a statistically significant relationship between the evaluation process and any phase. This is contrary to the findings from the case study where a number of phrases were extracted relating to an evaluation process. A potential explanation for this difference may be seen in the fact that the evaluation process was operationalised in terms of two activities that are reported in the literature but not identified in the case study findings – namely, the define evaluation criteria and write evaluation report activities. This suggests that the surveyed servitized manufacturers concur with BTS in not conducting the define evaluation criteria and write evaluation report activities within the evaluation process. Given the strong support in the literature for these activities when evaluation is conducted as a separate phase, further research is needed to determine whether evaluation is better considered as a separate phase or a process executed in a number of phases. Given the similarities with the product and service development literatures (Cooper 1986) and the case study findings, evaluation is included within the model of PSS development and is executed in a number of phases.

5.3.3 Proposing a new model of PSS development

Given the results of the case study and survey examining how representative the model of PSS development synthesised from the literature is at reflecting the PSS development practices of servitized manufacturers, a new model of PSS development is suggested to better reflect industrial practice (Figure 5-2).

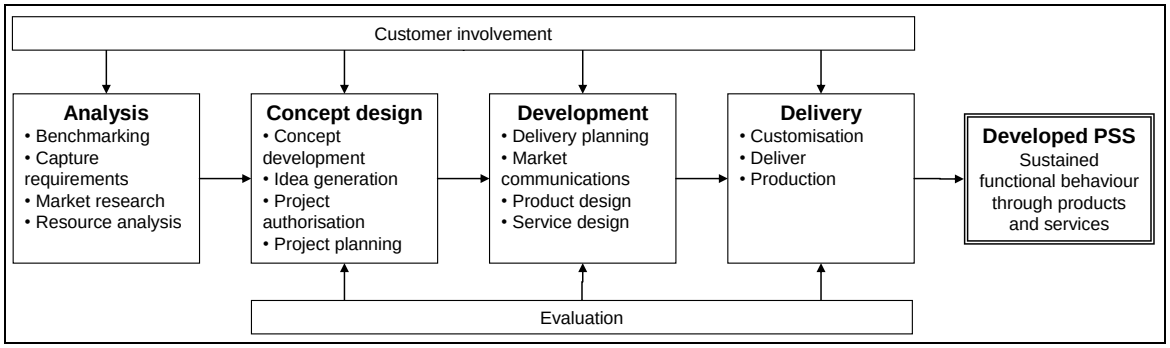

Figure 5-2: Proposed new model of PSS development

Whilst the model of PSS development synthesised from the literature consists of seven phases, the proposed new model of PSS development consists of four phases. The phases of the proposed new model represent a simplification of the phases reported in the literature, better reflecting the practice of servitized manufacturers. Additionally, whilst the literature reports fourteen processes, the research identified that two processes are not executed within the PSS development practice of servitized manufacturers. To better reflect industrial practice, the findings indicate that the benchmarking and resource analysis processes should replace the systems analysis process and that the project authorisation and project planning processes should replace the project initiation process. Additionally, the findings indicate that servitized manufacturers operationalise the capture requirements, service design, market communications, customisation and evaluation processes differently from approaches proposed within the existing literature.

5.4 Summary

During this stage of research the findings from a single case study and survey have been presented. The first stage of the case study sought to investigate whether the phases presented in the model of PSS development synthesised from literature reflected industrial practice. Findings from this stage of the case study suggest that whilst there are some similarities, a number of differences exist. Based on this, the phases within PSS development were simplified to four distinct phases: analysis, concept design, development and delivery. The second stage of the case study sought to investigate whether the processes presented in the simplified model of PSS development reflected industrial practice. The findings suggested that BTS executes a number of activities not reported in literature and does not execute a number of processes that are reported in literature. These differences suggest that the model of PSS development synthesised from literature does not accurately reflect the industrial practice of servitized manufacturers. A survey was conducted to provide validation of the simplified model of PSS development on a sample of servitized manufacturers. Analysis of the survey data identified that the systems analysis and project initiation processes do not accurately reflect the PSS development practice of the sample. Analysis of the data suggested the inclusion of benchmarking and resource analysis processes to replace the systems analysis process and project authorisation and project planning processes to replace the project initiation process. Findings from the survey validated the sequential relationship between the analysis and concept design phases and the concept design and development phases, but further research is needed to statistically validate the relationship between the development and delivery phases. Further analysis suggested agreement with the allocation of the processes to the phases reported from the case study, but additional research is needed to statistically validate whether the project authorisation process is executed in concept design and whether the customer involvement and evaluation processes are executed in any phase. Based on the results from the case study and survey, a new model of PSS development is proposed.

The following chapter presents the research conducted to operationalise and test the proposed model of PSS development through its application in practice.

6 Operationalising the proposed model of PSS development

The aim of this chapter is to provide a summary of the research undertaken to implement the proposed new model of PSS development in practice. Process modelling was used to represent the proposed model of PSS development in a workbook. In section 6.1 the requirements specifying the design of the PSS Development Workbook are summarised. Based on these requirements the PSS Development Workbook is summarised in section 6.2. Its application to identify possible PSSs that BTS could develop is summarised in section 6.3. Based on the results of this application, section 6.4 discusses the implications of applying the PSS Development Workbook before a summary of this chapter is presented in section 6.5.

6.1 Process model design

During process model design, requirements for the process modelling used to represent the workbook were identified before an appropriate process modelling framework and language was selected.

6.1.1 Requirements for the process modelling

Processes are complex and are often difficult to understand and communicate (Holt 2006). The aim of a process framework is to guide the modelling to ensure that the processes represented contain complete information, are realistic, successfully manage complexity and interactions, are traceable, and make use of partitioning and iteration where appropriate (Table 6-1).

Table 6-1: Process modelling requirements (Holt 2009)

Requirement	Description
Complete information	The process model must represent the required level of detail
Realistic	The processes modelled must reflect the practices executed in reality
Partitioning	Related processes must be grouped within the process model
Process iteration	The process model must describe how processes are carried out and re-used
Complexity and interactions	Relationships between elements at all levels within the process model must be visualised
Traceability	It must be possible to trace all artefacts (e.g. documents) back to the original project requirements
Tailoring	The generic process model must allow specialisation
Multiple views	To gain a full understanding of the process it must be represented from multiple perspectives

6.1.2 Requirements for the content of the workbook

Given that the PSS Development Workbook is a manifestation of the proposed model of PSS development (Figure 5-2), at a high-level the process model is made up of four phases and seventeen related processes.

To ensure that all elements within the proposed model of PSS development are adequately modelled, the requirements in Table 6-1 suggest that the framework for structuring the process modelling should contain a way of exhibiting different views. Although a number of process modelling frameworks have been proposed (Scholz-Reiter *et al.* 1999), Holt (2009) has proposed an approach to process modelling known as the *'seven views approach'* (Table 6-2).

Table 6-2: Views from the seven views approach (Holt 2009)

View	Description
Requirements view	Provides an understanding of exactly why the process model is needed and offers a way of validating the processes once completed
Process structure view	Shows a high-level representation of the structure of, and the terminology used throughout, the processes
Process content view	Encapsulates all processes within the process model and shows the actual content of the processes in line with the process structure view. The process content view can be thought of as a library of processes that are available to organisations for a particular task (e.g. developing PSSs)
Stakeholder view	Represents the roles that are involved in the processes and are consistent with the stakeholders identified on the process behaviour and requirement views
Information view	Shows the relationships between key artefacts (e.g. documents) within a process and how they relate to each other. Artefacts can also be related to other artefacts from different processes. This view ensures that processes are compatible and provides a method for reviewing documentation to eliminate replication and remove unused documents
Process instance view	Comprises a set of diagrams that show how processes can be run (from a theoretical point of view) or have been run (as a way to record their execution on a project). Process instance views provide the main validation of the process model to ensure each requirement has been met
Process behaviour view	Describes the behaviour of processes, showing the order in which activities are executed, decision points within a process and the artefacts consumed or produced. Stakeholders responsible for ensuring that activities are executed are also shown

The requirements for the PSS Development Workbook can be met using the views from the seven views approach (Table 6-3). Whilst the stakeholder view is not required to fulfil the process modelling requirements for PSS development, given that manufacturers and customer co-create

PSSs, the stakeholder view is included to give an indication of who is likely to be responsible for executing the activities within the processes.

Table 6-3: Mapping the seven views to the requirements

Requirement	View
Complete information	Process content view
Realistic processes	Process instance view
Complexity and interactions - very high level of abstraction - high level of abstraction - medium level of abstraction - low level of abstraction	 Requirements view Process instance view Process behaviour view Process behaviour view
Traceability	Information view
Process partitioning	Process structure view
Process iteration	Process behaviour view
	Process instance view

6.1.3 Selection of the process modelling language

A number of modelling languages are available to represent the different views within the PSS Development Workbook. Although Holt (2009) uses the Unified Modelling Language (UML) to model processes using the seven views approach, he makes it clear that this is not a prerequisite. Furthermore, Holt (2009) states that the views can be represented in any modelling language (or multiple languages) as long as they are consistent.

Table 6-4 lists a number of modelling languages and presents their ability to create models consistent with the views within the seven views process modelling framework.

Many of the languages presented in Table 6-4 are able to create a number of the required views, but only UML and SysML are capable of creating all of the views. Whilst it is not necessary to create all of the views within one language, doing so ensures a common approach to process modelling and enables the consistency of the models to be more easily assessed (Holt 2009). In contrast to UML and SysML, BPMN was created specifically for modelling business processes. BPMN, however, contains only one type of diagram – the business process diagram which is analogous to the activity diagram within UML/SysML. Whilst the notation within the business process diagram is richer than the activity diagram (White 2004), it is capable of representing only two views within the seven views approach – the process instance view and process content view. Although UML has its heritage in software engineering, it has been used widely in a number of different applications – e.g. requirements engineering (Hull *et al.* 2005), process modelling (Holt 2009), architectural frameworks (Mavris 2007), risk assessment (Brownsword 2009) and project management (Cantor 1998) indicating its wider applicability in modelling business processes.

Table 6-4: Modelling language options

Modelling language	Description	Requirements view	Process structure view	Process content view	Stakeholder view	Information view	Process instance view	Process behaviour view
Flowcharts (Lakin *et al.* 1996)	A schematic representation of algorithms or processes	N	N	N	N	N	N	Y
Business Process Modelling Notation (BPMN) (OMG 2011)	A general process modelling language	N	N	N	N	N	Y	Y
Integrated Definition methods (IDEF) (Mayer *et al.* 1992)	A family of modelling languages including IDEF3 for business process modelling	N	N	N	Y	Y	Y	Y
The Unified Modelling Language (UML) (OMG 2010b, OMG 2010c)	A modelling language that is an industry standard for specifying software intensive systems	Y	Y	Y	Y	Y	Y	Y
The Systems Modelling Language (SysML) (OMG 2010a)	A domain-specific modelling language for systems engineering that is defined as a profile of UML	Y	Y	Y	Y	Y	Y	Y

Much of the notation within UML is however software-oriented (Weilkiens 2008). The SysML, a subset of UML specialised for the systems engineering community, provides a more general purpose representation of the notation within UML, making it more appropriate for modelling business processes. Whilst using BPMN to model the process instance and process content views within the PSS Development Workbook would allow these views to be represented in greater richness, the inability of BPMN to model all views within the seven views approach limits its ability to model the proposed model of PSS development within the PSS Development Workbook. Given this, SysML was chosen as the most appropriate language. Whilst SysML consists of nine diagrams only a small number are needed to create the seven views (Table 6-5).

Table 6-5: Mapping of the seven views to the SysML diagrams

View	SysML diagram
Requirements view	Use case diagram *Or* Requirements diagram
Process structure view	Block definition diagram
Process content view	Block definition diagram
Stakeholder view	Block definition diagram
Information view	Block definition diagram
Process instance view	Sequence diagram
Process behaviour view	Activity diagram

Additionally, whilst a number of software tools are available for creating SysML models, many do not have profiles for classifying models within the sevens views approach (Table 6-6). Whilst a modeller can use the seven views approach without it being supported by a software tool, it makes it more difficult to structure, communicate and consistency check the models. As such, Artisan Studio was selected as the most appropriate software tool.

Table 6-6: Software tool options

Software	Vendor	SysML?	Seven Views profile?
Artisan Studio	Atego	Y	Y
MagicDraw	No Magic	Y	N
Microsoft Visio (SysML template)	Microsoft	Y	N
Modelio SysML Designer	Modelio Modelling Solutions	Y	N
Rhapsody	IBM	Y	N

6.2 Process model development

During process model development, the PSS Development Workbook was created in line with the requirements specified in section 6.1. The PSS Development Workbook consists of a number of diagrams, specifying how the proposed model of PSS development can be implemented in practice. This section provides a summary of some of the elements of the PSS Development Workbook. Although the models were created in Artisan Studio, they were subsequently exported into the PSS Development Workbook which took the form of an interactive website. The full version of the PSS Development Workbook can be seen in Appendix IV.

Reflecting the proposed model of PSS development, the PSS Development Workbook represents PSS development as being made up of four phases and seventeen processes (Figure 6-1). Each phase is made up of one or more processes which are executed during each phase. Each process is made up of one or more activities. The activities reported within the PSS Development

Workbook are the same as the activities reported in the literature, and amended given the findings from the case study and survey, to operationalise each process.

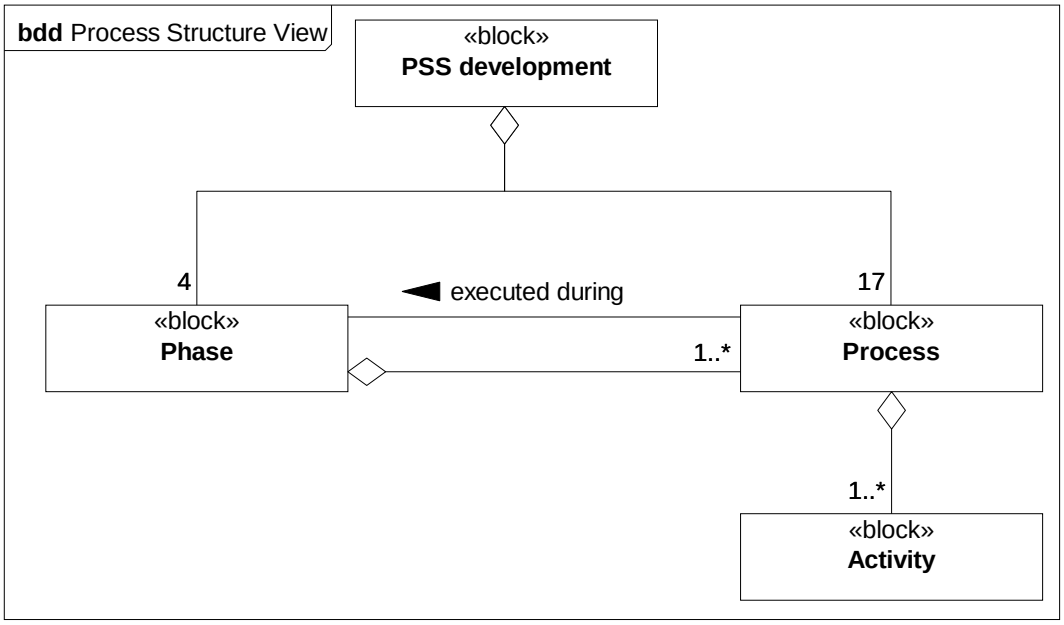

Figure 6-1: Process structure view of the PSS Development Workbook

The process content views provide a visual representation of the processes that make up each phase. For example, reflecting the proposed model of PSS development, Figure 6-2 represents the analysis phase as being made up of five processes: benchmarking, market research, resource analysis, capture requirements and customer involvement.

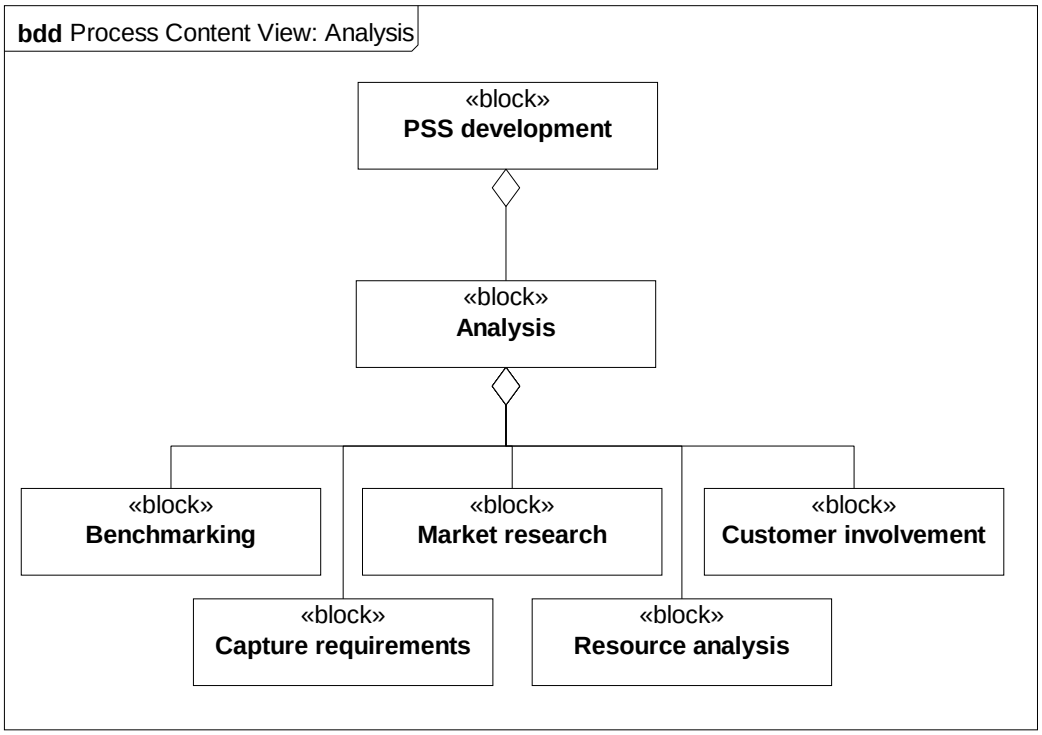

Figure 6-2: Example process content view for the analysis phase

The process behaviour views provide a visual representation of the activities that make up each process, giving an indication of the sequence in which the activities should be executed by practitioners (Figure 6-3). Although the research conducted within this thesis did not seek to investigate the sequence of activities within processes, for the purposes of the PSS Development Workbook activities were sequenced logically.

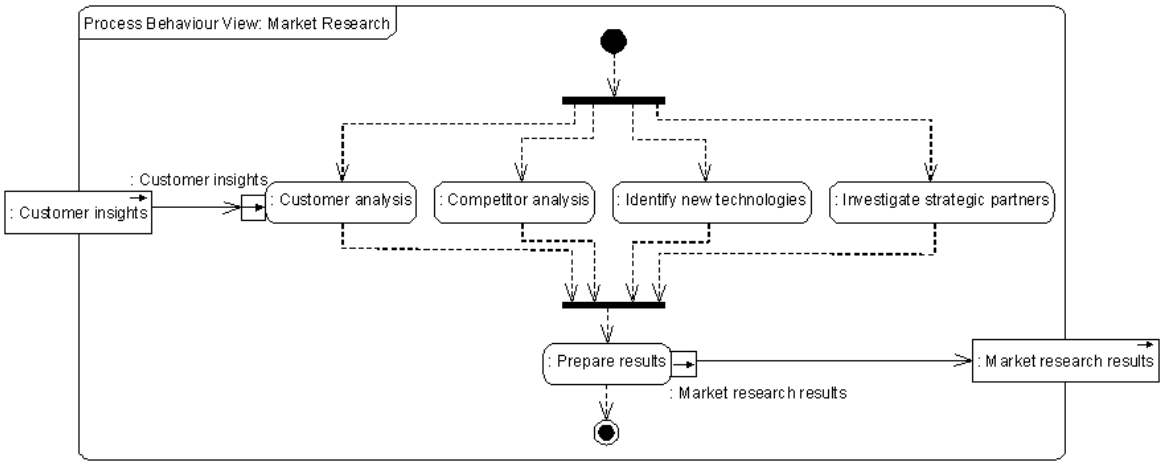

Figure 6-3: Example process behaviour view for the evaluation process

The process instance views provide a visual representation of the sequence of execution of the phases and processes during PSS development. For example, Figure 6-4 presents the sequential relationships identified between the phases.

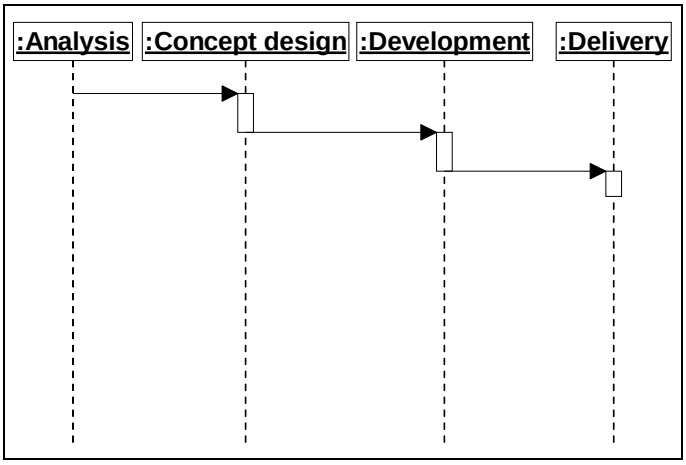

Figure 6-4: Process instance view representing the sequential relationships between phases

6.3 Process model testing

The PSS Development Workbook was tested through application at BTS to determine whether following it would lead to the creation of a PSS, and whether the application suggested changes to the proposed model of PSS development. The process model testing was conducted in three stages:

1. Initial analysis
2. Detailed analysis and concept design
3. Development

6.3.1 Initial analysis

During initial analysis, interviews were conducted to give each participant an understanding of the aims of the process model testing and to present the PSS Development Workbook. After the initial interviews, the twenty participants were separated four smaller groups. Each group was assembled for a half-day workshop to conduct initial market research. Each group was asked to use either a SIPOCR (suppliers, inputs, process, outputs, customers and regulation) or PESTLE (political, economic, social, technology, legislation and environment) analysis to investigate specific attributes of customers' businesses. For example, one group were asked to analyse a customer to understand the causes of their poor performance. The results of these analyses were captured and distributed to all participants for feedback.

6.3.2 Detailed analysis and concept design

Once the initial market research had been conducted, all twenty participants attended a three-day workshop to conduct more detailed analysis and concept design. The participants were split into four different smaller groups, each focusing on one of four particular types of stakeholder: train operators, train owners, infrastructure owners and BTS's suppliers. Building on the initial analysis, each group performed a detailed analysis of their stakeholder's business. The aim of this analysis was to identify potential opportunities to deliver new PSSs (the market research process). Once stakeholder needs were identified, they were documented and the requirements for the new PSS elicited (capture requirements). In addition, detailed analysis sought to investigate the potential risk from competitors if BTS were to deliver a new PSS (benchmarking). Based on the results of the benchmarking, further market research analysis was conducted to identify potential implications of delivering a PSS on customers needs (e.g. will delivering a PSS change/lead to new customer needs?) and to identify any new competitors (e.g. will delivering the PSS introduce new competitors into the industry?).

Once each group had determined their stakeholder's needs, ideas were generated to identify how these needs could be fulfilled (idea generation). For example, one group identified that a train owner is seeking to maximise the utilisation of their existing asset base whilst simultaneously trying to reduce the total whole life costs of their assets. The group identified six potential new PSSs that could be delivered whilst fulfilling these needs. Based on the results of the evaluation, a small number of ideas remained for further development. For these ideas, the potential PSS was defined in detail to give a clear indication of its value to the relevant stakeholder and an understanding of what the PSS might look like (concept development).

During the afternoon of the third day, each group's concept was evaluated by the Head of BTS. Whilst the majority of the concepts were given his authorisation to be further developed, one concept required further development before being authorised. A subsequent three-day workshop was planned and each group was required to perform a number of tasks consistent with the activities from the processes within the development phase.

A process instance view, representing the sequence of execution of the processes used within the detailed analysis and concept design stage of process model testing, is provided in Figure 6-5. The process instance view demonstrates that PSS development practice is iterative and non-linear, represented by the re-use of a number of processes.

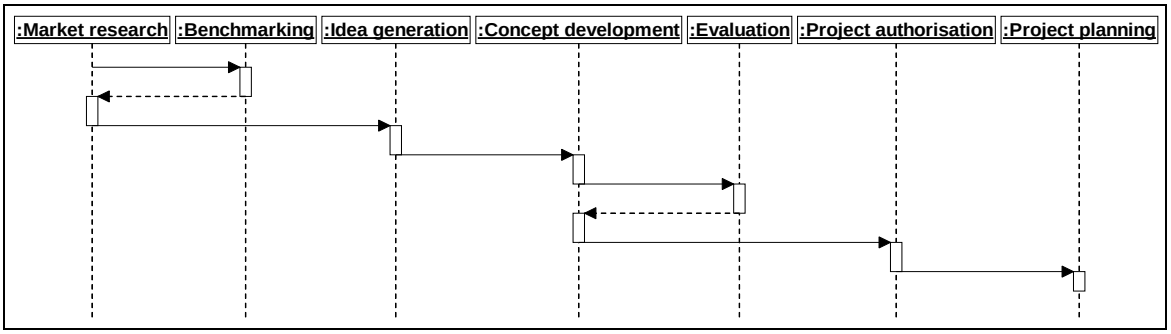

Figure 6-5: Process instance view of the detailed analysis and concept design stage of testing

6.3.3 Development

Before the follow-on three-day workshop, the groups met individually during two half-day workshops to begin developing their concepts further. Within these workshops each group sought to quantify the value of their PSS concept (from their customers' perspective) and identify potential mechanisms for generating revenue (market communications).

During the subsequent three-day workshop each group refined their results from the market communications process and sought to create roadmaps for delivering the PSS (delivery planning). The roadmaps were comprehensive, identifying what changes were needed within BTS's and customers' organisations to co-deliver the PSSs. One group identified 26 actions that BTS will need to perform to deliver their PSS concept. Some actions were specific to technology (e.g. predictive maintenance is linked to automatic parts ordering) whilst others identified organisational changes required to deliver the PSS (e.g. BTS encourages effective data sharing between all contracted parties).

During the third day, each group presented their developed concepts to the Head of BTS. Of the PSS concepts developed, one was selected for development into a complete PSS (evaluation). Since then, significant work has been conducted within BTS to determine the final design of the service element of the PSS (service design) and identify specific technology elements (product

design). Additionally, customers have been engaged to evaluate the PSS and identify areas for improvement before delivery (customer involvement).

A process instance view, representing the sequence of execution of the processes used within the development stage of process model testing, is provided in Figure 6-6. Reflecting the findings from the detailed analysis and concept design stage, the process instance view demonstrates that PSS development practice is iterative and non-linear.

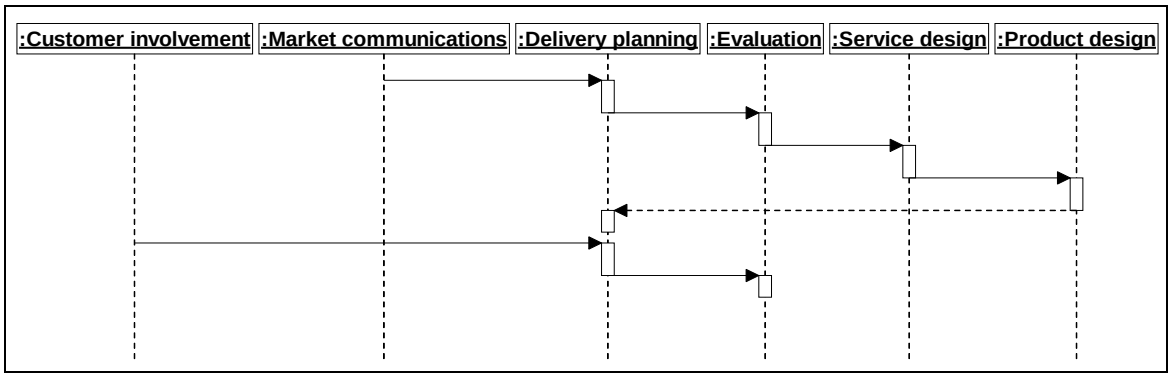

Figure 6-6: Process instance view of the development stage of testing

6.4 Implications for the proposed model of PSS development

Process model testing sought to evaluate whether following the PSS Development Workbook would lead to the creation of viable PSSs. The following sections reflect on the application of the PSS Development Workbook and discuss the implications for the proposed model of PSS development.

6.4.1 Implications for the phases

The PSS Development Workbook was applied in stages broadly consistent with the phases within the proposed model of PSS development (Table 6-7).

Table 6-7: Stages of process model testing mapped to phases

		Phases from the proposed model of PSS development			
		Analysis	**Concept design**	**Development**	**Delivery**
Stages of process model testing	**Initial analysis**	✓			*Processes within delivery were not executed*
	Detailed analysis and concept design	✓	✓		
	Development			✓	

Given the time disparity between developing new PSSs and the four years specified for the EngD programme, it was not possible to test the delivery phase within the proposed model of PSS development – i.e. the completion of process model testing did not result in the delivery of a new PSS. Consequentially the processes associated with delivery were not executed.

The execution of the phases during process model testing suggested agreement with the sequence presented in the proposed model of PSS development (i.e. analysis, concept design, development and delivery), but the findings suggest that the relationship between phases is more complex. For example, once the groups had developed a PSS concept they 'went back' into analysis to perform further market research. Specifically, competitors were analysed to determine whether the competition offer similar PSSs and, if they do not, how quickly they might be able to imitate the PSS. This suggests that whilst the sequential relationship between phases in the proposed model of PSS development reflects industrial practice, a number of processes are re-used in multiple phases giving the impression of feedback between phases. Further research is needed to investigate this phenomenon.

6.4.2 Implications for the processes

The processes within the proposed model of PSS development were applied within the stages of process model testing (Table 6-8). As previously discussed, the processes associated with the delivery phase (i.e. customisation, deliver and production) were not applied during process model testing.

Although thirteen processes were applied during process model testing, some processes were operationalised differently from that suggested by the proposed model of PSS development. For example, extant literature and findings from this research suggest that the market research process is operationalised in terms of: performing customer analysis, competitor analysis, investigating strategic partners and identify new technologies. During initial analysis, only the customer analysis activity was executed to gain a deep understanding of customer needs. Later in the detailed analysis and concept design stage, further analysis was conducted to identify new technologies and perform competitor analysis. This suggests that all of the activities within the processes do not always require executing in order to develop a PSS.

During feedback from the workshop participants, a number identified that the proposed model of PSS development does not have a process for identifying the risks associated with developing and delivering PSSs. One group of participants argued that risk analysis should be an explicit process executed during PSS development whilst another argued that risk analysis is inherent. Whilst no explicit mention of risk was made during the research, a number of questions were asked during the survey that pointed towards technical and financial risk assessments (Q1, Q2, Q5, Q6, Q9 and Q10). Given that the findings from the survey suggested that these activities are performed within the evaluation process and reflecting the stage-gate model of product development where risk is

assessed during 'gates' (Cooper 1986), risk was included as a criterion within the evaluation process.

Table 6-8: Processes within PSS development applied during process model testing

Processes	Stages of process model testing		
	Initial analysis	**Detailed analysis and concept design**	**Development**
Market research	✓	✓	
Benchmarking		✓	
Capture requirements	✓	✓	
Resource analysis*			
Concept development		✓	
Idea generation		✓	
Project authorisation		✓	
Project planning		✓	
Delivery planning			✓
Market communications			✓
Product design			✓
Service design			✓
Customisation	Processes not executed during process model testing		
Deliver			
Production			
Customer involvement			✓
Evaluation		✓	✓

* The resource analysis process was not executed during testing. Ongoing work within BTS is applying the resource analysis process to identify the personnel, competencies and skills needed to deliver the most promising PSS concept

One constraint placed on process model testing from BTS was the need not to include customers and suppliers in the early stages. This meant that investigating strategic partners was not conducted during market research. Similarly, the customer involvement process was not executed during the early stages of testing. This is contrary to existing research (Alam & Perry 2002, Tuli *et al.* 2007) which proposes involving customers in all stages of development. During the delivery planning process, in addition to the identification of technical obstacles and tools to aid delivery, organisational delivery obstacles were also identified. For example, personnel and skills gaps were identified that would potentially prevent the successful delivery of the PSS.

The process model testing did result in the development of a number of PSS concepts, one of which is being further developed within BTS before being delivered. Although the majority of

processes were executed in accordance with the proposed model of PSS development, a number of differences occurred. This suggests that not all of the processes are executed in the same manner in all PSS development projects. This was highlighted by one participant who suggested that the processes and activities executed during PSS development may be contingent upon the risk associated with developing specific PSSs, whether other organisations are involved in development and the size of the servitized manufacturer. Future research is needed to determine whether the processes executed during PSS development are contingent upon factors not considered in this research.

6.5 Summary

During this stage of research the proposed new model of PSS development has been operationalised in a workbook - termed the PSS Development Workbook. The PSS Development Workbook, implemented in SysML, represents the proposed model of PSS development from seven interrelated views. The seven views approach ensures that the processes within the proposed model of PSS development are represented consistently and at an appropriate level of detail to be understood and used by practitioners. The PSS Development Workbook was tested through implementation in practice to support BTS in developing new PSSs. Following the PSS Development Workbook did result in the creation of a number of PSS concepts, one of which is being further developed before being delivered. Although the majority of processes and activities were executed in accordance with the proposed model of PSS development, two significant differences emerged. First, the sequential relationships between the phases reflected practice, but the testing indicated that a number of processes are executed in multiple phases, giving the impression of feedback. Second, the findings indicate that not all of the activities are executed in the same manner in all PSS development projects, suggesting that the execution of activities may be contingent upon additional factors. Future research is needed to investigate the validity of the model when applied in practice to a number of PSS development projects.

The following chapter concludes the thesis, summarising the research reported and highlighting the contributions to knowledge and industry.

7 Conclusion

The primary aim of the research reported within this thesis was to investigate the development and delivery of integrated PSSs. Section 7.1 presents a summary of the research, discussing the principle findings. The contributions to knowledge are presented section 7.2 before the industrial impact of the research is presented in section 7.3. The limitations of the research are discussed in section 7.4 before directions for future research are established in section 7.5.

7.1 Summary of the research and principle findings

Whilst previous research within the PSS field has proposed a number of approaches to the development of integrated product-service offerings, little research has been dedicated to investigating the development of PSSs within servitized manufacturers. Addressing this research gap, the research reported within this thesis has investigated the validity of existing PSS development approaches to the development of integrated product-service offerings within servitized manufacturers. To achieve this, the research was conducted in three stages:

- Stage 1 : Exploring how PSSs could be delivered in the UK railway industry
- Stage 2 : Investigating PSS development
- Stage 3 : Operationalising the proposed model of PSS development

7.1.1 Summary of stage one

The dynamic complexity associated with transforming an organisation from delivering products and services separately to delivering them as a PSS, and the fact that PSSs consist of people, processes and tools all working concurrently, requires a systemic process of inquiry. Checkland's 'two-strands' representation of SSM (Checkland & Scholes 1990) was adopted to explore the changes required to deliver the traditional, separated product and service offerings as integrated PSSs.

Initially, rich pictures were created of the current situation. Analysis of these highlighted a disconnect between rolling stock manufacturing and servicing, often resulting in transactional and confrontational relationships. To structure the exploration of the changes required to deliver PSSs, twelve purposeful activity models were created. These models reflected interviewees' perspectives of the purpose of maintenance services and helped explore the transition required to provide maintenance services as a part of an integrated PSS. The purposeful activity models were used to stimulate debate with interview participants in order to identify changes required to deliver integrated PSSs. Based on the findings from these debates, rich pictures were created representing how BT could deliver one type of PSS, namely the result-oriented PSS where train operators procure the capability to move people. Interview participants felt that the result-oriented PSS will enable BT to be better able to meet the UK government's aspiration to procure fully financed packages of rolling stock manufacture and maintenance support. In the resulting rich

pictures, strategic alliances deliver bundled solutions which include the design, build, maintenance and financing of new rolling stock. Within the strategic alliances, ROSCOs provide the funding to manufacture and purchase the new rolling stock; BTMLN designs and manufactures the rolling stock, optimising for total cost of ownership; and BTS provides through-life maintenance services.

The findings from this stage of research gave the researcher an understanding of how PSSs could be delivered within the UK railway industry. Using this knowledge, the researcher was better prepared to investigate how similar PSSs could be initially developed.

7.1.2 Summary of stage two

During stage two, a model of PSS development was synthesised from the literature. The model consisted of seven distinct phases and fourteen processes. The synthesised model of PSS development was evaluated through a single in-depth case study to determine whether it reflected the PSS development practice of BTS. Results from the case study suggested that the seven phases within PSS development could be simplified to four: analysis, concept design, development and delivery. Significant evidence was found supporting the inclusion of the market research, service design, market communications, concept development and customer involvement processes, but the capture requirements, project initiation and delivery planning processes were under-represented. The findings pointed towards the inclusion of a production process within the delivery phase which refers to the realisation of the product elements within the PSS. Additionally, the findings indicate that during the PSS development processes BTS: (1) executes a number of activities not reported in literature; and (2) does not execute a number of activities reported in literature. Based on the results of the case study, a simplified model of PSS development was proposed.

Given the limitations on generalisability of single case study research (Yin 2003), a survey was conducted to evaluate the validity of the simplified model on a larger sample of servitized manufacturers. The survey asked respondents to rate on a 5-point likert scale whether they agreed or disagreed with a series of statements relating to the activities executed during the processes within the simplified model of PSS development. Analysis of the survey data identified that the systems analysis and project initiation processes are not reflected in the PSS development practice of the sampled servitized manufacturers. The findings suggested the inclusion of benchmarking and resource analysis processes to replace the systems analysis process and project authorisation and project planning processes to replace the project initiation process. The survey findings validated the sequential relationships between the analysis and concept design phases and the concept design and development phases. Further research is needed to statistically validate the relationship between the development and delivery phases. Furthermore, the survey findings suggested agreement with the allocation of processes to the phases reported from the case study, but additional research is needed to statistically validate whether the project authorisation process is executed in concept design and whether the customer involvement and

evaluation processes are executed in any of the phases. Additionally, the findings indicate that servitized manufacturers operationalise the capture requirements, service design, market communications, customisation and evaluation processes differently from approaches proposed within the existing literature.

Given the results of the case study and survey a new model of PSS development was proposed to better reflect the industrial practice servitized manufacturers (Figure 7-1).

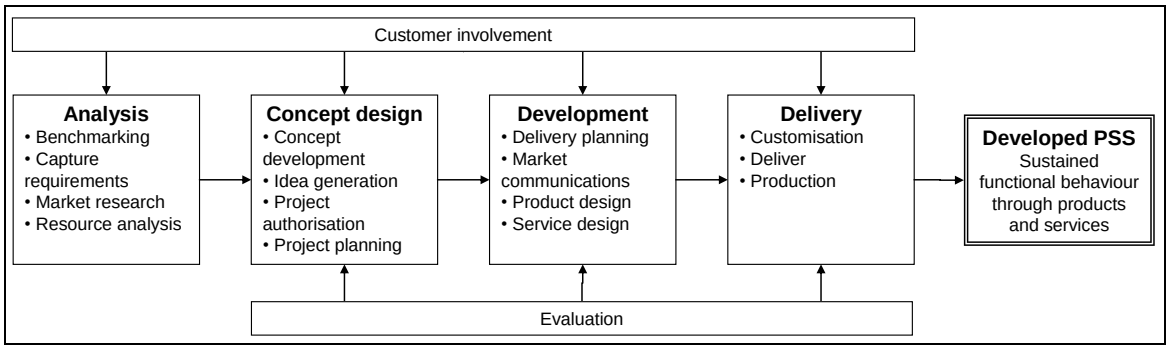

Figure 7-1: Proposed new model of PSS development

7.1.3 Summary of stage three

Stage three sought to evaluate the proposed new model of PSS development by applying it in practice to develop a PSS. Initially, the proposed model was operationalised in terms of a workbook. Process modelling was used to represent the workbook. At a high-level the PSS Development Workbook made up of four phases and seventeen related processes. The seven views approach (Holt 2009) was used as a framework for the process modelling, implemented in SysML using Artisan Studio.

The testing was concerned with evaluating the proposed model of PSS development through its manifestation in the PSS Development Workbook. The testing focused on assessing the proposed model of PSS development and not any resulting PSS. Given the time disparity between developing new PSSs and the four years specified for the EngD programme, it was not possible to test the delivery phase within the proposed model of PSS development – i.e. the end of process model testing did not result in the delivery of a new PSS. Additionally, the resource analysis process was not executed during process model testing, but it is subsequently being applied to identify the personnel, the competencies and the skills needed to deliver the most promising PSS concept.

Following the PSS Development Workbook did result in the creation of a number of PSS concepts, one of which is being further developed before being delivered. Although the majority of processes and activities were executed in accordance with the proposed model of PSS development, a number of differences were observed. First, the sequential relationships between the phases reflected practice, but the testing indicated that a number of processes are executed in multiple

phases, giving the impression of feedback. Future research is needed to investigate this phenomenon. Second, the findings indicate that the execution of activities within the processes may be different from those presented in the proposed new model of PSS development. For example, one activity may be executed in one phase of development and the others executed at a later stage of development. This suggests that the execution of processes and the activities within the processes may be contingent upon a number of factors. Future research is needed to investigate the validity of the model when applied in practice to a number of PSS development projects.

7.2 Contributions to knowledge

The research reported within this thesis contributes to knowledge by extending the existing models of PSS development to better reflect the PSS development practice of servitized manufacturers. Whilst some concurrence between the PSS development practice of servitized manufacturers and the literature was identified, the research reported within this thesis extends the existing models of PSS development in three ways.

1. Extending the phases

The existing literature reports PSS development as consisting of seven distinct phases - project initiation, analysis, idea generation & selection, detailed design, prototype the service, implementation and evaluation. The findings from the research indicate that the PSS development practice of servitized manufacturers can better be reflected in terms of four phases: analysis, concept design, development and delivery.

Although literature identifies project initiation as the first phase of PSS development, concerned with gaining authorisation to begin a PSS development project, creating a team and defining goals and deliverables (Brezet *et al*. 2001, Engelhardt *et al.* 2003 and Kar 2004), the findings from this research suggest that for servitized manufacturers projects are only initiated once opportunities to deliver new PSSs have been identified and potential solutions proposed. Consequently, this research builds on the models of Brezet *et al*. (2001), Engelhardt *et al.* (2003) and Kar (2004) by arguing that project initiation occurs as a process during the concept design phase and that analysis is the first phase of PSS development.

Whilst the literature reports idea generation & selection as the next phase (Brezet *et al*. 2001, Engelhardt *et al.* 2003, van Halen *et al.* 2005 and Aurich *et al.* 2006), concerned with generating and selecting the most promising PSS idea before developing a conceptual model of the most promising idea, this research extends these models by terming this phase: concept design. The concept design phase extends the idea generation & selection phase reported within the literature by including processes associated with authorising and planning projects and emphasises the development of PSS concepts that consider the total benefits that customers are likely to receive.

The detailed design phase reported in the literature (Brezet *et al*. 2001, Luiten *et al.* 2001, Engelhardt *et al.* 2003, Morelli 2003, Kar 2004, van Halen *et al.* 2005, Aurich *et al.* 2006 and Kindström & Kowalkowski 2009) is concerned with transforming the PSS concept into a viable PSS offering and is consistent with the development phase in the proposed model of PSS development.

The literature reports two phases concerned with delivering the PSS – prototype the service (Brezet *et al*. 2001, Luiten *et al.* 2001, Morelli 2003 and Kar 2004) is concerned with delivering the PSS to a small number of customers to test the PSS whilst implementation (Brezet *et al*. 2001, Luiten *et al.* 2001, Engelhardt *et al.* 2003, Kar 2004, van Halen *et al.* 2005 and Kindström & Kowalkowski 2009) is concerned with delivering the PSS to a larger population of customers. Reflecting the practice of BTS and the surveyed participants, this research extends the models within the literature by combining the prototype the service and implementation phases into one delivery phase. This reflects that similarities within the prototype the service and implementation phases which are concerned with delivering PSSs (although the number of customers delivered to will differ) and is closer to the service development literature (Froehle & Roth 2006) which suggests that it is not possible to prototype a service without it being co-delivered by service provider and customer.

Evaluation is reported as being the final phase of PSS development (Brezet *et al*. 2001, Engelhardt *et al.* 2003, Kar 2004 and Aurich *et al.* 2006) and is concerned with: assessing the market's response to the on-going delivery of the PSS to determine whether it is delivering the value and assessing the process used to develop the PSS. Reflecting the practice of BTS and the surveyed participants, the research reported within this thesis extends these models by reporting evaluation as a process executed in a number of phases. For example, PSS concepts are evaluated in the concept design phase to ensure that they will fulfil the opportunity identified in the analysis. Reflecting the stage-gate approach to product development where evaluation is conducted in 'gates' (Cooper 1986), executing evaluation in multiple phases better enables the risks associated with developing PSSs to be managed.

2. Extending the processes

The existing literature reports a systems analysis process being executed during analysis (van Halen *et al.* 2005), concerned with conducting analysis to: understand the usage profile of existing products and services, gaining customer feedback on existing products and services and identifying products that could be turned into PSSs. The research reported within this thesis extends the model reported by van Halen *et al.* (2005) by identifying that servitized manufacturers do not execute the systems analysis process. Instead, the findings indicate that the systems analysis process should be replaced by benchmarking and resource analysis processes. The benchmarking process extends two of the activities executed within the systems analysis process reported by van Halen *et al.* (2005) (understand the usage profile of existing products and services and gaining customer feedback) and combines them with activities to identify trends in customers'

business environments and identify market opportunities. Additionally, whilst the systems analysis process reported by van Halen *et al.* (2005) includes an activity for identifying products that could be turned into PSSs, the research reported within this thesis extends this analysis to include conducting assessments of whether existing personnel, skills and competences could be used to develop and deliver new PSSs. This extended analysis is termed resource analysis.

Findings from the research suggest that the project initiation process reported within the models proposed by Brezet *et al*. (2001), Engelhardt *et al.* (2003) and Kar (2004) does not reflect the practice of servitized manufacturers. Instead, the findings suggest that these models need extending to reflect the practice of servitized manufacturers. The research suggests that the project authorisation activity within the project initiation process is an independent process, separate from the remainder of the activities. The remaining three activities (define goals, create team and create project plan) are consistent as being executed within one process – termed project planning to reflect the planning work conducted in these three activities.

Whilst Brezet *et al.* (2001) reports an activity consistent with producing and purchasing all necessary products, the research reported within this thesis extends this model. The findings from the research point towards the execution of a production process within the delivery phase which is concerned with realising the product elements of the PSS. The producing or purchasing of all necessary product elements activity reported by Brezet *et al.* (2001) is encompassed within this wider production process which also includes an activity consistent with installing all necessary product elements required before the PSS can be delivered. For example, if the PSS is some type of integrated vehicle health monitoring service then it will be necessary to install a number of sensors before the service can be delivered.

3. Extending the activities

The findings indicate that servitized manufacturers operationalise the capture requirements, service design, market communications, customisation and evaluation processes differently from approaches proposed within the existing literature.

The literature reports that the capture requirements process is operationalised in terms of a define requirements activity (Brezet *et al.* 2001, Kar 2004 and van Halen *et al.* 2005) which is concerned with defining the requirements that describe the functionality that the PSS should deliver. The research conducted within this thesis builds on the models of Brezet *et al.* (2001), Kar (2004) and van Halen *et al.* (2005), identifying that in addition to a define requirements activity the capture requirements process also consists of a validate requirements activity. The validate requirements activity is concerned with confirming whether the defined requirements reflect the customers' needs.

The literature reports that the service design process is operationalised in terms of two activities: specify the service process and specify the service system (Aurich *et al.* 2006). Specifying the

service process is concerned with identifying all of the activities that will be executed by manufacturer and customer during the co-deliver of the PSS whilst specifying the service system is concerned with identifying all manufacturer and customer resources (technology, people, organisation, etc) needed to co-deliver the PSS. Whilst evidence was found confirming the existence of these activities within the PSS development practice of servitized manufacturers, the findings extend the model proposed by Aurich *et al.* (2006) in identifying an activity concerned with specifying the behaviour necessary from the manufacturer and customer to successfully co-deliver the PSS. During PSS development, servitized manufacturers will define the behaviour that they and their customers will need to exhibit in order to successfully co-deliver the PSS to maximise value-in-use.

Market communications is reported as consisting of activities consistent with quantifying the value that the PSS will deliver to customers and communicating this value to customers (Kar 2004 and van Halen *et al.* 2005). The research reported within this thesis extends the models proposed by Kar (2004) and van Halen *et al.* (2005), identifying that in addition to the quantify value and communication activities, the market communication process also consists of: create sales strategy and determine revenue mechanism. The create sales strategy activity focuses on developing all of the promotional material associated with the PSS. Determine revenue mechanism focuses on understanding the methods through which the manufacturer will generate an income from co-delivering the PSS.

Existing literature reports that the customisation process is operationalised in terms of two activities: describe main elements and propose variations (van Halen *et al.* 2005). The model proposed by van Halen *et al.* reports that the main elements of the PSS are communicated to customers before customer-specific variations are identified to tailor the PSS to specific customers' environments. The research reported within this thesis extends the model proposed by van Halen *at al.* (2005), identifying: (1) that the describe the main elements activity is consistent with the communicating with customers activity executed during the market communications process and (2) before variations are proposed an activity is conducted (termed: determine level of customer specificity) which is concerned which analysing customers to determine the level of variation required for each customer.

Finally, the models of PSS development reported within the existing literature operationalise the evaluation process in terms of five activities: define evaluation criteria, monitor customer's response and usage, measure the value perceived, evaluate the PSS and write evaluation report (Brezet *et al.* 2001 and Aurich *et al.* 2006). The findings from this research extend the models proposed by Brezet *et al.* (2001) and Aurich *et al.* (2006), identifying that the define evaluation criteria and write evaluation report activities are not executed by the servitized manufacturers investigated as part of this study.

Given the differences identified between the existing models of PSS development and the findings from this research, this research contributes to knowledge by extending the phases, processes and activities reported within the existing PSS development models. Based on this research, a new model of PSS development is proposed and initially tested which extends the PSS development models of Brezet *et al*. (2001), Luiten *et al.* (2001), Engelhardt *et al.* (2003), Morelli (2003), Kar (2004), van Halen *et al.* (2005), Aurich *et al.* (2006) and Kindström & Kowalkowski (2009) to better reflect the PSS development practice of servitized manufacturers.

In addition to this, during the course of the research a number of other advances have been made that are also important contributions to knowledge:

Application of SSM to PSS delivery in the UK railway industry

Although extant literature has sought to investigate how PSS can be delivered, limited research has been conducted that applies SSM to explore what changes might be required to deliver integrated product and service offerings. Of the existing research that has sought to apply SSM to understand how PSSs can be delivered (Morcos & Henshaw 2009, Dogan & Henshaw 2010), these have been confined to the aerospace and defence sectors. The research reported within this thesis contributes to knowledge by applying SSM to investigate how PSSs can be delivered in the UK railway industry. This contribution provides further evidence for the validity of applying soft systems approaches to explore the servitization and PSS phenomena.

Process modelling approach

Whilst the seven views approach to process modelling has been applied in a small number of applications, such as business process modelling (Holt 2009) and risk management (Brownsword 2009), the research reported within this thesis represents its first reported application to modelling PSS development. This contributes to knowledge by demonstrating the broader applicability of the seven views approach to modelling outside its traditional domain. Additionally, UML is the predominant language used to model the views within the seven views approach. The research reported within this thesis represents the first reported application of SysML to represent the views within the seven views approach. This contributes to knowledge by demonstrating: (1) the broader applicability of SysML to model business processes in addition to technical and software systems; and (2) the adaptability of the seven views approach to be implemented in a different language. Additionally, the application of SysML contributes to the broader debate on business process modelling. Whilst BPMN enables the modeller to create a richer representation of a small number of perspectives on a process (through in the business process diagram), the breadth and general purpose nature of the multiple diagrams within SysML better enable it to model all perspectives on a process. This expands upon the business process modelling literature (Harvey 2005 and Muehlen & Recker 2008) and re-enforces the argument by Holt (2009) that object-oriented modelling languages (such as SysML) can be successfully used to model business processes.

Application of action research to improve practice

The majority of papers within the servitization field are based on case study research and are largely descriptive, giving an illustration of the adoption of servitization by a small number of manufacturing organisations (Baines *et al.* 2009b). The research reported within this thesis contributes to knowledge by reporting one of the first adoptions of a prescriptive approach (namely, action research) to investigate the servitization and PSS phenomena. Here, the researcher was actively engaged in forming actions and developing a workbook to aid BTS develop PSSs. The success in applying an action research technique leads the author to agree with Baines *et al.* (2009b) and recommend that the research community should engage more prescriptively in the adoption of servitization, actively engineering tools and techniques that are needed by practitioners.

PSS development practice

The models of PSS development in the existing literature suggest that PSS development is largely sequential, exhibiting limited amounts of feedback. This was reflected during the case study and survey with respondents providing limited evidence of feedback within their PSS development practice. In contrast, during the course of the process model testing it became clear that PSS development is highly iterative and non-linear. Whilst the activities within the processes were executed during practice, the processes within the proposed model of PSS development were frequently re-used throughout a number of phases and a number of processes were executed in parallel. This suggests that whilst the proposed model of PSS development provides greater insight into the PSS development practice of servitized manufacturers compared to the models reported in the existing literature, further work is needed to determine whether it captures the full complexity associated with developing PSSs in practice.

Additionally, many of the models of PSS development have been described as “workshop methodologies” (Tukker & Tischner 2004) suggesting PSS development occurs in a series of one-off developments. Whilst it may be possible to execute a number of processes and activities within workshops (e.g. generating and screening new ideas for PSS concepts), the observed complexity of PSS development practice suggests that the representation of some of the existing models as workshop methodologies is inappropriate - it is unlikely that all phases, processes and activities could be completed in workshops. In contrast to the existing models of Brezet *et al.* (2001), Engelhardt *et al.* (2003), Morelli (2003) and van Halen *et al.* (2005), observations of practice indicate that to develop PSSs that are more likely to be successful PSS development should be integrated into an organisations day-to-day business activities and not conducted as a one-off development alongside their core business.

7.3 Industrial relevance/impact

The research reported within this thesis contributes to industry in three ways.

First, this research has reported that the existing approaches to PSS development do not reflect the practice of servitized manufacturers. Based on the research findings a new model of PSS development was proposed and guidelines for its application provided in the form of the PSS Development Workbook. This model and the associated workbook have a direct impact on industry by:

- Enabling servitized manufacturers to benchmark their existing approaches to PSS development against a rigorously defined model. This will enable servitized manufacturers to improve their existing approaches, increasing the likelihood of developing successful PSSs.
- Highlighting the activities that are needed to be conducted during PSS development will enable manufacturers who are starting out on a servitization journey to gain greater understanding of where they may need to develop new resources and capabilities.
- For servitized manufacturers such as BT, the model and workbook could replace their existing undocumented and informal approach, leading to greater transparency and repeatability within the PSS development initiatives.

Second, given that the UK railway industry is facing increasing pressure from the UK government to transition towards delivering fully-financed packages for the manufacture and servicing of rolling stock (Department for Transport 2008), the research reported within this thesis presents models of how these could be delivered. These models are directly relevant to industry, providing recommendations on the changes required to deliver these integrated offerings. These models can be used to aid the organisations within the UK railway industry deliver new PSSs that fulfil the DfT's aspirations.

Finally, given that BT is predominantly a product-focused organisation, the research reported within this thesis has contributed to BT more broadly by initiating a debate on the strategic importance of services and of the need to offer integrated PSSs. This is directly relevant to BT as it looks to win new DfT tenders for integrated offerings and significantly grow the revenue and profitability of its Services division through improving the delivery of, and developing new, PSSs.

7.4 Limitations of the research

The results of this research are subject to a number of limitations. First, the rich pictures describing how the result-oriented PSS could be delivered are specific to BT within its mainline UK operations. The rich pictures do not claim to represent how all result-oriented PSSs could be delivered by servitized manufacturers in other industries. Similarly, the rich pictures represent how one type of result-oriented PSS could be delivered and no claims are made regarding other examples of result-

oriented PSSs. Additionally, although the rich pictures were based on feedback from interviewees, the sample size was small. Whilst the results highlight how one type of result-oriented PSS could be delivered, a number of different organisational structures for delivering the same PSS are likely to exist.

Second, whilst a survey was used to overcome the limits on generalisability caused by the use of a single case study, the sample size was relatively small. Whilst the findings from the case study and survey suggest a different representation of PSS development from that reported in the literature, further research should investigate whether the proposed new model of PSS development is applicable to a larger sample of servitized manufacturers.

Third, it was assumed that all of the phases, processes and activities within the proposed new model of PSS development are required to successfully develop PSSs. Findings from applying the workbook suggest that the execution of the processes and the activities within them may be contingent upon a number of factors. Future research is needed to investigate the validity of the model when applied in practice to a number of PSS development projects.

Fourth, whilst the proposed new model of PSS development has been tested in practice, through the PSS Development Workbook, this is limited to one application. The applicability of the PSS Development Workbook to other large or small organisations in different cultural and national settings has not been investigated.

7.5 Future work

This study calls for further research in at least two areas. First, given the relatively small sample sizes, the proposed new model of PSS development is considered an initial model. Further research should be conducted with larger data sets to determine whether the model is generic or whether it is contingent on other factors. Going further, whilst the proposed new model reported within this thesis focuses on PSS development that is proactive, further research should be conducted to determine whether the model is valid given the other reported PSS development triggers.

Second, although a significant number of differences were identified between the model of PSS development synthesised from the PSS literature and the practice of servitized manufacturers, a number of similarities were also identified. Given the high-level of synergy reported between the PSS and servitization fields (Tukker & Tischner 2004, Baines *et al.* 2007, Neely 2007, Baines *et al.* 2009b, Neely 2008, Martinez *et al.* 2010,), the similarities and differences identified within this thesis should enthuse researchers to further homogenise the PSS and servitization fields.

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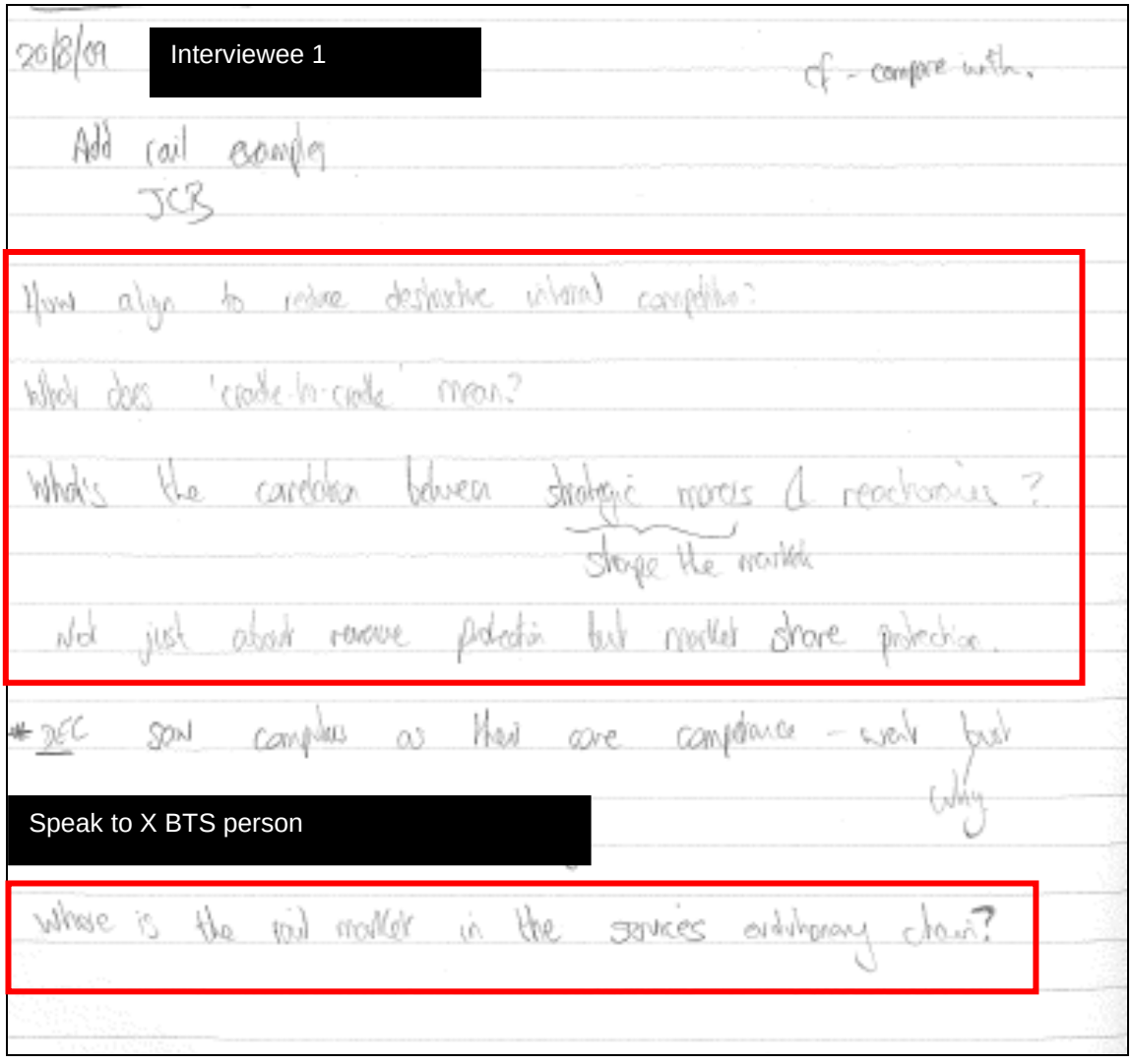
Appendix I – Examples of interview notes and their analysis

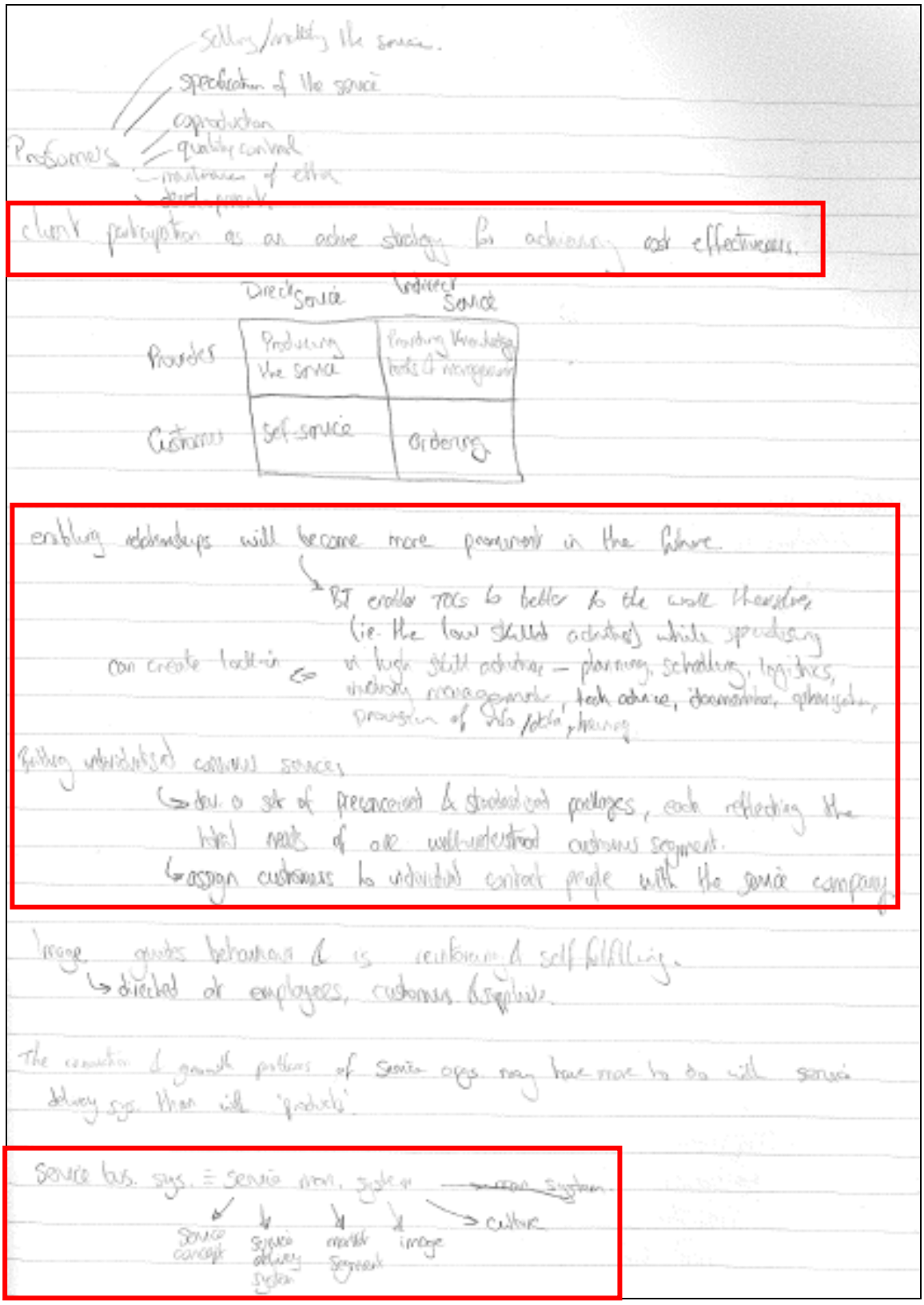
Examples of interview notes

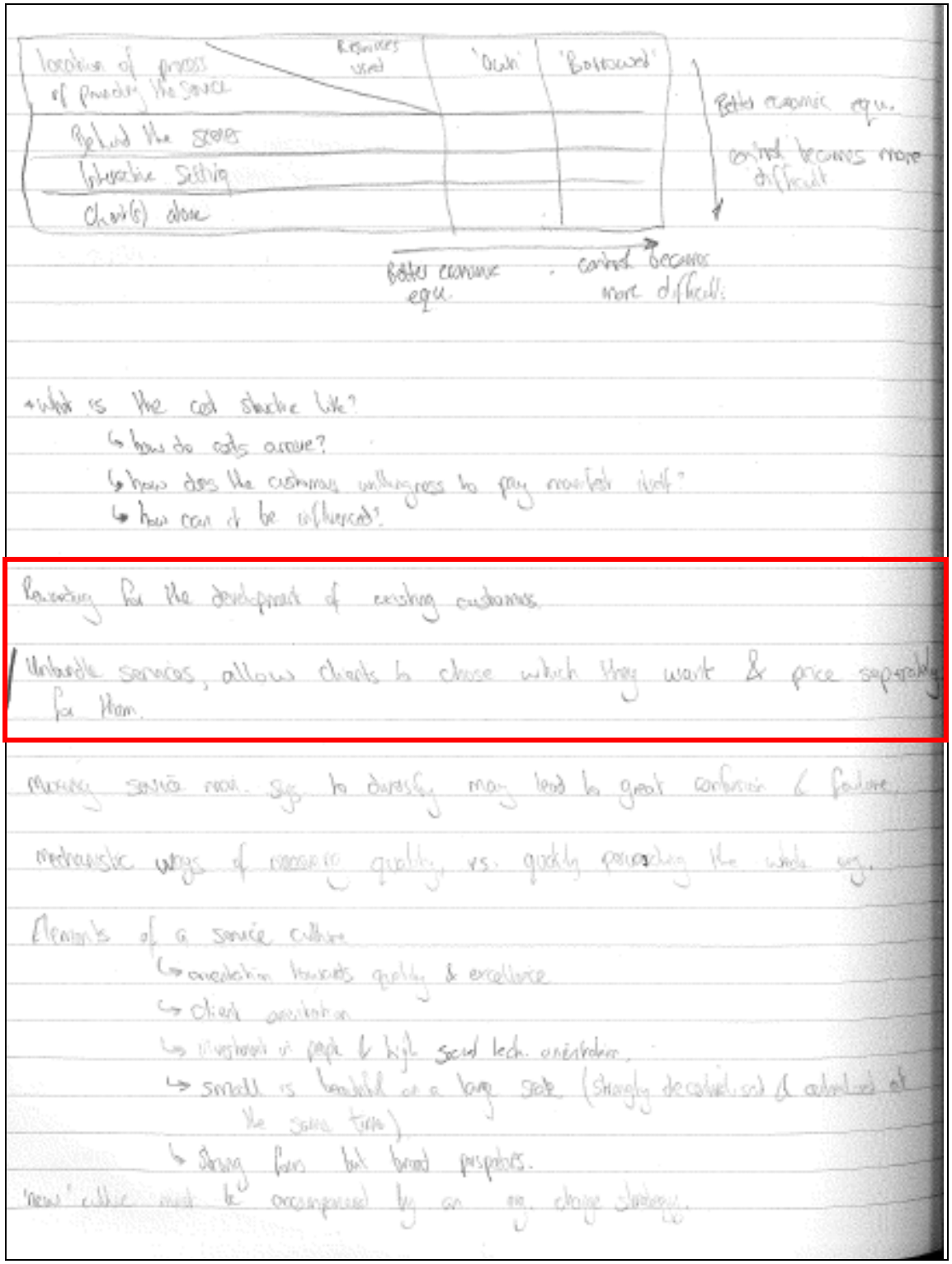
Two examples are provided of the interview notes. Example 1 presents the notes taken from one interview which sought to understand the concepts of servitization and PSSs with BTS. Example 2 presents the notes taken from one interview which sought to validate the model of BTS's PSS development practice.

In both examples, commercial sensitive information has been hidden and replace with more general terminology. Key points identified from each of the interview notes are highlighted in red.

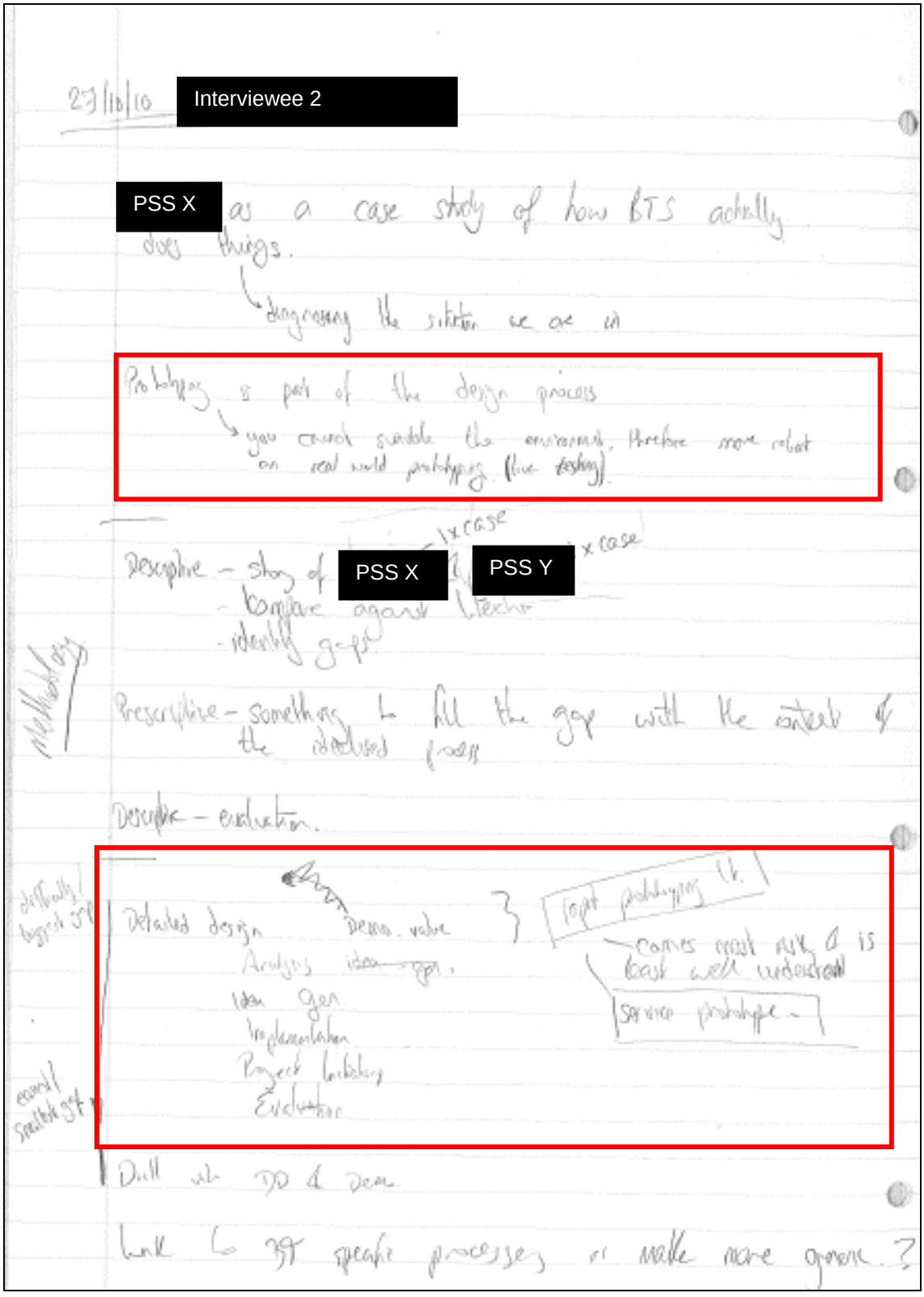
Example 1




selling/making the service
specification of the service
reproduction
quality control
maintenance of ethos
Processes
client participation as an active strategy for achieving cost effectiveness.
Direct Service
Indirect Service
Provides
Producing the service
Providing knowledge tools & management
Customers
self-service
Ordering
enabling relationships will become more prominent in the future
BT enable TOCs to better do the work themselves
i.e. the low skilled activities while specialising in high skill activities – planning, scheduling, logistics, industry management, tech advice, documentation, optimisation, provision of info/data, training
can create lock-in
Building individualised customer spaces
↳ for a set of preconceived & standardised packages, each reflecting the typical needs of one well-understood customer segment.
↳ assign customers to individual contact people with the service company
Image guides behaviour & is reinforcing & self fulfilling.
↳ directed at employees, customers, suppliers
The creation & growth patterns of service orgs may have more to do with service delivery sys. than with 'products'
Service bus. sys. = service arch. system
service concept
service delivery system
market segment
image
culture


Location of process of Provider the Service
Resources used
'Old'
'Backward'
Behind the scenes
Interactive Setting
Client(s) done
Better economic eqv.
control becomes more difficult
Better economic eqv.
control becomes more difficult

Example 2



Analysis of documented interviews to validate the initial model

To validate the model of BTS's PSS development practice, the initial model was presented to interviewees and their comments were documented (Table AI-1).

Table AI-1: Comments from interview notes

Interviewee	Comments
Commercial Director	• PSSs need to be developed which will start to change customer's perceptions of BTS and how we can work together to co-deliver new offerings
Director of Strategic Programmes	• PSS development is integrated with day-to-day business • Projects are initiated to deliver the PSS once implemented • PSS development primarily involves tailoring existing products and services in such ways that they can deliver more value-in-use to customers
Director, Head of Engineering	• The different perspectives on the model of PSS development must be emphasised
Director, Predictive Asset Management	• Use of scenarios as part of testing and analysis to determine how new PSS may be perceived • Customer analysis and competitor analysis exist inside one process • Although the processes standalone, there is an "integration layer" which links the processes together
Engineering Manager	• The model of PSS development must emphasise the selling of functionality
Fleet Project Manager	• PSS development is about determining the key drivers for customers – "their pain and pleasure" – and creating something that leverages this to generate value • BTS need formal tools for doing strategic development
Head of Business Process Improvement	• The model of PSS development must avoid price-based competition for new PSSs • Difficult to do ad hoc sales, instead new PSSs must be based on repeat business • Need to incorporate ongoing engineering value-add • Need to learn from our existing contracts to reduce engineering cost for future PSSs
Product Manager – Innovation	• Propose incorporating the roles responsible for executing each activity within the model (e.g. the market analysis process is executed by someone occupying a market analyst role)

Interviewee	Comments
Sales Proposals Manager	• The model of BTS's PSS development practice broadly reflects what occurs in practice
Vice President, Marketing, Product Planning and Strategy	• Analysis and concept design occur in parallel • New PSSs are developed when opportunities (identified from analysis) and product-services (that BTS have or could create) become aligned • Evaluation is conducted to determine whether fulfilling the opportunity will deliver the desired returns and fulfil customers' needs • If the results of the evaluation is positive, the PSS is developed and marketed to customers • Although customer willingness to pay is initially assessed, their actual willingness to pay will depend upon the amount of value-in-use that customers will receive from the PSS
Vice President, Head of Services UK	• PSS developments within BTS are typically local initiatives • The model of BTS's PSS development follows the approach applied on one PSS development project where: 1. Customers were analysed to determine there annual spend on fuel 2. Theoretical ideas were proposed to reduce customers' fuel spend 3. Detailed design was conducted demonstrating how the PSS would save money for customers, reducing their fuel consumption 4. The PSS was priced 5. There was feedback between the price and the PSS design to ensure that the resulting PSS would be affordable

Whilst a number of comments were general rather than referring to specific elements within the model representing BTS's PSS development practice (e.g. "The model of PSS development must avoid price-based competition for new PSSs"), a number of comments did suggest amendments to the initial model (e.g. "Customer analysis and competitor analysis exist inside one process"). Based on these comments, the initial model of BTS's PSS development practice was updated to include:

1. Project initiation placed within the concept design phase to reflect the comment that PSS development projects created to develop and deliver the most feasible PSS concepts
2. Incorporating customer analysis and competitor analysis within the same market research process
3. When operationalised, the model of PSS development should be represented from multiple perspectives
4. When operationalised, the model of PSS development should describe how the processes are integrated (i.e. how do the outputs from one process become the inputs to the next process?)
5. Analysis must be conducted during PSS development to learn from the development and delivery of existing products and services – reflected in the systems analysis process
6. Analysis is continuous
7. Evaluation occurs in multiple phases throughout PSS development and not just at the end
8. Quantifying that value that the PSS will deliver is an important activity executed within the market communications process

Appendix II – The UK Railway Industry

The railway system in the UK is highly complex with significant levels of interaction and inter-dependence between all stakeholders (Figure AII-1). Since the privatisation of British Rail (as a result of the Railways Act 1993) attempts have been made by various governments to re-structure the industry to

- better meet the needs of passengers and freight; and to
- better control the costs associated with operating a railway system

The Railways Act 1993 effectively broke up British Rail into over 100 separate companies based on its organisational sectors (e.g. Train Operating Units, Infrastructure Maintenance Units, etc). Most of the relationships between successor companies were established by contracts, although some relationships were through regulatory mechanisms. The Office of Rail Regulation (ORR) approved contracts for the use of railway facilities and franchise agreements (contracts between train operators and the state) were established within the Office of Passenger Rail Franchising (OPRAF).

The Transport Act 2000 was the first major change in structure to the privatised railway system. OPRAF was abolished and its powers transferred to the Strategic Rail Authority (SRA) whose main role was awarding and ensuring compliance with passenger rail franchises. The government wanted the SRA to take a more interventionist role with Railtrack (the group of companies that owned track, signalling, tunnels, bridges, level crossings and stations), but was never given the legal powers to do so. These powers rested with the ORR.

Following the aftermath of the Hatfield rail crash in 2000, Railtrack faced severe financial difficulties and was placed into administration in 2001. In 2002 the administration order was discharged and Network Rail purchased Railtrack. Network rail has no shareholders and is a company limited by guarantee (a not-for-profit private company operating as a commercial business).

The Railways Act 2005 once again changed the structure of the privatised railway system. The SRA was abolished. Some of its functions were transferred to the Secretary of State for Transport (franchise agreements, setting strategic decisions and leadership) whilst others were transferred to the ORR (consumer protection and health and safety responsibilities). The Act also reduced the financial jurisdiction of the ORR and created Passenger Focus – a single national consumer body.

Figure AII-1 provides a representation of the structure of the current UK railway system.

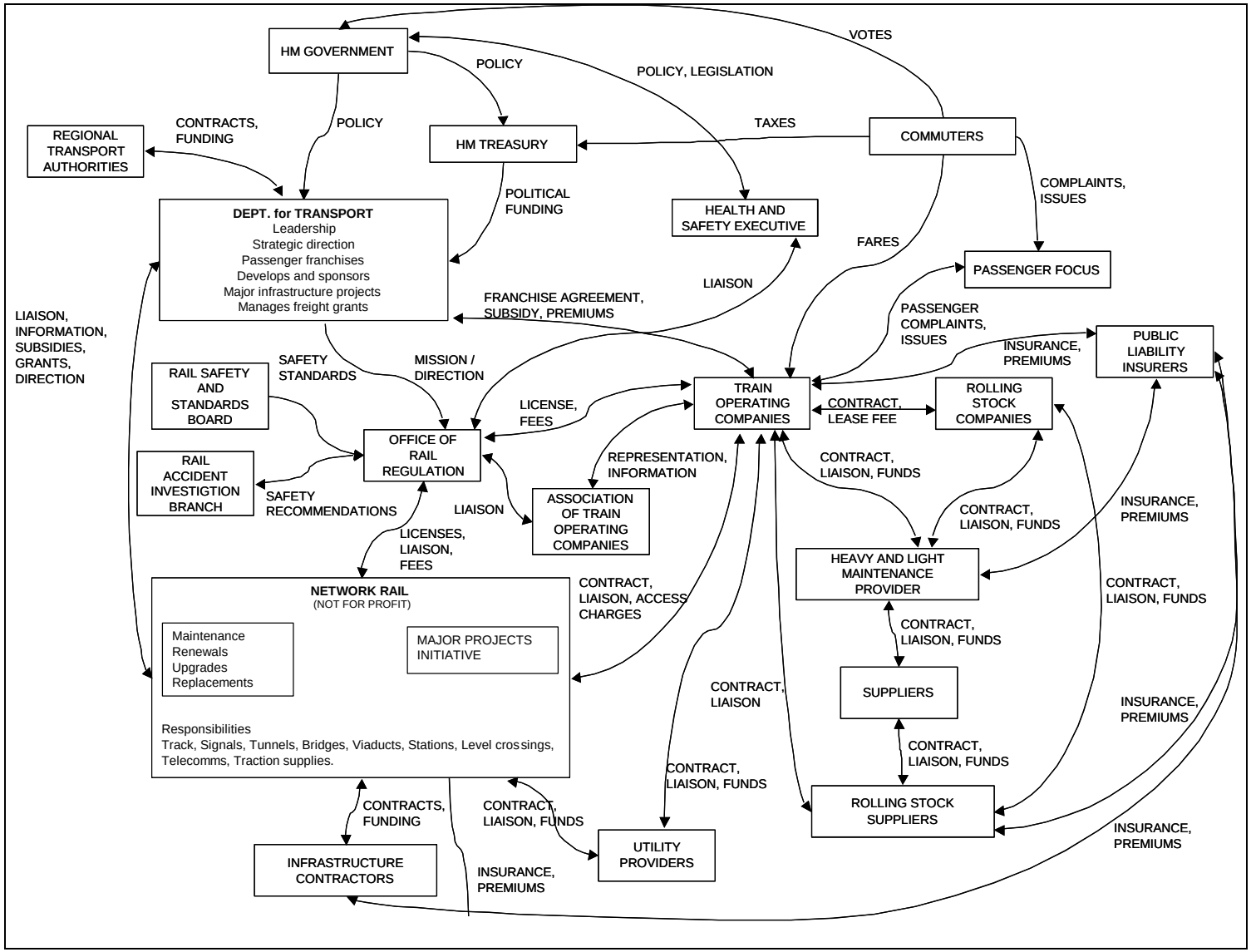


Figure AII-1: Rich picture of UK railway industry structure

Appendix III – Published Papers

Paper 1

Clayton, R.J., Backhouse, C.J., Dani, S., Lovell, J. 2009, "Generating value from whole-life solutions – A new opportunity for the UK railway industry", *Proceedings of the 20th Annual Production and Operations Management Society (POMS) Conference*, Florida

Abstract number: 011-0563

Generating Value from Whole-Life Solutions – A New Opportunity for the UK Rail Industry

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Orlando, Florida U.S.A.
May 1 to May 4, 2009

Abstract

The UK government has started to demand a "whole-life, whole-system" view of new contracts within the UK rail industry; requiring the industry to transform the way it does business in order to deliver this new paradigm. This paper describes the work of a collaborative academic-industry research project; based in one railway vehicle manufacturing company. The aim of the project is to maximise benefit across the value chain throughout the whole-life of a fleet of railway vehicles. This paper presents preliminary results and a review of the relevant literature to discuss how the traditional approach to value generation must change in order to deliver whole-life solutions. The discussion describes how an organisation's structure, approach to contracting and spares provisioning, supplier and customer relationships and people issues (behaviours and cultures) significantly impact upon the ability to deliver value to the manufacturer, their customers and suppliers in whole-life service contracts.

Keywords: Whole-life solutions, rail industry, whole-life service contracts, value chain

1 Introduction

The 2007 ‘Rail Technical Strategy’ (RTS) which accompanied the UK government’s ‘Delivering a Sustainable Railway’ white paper outlined the aim to have “world-class reliability of both infrastructure and rolling stock” [1]. In order to achieve this, the RTS highlighted the need for “government and industry [to work] together taking a whole-life, whole-system cost approach in exploiting opportunities” [1].

This commitment to taking a whole-life, whole-system viewpoint is reflected in current trends by government departments, through Public Private Partnerships / Private Finance Initiatives, in which the “public and private sectors join to design, build or refurbish, finance and operate new or improved facilities and services to the general public” [2].

The whole-life, whole-system paradigm has the potential to completely change the dynamic of UK railways; provided that the industry can transform itself to deliver whole-life service offerings, maximised to deliver benefit throughout the value chain.

Within this environment, traditional rolling stock manufacturers are facing increasing pressure to provide greater levels of service provision as part of their core product offerings. Academic literature suggests that this shift from product focused to product-service focused offers significant benefits not only to end-users but also to manufacturers [3-6]. The key arguments generally put forth include [4]:

1. Economic arguments – a substantial amount of revenue can be generated from a large installed based over its lifecycle [6] and services are usually more resilient to the economic cycles that drive equipment procurement
2. Customers are demanding more services – pressure to downsize and create more agile firms focused on delivering their core business leads to the outsourcing of non-core activities. This is reflected in the UK railway industry with more train operators choosing to outsource the maintenance activities traditionally performed internally
3. Competitive argument – as services are less tangible than products and more knowledge-intensive, they are much more difficult to imitate – setting up barriers to the competition and creating dependency, thus giving a more sustainable competitive advantage [5]

Despite these advantages, the list of manufacturing organisations that have strong service strategies is relatively small. In order to make the transition from offering products to product-services an organisation must overcome significant barriers, including:

1. Economic – there is a change in the way that profit is gained [7, 8] – it is much more difficult to place an economic value on services

2. Cultural shift – a change in mindset is required in both the market and organisation. It may be difficult for customers to place a value on having a need met as opposed to physical ownership [7]. Within the organisation it may prove difficult to excite the designers and engineers of multi-million pound pieces of equipment about a contract for maintaining the asset
3. Fear of risk absorption – by starting to take ownership of the life of assets; the risk of operation is being transferred from the end-user to the manufacturer – e.g. in availability contracts it is the manufacturer/service provider who is responsible for ensuring that an asset is available
4. Lack of experience – changing to become a service provider requires significant investment by the organisation. The organisation may need to be restructured and delivering a product-service is likely to be more complex than delivering product functionality
5. Co-operation with customers and suppliers – in the traditional product focused environment relationships between customers and suppliers are transactional and often confrontational (they are both trying to make money from one another) [8]. When delivering a product-service both customers and suppliers need to work together to deliver co-value propositions

Given the above considerations, it is no wonder that few manufacturers have strong service strategies - this is especially true in the UK railway industry. With the UK government now demanding whole-life contracts, there is an increasing need for traditional rolling stock manufacturers to deliver whole-life service solutions. This article reports on the traditional method of value generation within the UK railway rolling stock market and discusses how this is changing and the likely implications.

2 Background to the UK railway industry

The UK railway industry is highly complex with significant interactions and inter-dependence between all stakeholders. Since the privatisation of British Rail (as a result of the Railways Act 1993 [9]) attempts have been made by various governments to re-structure the industry to

- better meet the needs of passengers and freight; and to
- better control the costs associated with operating a railway system.

Figure 1 illustrates the current structure of the UK rail industry.

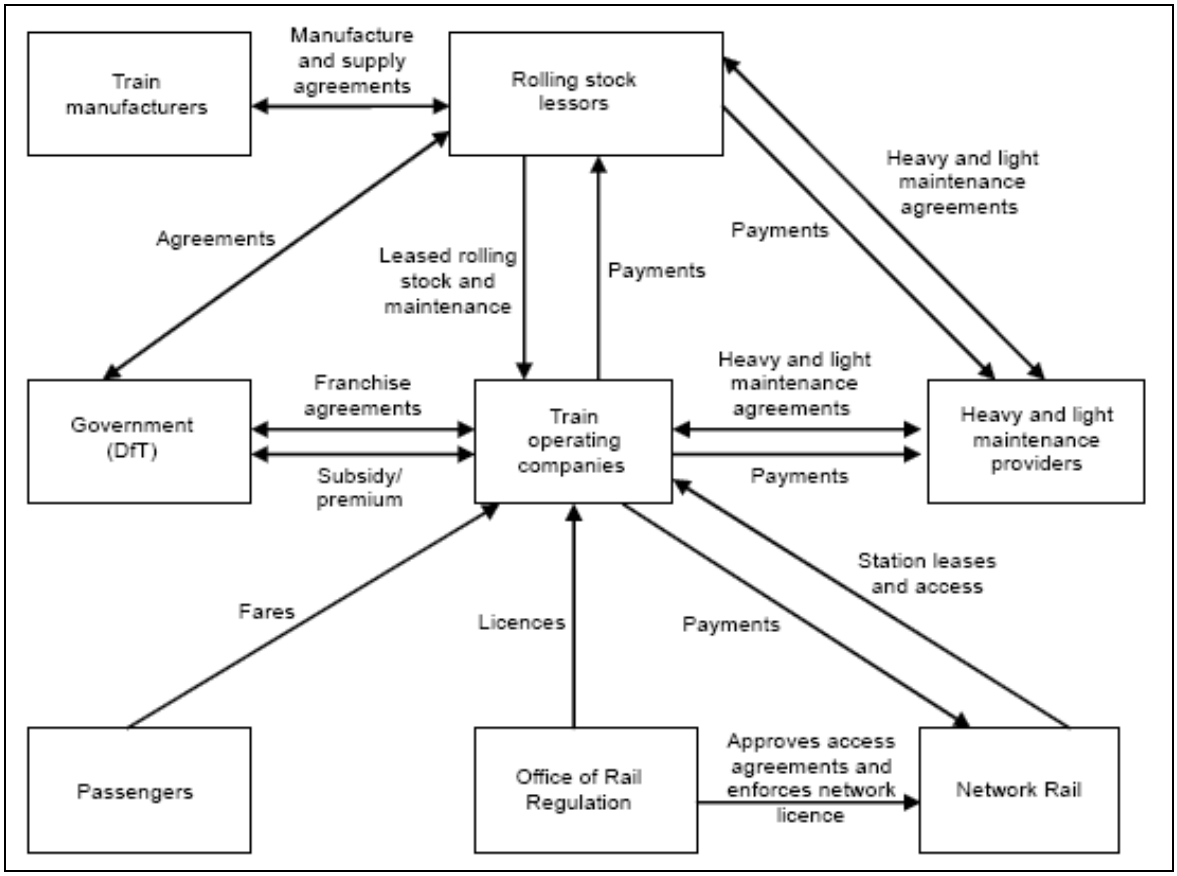

Figure 1: An overview of the structure of the UK rail industry [10]

The part of the railway industry which delivers passenger/freight movement consists of two key sectors – building, operating and maintaining rolling stock; and constructing and maintaining tracks (and all related infrastructure)[6]. These two sectors are jointly funded by the government and private companies. For example, in 2007 the UK government subsidised Network Rail £3.6 billion to manage the railway infrastructure and gave almost £1 billion in subsidy to train operators to run passenger services [11].

3 The traditional approach to value generation from rolling stock

In the UK railway market a tender is typically issued for the design, construction, delivery and warranty of a new fleet of rolling stock. Rail vehicle manufacturers will bid for the contract with the lowest cost offering usually winning. Manufacturers value their offering in terms of production costs plus a margin and aim to minimise production costs while maximising margin and undercutting the competition.

In most cases, the finance to procure a new fleet is provided by a Rolling Stock Company (ROSCO), who becomes the asset owner. They generate value by leasing the vehicles to train

[6] Other sectors include; train operation; train and track safety and inspection; insurance; utility provision; and regulation – not shown in Figure 1.

operators for the length of a franchise (~ 5 – 7 years). Once the franchise has expired, the ROSCO will look to lease the vehicles to another operator. This then continues until the vehicles reach the end of their useful lives (~ 30 years).

Once the fleet is about to enter service, the operator/ROSCO will tender a contract for the maintenance of their vehicles for the life of the franchise. Maintenance providers will then bid for this contract, with the operator/ROSCO awarding the contract to the lowest bidder.

Depending on the type of lease contract, maintenance is the responsibility of the ROSCO (wet lease), operator (dry lease) or both operator and ROSCO for light and heavy maintenance respectively (soggy lease). Whoever has responsibility for maintenance can choose to either carry out the work internally or outsource the work. If maintenance is outsourced by either operator or ROSCO then three types of maintenance agreement are typical:

1. Material supply agreement – the operator/ROSCO carries out the maintenance activities; spare parts are provided by the service provider. Value is created for the service provider by effectively managing the supply chain and inventory. The operator's perceived value comes from the risk transfer associated with consumption
2. Technical support, spares supply agreement – the operator/ROSCO carry out the maintenance activities; spares parts and a few on-site personal (for technical advice) are provided by the service provider. Value is created for the service provider by effectively managing the supply chain and inventory with some of the risk offset by having personnel on-site who understand the maintenance issues associated with a given class of vehicles. The operator's perceived value comes from the risk transfer associated with consumption and the detailed technical knowledge (provided by the on-site personnel) associated with maintaining a fleet
3. Full maintenance agreement – the operator/ROSCO pay the service provider a monthly fee to guarantee predetermined levels of availability, reliability and safety. The service provider is responsible for all maintenance work and spares provision. Value is created for the service provider by effectively managing the supply chain, inventory and maintenance activities. The operator's perceived value comes from complete risk transfer of service activities – they are able to concentrate on their core business, moving passengers

In the traditional model (shown in Figure 1) for each interaction there is a contract – e.g. the interaction between operator and ROSCO is managed via a leasing contract – and typically with each interactions is a flow of money in either direction. Organisations try to maximise value generation for themselves by managing these interactions – i.e. by trying to reduce the flow of money out of the organisations while maximising the flow of money into the organisation. For example, operators will try to maximise their number (and price) of fares while simultaneously trying to minimise the amount they pay for light and heavy maintenance. The perception of industrialist, interviewed in the course of this research, is that this has lead to very transactional

and confrontational relationships with one party trying to maximise their returns at the expense of another [12-14]. In this environment, the robustness of the contract and the precise allocation of responsibility and risk need clearly defining.

The current structure of the UK railway industry has created a disconnect between rolling stock manufacturing and servicing – service contracts are awarded immediately prior to a fleet entering service and follow a separate bidding process from that of buying the fleet. This has led to a complete separation of capital and operational expenditure, making it difficult to convert reduced lifecycle cost benefits to optimised total cost of ownership for all stakeholders [15-17].

In this context, manufacturers are not incentivised to improve the reliability of a fleet – the manufacturing organisation may not win the service contract, so why make it easier for your competition? If the manufacturing organisation did win the service contract then, depending on the type of maintenance contract, the manufacturer may actually to harmed by delivering too much reliability – e.g. with a material supply agreement if reliability is high then the organisation will sell fewer spares.

4 The 'new' approach to rolling stock procurement

When viewed as a system, the (primary) purpose of the UK railway industry is to safely transport passengers and freight. In order to achieve this, all elements within the railway industry need to work together in a holistic way – even though the individual elements may have their own goals. For example, operators want to maximise their profits by operating passenger services, Network Rail want to manage the existing fabric of the railway network, utility providers want to maximise their profits by providing electricity, gas and water to the railway network, etc.

The complexity within the railway system lies not in any technical aspect, although these are complicated, but in the interactions and relationships between the different stakeholders; aligning their often competing goals in order to deliver the system goal - safely transporting passengers and freight on-time. This becomes especially important with the whole-life approach and requires greater co-operation and communication between all stakeholders.

Recognising this, in a recent tender request (Thameslink programme) the Department for Transport are seeking an enterprise to deliver a bundled solution which includes design, build, maintenance and finance [18]. The manufacturer must provide a financed solution and are expected to work closely with the financier to provide an optimised solution. The financier will be paid a pre-determined monthly fee for the use of each vehicle by the operator, with the usage of the rolling stock guaranteed by the Department for Transport for part of its useful life.

In order to encourage the manufacturer to address whole-life costs and maintenance considerations when designing the trains, the Department for Transport is expecting that the

manufacturer will be responsible for the maintenance of the rolling stock [18]. Recognising the importance of having highly reliable rolling stock, the Department for Transport will introduce a reliability incentive and penalty regime. Whilst the maintainer will take in lead role in maintaining the rolling stock, the operator will support the planning and scheduling of the work.

Figure 2 describes the proposed structure of the Thameslink programme, with the umbrella agreement being the enterprise that will deliver the whole-life solution.

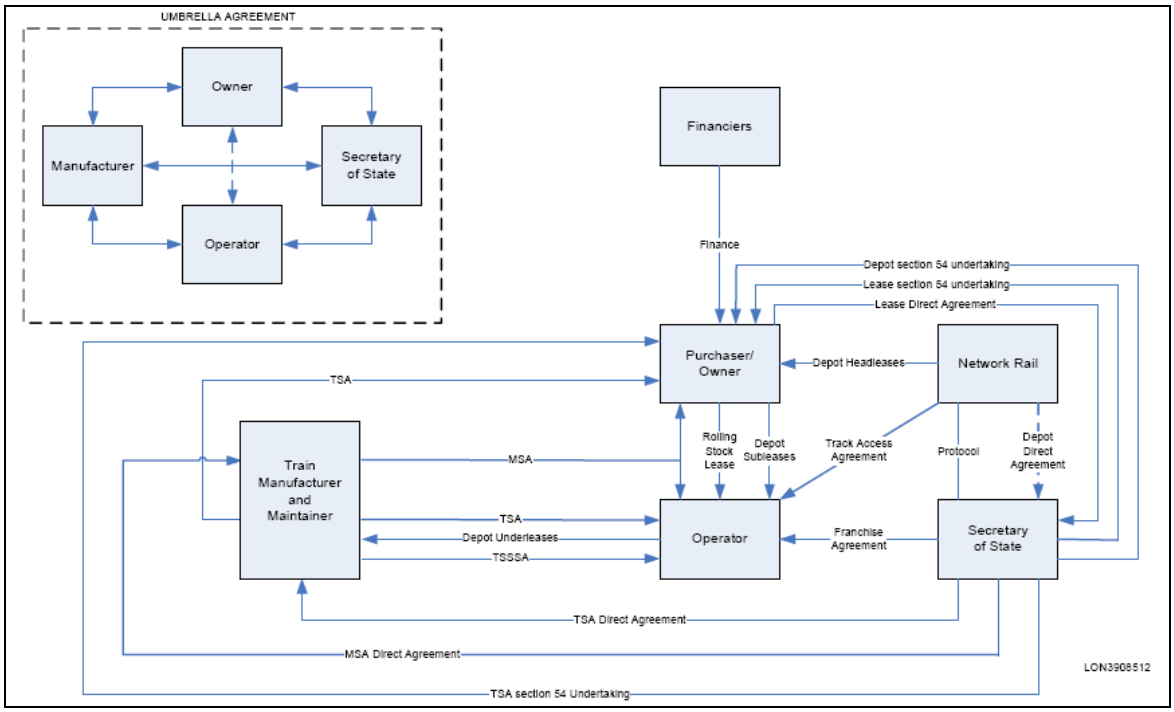

Figure 2: Proposed structure of the Thameslink programme [19]

5 Generating value from whole-life solutions

Through the Thameslink contract, the Department for Transport is demanding that rolling stock manufacturers supply greater levels of service provision alongside their traditional product offering, with the aim of providing more optimised whole-life solutions.

For a manufacturer, value is still generated upon the sale of rolling stock (to a ROSCO). However, now that the manufacturer is guaranteed to be the maintainer further value can generated by maintaining the fleet of rolling stock; effectively managing the supply chain, inventory and maintenance activities. This in itself is unremarkable. Indeed, in the traditional approach value would be generated in the same manner if the manufacturer chose to, and was successful in, bidding for the service contract – rolling stock manufacturers operating in the UK market all have separate service divisions.

The guarantee, offered by the Department for Transport ensuring that the manufacturer is the maintenance provider, offers a significant opportunity to enhance the value derived from a fleet of rolling stock by better linking capital and operational expenditure. In this new paradigm, the manufacturer is incentivised to design for reliability so long as whole-life cost is minimised.

Rail vehicle manufacturing divisions within the manufacturer's organisation need to work more closely with the service division in order to design the vehicles. The relationship with the other organisations in the enterprise (i.e. the financiers/ROSCO and train operator) must be much less transactional and confrontational; each partner must recognise that the only way to succeed is for the entire enterprise to make money. Contracts between organisations within the enterprise need to reflect this – championing the joint goals, identifying that problems are jointly owned, fairly sharing risk and creating an imperative towards continuous improvement. Ideally, if one organisation within the enterprise was making significant profit (above a predetermined threshold) this profit should be taken by the enterprise and shared. Similarly, some degree of loss sharing should also be accepted by the enterprise.

In the same way, a manufacturer's relationship with its suppliers must also become less transactional and confrontational. This is especially challenging in the UK railway industry where the suppliers tend to be either small specialist companies or large multi-national organisations. Spares contracts need to be agreed for the whole-life of the vehicles (or until the parts become obsolete). Small companies may be willing to transform in order to deliver whole-life contracts, however, may be incapable of accepting the additional risk incurred. Large organisations are probably capable of accepting the risk, however, the railway industry may be such a small part of their overall business that there is little incentive to change.

If manufacturers begin to realise that in order to maximise their long-term returns the entire enterprise and its suppliers must make money then economic growth becomes linked to customers' perception of the value of an offering and not necessarily to product streams. In this environment there is recognition that companies create value which is perceived by customers and that customers buy value [20].

In this scenario, the enterprise sees itself as a supplier of a system focused on understanding how value is created in the eyes of customers [3, 8]. The traditional approach to value generation by rolling stock manufacturers of assembly, selling and delivery, spare parts supply and upgrades expands to include all areas of customer concern – financing and leasing, maintenance, scheduling and capacity planning, catering and servicing, parts-depot operations, refurbishment and releasing, and driving the vehicles. This challenges manufacturers in how they define their value adding activities and requires the whole organisation to develop new capabilities in systems integration, operational service, business consulting and financing [3].

Perhaps the biggest challenge for rolling stock manufacturers in transitioning to become complete service providers focused on generating offerings based on customers' perception of value lies in people and their behaviours and culture. UK rolling stock manufacturers have over 150-years of internal inertia to overcome. Employees and their managers rightly take pride in their manufacturing excellence, however, the skills and abilities required to deliver this differ significantly the skills and abilities required to provide services. Even in service divisions within rolling stock manufacturers, the focus is typically on fixing the immediate concern and reacting fact enough. Although exciting, with success being easily measurable, this reactive nature does not lead to optimised whole-life solutions. Systemic thinking skills need engendering, encouraging managers to consider the long-term implications of their decisions on the whole enterprise and creating tools and processes to support this. Individuals and teams should no longer be rewarded for good fire-fighting but for preventing fires in the first place; the heroes in traditional manufacturing organisations are not likely to me the heroes in a service-oriented organisation.

6 Conclusion

This paper describes that the UK government is demanding a "whole-life, whole-system" view of contracts within the UK railway industry. Within this environment, rolling stock manufacturers are facing increasing pressure to provide greater levels of service provision within their core offerings. This will profoundly change the way a traditional manufacturer handles its customer and supplier relationships and defines its value adding activities.

The research has identified that the traditional approach to value generation is transactional and confrontational between manufacturers, suppliers and customers. The current structure of the UK railway industry has created a disconnect between rolling stock manufacturing and servicing leading to a complete separation of capital and operational expenditure. Manufacturers are not incentivised to improve the reliability of a fleet and, because of the contracting structure, are actively discouraged from doing so.

The Thameslink programme, tendered by the Department for Transport, is seeking an enterprise to deliver a bundled solution which includes design, build, maintenance and finance. The tender creates and incentive for manufacturers to deliver a highly reliable and cost effective solution by guaranteeing that the manufacturer will also be the maintainer – better linking capital and operational expenditure. In order to enhance the value generated from such contracts the relationships within an enterprise and with the supply chain must be seen as a partnership and no longer transactional or confrontational. There needs to be recognition that in order for an organisation to be successful the entire enterprise needs to be successful – i.e. organisations must develop co-value propositions. This recognition is slowly gaining ground in the UK railway industry – particularly that of rolling stock.

In the future, economic growth should become better linked to a customer's perception of value and not necessarily to product streams. In this context, customers buy value and traditional manufacturers need to develop new capabilities in systems integration, operational service, business consulting and financing to supply this value. This requires traditional rolling stock manufacturers to start to see themselves and their enterprise as suppliers of a system. Perhaps the biggest challenge to this is to overcome the internal inertia of the manufacturing organisation by changing the mindsets of employees and managers and acquiring the skills required for systemic thinking.

Future research will attempt to quantify, measure and track how value is generated throughout the enterprise in order to understand how value changes through time in different levels of whole-life service provision.

Acknowledgements

This paper would not have been possible without the financial support given by the UK government via EPSRC and the collaborating company. Neither would it have been possible without the support of the industrialist interviewed as part of the research and the access granted by the industrial partner. The views expressed are in this paper are those of the authors, but were derived from collaboration and discussion with these people. We thank them for their time, knowledge and invaluable insights.

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Paper 2

Clayton, R.J., Backhouse, C.J., Provost, M.J., Dani, S., Lovell, J. 2009, “Applying systems engineering to optimise the operation and maintenance of railway vehicles throughout the value chain”, *Proceedings of the 7th Annual Conference on Systems Engineering Research (CSER),* Loughborough University

Applying Systems Engineering to Optimise the Operation and Maintenance of Railway Vehicles throughout the Value Chain

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Abstract

A recent move by the UK government to purchase two new railway vehicle fleets from the provider offering the lowest whole-life, whole-system cost creates significant challenges to traditional manufacturers and their extended enterprises.

This paper describes the work of a collaborative academic-industry research project; applying systems engineering to enable the optimisation of the operation and maintenance of railway vehicles – one aspect of railway vehicles' lives which will need to be fully understood in order to offer optimised whole-life contracts.

A model of the current operation and maintenance extended enterprise is created using soft systems methodology with critical value generating parameters identified.

Explanations are presented for the perception of the current extended enterprise being too expensive, slow to respond and inflexible. Future work is discussed detailing how systems engineering approaches and systems thinking can be further used to bring about a more optimised approach to operating and maintaining railway vehicles in the UK.

Keywords: Systems engineering, value chain, extended enterprise, railway, modelling

1 Introduction

The 2007 *'Rail Technical Strategy' (RTS)* which accompanied the UK governments *'Delivering a Sustainable Railway'* white paper outlined the aim to have "world-class reliability of both infrastructure and rolling stock" [1]. In order to achieve this, the *RTS* highlighted the need for

"government and industry [to work] together taking a whole-life, whole-system cost approach in exploiting opportunities" [1].

This commitment to taking a whole-life, whole-system viewpoint is reflected in current trends by government departments, through Public Private Partnerships / Private Finance Initiatives, in which the "public and private sectors join to design, build or refurbish, finance and operate new or improved facilities and services to the general public" [2].

This whole-life approach has recently manifested itself into two tender requests made by the Department for Transport (DfT) to industry – the Intercity Express Programme (IEP) and the Thameslink programme. For the IEP, the DfT is seeking the minimum whole-life, whole-system cost for "IE Services" (the financing, procurement and delivery of the new trains and all other related services in connection with the provision of the required availability for the IEP) [3]. For the Thameslink programme, the DfT is seeking to procure a "fully financed package for the manufacture, entry into service and maintenance support of a new fleet of rolling stock" at minimum whole-life cost [4].

The whole-life, whole-system paradigm has the potential to completely change the dynamic of UK railways; provided that the industry can transform itself to deliver whole-life service offerings, maximised to deliver benefit throughout the value chain. This paper discusses the preliminary research findings of a Systems Engineering Doctorate, being undertaken at Bombardier Transportation (a railway vehicle manufacturing and servicing company), whose aim is to maximise the whole-life value of railway vehicles by optimising operations and maintenance throughout its value chain.

2 The UK railway system

A system is "a combination of interacting elements organized to achieve one more stated purposes" [5].

When viewed as a system, the (primary) purpose of the UK railway industry is to safely transport passengers and freight on time. In order to achieve this, all elements within the railway system need to work together in a holistic way – even though the individual elements may have their own goals. For example, train operators want to maximise their profits by operating passenger services, Network Rail want to manage the existing fabric of the railway network, utility providers want to maximise their profits by providing electricity, gas and water to the railway network, etc.

The complexity within the railway system lies not in any technical aspect, although these are complicated, but in the interactions and relationships between the different stakeholders; aligning their often competing goals in order to deliver the system goal - safely transporting passengers and

freight on time. This becomes especially important with the whole-life approach and requires greater co-operation and communication between all stakeholders.

The focus of this research paper is only a subset of the wider railway system, but it significantly influences, and is influenced by, the railway system. In fact, many of the interactions and relationships that exist within the railway system also exist in the operation and maintenance of railway vehicles. By modelling the relationships throughout the operations and maintenance extended enterprise, it should be possible to recommend changes to that enterprise with the aim of maximising value generation for all stakeholders (both within the extended enterprise and the railway system). These changes will affect the railway system (its structure and/or behaviour) and may drive change in that system towards greater levels of whole-life, whole-system approaches.

3 The Operation and Maintenance of Railway Vehicles

The operation and maintenance of railway vehicles is a complex process, with significant interactions amongst participants (including train operators, component suppliers and maintainers). These interactions are not uniformly defined and change depending on the type of maintenance contract between train operator, rolling stock lessor and maintainer.

Due to this complexity there is a perception that the current approach to managing the operation and maintenance of rolling stock in full maintenance contracts is too expensive and risk averse – resulting in difficulties achieving the profit margins and growth expected by senior management.

Through the use of Goldratt's Current Reality Trees [6, 7] it was felt that the core problem was that some managers make decisions to improve their short-term concerns without fully considering the long-term effects to the whole enterprise. In order to address this core problem it is necessary to tackle the problems' enablers:

1. A lack of understanding of the dependencies that exist between different business functions
2. Cost accounting rules stipulating projects/functions should always be generating a profit
3. Emphasis on localised initiatives
4. Emphasis on cost reduction

In an attempt to address the perceived core problem and better manage the complexity, a systemic analysis of the operation and maintenance of railway vehicles was carried out. This involved not only investigating the actual maintaining of railway vehicles but the extended enterprise required to deliver functional vehicles to the customer at contracted levels of availability and reliability – i.e. investigating the perceived problems across the entire value chain – from end-user back to material suppliers. The goal of this research was to visualise what the dependencies are between different business functions (problem enabler 1) and use this visualisation as a debating tool to critically

analyse the impact of management policies in creating the perceived problem(s) – initiating the discussion surrounding the more sensitive problem enablers.

4 Case Study: Operation and maintenance extended enterprise

For the purposes of this research, the extended enterprise of a full UK maintenance contract was modelled. Full maintenance contracts represent a significant proportion of Bombardier Transportation's service contracts and, in any move towards long-term asset management, will be the contract type which will deliver the most value to the company.

As the perceived problem has been well defined and the scope of the work bounded to the operation and maintenance of railway vehicles and its extended enterprise; case study research was chosen as the primary method of analysis. Specifically, an intrinsic case study was chosen as the focus of the research was on the case itself [8]

4.1 Modelling methodology

The dynamic complexity of the extended enterprise; the fact that it consists of people, processes and tools all working concurrently to operate and maintain railway vehicles requires a systemic process of inquiry. Checkland's Soft Systems Methodology (SSM), developed by Peter Checkland at Lancaster University in the 1960's after the failure of using traditional "hard" systems engineering approaches on messy organisational problems, takes the "concept of a system and applies it to the process of dealing with the world" [9]. SSM not only consists of a logic-based stream of analysis, it also consists of a cultural and political stream – viewed to be a significant factor in the railway system and the operation and maintenance extended enterprise.

Although SSM has evolved during the course of its application to real-life situations over many years, the basic concept of SSM remains the same – a methodology of taking purposeful action to continually improve the current situation based on experience [10]. As such, SSM is a methodology for systemically learning about the problem situation and has been applied in this case to specifically learn about the operation and maintenance extended enterprise of railway vehicles and initiate debate on possible action to improve the situation.

The methodology, presented in Figure 1, consists of a "logical" analysis component, which identifies and analyses human activity systems, and three "cultural" analyses [11]. It can be viewed as four interdependent and interacting activities:

1. Finding out about the problem situation, including culturally and politically
2. Formulating some relevant purposeful activity models
3. Debating the situation, using the models, seeking from the debate:

a. Changes which could improve the situation and are regarded as both desirable and (culturally) feasible
b. The accommodation between conflicting interests which will enable action-to-improve to be taken

4. Take action to bring about the improvement

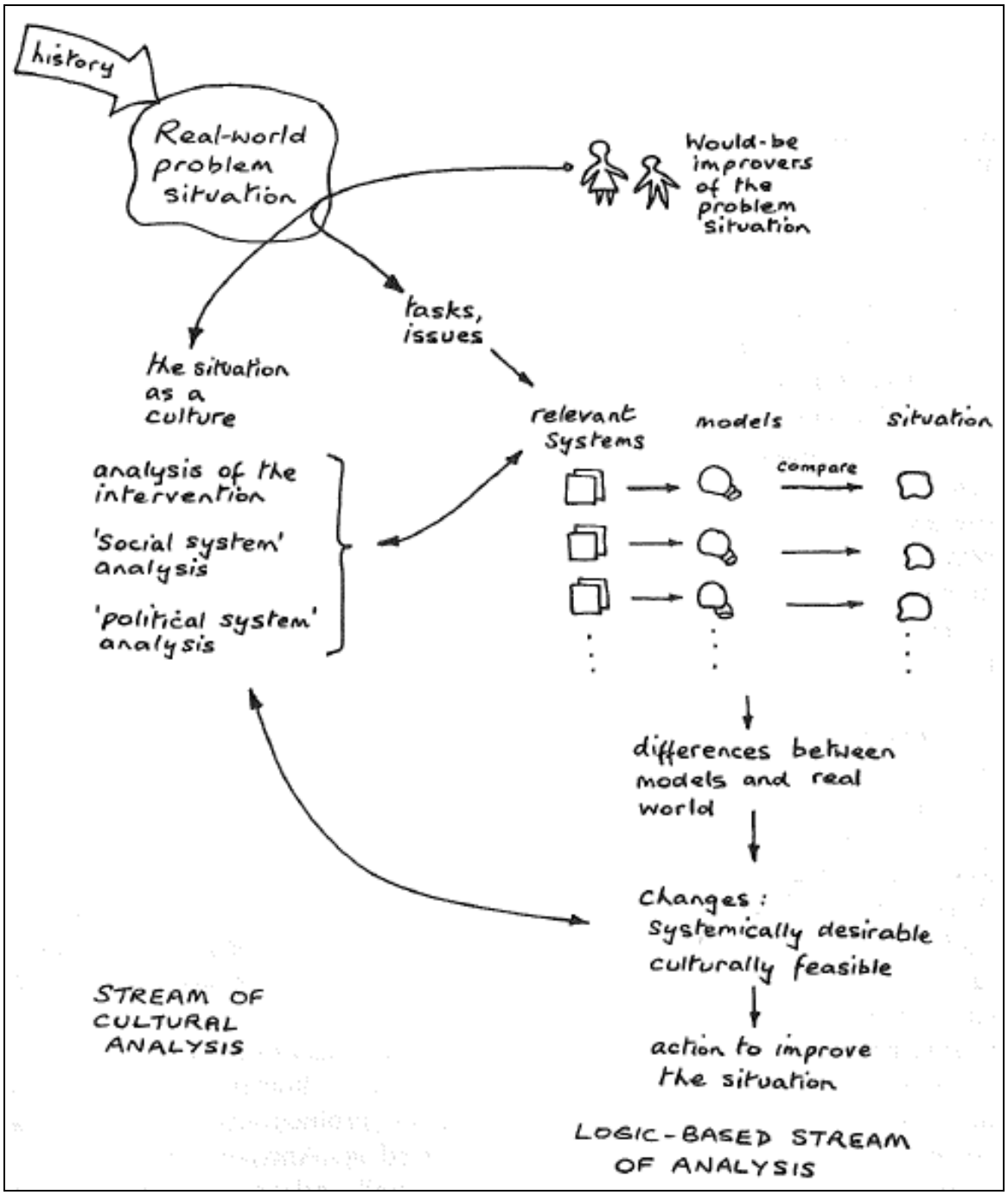

Figure 1: SSM enquiring process [10]

4.2 Applying SSM to the Operation and Maintenance Extended Enterprise

SSM can be applied in two different modes, which Checkland refers to as Mode 1 and Mode 2 [10]. Mode 1 is methodology-driven and refers to the case where a conscious choice is made to use SSM and the practitioner will move from one stage to the next sequentially. Mode 2 is situation-driven and refers to the case where the methodology has been internalised by the decision-maker and is used unconsciously in an everyday environment. The mode in which the methodology is employed in this research is somewhere in between the two. Although SSM was specifically chosen, it was used in an interactive and iterative manner in order to better understand the problem situation. This is because much of the investigation into the current extended enterprise was performed through relatively short interviews and it was impractical within the time constraints to instruct each interviewee on the methodology.

Interviews were chosen as the primary means of finding out about the problem situation. Due to time constraints on some stakeholders interviews were typically carried out on a one-to-one basis, lasting for 90 minutes each. Some stakeholders were approached on more than one occasion in order to better understand some of the contextual and situational factors involved.

Initially, the first few interviews were used to gain an overview of the extended enterprise. From these a rich picture and conceptual models were produced. These were then used in subsequent interviews as a technique for interactively eliciting greater understanding about the extended enterprise, its interactions and dependencies. The rich picture was amended and conceptual models created, amended or removed before being used in further interviews to elicit more information (Figure 2) and instigate debate.

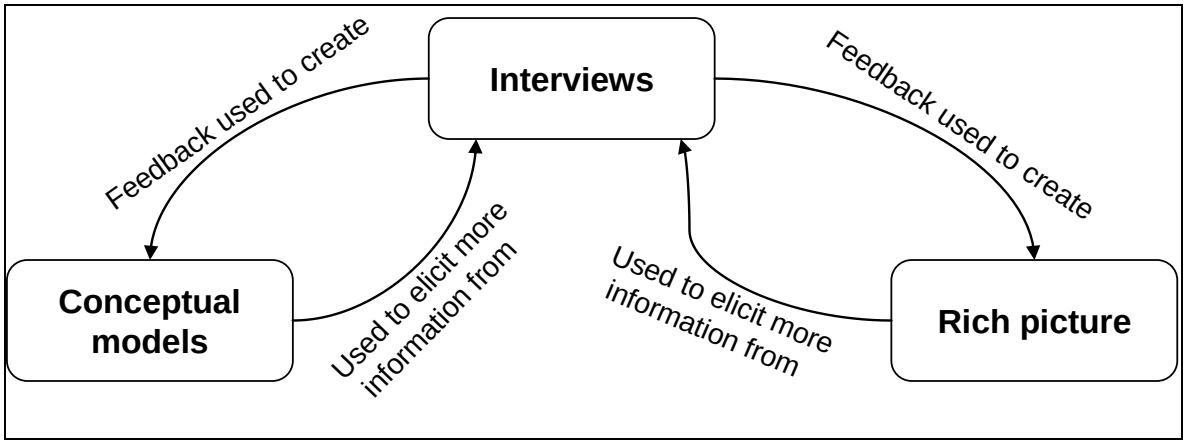

Figure 2: Iterative use of SSM to understand the extended enterprise

Over the course of the research a picture of the problem situation developed which reveals some of the complexity and relationships inherent in the operation and maintenance extended enterprise. A high-level overview of the situation can be seen in Figure 3, which has been simplified ensure the

research is suitable for publication and make it more presentable. The speech bubbles within Figure 3 highlight the core concern of each function.

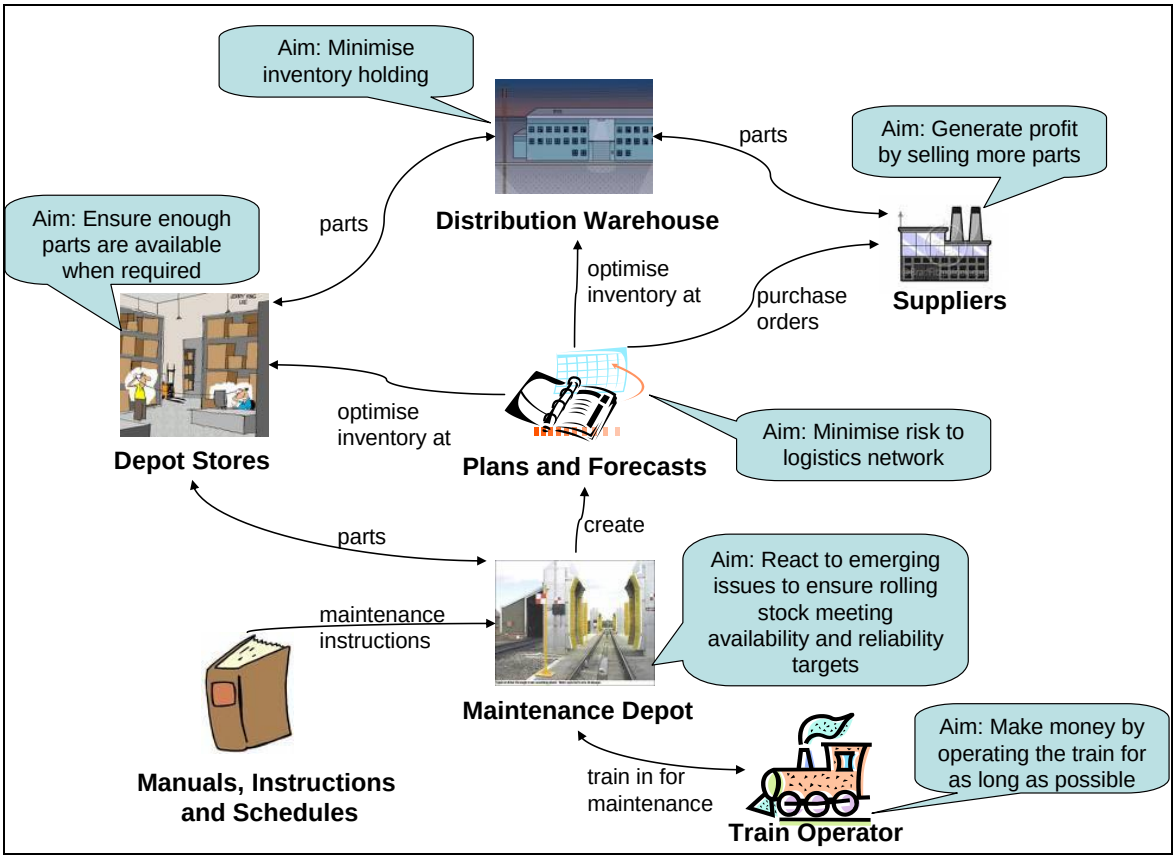

Figure 3: Rich picture model of the railway vehicle operation and maintenance extended enterprise

Throughout the research relevant purposeful systems were being identified and (conceptually) modelled as a starting point for debate and to further the understanding of the problem situation. An example of one relevant purposeful system and conceptual model is given in Figure 4.

During the debates it became apparent that the significance of the relationships in the rich picture model cannot be underestimated. As such, further work categorised the relationships as either:

- Physical flows
- Lines of reporting
- Information flows

The discussions following the rich picture creation and modelling allowed all participants to visualise the dependencies between the various functions in delivering the operations and maintenance service. All participants agreed that information flows are the most common type of relationship. Indeed, the physical flows (the movement of parts) are contingent upon some form of information flow taking place.

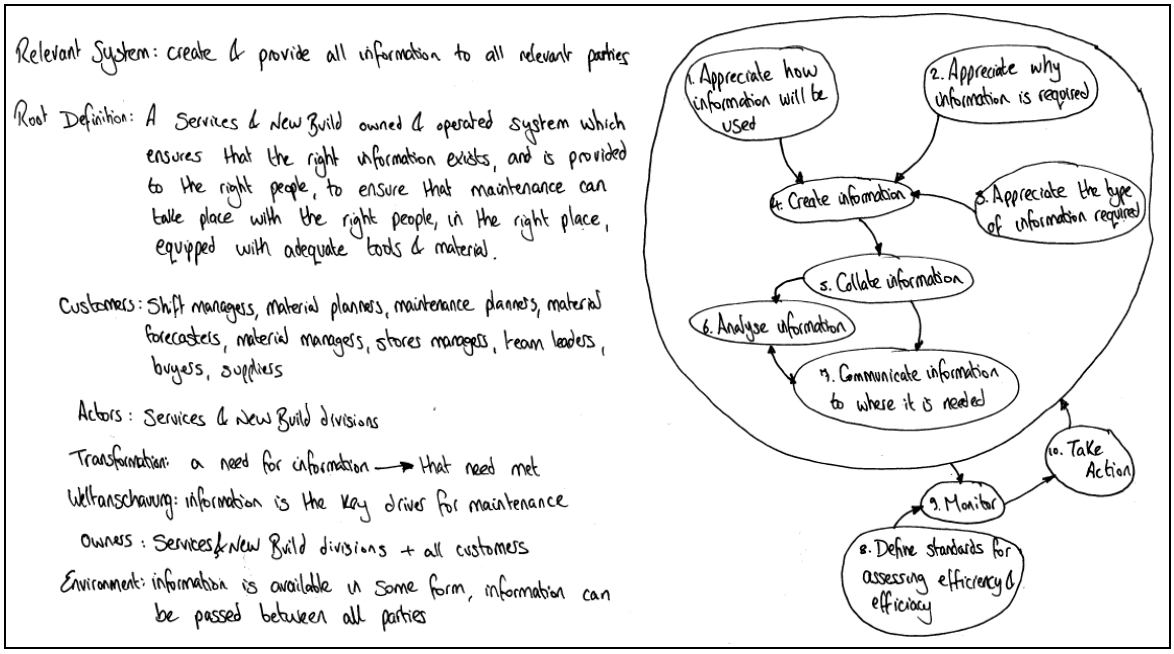

Figure 4: An example of one relevant purposeful system and conceptual model

4.3 Identifying Value in the Operation and Maintenance Extended Enterprise

A value stream/chain is a sequence of activities. "Products" pass through all activities of the chain in order and at each activity value is added [12]. From this definition two questions arise:

1. What are the "products" that pass through the extended enterprise?
2. What are the value metrics in the extended enterprise?

The operation and maintenance extended enterprise can be considered an integral part of a service support value chain in which the maintainer adds value by ensuring contracted levels of availability and reliability.

From the discussions arising as part of the case study analysis, participants felt material and information are the main "products" in the operation and maintenance extended enterprise.

An unanticipated advantage of using SSM was in the identification of value metrics as an extension of formulating relevant purposeful activity models. As "no human activity system is intrinsically relevant to any problem situation" [13], the purposeful activity models give, at a high-level, an indication of one person's view of what is valuable – their perception of value is inherently linked to their perception of the system. For example, the person who views "generate a profit for the company" as a purposeful activity system sees value measured in terms of system profitability.

Using this approach and discussing value metrics with stakeholders in the debate stage led to the following critical value-generating parameters being identified:

- Quality and timeliness of information
- Quality of the relationship with suppliers
- Level of material float in the system
- System profitability
- Number of in-service failures
- Quality of the relationship with customers
- Staff turnover levels
- Number of additional revenue streams generated

While improving all of the value metrics should ultimately be reflected in improved profitability, the measures of value are not purely financial. Many of the value metrics are intangible and emerge because of the behaviour of the operation and maintenance extended enterprise as a whole.

Future work will focus on trying to further quantify the aspects of value within the service value chain (of which the operation and maintenance extended enterprise is an integral part). Once value metrics have been defined, research will focus on:

- how to measure and track whether entire service offerings are creating value for the customer;
- how value streams can be optimised to give better performance; and
- identifying new value streams within the current service value chain.

4 Conclusion

The research has shown that the maintenance of railway vehicles is a complex business process, with significant interactions amongst participants (including train operators, component suppliers and maintainers). Optimising the whole-life service performance of railway vehicles is a critical success driver to the whole-life contracts being proposed by the UK government.

The research has identified that the core problem to optimising the whole-life performance of railway vehicles is that some managers make decisions to improve their short-term concerns without fully considering the long-term affects to the whole enterprise. In order to address this core problem it is necessary to tackle the problems' enablers:

1. Lack of understand between the dependencies that exist between different business functions
2. Cost accounting rules stipulating projects/functions should always be generating a profit
3. Emphasis on localised initiatives
4. Emphasis on cost reduction

Soft Systems Methodology (SSM) has been used to help understand the operation and maintenance extended enterprise for a fleet of railway vehicles and, through the accompanying

discussions, critical value generating activities, relationships and dependencies have been identified. Many of these are intangible (e.g. quality of the relationship with suppliers) and are difficult to pinpoint as belonging to any particular stakeholder: instead they are properties that the whole operation and maintenance extended enterprise system exhibit.

The research has helped all participants to visualise the dependencies between the various functions in delivering the operations and maintenance services. Information flows have been identified as the most common type of relationship and there is a perception that these flows are the main value carrier.

Future work will focus on trying to map these value metrics onto the operation and maintenance extended enterprise with the intention of determining where value is being created and lost. This will require taking an holistic viewpoint, using systems engineering approaches and systems thinking techniques, to quantify, measure and track value throughout the operations and maintenance extended enterprise to understand how value changes through time in different scenarios.

Acknowledgements

This paper would not have been possible without the financial support given by the UK government via EPSRC and Bombardier Transportation. Neither would it have been possible without the support of the industrialist interviewed as part of the research and the access granted by the industrial partner. The views expressed are in this paper are those of the authors, but were derived from collaboration and discussion with these people. We thank them for their time, knowledge and invaluable insights.

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Paper 3

Clayton, R.J., Backhouse, C.J., Dani, S. 2012, “Evaluating existing approaches to product-service system design: A comparison with industrial practice”, *Journal of Manufacturing Technology Management*, vol. 23, no. 3, pp.272-298

Evaluating existing approaches to product-service system design: A comparison with industrial practice

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Abstract

Purpose – The aim of this paper is to reflect on how representative the literature is in identifying industrial practice to designing product-service systems (PSSs).

Design/methodology/approach – The paper analyses literature to report on the existing approaches used to design PSSs. A single exploratory case study approach, based on semi-structured interviews and archival data analysis, was used to understand an existing product-service organisation's approach to designing PSSs. A total of 12 senior managers were interviewed from a cross section of the organisation to gain multiple perspectives on the PSS design process and 10 company reports where analysed.

Findings – The research has identified that the PSS design process reported by literature is not representative, lacking inputs and outputs to some phases and feedback. 18 inputs and 11 outputs have been identified from the case study that are not reported by the literature. These create five feedback loops within the PSS design process used by the case study organisation. This suggests that the PSS design process is cyclic and iterative and not sequential as reported by existing literature.

Research implications/limitations – This research is based on a single-case study approach, limiting the ability to generalise findings, and does not provide a complete PSS design approach.

Practical implications – This research compares literature against industrial practice to PSS design, presenting insight to aid practitioner's design PSSs.

Originality/value – This paper fills a gap in the servitization and PSS literatures; evaluating the approaches reported by literature against existing industrial practice.

Keywords: Servitization, product-service system, PSS, design process

Paper type Research paper

1 Introduction

The concept of manufacturers providing services is not new (Schmenner 2009). Indeed, Levitt proposed that "everybody is in service" (1972, p.42). In reality, the majority of manufacturers have always provided some form of service with their product (e.g. warranty, maintenance, etc) (Childe

2007), however, these services have traditionally been seen as add-ons – a cost centre. More recently, manufacturers in developed economies have been encouraged to view services more strategically in order to compete on the basis of most value rather than lowest cost (Lord Sainsbury of Turville 2007, Wise & Baumgartner 1999).

The transition by organisations to providing integrated product-service systems (PSSs) is known as servitization (Vandermerwe & Rada 1988, Baines *et al.* 2009). The concept of PSS has been evolving since the late 1990s and contributions have been made predominantly from environmental and social science fields (Baines *et al.* 2007, Goedkoop *et al.* 1996, Mont 2000). Originally defined as a "marketable set of products and services capable of jointly fulfilling a user's need" (Goedkoop *et al.* 1996, p.18), work by Baines *et al.* (2009) began to converge the PSS and servitization literatures. Hence servitized manufacturers' value propositions are formed from one or more of the five generic types of PSS: integration-, product-, service-, use- or result-oriented PSSs (Baines *et al.* 2007, Neely 2008).

Previous research within the servitization literature has identified that manufacturers face challenges with respect to service design, organisational strategy and organisational transformation (Baines *et al.* 2009). Furthermore, Baines *et al.* (2009) asks the question, "how can/should competitive integrated product-service offerings be designed within the context of an industrial organisation?" (p.562). The related PSS literature is more mature in this area and various tools and methodologies have been proposed (e.g. Brezet *et al.* 2001, Engelhardt *et al.* 2003, Kar 2010, Kar & Groeneweg 2007, Morelli 2003, Morelli 2002, van Halen *et al.* 2005, Luiten *et al.* 2001). However, whilst a range of tools and methodologies exist for designing PSSs, there is a lack of evidence to demonstrate whether they represent industrial practice (Baines *et al.* 2007).

Traditional approaches to product design such as the Waterfall model (Royce 1970), V model (INCOSE 2007, NASA 1995) and the spiral model (Boehm 1988) have focused on the design of products separately from services. Similarly new service development models (e.g. Scheuing & Johnson 1989, Edvardsson & Olsson 1996, Bullinger *et al.* 2003) have focused on service design separately from product design. Whilst limited research has been conducted that attempts to combine the two design paradigms (Wild 2007), many authors report that product design approaches are not suitable for service design (Ian Stuart 1998, Kelly & Storey 2000, Reinoso *et al.* 2009). When developing an integrated product and service offering, existing product or service design approaches may be appropriate where either the product or service element is significantly dominant over the other (e.g. in integration-, product- or result-oriented PSS). However, when products and services are tightly coupled, products and services must be designed concurrently (Alonso-Rasgado *et al.* 2004, Kimita *et al.* 2009).

At present, more research is needed to support companies to successfully develop tightly coupled service- or use-oriented PSSs (Sakao *et al.* 2009). This represents a knowledge gap within the

servitization literature. Evaluating whether existing PSS design tools and methodologies represent industry practice will enable general guidelines, tools and techniques to be developed to aid practitioners within servitized manufacturing organisation design new PSS offerings.

This paper reports the on an exploratory single-case study that identifies how one global transportation company creates its integrated PSSs. The paper begins by reviewing the servitization and PSS literatures, specifically focusing on the recommendations that have been made regarding the design of PSSs. The global transportation company is then investigated to determine its approach to PSS design and compared with literature.

2 Background

2.1 Product-service systems

Chase (1981) uses the concept of a continuum to distinguish between pure-product and pure-service providers. Olivia & Kallenberg (2003) expanded this concept in their research to understand how organisations manage the transition from products to services. Manufacturing firms move along the axis as they servitize; incorporating more services. At the extreme, Olivia & Kallenberg (2003) envisage a service organisation for which products are only a small part of the organisation's value proposition (e.g. IBM Global Services). Similarly some service organisations starting from the other end of the continuum have begun 'productizing'; incorporating products into new service offerings. The convergence of these trends is the consideration of the product and service as a single offering – the PSS (Baines *et al.* 2007) (Figure 1).

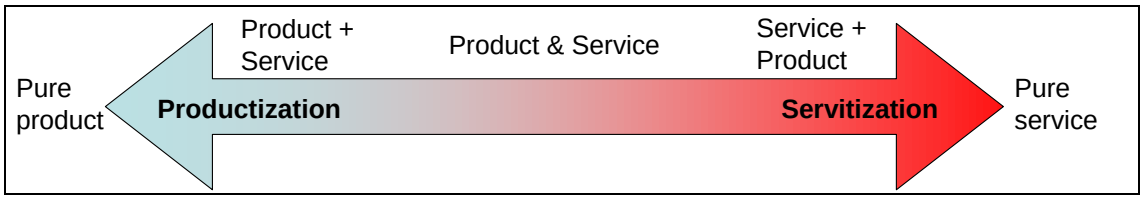

Figure 1: Product-service continuum

Although the PSS concept refers to offerings where products and services have been combined, different types of PSS exist, classified by the level of integration between product and service (Table 1).

The integration- and product-oriented PSSs can be seen as products plus services as the product is generally sold separately and services are offered that can support that product throughout its life. The service-oriented PSS can be seen as products and services as services are incorporated into the product – i.e. the product is sold with a service package which may be enabled by onboard equipment. The use- and result-oriented PSSs can be seen as services plus product where the focus is on the service element. Typically the use-oriented PSS focuses on selling the functionality of the product (e.g. Rolls-Royce's Power-By-The-Hour™ availability contracts) whereas the result-

oriented PSS focuses on removing the product from the offering (e.g. video conferencing services to remove the need for business travel).

Table 1: Generic types of PSS

Type of PSS	Definition
Integration-oriented	Adding services through vertical integration. Ownership is transferred to the customer, but the supplier seeks vertical integration (e.g. by adding retail, transportation services, etc) (Neely 2008)
Product-oriented	Ownership of the tangible product is transferred to the customer, while included in the original act of sale are additional services (e.g. maintenance, repair, re-use, recycling, training, consulting, etc) (Baines *et al.* 2007)
Service-oriented	Incorporate services into the product itself. Ownership of the tangible product is transferred to the customer, but additional value added services are offered as an integral part of the offering (e.g. health usage monitoring systems) (Neely 2008)
Use-oriented	Ownership of the tangible product is often retained by the service provider. Functions of the product are sold via modified distribution and payment systems (e.g. through sharing, leasing, etc.) (Neely 2008)
Result-oriented	Selling the result or capability instead of a product (e.g. web information replacing directories). Companies offer a customised mix of services where the producer maintains ownership of the product and the customer pays only for the provision of agreed results (Baines *et al.* 2007)

The five generic types of PSS can be seen to fit within the product-service continuum to create a range of product-service offerings (Figure 2). It is important to note that a servitized (or productized) organisation will not solely offer result- or use-oriented PSSs. For example, although Power-By-The-Hour™ availability contracts (use-oriented PSS) make up the significant majority of Rolls-Royce's business, they still sell engines as standalone products with limited service (integration- or product-oriented PSS). Thus a servitized manufacturer will likely operate many business models driven by the maturity of the customer (Kujala *et al.* 2009).

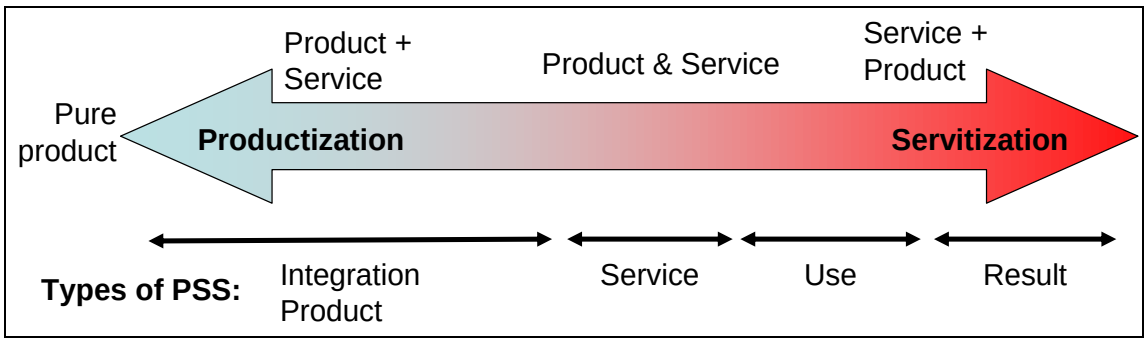

Figure 2: Continuum of product-service offerings

In the context of this research a PSS is considered combinations of products and services (i.e. service-oriented PSSs). For example, an asset health monitoring service consists of various product (e.g. onboard sensors, communication equipment, computers to analyse data, etc) and service elements (e.g. providing maintenance instructions to customers). Whilst existing product design approaches may help organisations design the product elements and service design approaches help design the service elements, the tight coupling of the product and service elements (e.g. the design of a sensor will impact upon the type of data that could be captured onboard an asset which will impact upon the level and quality of advice that could be provided to customers) requires product and service elements to be designed concurrently (Alonso-Rasgado *et al.* 2004, Kimita *et al.* 2009). Thus the output of a PSS design process is a customer-focused service offering enabled by product elements and/or business processes and activities provided by either a focal organisation or a supply network.

2.2 Product-service system design approaches

The literature reports on various tools and methodologies that have been created specifically for designing complex product-service offerings: designing eco-efficient services (DES) (Brezet *et al.* 2001); Austrian eco-efficient PSS project (AEPSS) (Engelhardt *et al.* 2003); methodology for product-service system innovation (MEPSS) (van Halen *et al.* 2005); the Kathalys method (Luiten *et al.* 2001); the design exploration process (DEP) (Morelli 2003, Morelli 2002); and the service system design (SSD) approach (Kar 2010). These approaches cover the whole of the PSS development process and have emerged from various areas. For example, MEPSS and DES were developed within the PSS research community with a focus on developing more sustainable product-services whilst Morelli (2002, 2003) focuses on methodological issues for the design profession. Similarly, whilst DES was adapted from the product development process presented by Roozenburg & Eekels (1995), SSD was developed primarily for designing mobile information services and was based on the 'ways of' design approach (Kar 2010)

In addition to these, Mont (2000) proposes creating PSSs in an incremental fashion based on the Deming plan-do-check-act cycle, whilst Goedkoop *et al.* (1996) offers a four-axis model for auditing PSSs (ecology, economy, identity/strategy and client acceptance axes). Maxwell & Vorst (2003) report on the creation of the sustainable product and services development (SPSD) method, however, it predominately advises the designer of the important criteria when optimising for sustainability in products and services. The Kathalys method (Luiten *et al.* 2001), DEP (Morelli 2003, Morelli 2002) and SPSD (Maxwell & Vorst 2003) have been created and tailored to specific projects, however, within the Kathalys method and DEP there is a strong generic flavour that is also reflected in the non-specific approaches (Baines *et al.* 2007)

From 2002-2004 the SusProNet project (an EU Fifth Framework Programme), which aimed to develop and exchange expertise on the design of PSSs for sustainable competitive growth, identified 13 separate methodologies (Tukker & Tischner 2004). However, the majority of these

focus on specific phases of the development process – e.g. the INNOPSE (Innovation studio and exemplary developments for product service engineering) project focused primarily on the idea development process. Additionally, other methodologies also focus on a subset of the whole PSS design process – e.g. Rexfelt & Ornas (2009) report procedures for requirements elicitation and conceptual design whilst Morelli (2009) identify a series of techniques for service design structured around design as a collective decision making process: identification of problems, development of solutions and selection of policies. Whilst these approaches all have merit, due to their incompleteness, it is unlikely that practitioners could use them to design their servitized offerings. Therefore, the remainder of this literature review will focus on analysing the six methodologies that cover all of the stages within development process - DES (Brezet *et al.* 2001); AEPSS (Engelhardt *et al.* 2003); MEPSS (van Halen *et al.* 2005); the Kathalys method (Luiten *et al.* 2001); DEP (Morelli 2003, Morelli 2002); and SSD (Kar 2010).

2.2.1 Synthesising the common phases

Analysing the six design approaches that cover the whole development process and synthesising the various phases within each approach leads to the identification of six common phases: project initiation, analysis, idea generation and selection, detailed design, prototyping and implementation. The purpose of a PSS design approach is as a methodology for converting client requirements, competitive pressure and organisational capabilities into new service- or use-oriented PSSs which are sold on the market for a profit. Interestingly, the final phase in the AEPSS is a process evaluation phase which is not included within the alternative methodologies (Engelhardt *et al.* 2003). The process evaluation phase acts as a feedback loop, allowing for re-design of the process based on experience from application. Additionally, the SSD approach has activities consistent with evaluation (e.g. analyse business case, gather feedback, monitor and provide support), however, these activities focus on assessing the offering whilst in-service rather than the process used to create them. Thus evaluation is considered a core phase within the PSS design approach and additional outputs of the methodology are feedback to allow for re-design of the process and feedback to enable upgrades of the offering (Table 2).

Table 2: Linking seven PSS design phases to existing literature

Phase	DES	AEPSS	MEPSS	Kathalys	DEP	SSD
Project initiation	■	■				■
Analysis	■	■	■	□	□	■
Idea generation & selection	■	■	■			
Detailed design	■	■	■	□	□	■
Prototype the service	■			□	□	■
Implementation	■	□	□	□		■
Evaluation	■	□				■

■ Recognises phase and breaks it down into activities

□ Recognises phase but no activity breakdown

2.2.2 Synthesising the common inputs and outputs

From the literature only MEPSS identifies inputs and outputs at the activity level (van Halen *et al.* 2005) whilst DES and the Kathalys method identify inputs and outputs at the phase level (Brezet *et al.* 2001, Luiten *et al.* 2001). AEPSS, DEP and SSD provide no data on the inputs and outputs at either the activity or phase level (Engelhardt *et al.* 2003, Kar 2010, Morelli 2003, Maxwell & Vorst 2003). This is not unexpected given that MEPSS and DES are aimed at supporting organisations to develop new product-service offerings whilst DEP proposes methods to be used by the design profession in analysis, idea generation, detailed design and prototyping. Given the limitations of the existing literature, common inputs and outputs have been identified at the phase level where industry trends, clients' capability gaps and clients' business environment act as inputs to the PSS design process. These inputs are transformed through the various phases and activities in order to output a PSS which is sold on the market for a profit (Table 3 and Table 4). Although DES recognises the project initiation, analysis and prototype phase it does not identify inputs for the project initiation phases and outputs for the prototype phase.

Table 3: Linking PSS design phase inputs to existing literature

Phase	Input(s)	DES	MEPSS	Kathlays
Project initiation	*None reported*			
Analysis	Industry trends		■	■
	Clients' capabilities		■	
	Supplier capabilities		■	
	Clients' business environment			■
Idea generation & selection	An understanding of the benefits a client desires from a new offering			■
	A description of the system within which the innovation should take place	■	■	■
	Solution requirements	■	■	■
Detailed design	Service idea	■		■
Prototype the service	Service concept	■		■
	Client and supplier business cases			■
	Sales strategies			■
Implementation	Tested service concept	■	■	■
	Refined business cases			■
	Refined sales strategies			■
Evaluation	*None reported*			

Table 4: Linking PSS design phase outputs to existing literature

Phase	Output(s)	DES	MEPSS	Kathlays
Project initiation	A team with a mission	■		
	A project plan	■		
	A business coalition	■		
Analysis	An understanding of the benefits a client desires from a new offering			■
	A description of the system within which the innovation should take place	■	■	■
	Solution requirements	■		■
Idea generation & selection	Service ideas	■	■	
Detailed design	Service concept	■	■	■
	Client and supplier business cases			■
	Sales strategies			■
Prototype the service	Tested service concept			■
	Refined business cases			■
	Refined sales strategies			■
Implementation	PSS which is sold on the market for a profit	■	■	■
Evaluation	*None reported*			

2.2.3 Synthesised PSS design approach from literature

A seven phase process has been identified that is common to the majority of the six PSS design approach reported in the existing literature. For each phase, inputs and outputs have been identified from the approaches where they are recognised, however, the project initiation phase lacks inputs and the evaluation phase lacks both inputs and outputs (Table 5).

From the synthesis of PSS design approaches and wider literature review three key findings have been identified:

Finding 1: The existing approaches to PSS design are not complete - the project initiation phase lacks inputs and the evaluation phase lacks both inputs and outputs.

Finding 2: There is no feedback between phases within the methodology. The exception to this is AEPSS where the final phase creates feedback which can be used as an input to change the process for future designs (Engelhardt *et al.* 2003, Kar 2010), however, the lack of outputs from the evaluation phase is particularly problematic as these feedback loops are not currently identified in the existing literature. This represents a major weakness of existing approaches.

***Finding 3*:** The relationships between the phases in the six PSS design approaches are sequential where the output from each phase becomes the input to the next.

Table 5: PSS design process synthesised from literature

Inputs	Phase	Outputs
None reported	**PROJECT INITIATION**	- A team with a mission - A project plan - A business coalition
- Industry trends - Client's capabilities - Supplier capabilities - Client's business environment	**ANALYSIS**	- An understanding of the benefits a client desires from a new offering - A description of the system within which the innovation should take place - Solution requirements
- An understanding of the benefits a client desires from a new offering - A description of the system within which the innovation should take place - Solution requirements	**IDEA GENERATION & SELECTION**	- PSS idea(s)
- PSS idea(s)	**DETAILED DESIGN**	- PSS concept - Client and suppliers business cases - Sales strategy
- PSS concept - Client and suppliers business cases - Sales strategy	**PROTOTYPE THE PSS**	- Tested service concept - Refined business cases - Refined sales strategies
- Tested concept - Refined business cases - Refined sales strategies	**IMPLEMENTATION**	- PSS sold on the market for a profit, fulfilling client's needs
None reported	**EVALUATION**	*None reported*

3 Research question and methodology

3.1 Research question

Current research within the servitization field offers little advice to product-service providers for designing new PSSs. Whilst the PSS literature reports on a limited number of proposed

methodologies, these have not been evaluated with respect to an industrial organisations seeking to servitize.

The research reported within this paper was motivated by a desire to fill this knowledge gap by answering the following research question:

RQ: How does industrial practice reflect the approaches described in literature for the design of PSSs?

3.2 Research methodology

In order to evaluate the processes reported for designing PSSs, it is necessary to first understand how PSSs are currently being designed in practice. Since the design of PSSs is a complex phenomenon and to ensure that industrial practice was understood at sufficient detail, the adoption of a single exploratory case study is appropriate as it permits for a deep research enquiry and comes as close as possible to the research phenomena (Dyer & Wilkins 1991).

3.2.1 Data collection instrument

The unit of analysis for the research is the design process for new PSSs that a product-service provider follows in order to deliver innovative, new and marketable value propositions. A semi-structured interview was developed as the primary instrument for collecting industrial practice. The interview questionnaire was developed from feedback provided by researchers from different disciplines and industrial sponsors. Initial interview responses were used to refine the interview structure for subsequent interviews (Figure 3).

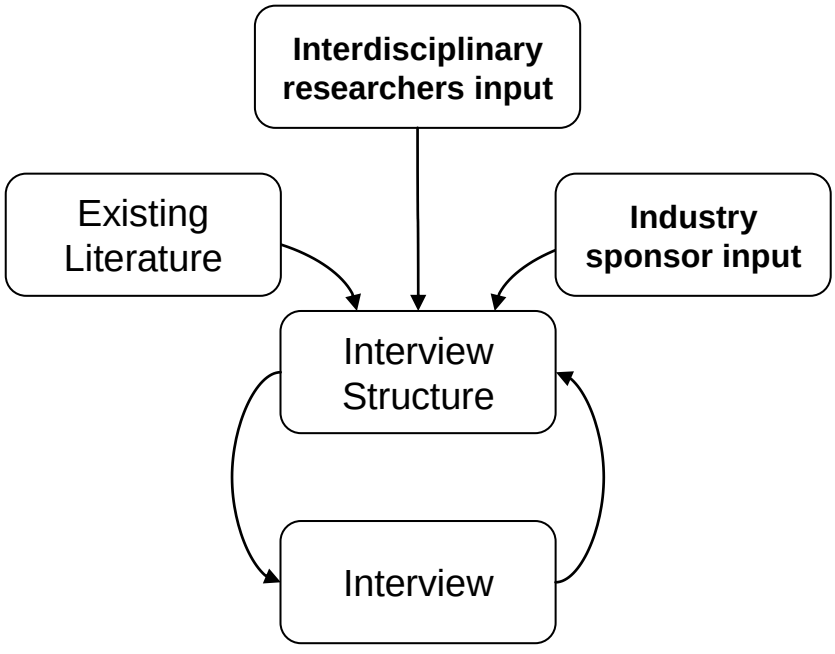

Figure 3: Interview data collection instrument development

The semi-structured interview focused on determining how a servitized manufacturer designed PSSs and any lessons learnt from the application of that process. Given that the existing literature adopts a phased structure, the interview design also adopted a phase structure in order to enable greater comparison with existing literature. The approach to data collection meant that specific questions changed between interviews, however, common topic areas were covered, including:

- The interviewee's perspective of the PSS design process
- The inputs and outputs to each phase within the process
- The tools, methods and techniques used within the design process
- Examples of unsuccessful projects and why the interviewee believed weaknesses in the design process made the project unsuccessful
- Examples of successful projects and why the interviewee believed strengths in the design process made the project successful

At the start of each interview, the interviewer defined service- and use-oriented PSSs to the interviewees. Interviewees were asked to provide examples of PSSs from their organisation's existing product-service offerings. For example, one Bid Director identified eight product-service offerings that could be classed as either service- or use-oriented PSS (e.g. asset information management services enabled by on-board condition monitoring equipment as a service-oriented PSS). In addition to semi-structured interviews, archival documents; process directives; and documents specifically referenced by interviewees were collected and analysed.

3.2.2 Selection of focal organisation

To gain sufficient understanding of industrial practice, the research sought to investigate a manufacturer who has made significant gains in transitioning to being a product-service provider, providing either service- or use-oriented PSSs. For this reason the UK division of an original equipment manufacturer that designs, manufacturers and services high-value capital equipment for the railway sector was chosen. For confidentiality reasons and to ensure greater freedom in discussing the findings, the company is referred to as RailCo. RailCo operates globally and today generates over 15% of its revenues from services. Within its UK division (the focal organisation for the research), RailCo generates approximately 50% of its revenue from services that are closely coupled to its products (e.g. maintenance, spares supply, technical support, energy management and data provision services).

3.2.3 Data collection and analysis

During the course of data collection it became clear that RailCo do not follow any documented process for designing their PSSs. This was confirmed by a number of respondents who described the process as "informal": *"Is there a process? I don't think there is today. As far as I am aware there certainly isn't a formalised process"* (Director of Strategic Programmes). To ensure that the undocumented (and informal) process was fully understood, respondents from different functional

areas were interviewed, along with company documents, to triangulate the data and increase the internal validity of the research (Yin 2003). Respondents were selected based on a simplified version of the generic system lifecycle stages (INCOSE 2007) – namely, designing the offering; marketing and selling the offering; implementing the offering; and the governance view. Each of the 12 interviews, representing six functional areas within RailCo, lasted between 40 minutes and 120 minutes and was recorded and subsequently transcribed verbatim. In addition to the interviews, 10 company reports were analysed.

Similar to a grounded theory approach (Glaser & Strauss 1967), responses were coded to identify phases, inputs and outputs. Similar codes were then grouped into concepts that were then used to determine RailCo's PSS design process. To determine whether RailCo used different phases, inputs or outputs to their PSS design process than that reported by the literature, an open coding method was employed. The coding process was iterative and as new concepts emerged existing codes were renamed and modified. Once all data was analysed, the results of each interview were fed back to interviewees who were provided with the opportunity to amend their view. From this, the interviewees perspectives where synthesised to produce an emergent perspective of how RailCo design their PSSs. This emergent perspective was then compared to the PSS design process identified from the existing literature (Figure 4).

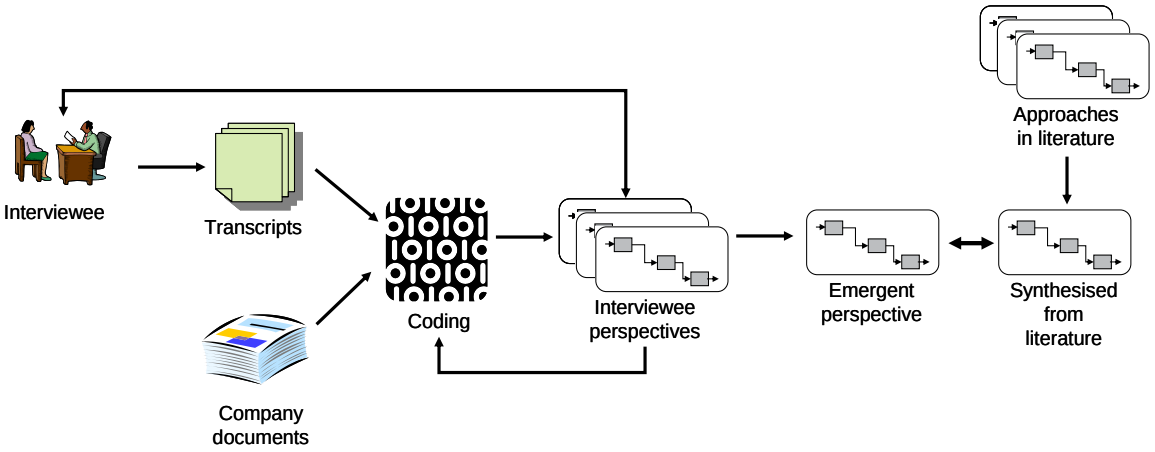

Figure 4: Data collection and analysis protocol

4 Results

Although RailCo does not follow a documented process for designing PSSs, analysis of the interviews identified an emerging perspective of an undocumented process that RailCo typically aims to follow. The following sections summarise the findings and report on this emergent perspective.

4.1 Phases within RailCo's PSS design process

The data coding initially identified 31 terms that interviewees used to describe the phases within the PSS design process, ranging from '*articulate value proposition'* to *'selling'*. Where codes had the same meaning (e.g. *'develop offering'* and *'detailed design'*) they were grouped into the same

concept. Eight concepts were identified by grouping the codes. Four codes had no similarities with any other code (Table 6).

Table 6: Synthesis of the codes determined from the data

Concept / Phase codes:	Create team	Analyse customers	Design	Idea generation	Articulate value proposition	Prototype	Implementation	Evaluation
Articulate value proposition					■			
Assess cost					■			
Assess resource needs*								
Assess worthwhileness								■
Build team	■							
Commercialise							■	
Concept design			■					
Cost offering					■			
Create price					■			
Create project plan*								
Create team	■							
Demonstrate value						■		
Detailed design			■					
Develop delivery mechanism			■					
Develop offering			■					
Develop service proposition			■					
Evaluation								■
First application						■		
Gap analysis*								
Generate ideas				■				
Idea development				■				
Idea generation				■				
Identify client pain		■						
Identify customer needs		■						
Identify expressed customer needs		■						
Identify unexpressed needs		■						
Implementation							■	
Price Offering					■			
Prototype						■		
Production*								

* Codes that have no similarities with the other codes

The remaining twelve codes and concepts were considered as the phases within RailCo's PSS design process. Respondents were asked to verify that these were the phases guiding their thinking and to define each phase. These definitions were compared to identify themes. For example, one Bid Director defined the 'Analyse Customers' phase as:

…the identification of the opportunity and setting out what our offering is, should be or think it should be is the start of the process. Within that, it captures what the customers needs are (Bid Director)

Themes identified from this definition include the identification of opportunity, capturing customer needs and setting out the offering. Based on these themes, and those from other respondents' definitions, a common definition was synthesised. Respondents were given the opportunity to make amendments. Due to space considerations it is not possible to present this analysis, however, a summary of the synthesised definitions is proved in Table 7.

Table 7: Definitions of RailCo's phases

Phase	**Definition**
Create Team	Describes the creation of a project team to perform the PSS design activities
Analyse Customers	The identification of opportunities for the design of a PSS that will overcome customers' needs or pain
Design	Describes the design of the PSS from the most promising idea identified in Idea Generation and determines how it will be delivered to customers
Idea Generation	Identifies possible ideas that the product-service provider could develop into PSS that resolve the needs or pain identified in Analyse Customers
Articulate Value Proposition	Describes how the product-service provider will cost and price the offering and identifies how the offering will be articulated to customers
Prototype	Is the first application of the PSS in one customer's environment in order to test that the product element functions and that the service is deliver as expected
Implementation	Is the large scale roll out of the PSS provided that the Prototype was successful
Evaluation	Is an assessment of the worth of the PSS
Assess resource needs	Identifies the resource needs that RailCo must have in order to deliver the PSS
Create project plan	The creation of a schedule that identified the activities that need to be completed during the PSS development project, the major milestones and deliverables
Gap analysis	The identification of differences between RailCo's existing resources/capabilities what it needs in order to deliver the PSS
Production	The realisation of the product elements within the PSS

Many respondents argued that once a PSS is in operation they are constantly assessing it to determine how to improve its performance and identify potential opportunities for new PSSs:

I think there have been iterations on a theme, enabled by technology, processes or by changes in the environment…So you get various add-ons or reductions on a theme [PSS] which then creates new standard models for product offerings. So I think that's the sort of genesis of a number of our products. Other products and services have been either technology-led or process-led – e.g. [PSS example]. The technology there has enabled us to define new service offerings that weren't there before because the technology didn't allow you to do it. In combination with design of the vehicle we've managed to create some unique opportunities – primarily around knowledge and IPR

(Vice President, ex-Head of Marketing and Product Planning)

Interviewees also reported that different teams are created for different phases within the PSS design process. At RailCo, Analyse Customers and Idea Generation are continuous activities traditionally performed by a dedicated marketing and product planning team. When PSS ideas are sufficiently mature to be considered marketable, a specific project is initiated with the aim of developing one PSS idea into a widely deployable concept. Once the PSS concept is sufficiently mature to be considered deployable, another project is initiated with the aim of selling, installing, operating and supporting the PSS.

4.2 Inputs and Outputs within RailCo's PSS design process

For each of the concepts and ungrouped codes relating to phases within RailCo's PSS design process, the coding method identified interviewee's perceptions of what the inputs and outputs are. Initially, data coding identified 37 and 42 terms that were used to described inputs and outputs respectively. Similar to the analysis of the phases, many of the codes referring to inputs or outputs have the same meaning (e.g. *'customer needs'* and *'expressed needs'*). Due to space considerations it is not possible to present the synthesis of the codes determined for all inputs and outputs. Instead, only the analysis of the codes referring to outputs is discussed. The result of the analysis of the codes referring to inputs is presented in Table 10 alongside the phases and outputs.

For the outputs, eight concepts were identified by grouping the codes and 20 codes had no similarities with any other codes (Table 8). The remaining concepts and codes were considered as the outputs and respondents we asked to verify that these captured their thinking. Thus the respondents identified 28 distinct outputs to the phases.

Table 8: Synthesis of output codes

Concept / Output codes:	Project plan	PSS Concept	Sales strategy	Business case	Requirements set	Detailed offering	Value proposition to customer	Successful test
A team with a mission*								
An understanding of customers' businesses*								
An understanding of where RailCo can add value*								
BTS revenue mechanisms				■				
Business case				■				
Client benefits							■	
Client capability gaps*								
Client impact assessment							■	
Client ROI and pricing							■	
Client, RailCo and supplier people, processes, organisation, information and technology							■	
Competition strategy*								
Complete requirements set					■			
PSS Concept		■						
Cost model*								
Customer needs					■			
Demonstrable value to customer							■	
Demonstrated benefits*								
Design briefs						■		
Detailed design						■		
Detailed offering						■		
Formal budget*								
Ideas for improvements*								
Ideas for improvements*								
Identified risks and mitigations*								
Incentive to implement*								
Initial requirements					■			
Innovative new PSS sold on the market*								
New pain / needs*								
Organisation required to deliver*								
Project plan	■							
Promising scenarios*								
Refined sales pitch*								

Output codes: \ Concept	Project plan	PSS Concept	Sales strategy	Business case	Requirements set	Detailed offering	Value proposition to customer	Successful test
Sales literature			■					
Sales strategy			■					
Service offering		■						
Service offering in principle		■						
Size of addressable market*								
Successful test								■
Theoretical solution		■						
Time schedule	■							
Understanding of the value brought*								
Unfulfilled requirements*								

*Codes that have no similarity with other codes

Respondents were subsequently asked to identify which outputs relate to which phases. Table 9 presents a summary of the reported relationships for the identified outputs.

Table 9: Outputs identified from interviews linked to phases identified from interviews

Output codes: \ Phase	Create team	Analyse customers	Design	Idea generation	Articulate value proposition	Prototype	Implementation	Evaluation	Assess resource needs*	Create project plan*	Gap analysis*	Production*
A team with a mission*	■											
An understanding of customers' businesses*		■										
An understanding of where RailCo can add value*		■										
Business case					■							
Client capability gaps*		■										
Competition strategy*												
Cost model*					■							
Demonstrated benefits*						■						

Phase / Output codes:	Create team	Analyse customers	Design	Idea generation	Articulate value proposition	Prototype	Implementation	Evaluation	Assess resource needs*	Create project plan*	Gap analysis*	Production*
Detailed offering			■									
Formal budget*												
Ideas for improvements*						■		■				
Identified risks and mitigations*			■									
Incentive to implement*						■						
Innovative new PSS sold on the market*							■					
New pain / needs*								■				
Organisation required to deliver*									■			
Project plan										■		
Promising scenarios*		■										
PSS Concept				■								
Refined sales pitch*						■						
Requirements set		■										
Sales strategy			■									
Size of addressable market*		■										
Successful test						■						
Understanding of the value brought*						■						
Unfulfilled requirements*						■						
Value proposition to customer					■							

*Codes that have no similarity with other codes

Interviewees agreed that the synthesised inputs and outputs reflected their perspective of the PSS design process. However, although respondents identified 'Production' and 'Gap Analysis' as phases, no inputs or outputs were correspondingly identified. Similarly, although respondents initially identified 'competition strategy' and 'formal budget' as outputs, they did not identify which phase they output from. Respondents also identified 'technology enablers' and 'offers from suppliers' as inputs, however, respondents did not then identify which phase they were inputs to.

As such, it is not possible to determine which phases these inputs and outputs relate. More research is needed in order to gain greater insight.

By synthesising Table 6, Table 9 and the reported inputs, a summary of all the phases and the corresponding inputs and outputs identified by respondents are reported in Table 10.

Table 10: RailCo's PSS design process

Inputs	Phase	Outputs
- Skill sets - Availability of resources	**CREATE TEAM**	- A team with a mission
- A team with a mission	**CREATE PROJECT PLAN**	- Project plan
- Customer needs - Client's capabilities - RailCo capabilities - Client's business environment - Client requirements - Competitive pressure - Industry trends - PSS concept (from Idea Generation)	**ANALYSE CUSTOMERS**	- An understanding of customers' businesses - An understanding of where RailCo can add value - Client capability gaps - Requirements set - Size of addressable market - Promising scenarios
- An understanding of customers' businesses - An understanding of where RailCo can add value - Promising scenarios - Client capability gaps - Requirements set - New needs (from Evaluation)	**IDEA GENERATION**	- PSS concept (feeds back to Analyse Customers)
- PSS concept - Ideas for improvement (from Prototype and Evaluation) - Unfulfilled requirements (from Prototype)	**DESIGN**	- Detailed offering - Identified risks and mitigations - Sales strategy
- Detailed offering	**ASSESS RESOURCE NEEDS**	- Organisation required to deliver
None reported	**GAP ANALYSIS**	*None reported*

Inputs	Phase	Outputs
None reported	**PRODUCTION**	*None reported*
- Detailed offering - Organisation required to deliver	**ARTICULATE VALUE PROPOSITION**	- Business case - Cost model - Value proposition to customer
- Detailed offering - Sales strategy - Business case - An understanding of where RailCo can add value - Organisation required to deliver	**PROTOTYPE**	- Demonstrated benefits - Ideas for improvements (feeds back to Design) - Incentive to implement - Refined sales pitch - Successful test - Understanding of value brought - Unfulfilled requirements (feeds back to Design)
- Incentive to implement - Demonstrated benefits - Successful test	**IMPLEMENTATION**	- Innovative new PSS sold on the market
- Innovative new PSS sold on the market	**EVALUATION**	- Ideas for improvement (feeds back to Design) - New needs (feeds back to Idea Generation)

5 Discussion

This section contrasts the PSS design processes reported by literature and RailCo and reports on any limitations of RailCo's PSS design process.

5.1 Contrasting the processes

Although the PSS design process reported by RailCo participants is not the same as that reported by literature, there are similarities. Participants identified the 'Analyse Customer', 'Idea Generation', 'Prototype', 'Implementation' and 'Evaluation' phases which are consistent with the 'Analysis', 'Idea Generation & Selection', 'Prototype the PSS', 'Implementation' and 'Evaluation' phases reported by literature. Additionally, the outputs from the 'Project Initiation' phase include: 'a team with a mission' and 'a project plan'. These outputs are the same as those reported from the 'Create Team' and 'Create Project Plan' phases reported by RailCo (Table 11). As such, RailCo's 'Create Team' and 'Create Project Plan' could be considered sub-phases within a wider 'Project Initiation' phase that the literature reports.

Complementing this finding, existing project management methodologies identify skill sets, availability of resources and recommendations for improvements based on experience as inputs to the project initiation phase and a formal budget as an output (Bentley 2010, Kerzner 2009). Whilst skill sets and availability of resources are necessary for creating a project team, the project management methodologies extend the number of inputs to include the triggers for starting the project in the first place – e.g. from a market demand, business need, customer request, technological advance or legal requirement (Grant 2010).

Table 11: Comparison of phases between RailCo and literature

		Literature reported PSS design process						
		Project Initiation	Analysis	Idea Generation & Selection	Detailed Design	Prototype the PSS	Implementation	Evaluation
RailCo's reported PSS design process	Create team	□						
	Create project plan	□						
	Analyse customers		■					
	Idea generation			■				
	Design				■			
	Assess resource needs				□			
	Gap analysis				□			
	Production							
	Articulate value proposition							
	Prototype					■		
	Implementation						■	
	Evaluation							■

■ Phases are the same between RailCo and literature

□ RailCo phase included as a sub-phase within literature phase

These triggers are reported in both literature and RailCo processes as inputs to the analysis phase. RailCo do not identify the creation of 'a business coalition' as a specific output. If a new PSS design project is sufficiently large, it is likely that the detailed design, prototyping and implementation phases will be completed through partnership with other organisations, however, RailCo generally perform the analysis and idea generation phases internally. If a new PSS design project is small then RailCo perform all of the phases.

During the 'Analysis' phase, many of the inputs reported by the literature (see Table 5) correspond to the inputs reported within RailCo's 'Analyse Customers' phase (see Table 10) – e.g. 'industry

trends', 'client's capabilities', 'supplier's capabilities' and 'client's business environment'. In addition to these, participants further identified 'customer needs', 'client requirements', 'competitive pressure' and 'PSS concept' as inputs. Historically, RailCo's main business has come from customer requests (usually in the form of a tender). Although RailCo is making efforts towards proactively identifying customer needs and requirements before a tender, it is not surprising that many participants identify these requirements as inputs. Participants also identify 'PSS concept' as an input into the 'Analyse Customers' phase to determine whether other customers have a need for the PSS (i.e. to answer: "how scalable is the solution?"). Existing processes within literature fail to recognise competitive pressure as an input to an analysis phase, however, understanding the nature of the competition and how they might react to a new market offering is a part of the analysis for RailCo. Grant (2010) identifies that for an organisation to achieve a competitive advantage in their product or service offerings they must have knowledge on the competitor's organisation and resources. Taking this further, resource-based theory argues that for an organisation to achieve a sustainable competitive advantage through product-service offerings, its resources must be more valuable and rare compared to a competitors resources. Additionally, competitors must not be able to directly copy or substitute resources (Wernerfelt 1984, Barney 1991, Peteraf 1993).

RailCo do not identify 'a description of the system within which the innovation should take place' as an output within their process. This output was reported by DES resulting from the action 'determine the system that will be the 'playing field' of the project' (Brezet et al. 2001). Here DES is attempting to focus the scope of the PSS development into a specific area of the customer's business operation – e.g. energy, maintenance, etc. However, participants identified 'an understanding of customers' business' and 'client capability gaps' which could be considered within 'a description of the system within which the innovation should take place'. A description of the system will include elements of a customer's business (i.e. the environment in which the innovation will be implemented) and any weaknesses in that business. Similarly, 'an understanding of customers' business' (RailCo output) is required before 'understanding the benefits a client desires from a new offering' (literature output). This output is also similar to the 'understanding of where RailCo can add value' identified by participants. In addition, participants identified 'promising scenarios' as outputs. Typically, RailCo identify a number of potential future states and design PSSs that fit within these potential futures. RailCo also use the term 'requirements set' instead of 'solution requirements' - these outputs are analogous.

In addition to the similarities between the phases, RailCo report 'Assess Resource Needs', 'Gap Analysis', 'Production' and 'Articulate Value Proposition' phases that do not have a direct comparison with the phases reported within literature. Based on the definitions, the 'Assess Resource Needs' and 'Gap Analysis' phases are very similar - 'Assess Resource Needs' identifies resources that are needed to deliver the PSS whilst 'Gap Analysis' identifies whether RailCo currently have these resources. Although RailCo report these phases separately from the 'Design'

phase, literature within the service design field reports that the design phase includes the design of the service concept (the customer utility and benefits the service is intended to provide), the service process (the activities that must function if the service is to be produced) and the service system (the resources available to the process for realising the service concept) (Edvardsson & Olsson 1996). Within the context of product-service design it can be seen that 'Assess Resource Needs' and 'Gap Analysis' can be considered as sub-phases within the design of the (product-)service system in the 'Design' phase. Whilst the outputs from the expanded 'Design' phase are consistent with the 'Detailed Design' phase reported by literature, participants also identify 'organisation required to deliver' as a specific output. Participants argue that, for some PSSs, new resources and organisational capabilities will need to be developed in order to deliver them ("*I'm sure we have looked properly at the organisational impact of that – how do we re-organise to implement that new way of managing [PSS example]?*" (Director of Strategic Programmes). This has similarities with Edvardsson & Olsson (1996) who argue that organisations need to develop their customers, internal physical/technical resources, employees and existing control structures in order to design a service system.

Whilst RailCo's 'Articulate Value Proposition' phase has an output that is similar to the 'Detailed Design' phase within the literature (namely, 'business case' and 'client and suppliers business cases'), there are other outputs that are not reported. Given the findings reported, there is no evidence to support incorporating 'Assess Value Proposition' as a sub-phase within a broader phase. As its inputs are the outputs from the 'Design' phase (which includes the 'Assess Resource Needs' phase) it is likely that 'Articulate Value Proposition' occurs after 'Design'. Additionally, the definition of the 'Production' phase suggests that it may be an activity performed immediately prior to any form of implementation (i.e. the 'Prototype' or 'Implementation' phases), however, since the research did not identify either inputs or outputs to the 'Production' phase, there is no evidence to suggest that this is the case.

Once the 'Analyse Customers' phase is completed, inputs to following phases are mostly sequential (e.g. the 'requirements set' from the 'Analyse Customers' phase becomes one input to the 'Idea Generation' phase). However, one significant difference between the PSS design process reported in literature and that identified from the data is the significant amount of feedback. There is limited use of feedback with the PSS design processes proposed by literature. The exception to this is AEPSS where the final phase – process evaluation – creates feedback that can be used as an input to change the process for future designs, however, it is difficult to know what is fed back as no outputs are identified (Engelhardt *et al.* 2003). Participants identified that RailCo make use of five feedback loops within their PSS design process (Figure 5). Feedback loop 1 iterates between the 'Analyse Customers' and 'Idea Generation' phases to determine whether PSS concepts generated are scalable to other customers and markets. Feedback loops 2 and 3 encourage iteration of the detailed offering based on findings from prototyping the offering. For example, did the prototyping identify any requirements that the PSS does not fulfil? If the answer is

yes, these requirements become inputs into another iteration of the 'Design' phase. Similar to feedback loop 2, feedback loop 4 encourages continuous improvement in the PSS once it is in-service. Additionally, through delivering an existing PSS, the product-service provider may identify new problems or needs that the customer has. These are fed back to the 'Idea Generation' phase, triggering the start of a new PSS design process (feedback loop 5).

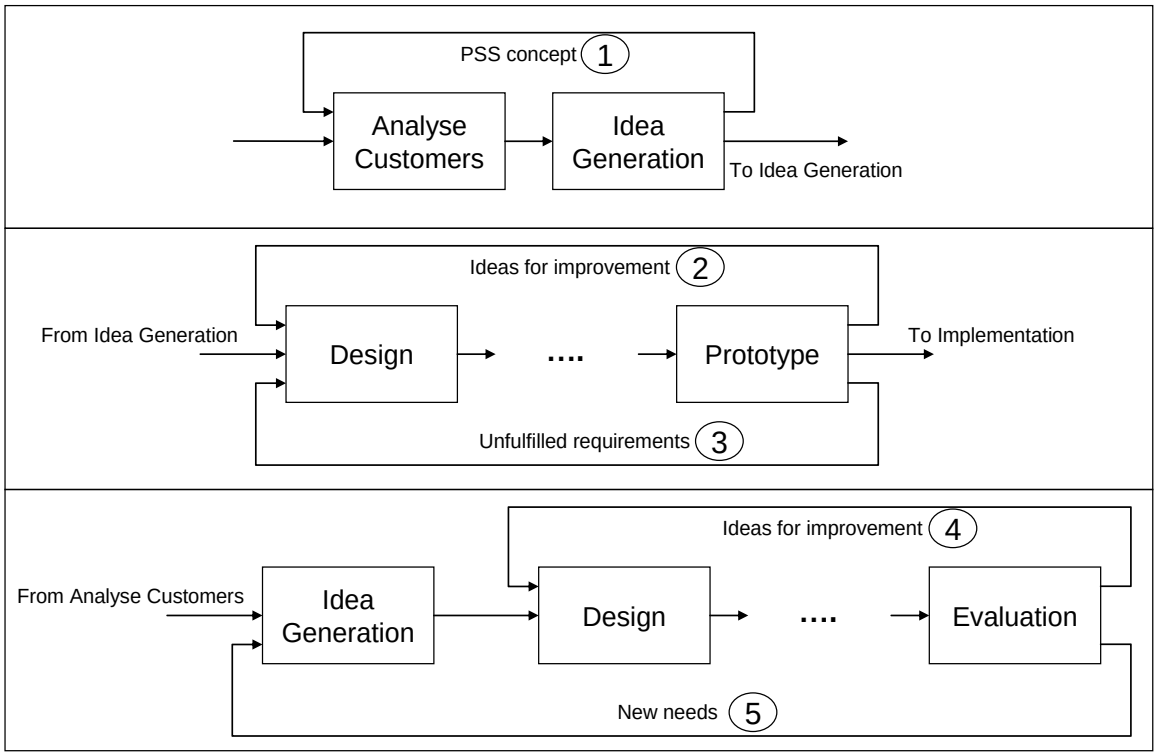

Figure 5: Summary of the feedback loops in RailCo's PSS design process

The nature of the feedback represented in Figure 5 makes it clear that RailCo's PSS design process is not sequential. Instead, there is iteration between phases to improve PSS ideas and concepts throughout the development, and the in-service support, of PSSs. This has synergies with iterative and incremental development where the design process is more cyclic, allowing for a more evolutionary approach to design. This iterative process of PSS design is fundamentally different from the approaches reported in the existing PSS design literature where the output of one phase becomes the input to the next in a linear way. DES recognises that "real development is never linear…sometimes it is necessary to jump back and forth between stages or to repeat stages more than once" (Brezet *et al.* 2001, p.13), however, without making explicit what the inputs and outputs are, it is difficult to determine what the feedback is, why something is fed back and the benefits of doing so.

5.2 Limitations of RailCo's PSS design process

So far the discussion has contrasted the six existing PSS design processes with the findings from RailCo. During the course of the interviews, some participants identified that they do not consider the design of products to be significantly different from the design of services:

I'm a bit more simplistic in that developing a solution, whether a service or a product, goes through similar sorts of phases. I think the difficulty comes in how you articulate…if you say to someone "here is a new pen and it writes upside down". If someone needs a pen that writes upside down they can think "yeah, I need one of them". Whereas if you are saying…in our way services are not necessarily about doing something – it might be around helping the client do something different (Head of Services Engineering)

The process identified by participants does have similarities with product design models – e.g. 'Idea Generation' could be mapped to 'Preliminary Conceptual Design' on the V-model (Wild 2007). This is not surprising given RailCo's heritage in engineering and manufacturing, however, as it looks to expand its services into less traditional areas (e.g. asset management, health monitoring and consultancy services) it may be necessary to design and develop services (and PSSs) separately from traditional products (Olivia & Kallenberg 2003).

Participants also identified that in some projects RailCo use approaches to PSS design that are not consistent with the process reported in Table 5. For RailCo, the lack of a documented process leads to variations in the design approach for different PSSs. It is this lack of repeatability in the approach to designing PSS that was often cited as the cause of many of the problems with existing PSSs. For example, one Bid Director commented: "*[PSS example X was a] good concept but not fully thought through in terms of how the benefits are delivered and the roadblocks to them being delivered*", however, understanding how benefits will be delivered is a part of the process identified by participants (Table 10). Interviewees when asked to identify the most successful PSS always selected a traditional offering:

I guess the most successful service offering we currently have…is actually our bread-and-butter maintenance offering where we've been able, because of the experience, to deliver something that we know works and can deliver with respect to what the customer wants in terms of availability and reliability (Director of Quality, Health, Safety and Environment)

This suggests that without a documented process RailCo are capable of designing traditional maintenance (product-related) PSSs because of the experience its employees have gained doing so over a number of years – teams develop routines for solving problems and learning consists of the process of exploring, selecting and replicating new routines for performance improvement (Zollo & Winter 2002). Thus, with greater experience, teams get better at executing existing routines (Huckman *et al.* 2009). However, RailCo are seeking to complement its traditional

(integration- and product-oriented) PSS offerings through the provision of optimised availability and reliability enabled by onboard condition monitoring equipment – a move towards service- and use-oriented PSSs. Where the organisation has limited experience in designing less traditional offerings, superior service is rarely delivered after being conceived and designed in an ad hoc, non-repeatable fashion (De Jong & Vermeulen 2003, Reinoso *et al.* 2009). Thus the RailCo process reported can, at best, be described as an "ideal" process that RailCo aspires to achieve for the design of all of its new PSS.

6 Conclusion and future work

This research has reported that within the servitization field, the existing literature offers little advice to product-service providers seeking to design new PSSs. Whilst the existing literature reports on a small number of proposed methodologies, these have not been evaluated with respect to an industrial organisation seeking to servitize. Through an exploratory single-case study of one successful product-service organisation, the research reported within this paper builds upon existing literature by contrasting existing approaches to PSS design with an industrial organisation.

Key findings from this research suggest that the existing PSS design process reported by literature do not fully reflect industrial PSS design practice. This research paper reports on four significant differences that have been identified between literature and the case study organisation:

- Two new phases were identified – 'Production' and 'Articulate Value Proposition' – however, more research is needed to determine whether these are sub-phases within much larger phases or should remain as phases in their own right. More research is also needed to identify the inputs and outputs to the 'Production' phase
- 18 inputs and 11 outputs were identified that are not included within the processes reported by the existing literature; including inputs to the 'Project Initiation' phase and inputs and outputs to the 'Evaluation' phase where the existing literature identified none
- Whilst there is limited discussion of the role of feedback within the existing literature, the reported PSS design process from an industrial organisation makes use of five feedback loops
- The presence and nature of the feedback loops identified suggest that the PSS design process has synergies with iterative and incremental development, following a cyclic process with iteration between phases. This is in stark contrast to the PSS design process reported in literature where outputs from one phase become the inputs to the next in a sequential manner

Given these findings, the processes reported within the existing literature can not be considered complete and more research is needed before general guidelines, tools and techniques can be created to aid practitioners within servitized manufacturing organisation design new PSS offerings.

The research reported in this paper is intended for use by both the academic and practitioner communities. It is hoped that these findings will open a debate around how product-service providers can/should design PSSs and begin to build a body of theory that addresses the current gap in the literature. The literature analysis, the experiences of the case study organisation and the discussion presented should provide practitioners with examples of how they could potentially design new PSSs within their own organisations. A specific recommendation for RailCo is that they should rapidly document their "ideal" PSS design process and mandate its use on all future PSS design projects to reduce the variation in the quality of the outputs of PSS design projects.

6.1 Research limitations and future work

The research presented in this paper has three main limitations. Firstly, the research is based on a singe-case study. Thus the different phases, inputs and outputs identified in the PSS design process are limited to one organisation operating exclusively in one market. Insights from other organisations operating in different or multiple markets would provide additional depth and perhaps yield converging findings. Secondly, since RailCo do not follow a documented process for designing new PSSs, the identified design process represents, at best, the "ideal" process that they would like to follow for all projects. As such the process that an industrial organisation could follow to create integrated PSS may not be at a sufficient level of detail to be immediately used by practitioners and some tailoring may be required. Thirdly, although the research identifies that the existing approaches to PSS design within the literature are not complete, the research methodology did not elicit a complete PSS design process from RailCo. Further research in this area should be conducted to evaluate, in greater detail, whether the existing approaches are complete and to provide practitioners with specific tools, methods, techniques and guidelines for creating new product-service systems.

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Paper 4

Clayton, R.J., Backhouse, C.J., Dani, S. 2012, “Comparing existing approaches to product-service system development with the practice of servitized manufacturers”, *International Journal of Production Economics*, vol.XX, no.XX, ppXX-XX (Submitted)

Comparing existing approaches to product-service system development with the practice of servitized manufacturers

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Abstract

Driven by the highly cyclical nature of their increasingly commoditised product offerings, many capital goods manufacturers are seeing the benefits of delivering services integrated with their product offerings. Whilst existing research is almost unanimous in advocating the value of a servitization strategy, understanding how these product-service systems (PSSs) can be developed within manufacturing organisations remains a significant challenge. The closely related PSS field is more mature in this area proposing a number of models, but these focus on developing products and services with lower environmental impacts rather than as competitive propositions. The research reported builds on the existing approaches to create a model of PSS development that better reflects the practice of servitized manufacturers. Initially, the existing models were synthesised and compared to the practice of one servitized manufacturer through a single case study. Findings from the case study highlighted differences relating to the activities used to operationalise the processes within PSS development, suggesting that the processes are executed differently from that reported by existing literature. A survey was used to investigate whether the differences were generalisable to a larger sample of servitized manufacturers. Findings from the survey validated much of the case study results, but findings suggest that two processes reported by the literature are not executed in the PSS development practice of servitized manufacturers and four new processes were identified. Based on the results, a new model of PSS development is proposed, better reflecting the practice of servitized manufacturers and aiding them improve their PSS development endeavours.

Keywords Servitization, product-service system; PSS; PSS development

1 Introduction

Driven by the highly cyclic nature of their increasingly commoditised product offerings, the literature reports that organisations are transitioning from producing products to providing services (Wise & Baumgartner 1999, Parry *et al.* 2011). Within capital goods manufacturers, this transition often results in the provision of integrated product-service systems (PSS) (Neely 2008, Baines *et al.* 2009) (e.g. the provision and ongoing support of an aeroengine). The transition towards providing

PSSs is known as servitization (Vandermerwe & Rada 1988) with Baines *et al.* (2009) defining it as "the innovation of an organisations capabilities and processes to better create mutual value through a shift from selling product to selling PSS" (p.555). Users of PSSs experience enhanced value due to the comprehensive nature of the propositions and improvements in through-life support (Johnson & Mena 2008).

Originating from the environmental and social sciences literature, many authors see the purpose of a PSS as a competitive proposition that achieves greater environmental sustainability than purely products or services (Goedkoop *et al.* 1996, Mont 2000, Manzini & Vezzoli 2003). Although not emerging from the servitization field, numerous authors have reported that the PSS and servitization literatures are closely related (Neely 2008, Baines *et al.* 2009, Baines *et al.* 2007, Neely 2007, Martinez *et al.* 2010) with many identical principles (Tukker & Tischner 2004). Given this, a PSS is defined as "a marketable set of products and services capable of jointly fulfilling a user's need" (Goedkoop *et al.* 1996, p.18). Within the context of this research, the PSSs provided by capital goods manufacturers contain a physical core product which is supplemented by specific services (Aurich *et al.* 2009), enabling the system to deliver sustained functional behaviour (Vasantha *et al.* 2011). For example, the PSSs provided by rolling stock manufacturers might include, in addition to the train as the physical product: maintenance, spares provision or remote condition monitoring services which enable the on-going operation of the product. However, this represents one potential servitization strategy – providing maintenance and operational services (Olivia & Kallenberg 2003). Other strategies such as professional services are not considered within this research.

Within the servitization field few research studies have sought to investigate integrated product-service development in manufacturing firms (Neely 2008, Baines *et al.* 2009). However, research outside of the servitization field has reported that "it seems to be worthwhile to explicitly organize the process of developing new services" (De Jong & Vermeulen 2003, p.844) with the most successful firms being those that have formal processes (de Brentani 1991, Kelly & Storey 2000).

Although limited research has been conducted within the servitization field proposing approaches for developing PSSs, a number have been proposed within the product and service development literatures. However, traditional approaches to product development such as the 'V' model (Royce 1970) or the stage-gate model (Cooper 1986) have focused on the development of products separately from services. Similarly within the service development literature, processes such as the normative model of new service development (Scheuing & Johnson 1989) and the new service development process cycle (Johnson *et al.* 2000) have focused on service development separately from product development. Whilst research has been conducted that attempts to systemise the development of services in an approach to capture services as an R&D object (termed 'service engineering) (Bullinger *et al.* 2003), little emphasis has been place on the design of products and services concurrently (Alonso-Rasgado *et al.* 2004, Kimita *et al.* 2009).

The PSS literature is more mature in this area and a number of approaches have been proposed (e.g. Brezet *et al.* 2001, Engelhardt *et al.* 2003, Luiten *et al.* 2001, van Halen *et al.* 2005). However, these approaches principally focus on developing PSSs that are optimised to decrease the environmental impact of products and services. Limited research has been conducted to investigate whether they can be applied by servitized manufacturers to develop competitive PSSs. This represents a knowledge gap within the servitization literature. Investigating whether the PSS development approaches, reported within the PSS literature, reflect the PSS development practice of servitized manufacturers will lead to an improvement in industrial practice through the creation of guidelines, tools and techniques to aid practitioners develop new PSSs.

This paper reports the results of an exploratory single-case study and survey to investigate the PSS development practice of servitized manufacturers. The paper begins by reviewing the extant literature associated with PSS development, synthesising a model of PSS development. The results from the case study are then presented and a number of differences between the PSS development practice of one servitized manufacturer and the literature are identified. To determine whether the findings from the case study are generalisable to a larger sample, the results of a survey are presented. By synthesising the case study and survey results, a new model of PSS development is proposed that better reflects the PSS development practice of servitized manufacturers. This model can be used by organisations improve their PSS development practices and increase the likelihood of developing successful PSSs.

2 Literature review

Within the context of this research, the PSSs provided by capital goods manufacturers contain a physical core product which is supplemented by specific services (Aurich *et al.* 2009), enabling the system to deliver sustained functional behaviour (Vasantha *et al.* 2011). This emphasises the 'sale of use' rather than the 'sale of product' where customers pay for using an asset (Baines *et al.* 2009). This restructures the risks, responsibilities and costs traditionally associated with owning and operating assets; enabling the manufacturer to focus on sustaining the functional performance and reducing total cost of ownership. Given this, PSS development is defined as: a*n overall approach to creating products and services that, when integrated, are capable of fulfilling customers' needs and delivering sustained functional performance*. To achieve this, PSS development consists of processes executed within phases by members of a PSS development team. Here, a phase is defined as "a period within the life cycle of a system that relates to the state of the system" (ISO 15288 2002, p.4) whilst a process is defined as a "set of interrelated or interacting activities which transforms inputs into outputs" (ISO 15288 2002, p.4). By identifying phases and processes, it is possible to identify the "set of activities, actions, tasks, and evaluations" (Cooper *et al.* 1994, p.283) that organisations need to conduct to develop PSSs.

2.1 Existing approaches to PSS development

A number of PSS development approaches have been proposed. From 2002 to 2004 the SusProNet project (an EU Fifth Framework Programme), which aimed to develop and exchange expertise on the design of PSSs for sustainable competitive growth, identified thirteen separate approaches (Tukker & Tischner 2004). The majority of these focus on specific phases within the overall development process. For example, the INNOPSE (Innovation Studio and exemplary developments for Product Service Engineering) project primarily focused on the idea development process (Rovida *et al.* 2009). Similarly, the PSS Innovation Scan for Industry (Tukker & van Halen 2003) and the Service Innovation Workbook (James 2001) focus on analysing customer needs before generating and screening ideas. Whilst these approaches have their merit, due to their incompleteness they do not provide enough information to describe all of the phases within PSS development. Of the approaches identified within the SusProNet project, four cover all phases within PSS development: designing eco-efficient services (Brezet *et al.* 2001), the Austrian eco-efficient PSS project [7] (Engelhardt *et al.* 2003), the methodology for product-service system innovation (van Halen *et al.* 2005) and the Kathalys method (Luiten *et al.* 2001).

In addition to these, but still emerging from the PSS literature, Mont (2000) proposes creating PSSs in an incremental fashion based on the Deming plan-do-check-act cycle, whilst Goedkoop *et al.* (1996) offers a four-axis model for auditing PSSs (ecology, economy, identity/strategy and client acceptance axes). Maxwell & Vorst (2003) report on the creation of the sustainable product and service development method, but it predominately advises the designer of the important criteria when optimising for sustainability in products and services. Differing from these approaches, Morelli (2003) use a design exploration process to investigate how technology, organisation and culture impact upon the design profession when creating PSSs. Whilst this approach provides information to describe all of the phases within PSS development, it is aimed at supporting the design profession to think about PSSs and not at supporting organisations to develop new product-service offerings. Given that Morelli (2003) reports the successful application of the design exploration process to developing a PSS, it is considered within the context of this research.

Outside the PSS literature, a small number of approaches have been proposed that seek to integrate product and service development. For example, Aurich *et al.* (2006) proposes an approach for technical service development that has been modified from the product development approach proposed by Wheelwright & Clark (1992). Here, the technical service development process consists of six phases. Each phase is made up of a number of processes (e.g. situation analysis is executed within the demands identification phase). Aurich *et al.* (2006) proposes that integrated PSSs can be developed by combining different processes from the product and technical service development approaches. Additionally, modified from the service development literature, Kindström & Kowalkowski (2009) and Kar (2004) propose approaches to industrial service and information service developments respectively. Kindström & Kowalkowski (2009)

[7] This publication is only available in German

propose a cyclic framework consisting of four phases: market sensing, development, sales and delivery. In contrast, Kar (2004) proposes a linear approach to developing PSSs consisting of five phases: analysis, preparation, synthesis, implementation and test. Although created specifically for information services, Kar's methodology is described as a service system design approach, suggesting that it may be applicable more generically. Consequently, Kar's model of information service development is considered within this research. Similarly, although outside the PSS development literature, Kindström & Kowalkowski's model relates directly to developing services within manufacturing organisations and is considered within this research.

2.2 Identification of common phases

Analysing the eight identified approaches to PSS development and synthesising the various phases leads to the identification of eight phases: project initiation, analysis, idea generation and selection, detailed design, production, prototype, implementation and evaluation.

The literature reports project initiation as being the first phase within PSS development. Project initiation begins when "one person, company or institute gets the idea for a function or system level innovation and makes sustainability part of this innovation" (Brezet *et al.* 2001, p.13). The project management literature, however, reports that projects are triggered from a market demand, business need, customer request, technological advance or legal requirement (Grant 2010). This suggests that some form of analysis is required prior to project initiation to identify the market demand, business need or technological advance. Going further, the PRINCE2 project management methodology reports that "before any work is commenced or resources are committed, there is a requirement to be able to answer the following question: 'Do we have a viable and worthwhile project?'" (OGC 2009, p.121). This suggests that project initiation occurs after a concept design phase where a PSS concept has been created and evaluated for its viability. This has similarities the PSS development approach reported by Luiten *et al.* (2001) who describe that "building a partnership and reaching commitment is very important in this [systems design] phase" (p.192). Similarly, in the service development approach proposed by Johnson *et al.* (2000) and expanded on by Froehle & Roth (2007) a project authorization activity is executed within a phase where the viability of the concept is evaluated. Froehle & Roth (2007) term this phase analysis. Here, the service concept is initially designed before analysis is conducted to evaluate the viability of the new service concept. If the service concept is considered viable, a project is authorised to develop the service concept into an implementable service offering. Whilst project authorization refers to the act of approving the new service development project (Froehle & Roth 2007), the reported project initiation phase also consists of activities consistent with project authorisation (van Halen *et al.* 2005).

Given that there is some agreement between the new service development and project management literatures in reporting project initiation as occurring after the analysis and a concept design phases, it is curious that the PSS development literature proposes it as the first phase. One

possible explanation is made by Tukker & Tischner (2004) who describe a number of the PSS development approaches as 'workshop methodologies'. Here, the identification of future markets and identification of possible PSS ideas is conducted by a team in a series of workshops. In this workshop approach, project initiation is consistent with being performed as the first phase as it involves the creation of a project team (i.e. identification of workshop participants) and the definition of a number of goals or deliverables. Given the definition of PSS development, it is unlikely that all phases within the PSS development could be completed in workshops; although it is likely that a number of activities might be – e.g. generating and screening new ideas for PSS concepts (Tukker & van Halen 2003, James 2001). Consequently, project initiation is not considered to be the first phase of the PSS development. Reflecting the new service development process of Froehle & Roth (2007), process initiation is considered to be a process within a concept design phase that is concerned with formally instigating a project to develop and deliver a PSS once a PSS concept has been defined and evaluated for its viability.

Whilst it has been suggested that production should be considered as a separate phase within PSS development (Clayton *et al.* 2012), its definition ("the act of realising the product elements") has similarities with the definition of implementation ("the product components are produced"). This has similarities with the product development literature where products are produced during a 'realisation' phase (Roozenburg & Eekels 1995). As such, throughout this paper the production phase is not considered separately from implementation but a process within it.

Additionally, whilst the literature reports evaluation as a separate phase within PSS development, its definition ("activities associated with making an assessment of the PSS") suggests that it can be considered as a process applied within a number of phases. This has similarities with the stage-gate approach to product and service development where progression between phases is determined by 'gates' (Cooper 1986). During each gate the continuation of the project is decided as a result of an evaluation of the information available (e.g. risk analyses, business cases, availability of resources, etc) (Cooper 1986).

The above discussion suggests that of the 'phases' synthesised from the literature, a number can be considered processes within broader phases (e.g. prototype and implementation could both be considered to refer to a broader delivery phase). Given this, the phases within PSS development can be simplified to analysis, concept design, development and delivery (Table 1).

Table 1: Definitions of the phases within PSS development

Phase	Definition
Analysis	Building an understanding of the manufacturing organisation's customers, its installed base, competitors and internal organisation (van Halen et al. 2005, Kindström & Kowalkowski 2009) in order to identify a first set of objectives and requirements for the PSS concept (Aurich et al. 2006). Analysis is performed continuously (Day 1994) to identify customers' latent needs (i.e. those needs that customers have not articulated but could be fulfilled through PSSs)
Concept design	The generation, evaluation and screening of ideas and development of PSS concepts (Aurich et al. 2006) fulfilling the identified customer needs. Projects are initiated to further develop the most feasible and financial viable PSSs
Development	Transforming the PSS concept into a viable, marketable PSS offering (Aurich et al. 2006). All product elements of the PSS are developed concurrently with the service elements and preparations are made for delivery.
Delivery	The product elements are produced and all preparations to execute the service elements are made (Brezet et al. 2001). The delivery phase can be applied with one customer specifically, principally to test and prototype the PSS, before being delivered to customers in the wider market. Delivery is ongoing, ensuring that functional behaviour is sustained over time

2.3 Identification of the processes within the phases

Although the existing PSS development approaches are consistent in reporting phases, current literature is inconsistent in reported further levels of detail. For example, van Halen *et al.* (2005) reports that phases consist of steps, which are made up of processes in which activities are executed, whilst Luiten *et al.* (2001) and Morelli (2003) do not report at the process or activity level.

Given this inconsistency, processes were synthesised by identifying the interrelated and interacting activities reported in the literature. Activities were considered as specific actions that seek to operationalise processes. Where no activities were reported, processes were used. If processes were not reported (e.g. Luiten *et al.* 2001), this source was not used to synthesise common processes. For example, literature reports that the following activities are performed during the analysis phase:

- Customer analysis - build an understanding of customers' latent needs and how these may evolve over time (van Halen *et al.* 2005, Kindström & Kowalkowski 2009)
- Competitor analysis - identification of potential rivals for meeting the customers' needs (Bergen & Peteraf 2002)
- Identify new technology - develop an understanding of how new technologies might be used to assist customers' practices (Neely 2008)

- Identify strategic partners - identify potential partners to aid in the development and delivery of PSSs (Brezet *et al.* 2001, Kar 2004)

These activities are interrelated – they all refer to performing analysis on different aspects of the servitized manufacturer's business and market to identify opportunities to offer PSSs. Given the high level of interaction between these activities, they were combined into one process – market research. A total of 41 separate activities were identified as terms that operationalise fifteen processes (Table 2).

2.4 Synthesised model of PSS development

Given the common phases and processes identified from within the PSS development literature, PSS development can be said to be made up of four distinct phases. For each phase, processes have been synthesised from the approaches where they (or activities) have been reported. The customer involvement and evaluation processes are reported as being executed in numerous phases (Figure 1).

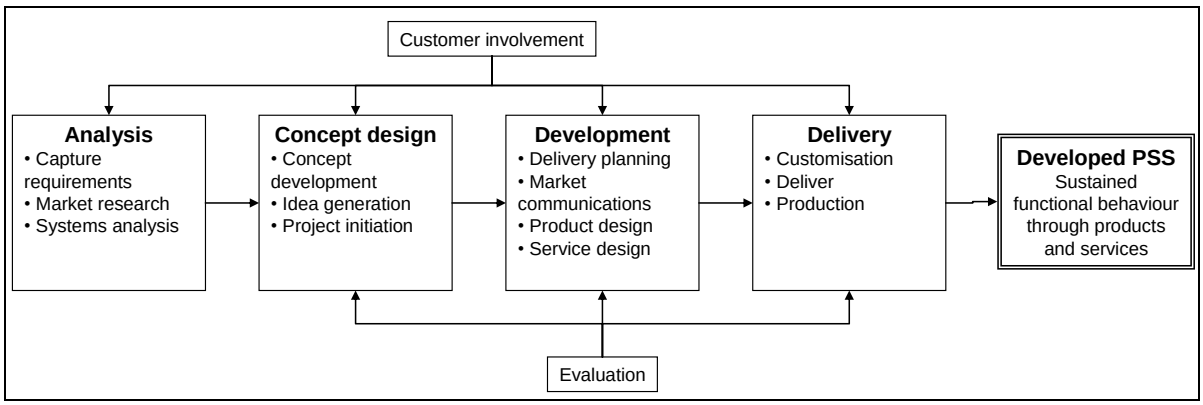

Figure 1: Model of PSS development synthesised from literature

Table 2: Common processes within PSS development

Processes	Definition	Activities	Sample reference
Capture requirements	Requirements are defined that describe the functionality that the PSS should deliver	Define requirements	Brezet et al. (2001), Kar (2004) and van Halen et al. (2005)
Concept development	Identifies: the total benefits that customers are likely to receive from the PSS and estimates what this might be worth to customers; and the form of the service and the characteristics of the products required to enable the service to be delivered are designed	Define value of offering; design the service and product characteristics	Brezet et al. (2001) and van Halen et al. (2005)
Customer involvement	Customers are involved in dialogue to identify their needs and co-design and co-produce the PSS	Generate an understanding of the objectives; selection of engagement method; involve customer; integrate insights	van Halen et al. (2005)
Customisation	The tailoring of the product and/or service elements to specific customers' businesses	Describe main elements; propose variations	van Halen et al. (2005)
Deliver	Both manufacturer's and customers' staff are executing the agreed work procedures/service process (i.e. co-production)	Provide resources; execute agreed work procedures	Kindström & Kowalkowski (2009)
Delivery planning	Providing guidelines for delivering the PSS, identifying potential obstacles and specifying tools and technologies that might aid in delivery	Identify delivery issues; identify delivery tools and instruments	Aurich et al. (2006)
Evaluation	Occurs throughout PSS development and is ongoing during delivery. During development 'evaluation' primarily involves making an assessment of the PSS concept to determine its technical and financial feasibility. Once the PSS is being delivered, 'evaluation' is ongoing to monitor customers' use of PSSs	Define evaluation criteria; monitor customer's response and usage; measure the value provided; evaluate the PSS; write evaluation report	Brezet et al. (2001), Aurich et al. (2006)

Processes	Definition	Activities	Sample reference
Idea generation	Generating, evaluating and screening potential PSS ideas that will fulfil the identified customer needs	Generate ideas; select ideas; evaluate ideas	Brezet et al. (2001)
Market communications	Creating and implementing a strategy to communicate the value of the PSS to existing and potential customers	Quantify value of the PSS; communicate	Kindström & Kowalkowski (2009)
Market research	An ongoing process to Identify customer needs as well as monitoring competitive activities, staying on top of industry events, analysing new business opportunities and searching out strategic partners	Customer analysis; competitor analysis; identify strategic partners; identify new technology	Kar (2004) and van Halen et al. (2005)
Product design	Identification, selection and specification of the technical components required to enable the PSS to be delivered	Specification of technical components; identification of technical components; selection of technical components	Kar (2004) and Aurich et al. (2006)
Production	The realisation of the product elements within the PSS	Realise the product elements; install the product elements	Clayton et al. (2012)
Project initiation	Authorisation to begin a PSS development project is given and the resulting goals and plans are documented	Project authorisation; define goals; create team; create project plan	Kar (2004) and van Halen et al. (2005)
Service design	The co-design of the service process and service system between manufacturer and customer	Specify the service process; specify the service system	Aurich et al. (2006)
Systems analysis	Gaining an understanding of the use of current products and services to identify opportunities for new PSSs	Understand usage profile of existing products and services; gain customer feedback; identify products	van Halen et al. (2005)

3 Research question and methodology

3.1 Research question

Whilst both theoretical and empirical evidence has been cited from the PSS development and wider literature to support the identification of, and relationships between, the phases and processes within Figure 1, its ability to represent PSS development within servitized capital goods manufacturers remains untested.

The research reported within this paper was motivated by a desire to fill this knowledge gap by answering the following research question:

To what extent does the model of PSS development, synthesised from the PSS literature, reflect the PSS development practice of servitized manufacturers?

Answering this question will allow for the creation of guidelines, tools and techniques to aid practitioners improve their PSS development practice.

3.2 Research methodology

To investigate the model of PSS development in practice, a mixed methods strategy was adopted (Cresswell 2007, Cresswell & Plano Clark 2007). Three main arguments are presented in favour of mixed methods approaches:

- Real world problem situations are multi-dimensional (Boyer & Swink 2008)
- Different approaches are suitable at different stage of research intervention (Cresswell 2003)
- Using mixed methods can provide triangulation, validating the results (Jick 1979)

Mixed methods strategies are gaining popularity in the operations management literature (Boyer & Swink 2008); providing an opportunity to develop a more holistic understanding of real world problem situations (Mingers & Gill 1997).

Mixed methods research is defined as “the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g. use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breath and depth of understanding and corroborations” (Johnson *et al.* 2007, p.123). Since the development of PSSs is a complex phenomenon and to ensure that industrial practice was understood, a single-case study was adopted as it permits for deep research enquiry and comes as close as possible to the research phenomena (Dyer & Wilkins 1991). Given the limitations on generalisability caused by the use of a single-case study (Yin 2003), a survey was used as a secondary research method to increase the validity of the findings.

3.3 Case study

3.3.1 Selection of focal organisation

The research sought to investigate a manufacturer who has made significant gains in transitioning to being a product-service provider. Applying the definition of the term 'case' presented by Miles & Huberman (1994) as "a phenomenon of some sort occurring in a bounded context" (p.25), the case selection criterion was set as:

A contemporary manufacturing organisation that supplies products and services in the business-to-business environment that, when integrated, fulfil customers' needs and deliver sustained functional behaviour

Complying with these selection criteria, the UK division of an original equipment manufacturer that designs, manufactures and services high-value capital equipment for the railway sector was chosen. For confidentiality reasons and to ensure greater freedom in discussing the findings, the company is referred to as RailCo. Within its UK division, RailCo generates approximately 50% of its revenues from services related to its products – e.g. maintenance, spares services and data provision services.

3.3.2 Data collection instrument

A semi-structured interview was developed as the primary means of data collection. Given that previous research is consistent in reporting the phases within PSS development, the interviews conducted within this research focused on determining the processes and their relationships to the phases. To enable greater comparison with the literature, the interview design sought to identify the activities executed during PSS development. Similar to the analysis conducted in the literature review, activities reported by interviewees were synthesised to identify processes within RailCo's PSS development practice. The approach to data collection meant that specific questions changed between interviews, but common topic areas were covered including:

- The interviewee's perspective of PSS development
- The activities that are performed within PSS development projects
- The tools, methods and techniques used within PSS development
- Examples of unsuccessful projects and why the interviewee believed weaknesses in development made the project unsuccessful
- Examples of successful projects and why the interviewee believed strengths in development made the project successful

At the start of each interview, the interviewer defined the PSS concept to interviewees. Interviewees were asked to provide examples of PSSs from RailCo's existing product-service offerings. For example, one Commercial Account Director identified eight product-service offerings (e.g. asset information management services enabled by on-board condition monitoring equipment).

During the course of data collection it became clear that RailCo do not follow a documented approach to PSS development. To ensure that the undocumented approach was understood, respondents from different functional areas were interviewed. Each of the ten interviews, consisting of twelve interviewees and covering four functional areas, lasted between 40 and 120 minutes and was recorded and subsequently transcribed verbatim. In addition to semi-structured interviews, company reports and documents specifically referenced by interviewees were used to collect data.

3.3.3 Data analysis

The aim of data analysis was to interpret the data collected from interviews and company documents in a manner that provided insights into PSS development. To achieve this, it was important to reduce the data into categories through a process of coding (Miles & Huberman 1994, Glaser & Strauss 1967). Closed coding was used to extract phrases relating to the activities and processes reported within the model of PSS development. Additionally, to determine whether RailCo's PSS development practice makes use of processes or activities not reported in the literature, open coding was used to identify new constructs. Once all data was analysed the results were fed back to interviewees who were provided with an opportunity to amend their view. Based on the findings, five hypotheses were proposed.

3.4 Survey

3.4.1 Survey design and pre-test

The survey consisted of six sections (). The first section sought background information about the respondents (e.g. their job title, how many years experience they have developing PSS, the number of PSS development project they have been involved with and examples of PSSs that they have been involved in developing). Sections two to six presented respondents with a series of statements. Using a five-point Likert scale, respondents were asked the extent to which they agreed or disagreed that each statement was always conducted during the PSS development projects that they have been involved in. The initial survey instrument was pre-tested using representatives from the target population. Respondents' experiences regarding the ease of filling out the survey (in terms of time and complexity) and the nature of the questions were evaluated. As a result, changes were made to approximately 10% of questions and the survey was shortened by around 20%.

3.4.2 Definition of population and respondents

To obtain results from the survey that were comparable with the results from the case study, the same criterion for selecting focal organisations was used. To identify this target population, companies were identified from Bureau van Dijks's FAME database of UK and Irish companies. After Neely (2008), initially firms with SIC codes in the range 10-39 were extracted. This resulted in 119,990 companies. The second step involved adding a control for company size. Only firms with over 100 employees were included. This resulted in 5,933 companies. Finally the 'trade

description' field (a text based description of the company) was searched for the term "service". This resulted in 129 companies. A review of the descriptions of these firms highlighted that a number are not servitized manufacturing firms (e.g. Counterline Limited who manufacture food service counters and displays). These organisations were removed, resulting in a population of 109 companies.

3.4.3 Application of the survey instrument

Whilst Dillman *et al.* (2009) reports that self-administered surveys generally result in a lower response rate compared to oral surveys, oral surveys increase the risk of respondents providing answers that would please the researcher. Given that this survey sought to investigate respondents' perceptions of PSS development within their organisations, a self-administered survey was adopted to increase the likelihood of reporting negative information and attitudes; increasing the chances of full and frank responses. As such, respondents were asked to complete a document based questionnaire in isolation from the researcher. To further encourage respondents to answer questions fully, the survey did not seek information regarding the respondents' identities or organisations.

The data collection took place between July and September 2011 and yielded 31 fully filled out responses, providing a response rate of 28.4%.

3.4.4 Processing the survey data

The analysis of the survey data was conducted in SPSS 18 and took place in three stages. First, to identify whether the survey data reflected the processes reported by literature, factor analysis was conducted. To ensure that a set of measures referred to a single process, the first eigenvalue had to be greater than one and no subsequent eigenvalue could be greater than or equal to one (Norusis 2005). Given that a number of measures were used to operationalise each process, the reliability of all measures in the form of internal consistency was tested using the Cronbach's alpha coefficient (Cronbach 1951). Whilst a Cronbach's alpha coefficient of 0.7 is often reported being the minimum coefficient for acceptable reliability (Nunnally 1978), for identifying new constructs a coefficient of 0.6 is sufficient (Robinson *et al.* 1991). Based on these results, the hypotheses generated from the case study findings were updated to reflect any changes to the processes suggested from the survey data.

Once valid processes were identified, the second stage of analysis sought to test whether the relationships between the phases (hypothesis 1) are sequential, as reported within the literature, using an ordinary least squares regression analysis. The third stage of analysis sought to validate the allocation of the processes to each phase (hypotheses 2 to 5) determined from the case study findings and factor analysis. These allocations were tested using an ordinary least squares regression analysis.

4 Case study results

The aim of this analysis was to identify whether the processes reported within the model of PSS development synthesised from literature are executed during the PSS development practice of RailCo. During the closed coding, 184 phrases were extracted from the interview transcripts which related to the activities used to operationalise the processes reported within the model of PSS development. Table 3 presents a summary of the number of phrases extracted from each interview relating to the processes.

Table 3: Count of phrases referring activities within each process

Phase	Process	Interview										Total
		1	2	3	4	5	6	7	8	9	10	
Analysis	Systems analysis	0	1	1	0	1	1	0	0	3	0	7
	Market research	2	1	2	3	6	4	10	0	3	2	33
	Capture requirements	2	1	1	0	0	0	0	0	0	0	4
Concept design	Idea generation	1	1	3	2	1	1	0	0	0	0	9
	Concept development	2	2	1	4	3	1	0	0	1	3	17
	Project initiation	4	0	1	0	0	0	0	0	0	0	5
Development	Product design	0	4	0	2	0	1	0	0	0	0	7
	Deployment planning	0	0	2	0	0	1	0	0	0	1	4
	Service design	2	1	2	4	5	12	0	0	1	0	27
	Market communications	1	1	0	1	6	2	1	1	0	4	17
Delivery	Production	0	0	0	2	0	0	0	0	1	0	3
	Deliver	2	0	1	3	0	2	1	0	1	0	10
	Customisation	0	0	0	1	0	0	1	2	0	3	7
	Evaluation	2	1	3	1	1	1	0	0	2	2	13
	Customer involvement	4	2	3	4	3	3	1	0	0	1	21
Total												184

Of the phrases extracted, two-thirds of them refer to activities performed within five processes: market research, service design, market communications, concept development, and customer involvement. For example, the phrase: *"…understand what it is that the customer wants, what are they trying to do, what is their business strategy saying, where are they trying to go?"* (#6)[8] relates to activities performed within the market research process. Specifically, they provide evidence for the customer analysis activity. The high proportion of phrases referring to activities within these

[8] Quotes are provided that have been taken directly from the interview transcripts. To ensure anonymity, the quotes are followed by a reference indicating the interview number from which the extract was taken.

processes suggests that the majority of the respondents agree that these processes were executed during the PSS development projects they have been involved in.

In contrast, only a small number of the phrases refer to the capture requirements, project initiation, delivery planning and production processes. For example, the phrase: *"…you move it into the next stage and productionise it"* (#4) relates to production process. The low proportion of phrases referring to activities conducted within these processes suggests that whilst a small number of respondents agree that these processes were executed on the PSS development projects that they have been involved with, the majority of respondents do not.

In addition to the phrases relating to the activities reported from the literature, a further 34 phrases were extracted from the interview transcripts which provide evidence for activities not reported in the literature. The open coding data analysis is presented in Appendix II. The open coding led to the identification of nine codes that represent activities conducted by RailCo but not reported in the literature. Table 4 presents these activities and the processes within which they are executed.

Table 4: New activities suggested by respondents

Phase	**Process**	**Code representing activities not reported in literature but executed by RailCo**
Analysis	Systems analysis	Resource analysis
	Market research	Market trend analysis
	Capture requirements	Validate requirements
Concept design	Concept development	Position offering
Development	Service design	Specify behaviours
	Market communications	Create sales strategy
		Determine revenue mechanism
	Customisation	Determine level of customer specificity
	Customer involvement	Identify engagement customers

No evidence was found for the: understand usage profile of existing products and services; define goal; create project plan; identify delivery tools and instruments; describe main elements; define evaluation criteria; and write evaluation report activities.

The results from the case study found significant differences relating to the activities used to operationalise the processes within PSS development. This suggests that the processes are executed differently during RailCo's PSS development practice than has previously been reported in the literature. However, given that the case study focused exclusively on one organisation, there is insufficient evidence to determine whether any of the differences reported reflects more general differences between servitized manufacturers' and the extant literature.

Based on the findings from the case study, five hypotheses were proposed for testing through the survey:

Hypothesis 1: *There is a sequential relationship between the analysis, concept design, development and delivery phases within PSS development*

Hypothesis 2: *The analysis phase within PSS development is made up of the capture requirements, market research, systems analysis and customer involvement processes*

Hypothesis 3: *The concept design phase within PSS development is made up of the concept development, idea generation, project initiation, customer involvement and evaluation processes*

Hypothesis 4: *The development phase within PSS development is made up of the delivery planning, market communications, product design, service design, customer involvement and evaluation processes*

Hypothesis 5: *The delivery phase with PSS development is made up of the customisation, deliver and production processes*

5 Survey results

A survey was conducted to provide validation of the simplified model of PSS development by testing the five hypotheses proposed from the analysis of the case study findings. Given that no differences in the activities used to operationalise the idea generation and product design processes were reported from case study, these processes were not included in the survey.

5.1 Factor and reliability analyses

Analysis of the principle components and factor analysis of the responses for each process indicates that for the majority of processes a single factor exists. However, the analysis indicated that the systems analysis and project initiation processes are not reflected in the PSS development practices of respondents. Instead, the analysis indicated that systems analysis should be replaced by benchmarking and resource analysis processes whilst project initiation should be replaced by project authorisation and project planning processes. Furthermore, the analysis suggested a broader definition of the market communications process and support for the deliver process. Full details of the reliability and factor analyses can be found in Table 5.

Based on the results of the principal factor analysis, hypotheses 2 and 3 were updated to reflect the changes suggested from the survey data:

Hypothesis 2-updated: *The analysis phase within PSS development is made up of the capture requirements, market research, benchmarking, resource analysis and customer involvement processes*

Hypothesis 3-updated: *The concept design phase within PSS development is made up of the concept development, idea generation, project authorisation, project planning, customer involvement and evaluation processes*

Table 5: Reliability and validity for the PSS development processes

Phase	Process	Cronbach's alpha	# of items	1st Eigenvalue	2nd Eigenvalue	Variance explained
	Customer involvement	0.680	3	1.830	0.693	61.0%
	Evaluation	0.786	6	3.039	0.911	50.6%
Analysis	Systems analysis[1]	0.776	7	3.165	1.744	70.1%
	→ Benchmarking	0.765	4	2.409	0.734	60.2%
	→Resource analysis	0.847	3	2.326	0.400	77.5%
	Capture requirements	0.856	5	3.235	0.746	64.7%
	Market research	0.655	3	1.813	0.737	60.4%
Concept design	Project initiation[2]	0.894	12	5.849	1.566	72.9%
	→Project planning	0.893	8	4.664	0.973	58.3%
	→Project authorisation	0.770	3	2.079	0.781	69.3%
Development	Delivery planning	0.633	4	1.908	0.951	47.7%
	Market communications[3]	0.908	7	4.515	0.733	64.5%
	Service design	0.791	4	2.473	0.797	61.8%
Delivery	Production	0.832	6	3.411	0.809	56.9%
	Customisation	0.666	3	1.804	0.687	60.1%
	Deliver	0.657	2	1.495	0.505	74.8%

[1] Factor analysis suggested that the systems analysis process is too broad a concept. The results suggest Q14, Q19 and Q24 can be considered one process (termed resource analysis) whilst Q13 and Q18 when combined within Q15 and Q25 can be considered a separate process (termed benchmarking)

[2] Factor analysis suggested that the project initiation process is too broad a concept. The results suggest that Q29, Q34 and Q39 can be considered one process (termed project authorisation) whilst Q30, Q31, Q32, Q36, Q37, Q40, Q41 and Q42 can be considered a separate process (termed project planning)

[3] Refers to the enlarged market communications process consisting of Q46, Q47, Q51, Q52, Q56, Q57 and Q69

5.2 Regression analysis

5.2.1 Relationship between phases

Hypothesis 1 predicts a sequential relationship between the phases within PSS development. This hypothesis was tested by running three linear regression models. In the first model (equation 1) the indicators of the concept design phase (CONDES) were the dependent variable and the indicators of the analysis phase (ANAL) the independent variable. In the second model (equation 2) the indicators of the development phase (DEV) were the dependent variable and the indicators of the concept design phase (CONDES) the independent variable. In the third model (equation 3) the indicators of the delivery phase (DEL) were the dependent variable and the indicators of the development phase (DEV) the independent variable. Complexity of the PSS (CPLX) and respondents' experience in developing PSSs (EXP) were used as control variables in the regression models.

$$CONDES = \beta_0 + \beta_1(ANAL) + \beta_4(CPLX) + \beta_5(EXP) \quad (1)$$

$$DEV = \beta_0 + \beta_2(CONDES) + \beta_4(CPLX) + \beta_5(EXP) \quad (2)$$

$$DEL = \beta_0 + \beta_3(DEV) + \beta_4(CPLX) + \beta_5(EXP) \quad (3)$$

The results of the regression models are presented in Table 6.

The results confirm a significant relationship (95% confidence level) between concept design and analysis phases and the development and concept design phases, suggesting agreement with the sequential relationships proposed in the literature. In contrast to what was expected, the results do not show a statistically significant relationship between the development and delivery phases.

Table 6: Regression analysis results of relationship between phases

	Model 1			**Model 2**			**Model 3**		
	CONDES			**DEV**			**DEL**		
	β	Sig.	SE	β	Sig.	SE	β	Sig.	SE
Constant (β_0)	2.625	0.002	0.768	1.784	0.014	0.682	2.831	0.000	0.538
ANAL (β_1)	0.435	0.035	0.196						
CONDES (β_2)				0.380	0.020	0.153			
DEV (β_3)							0.297	0.057	0.149
CPLX (β_4)	-0.047	0.491	0.017	0.106	0.084	0.059	-0.001	0.951	0.012
EXP (β_5)	-0.018	0.281	0.017	0.010	0.488	0.015	-0.049	0.358	0.052
R^2	0.187			0.238			0.133		
N	31			31			31		

5.2.1 Phases and processes

Analysis

Hypothesis 2-updated predicts that the analysis phase is made up of five processes: capture requirements, market research, benchmarking, resource analysis and customer involvement. This hypothesis was tested by running a linear regression model (equation 4). The indicators of the analysis phase (ANAL) were the dependant variable and the benchmarking (A_BEN), resource analysis (A_RES), market research (A_MR), capture requirements (A_CR) and customer involvement (CI) processes as the independent variables. Complexity of the PSS (CPLX) and respondents' experience in developing PSSs (EXP) were used as control variables in the regression model.

$$ANAL = \beta_0 + \beta_1(A\_BEN) + \beta_2(A\_RES) + \beta_3(A\_MR) + \beta_4(A\_CR) + \beta_{13}(CI) + \beta_{15}(CPLX) + \beta_{16}(EXP) \quad (4)$$

The results of the regression model are presented in Table 7. Results confirm significant relationships between the benchmarking, resource analysis, market research and capture requirements processes and the analysis phase; suggesting that these processes are executed during analysis. In contrast to what has been reported in the literature and the case study findings, no signification relationship was observed between the analysis phase and the customer involvement process.

Concept design

Hypothesis 3-updated predicts that the concept design phase is made up of concept development, idea generation, project authorisation, project planning, customer involvement and evaluation processes. This hypothesis was tested by running a linear regression model (equation 5). The indicators of the concept design phase (CONDES) were the dependent variable and the project authorisation (CD_PA), project planning (CD_PP), customer involvement (CI) and evaluation (EVAL) processes as the independent variables. Complexity of the PSS (CPLX) and respondents' experience in developing PSSs (EXP) were used as control variables in the regression model. Given that the factor analysis of the concept development process failed to produce a workable construct, this process was not included in the regression analysis.

$$CONDES = \beta_0 + \beta_5(CD\_PA) + \beta_6(CD\_PP) + \beta_{13}(CI) + \beta_{14}(EVAL) + \beta_{15}(CPLX) + \beta_{16}(EXP) \quad (5)$$

The results of the regression model are presented in Table 7. Results confirm significant relationships between the project planning and evaluation processes and the concept design phase; suggesting that these processes are executed during concept design. In contrast to what has been reported in the literature and the case study findings, no signification relationship was observed between the concept design phase and the project authorisation, customer involvement and evaluation processes.

Development

Hypothesis 4 predicts that the development phase is made up of delivery planning, market communications, product design, service design, customer involvement and evaluation processes. This hypothesis was tested by running a linear regression model (equation 6). The indicators of the development phase (DEV) were the dependent variable and the delivery planning (DEV_DP), service design (DEV_SD), market communications (DEV_MC), customer involvement (CI) and evaluation (EVAL) processes as the independent variables. Complexity of the PSS (CPLX) and respondents' experience in developing PSSs (EXP) were used as control variables in the regression model.

$$DEV = \beta_0 + \beta_7(DEV\_DP) + \beta_8(CD\_SD) + \beta_9(DEV\_MC) + \beta_{13}(CI) + \beta_{14}(EVAL) + \beta_{15}(CPLX) + \beta_{16}(EXP) \quad (6)$$

The results of the regression model are presented in Table 7. Results confirm significant relationships between the delivery planning, service design, market communications and evaluation processes and the development phase; suggesting that these processes are executed during development. In contrast to what has been reported in the literature and the case study findings, no signification relationship was observed between the development phase and the customer involvement and evaluation processes.

Delivery

Hypothesis 5 predicts that the delivery phase is made up of customisation, deliver, production, customer involvement and evaluation processes. This hypothesis was tested by running a linear regression model (equation 7). The indicators of the delivery phase (DEL) were the dependent variable and the production (DEL_PRO), customisation (DEL_CUST), deliver (DEL_DEL), customer involvement (CI) and evaluation (EVAL) processes as the independent variables. Complexity of the PSS (CPLX) and respondents' experience in developing PSSs (EXP) were used as control variables in the regression model.

$$DEL = \beta_0 + \beta_{10}(DEL\_PRO) + \beta_{11}(DEL\_CUST) + \beta_{12}(DEL\_DEL) + \beta_{13}(CI) + \beta_{14}(EVAL) + \beta_{15}(CPLX) + \beta_{16}(EXP) \quad (7)$$

The results of the regression model are presented in Table 7. Results confirm significant relationships between the production, customisation, deliver and evaluation processes and the delivery phase; suggesting that these processes are executed during delivery. In contrast to what has been reported in the literature and the case study findings, no signification relationship was observed between the delivery phase and the customer involvement and evaluation processes.

Table 7: Regression analysis results for the relationships between processes and phases

	Model 4			Model 5			Model 6			Model 7		
	ANAL			CONDES			DEV			DEL		
	β	Sig.	SE	β	Sig.	SE	β	Sig.	SE	β	Sig.	SE
Constant (β_0)	-0.001	0.838	0.004	-2.853	0.319	2.806	-0.001	0.826	0.005	-0.009	0.140	0.006
A_BEN (β_1)	0.265	0.000	0.001									
A_RES (β_2)	0.200	0.000	0.001									
A_MR (β_3)	0.200	0.000	0.001									
A_CR (β_4)	0.334	0.000	0.001									
CD_PA (β_5)				0.919	0.221	0.731						
CD_PP (β_6)				0.811	0.000	0.067						
DEV_DP (β_7)							0.267	0.000	0.001			
DEV_SD (β_8)							0.266	0.000	0.001			
DEV_MC (β_9)							0.467	0.000	0.001			
DEL_PRO (β_{10})										0.550	0.000	0.001
DEL_CUST (β_{11})										0.180	0.000	0.001
DEL_DEL (β_{12})										0.273	0.000	0.001
CI (β_{13})	0.001	0.266	0.001	-0.69	0.142	0.045	0.000	0.972	0.001	0.000	0.573	0.001
EVAL (β_{14})				0.094	0.174	0.067	-0.001	0.681	0.001	-0.002	0.099	0.001
CPLX (β_{15})	0.000	0.489	0.000	-0.007	0.747	0.022	0.000	0.397	0.000	0.001	0.137	0.000
EXP (β_{16})	0.000	0.393	0.000	-0.006	0.309	0.006	0.000	0.693	0.000	0.000	0.718	0.000
R^2	1.000			0.935			1.000			1.000		
N	31			31			31			31		

6 Discussion

The results from the case study and survey were cross referenced to establish similarities and differences between these data sources.

6.1 Contrasting the phases and processes

Based on the literature review, fifteen processes were identified as being executed during four phases of PSS development. The findings from the case study indicate that during the processes RailCo: (1) executes a number of activities not reported in literature; and (2) does not executed a number of activities which are reported in literature. Whilst some concurrence between the activities executed within RailCo's PSS development practice and literature was highlighted, the differences suggest the model of PSS development synthesised from the literature does not accurately reflect the industrial practice of RailCo. Furthermore, analysis of the survey data identified that the systems analysis and project initiation processes do not accurately reflect the PSS development practice of the sampled servitized manufacturers. Analysis of the data suggested the inclusion of benchmarking and resource analysis processes to replace the systems analysis process and project authorisation and project planning processes to replace the project initiation process.

Literature reports that during systems analysis an understanding of the usage profile of products and services is gained in order to assess whether they are fulfilling customers' needs (Aurich *et al.* 2006). Results from the case study point towards the inclusion of systems analysis within the model of PSS development, suggesting that resource analysis is an additional activity conducted within this process. Results from the survey suggest that systems analysis is too broad a concept. Analysis of the data suggests that systems analysis is better described in terms of two separate processes: resource analysis and benchmarking. Whist the PSS development approaches proposed in the existing literature provide little evidence for the inclusion of a resource analysis process, Froehle & Roth (2007) has examined how resources fit within new service development practices. Froehle & Roth's findings suggest that human, organisational and physical resources significantly impact upon new service development practice, indicating more broadly that resource analysis should be considered a viable process within new service (and PSS) development. Whilst Froehle & Roth (2007) provides evidence for the inclusion of human, organizational and physical resources, resource analysis within this thesis focuses principally on human resources. Future research examining organisational and physical resources may lead to a strengthening of the resource analysis concept. Additionally, although the term benchmarking is not used within the PSS development approaches proposed in the existing literature, the benchmarking process suggested by the survey data includes constructs used to operationalise parts of the systems analysis and market research processes. Benchmarking has been widely used within new product and service development as a process for analysing existing products and services offered by an organisation and its competitors to identify opportunities for new, or improvement to existing, products and services (Kelly & Storey 2000, Cooper 1986). Given their use within the broader product and service development literatures, resource analysis and benchmarking are considered as separate processes within the model of PSS development, replacing systems analysis.

During project initiation, senior management will define the goals for the project; identify key deliverables and milestones; and create a team to take the project forward (Brezet *et al.* 2001). Results from the case study offers some evidence for project initiation within PSS development, but the survey data suggested that project initiation is better described in terms of two separate processes – project authorisation and project planning. Although project authorisation is reported within the new service development literature as being a distinct process (Froehle & Roth 2007), the existing PSS development approaches proposed by literature consider it an activity within project initiation. Given the findings from the survey, and the evidence for the existence of a project authorisation activity from the case study, project authorisation is considered a process within PSS development Additionally, the project planning process suggested by the survey analysis synthesises the define goals, create team and create project plan constructs that were used, in part, to operationalise project initiation. Given the findings from the survey, and the evidence from the case study for the existence of the define goals and create project plan constructs, project planning is considered a process within PSS development. However, future research is needed to further validate and strengthen these concepts.

Concept development refers to the definition of the product specification and the product's basic physical characteristics (Krishnan & Ulrich 2001), identifying: the total benefits that customers are likely to receive from the PSS and estimating what this might be worth to customers; and the form of the service and the characteristics of the products required to enable the service to be delivered are designed (Clark *et al.* 2000). Whilst results from the case study suggest that concept development can be operationalised in terms of a position offering activity, no evidence was found from the survey linking this activity with concept development. Further investigation of the interview transcripts suggests that positioning the offering has similarities with determining the form and characteristics of the PSS: *"…what business are we in - selling the piece of kit, selling and fitting the kit, are we into deriving a value gain share from the benefit of the kit and, if so, to what degree?"* (#8). This points towards a broader activity concerned with determining the form and characteristics of the PSS activity. Given that concept development was not operationalised with respect to this term, further research is needed to investigate whether this is the case. Although no additional measures were used within the survey to determine whether concept development is a valid process within PSS development, concept development is a process consistently reported within the product (e.g. Pugh 1991, Ullman 2003) and service (Bitran & Pedrosa 1998, e.g. Bowers 1993) development literatures. Given this, and the evidence reported in the case study, concept development is considered a process within the model of PSS development, however, future research is needed to strengthen this concept.

Although the idea generation and product design processes were not included within the survey, findings from the case study and extant literature provide significant evidence for their inclusion within the model of PSS development. For example, idea generation was identified by half of the existing approaches to PSS development with interview respondents identifying that at RailCo

"…there is a call for ideas" (#10) or *"…someone come[s] up with a good idea […] because a part of the solution is close to their role"* (#2). Given the findings from the case study and extant literature, idea generation and product design are considered processes with the model of PSS development, however, future research is needed to provide further validation and strengthen these concepts.

6.2 Contrasting the relationships between phases and processes

The model of PSS development synthesised from the literature presents a sequential relationship between the analysis, concept design, development and delivery phases. Furthermore, the model of PSS development identifies the processes executed during each phase. The findings from the case study concurred with these relationships, but differences were identified from analysis of the survey data.

Literature reports sequential relationships between the analysis, concept design, development and delivery phases suggesting linear progression through the phases. Findings from the case study suggest agreement with the relationships reported in the literature. Analysis of the survey data found statistically significant relationships between the analysis and concept design phases and the concept design and development phases, but no statistically significant relationship between the development and delivery phases was observed. This would seem to disagree with the results from the case study and literature. Further analysis of data indicates a positive relationship between development and delivery, as expected, at a significance level of 0.057. Whilst this is not statistically significant at the 95% confidence level, the relationship is almost statistically significant. This suggests that, although not statistically significant, there is a strong sequential relationship between development and delivery. This is reflected in the broader service development literature (Johnson *et al.* 2000, Froehle & Roth 2007) which reports development as occurring before a launch phase. Given the agreement between the literature and the case study reporting development as occurring before delivery, and the strong positive relationship between these phases determined from the survey data, a sequential relationship is included within the model of PSS development. Future research is needed which may lead to a strengthening of the relationship between these two phases.

Whilst the case study and literature report project authorisation (activity) as occurring within the concept design phase, the results from the analysis of the survey data did not find a statistically significant relationship between project authorisation and concept design. This would seem to disagree with the results from the case study and literature, suggesting project authorisation is not an activity executed during PSS development. Further analysis identified a standard error for this relationship of 2.518, suggesting significant variation in the responses to the questions associated with this process. This would seem to indicate that the measures used to operationalise this process are not precise enough. Given the agreement between the literature (Froehle & Roth 2007) and case study results, project authorisation is provisionally included within the concept design phase. Further research is needed to develop more precise measures of project authorisation and strengthen its reported relationship with the concept design phase.

Although significant evidence is presented in the literature (Alam & Perry 2002) and the case study for the execution of customer involvement in a number of phases, the results from the survey data did not find a statistically significant relationship between customer involvement and any phase. A potential explanation for this difference may be seen in the fact that the customer involvement process was operationalised in terms an identify engagement customers activity (identified from the case study results and not the literature). This indicates that the identify engagement customers activity reported by respondents at RailCo is not reflected in the PSS development practice of the sampled servitized manufacturers. Future research should seek to operationalise customer involvement in terms of all of the activities reported from the literature and case study, potentially validating the role of customer involvement in the all of the phases of PSS development. Given the strong support in the existing literature for involving customers in all phases of PSS development (Alam & Perry 2002) and concurrence with the case study results, customer involvement is included within the model of PSS development.

The results from the survey data did not find a statistically significant relationship between the evaluation process and any phase. This is contrary to the findings from the case study where a number of phrases were extracted relating to an evaluation process. A potential explanation for this difference may be seen in the fact that the evaluation process was operationalised in terms of two activities that are reported in the literature but not identified in the case study findings – namely, a define evaluation criteria and write evaluation report activities. This suggests that the sampled servitized manufacturers concur with RailCo in not conducting the define evaluation criteria and write evaluation report activities within the evaluation processes executed within the phases. Given the strong support in the literature for these activities when evaluation is conducted as a separate phase, further research is needed to determine whether evaluation is better considered as a separate phase or a process executed in a number of phases. Given the similarities with the product and service development literatures (e.g. Cooper 1986) and the case study findings, evaluation is included within the model of PSS development and is executed in a number of phases.

6.3 Synthesising the case study and survey results

Given the results of the case study and survey, a new model of PSS development is suggested to better reflect industrial practice (Figure 2).

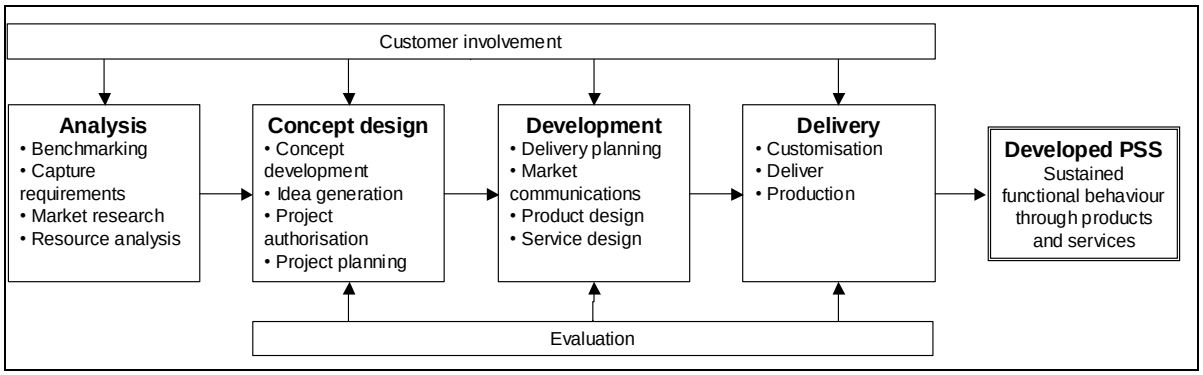

Figure 2: Proposed new model of PSS development

Whilst the model presented in Figure 2 consists of the same phases as that reported within the literature, a number of new processes are proposed – benchmarking, resource analysis, project authorisation and project initiation. Additionally, the findings from the case study and survey suggest that different activities are executed by servitized manufacturers to operationalise the market research, capture requirements, service design, market communications, customisation, delivery planning and evaluation processes compared to those reported by the literature.

7 Conclusion

The paper has reported that more research is required within the servitization field to aid manufacturer's develop integrated product-service offerings. Whilst the closely related PSS field is more mature in this area, proposing a number of approaches for developing PSSs, these have not been investigated with respect to servitized manufacturers. Analysis of the literature led to the synthesis of fifteen processes that are executed during four phases of PSS development – termed the model of PSS development. Through a single-case study and survey, the research reported within this paper contributes to existing literature by determining the extent to which the model of PSS development reflects the PSS development practice of servitized manufacturers.

The findings from the case study indicate that during the processes RailCo: (1) executes a number of activities not reported in literature; and (2) does not executed a number of activities which are reported in literature. Whilst some concurrence between the activities executed within RailCo's PSS development practice and literature was highlighted, the differences suggest the model of PSS development synthesised from the literature does not accurately reflect the industrial practice of RailCo. Analysis of the survey data identified that the systems analysis and project initiation processes do not accurately reflect the PSS development practice of the sampled servitized manufacturers. Analysis of the data suggested the inclusion of benchmarking and resource analysis processes to replace the systems analysis process and project authorisation and project planning processes to replace the project initiation process. Findings from the survey validated the sequential relationship between the analysis and concept design phases and concept design and development phases as described in literature, but further research is needed to statistically

validate the relationship between the development and delivery phases. Furthermore, analysis of the survey data suggested agreement with the allocation of processes to phases reported from the case study, but additional research is needed to statistically validate whether the project authorisation process is executed in concept design and whether customer involvement is executed in any phase.

Based on the results from the case study and survey, a new model of PSS development is suggested. Whilst the new model of PSS development consists of the same phases as reported by the literature, significant changes to the activities executed with the processes, and four new processes, are proposed to better reflect the industrial practice of servitized manufacturers.

The proposed new model of PSS development industrial practice of PSS development by:

- Enabling servitized manufacturers to benchmark their existing approaches to PSS development against a rigorously defined model. This will enable servitized manufacturers to improve their existing approaches, increasing the likelihood of developing successful PSSs.
- Highlighting the activities that are needed to be conducted during PSS development enables manufacturers who are starting out on a servitization journey to gain greater understanding of where they may need to develop new resources and capabilities.
- For servitized manufacturers who do not have a formal approach to PSS development, the model could form the basis of their future PSS development practices, leading to greater transparency and repeatability within the PSS development initiatives.

7.1 Research limitations and future work

The research presented within this paper has two main limitations. First, whilst a survey was used to overcome the limits on generalisability created by the use of a single-case study, the sample size is relatively small and restricted to servitized manufacturers operating in the UK and Ireland. As such, the proposed model of PSS development proposed within this paper can best be described as an initial model. Future research should be conducted with larger data sets to determine whether the proposed model is generic or whether it is contingent upon other factors. Second, whilst a new model of PSS development was proposed based on the findings from the case study and survey, its application in practice has not been tested. Further research is needed to operationalise the proposed model of PSS development into a tool to determine whether following it leads to the successful development of PSSs in practice.

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Appendix I – Survey questions

Section 1 - Background

What is your job title?

How many years' experience do you have developing PSSs?

Approximately, how many PSS development projects have you been involved in?

Please provide some examples of PSSs that you have been involved in developing?

Section 2 – General questions

Evaluation

Q1	Specific criteria are used to assess the developing PSS
Q5	Technical feasibility of the PSS is assessed at least once during the project
Q9	Financial implications to your company from developing and delivering the PSS are assessed at least once during the project
Q2	The results of assessments into the evolving PSS are documented
Q6	Evaluation reports are created of the PSS as it is evolving
Q10	Formal or informal reporting tools are used to capture the results of technical and/or financial analyses

Custom involvement

Q3 Specific launch customers are identified

Q7 A small number of potential customers are identified to prototype the PSS

Q11 Formal of informal techniques are used to identify customers who might be willing to be involved during the project

Section 3 - Analysis

Systems analysis

Q13 Analysis is conducted to determine how customers are using existing products and services offered by your company

Q18 Analysis is conducted to determine the operating profile of current products and services offered by your company

Q23 Analysis is conducted to determine customers' perceptions of existing products and services offered by your company

Q14 Existing skills are identified to determine whether they might be suitable for development into PSSs

Q19 Analysis is conducted to identify whether existing personnel could be used to deliver new PSSs

Q24 Analysis is conducted to identify whether existing resources within your company could be used to deliver new PSSs

Market research

Q4 Customers are involved in helping determine their needs

Q8 Dialogue is used with customers to understand their businesses

Q12 Formal or informal techniques are used to engage customers in determining their requirements

Q15 Analysis is conducted of your company's market to identify opportunities for new PSSs

Q20 Analysis is conducted of markets that your company does not operate in to identify potential PSSs that could be delivered in your industry

Q25 Analysis is conducted to identify trends in your customers' business environment

Capture requirements

Q16 Customer needs are documented

Q21 Requirements for the new PSSs are documented

Q26 Potential opportunities to deliver PSSs are documented

Q17 Customers are asked whether the identified requirements for a PSS would meet their needs

Q22 Customers are asked whether they agree or disagree with the identified requirements for the PSS

Q27 Customer confirmation is important in ensuring that their needs can be met through the identified PSS requirements

Section 4 - Concept design

Concept development

Q28 A formal or informal decision to either sell the PSS separately or integrate it into a wider

offering is made

Q33 New PSSs are positioned relative to existing products and/or services

Q38 Formal or informal decisions are made to determine whether the PSS offers competitive advantage in its own right or as part of a wider offering

Project initiation

Q29 Projects are sponsored by senior management

Q34 Formal authorisation is given to begin PSS projects

Q39 Approval is given to begin PSS projects

Q30 Goals for the project are defined

Q35 A mandate is created to document what the project is aiming to deliver

Q40 The deliverables for the project are specified

Q31 Projects are executed by teams

Q36 Formal or informal techniques are used to identify potential team members

Q41 A team leader is appointed to manage the people involved in the project

Q32 Project time schedules are specified

Q37 Project milestones are specified

Q42 Projects are managed with the aid of project plans

Section 5 - Development

Delivery planning

Q43 An assessment is conducted to determine what factors will influence the delivery of the PSS

Q48 It is identified how your company and customers will work together to deliver the PSS

Q53 Plans are created to represent how the PSS will be deployed

Q44 Tools are identified to ease PSS delivery

Q49 Additional technology is identified to overcome potential delivery obstacles

Q54 Guidelines and checklists which are applied by service staff during delivery are created

Service design

Q45 Assessments are made to determine the behaviours that your company's service staff have to exhibit

Q50 Assessments are made to determine the behaviours that your customers' staff have to exhibit

Q55 Assessments are conducted to determine whether changes are required to either your company's or customers' staffs' behaviours

Market communications

Q46 A sales proposition is created

Q51 A clear sales strategy is developed

Q56 An approach to selling the PSS is devised

Q47 How much customers will be charged for the PSS is calculated

Q52 The pricing strategy for the PSS is determined

Q57 The revenue generation mechanism is identified

Section 6 - Delivery

Production

Q58	A decision is made to manufacture the technical components of the PSS internally or procure them from external sources
Q62	The product is made available in order for a service to be delivered
Q66	Products or technical elements are produced
Q59	Technical elements of the PSS are installed
Q63	Technical elements are installed before the service can be delivered
Q67	In order to deliver the service, technological components are fitted to your company's, customers' or suppliers' premises/assets

Customisation

Q60	Assessments are made to determine whether PSSs need tailoring to specific customers' businesses
Q64	Customers' business environments are analysed to determine whether the PSS could be delivered without being customised
Q68	Customers' operations are taken into account to identify whether variations are required to the PSS
Q61	The PSS is proposed to customers before potential variations are identified
Q65	Potential variations are identified once the main elements of the PSS have been described to customers
Q69	Customers are informed of the principle features of the PSS before customer specific features are identified

Appendix II – Open coding results

	Codes								
Phrases extracted from the interview transcripts	**Resource analysis**	**Market trend analysis**	**Validate requirements**	**Position offering**	**Specify behaviours**	**Create sales strategy**	**Determine revenue mechanism**	**Determine level of customer specificity**	**Identify engagement customers**
"…customer's actions support the development of a good contract" (#1)					✓				
"…come up with an indicative price" (#1)							✓		
"…we basically understand what the market price is and we know where we need to be pitching							✓		

Phrases extracted from the interview transcripts	Codes								
	Resource analysis	Market trend analysis	Validate requirements	Position offering	Specify behaviours	Create sales strategy	Determine revenue mechanism	Determine level of customer specificity	Identify engagement customers
[however] with the newer stuff we don't know" (#1)									
"…the value that it brings to the customer" (#1)							✓		
"…look at what they are doing over at Rolls-Royce. They do similar things" (#2)		✓							
"…market research to guide us into what are the general trends in the railway industry going forward" (#2)		✓							
"…I would pull it [the concept requirements document] to bits and absolutely stress test it…" (#2)			✓						
"…'how will you sell this to people?" (#2)						✓			
"How will you capture what your sales literature will be?'" (#2)						✓			
"There were some capability gaps that we recognised" (#2)	✓								
"…we were developing the capability initially as it would be something we would deploy and that this new service capability would be integrated within a wider service offering" (#3)				✓					
"…incentivise behaviours in the right kind of way" (#3)					✓				
"…that hasn't managed to create aligned incentives for us and the customer and therefore our behaviours (ours as suppliers and our customers) are not pulling in					✓				

Phrases extracted from the interview transcripts	Codes								
	Resource analysis	Market trend analysis	Validate requirements	Position offering	Specify behaviours	Create sales strategy	Determine revenue mechanism	Determine level of customer specificity	Identify engagement customers
the same way" (#3)									
"…the operator or their maintainer to behave in a substantially different way" (#3)					✓				
"… [we] have the marketing material" (#4)						✓			
"…if you start thinking about how you are going to do benefit share and translate it into something that is workable is much harder than you would think" (#4)							✓		
"…you want to work with clients who consider an equitable share of the risk as being acceptable" (#5)									✓
"…behaviours and attitudes that is going to make this offering work" (#6)					✓				
"What attitudes and beliefs do you want people to have" (#6)					✓				
"…there is an impact of how they, as a customer, have to behave in order to get true value" (#6)					✓				
"…if you look at the maintenance contracts that we have around the UK they are all based around a pence per mile approach [however] [Customer] didn't want to do that. They wanted a menu driven approach" (#6)							✓		
"…the offering is that we maintain their trains, but the method that we recover our costs and profitability is							✓		

Phrases extracted from the interview transcripts	Codes								
	Resource analysis	Market trend analysis	Validate requirements	Position offering	Specify behaviours	Create sales strategy	Determine revenue mechanism	Determine level of customer specificity	Identify engagement customers
different, which makes the service offering very different" (#6)									
"…you've got to look at other markets as well" (#7)		✓							
"…marketise the thing that we've developed and understand whether it is sub-part of a bigger offering that gives us competitive advantage for the bigger offering or is it a product in and of its own right?" (#7)				✓					
"…you need to be in a position where you can almost partner with someone to do some innovative stuff" (#7)				✓					
"…what business are we in - selling the piece of kit, selling and fitting the kit, are we into deriving a value gain share from the benefit of the kit and, if so, to what degree?" (#8)				✓					
"…what is it? Is it something that enables us to provide the best maintenance contracts in the world […] or is it in and of itself something we want to sell and if we do how?" (#8)				✓					
"...are we developing them to be a part of a bigger offering - is that their purpose in life? (#8)									✓
"…you often find things that are client specific" (#8)								✓	
"…I am not saying that it hasn't								✓	

Phrases extracted from the interview transcripts	Codes								
	Resource analysis	Market trend analysis	Validate requirements	Position offering	Specify behaviours	Create sales strategy	Determine revenue mechanism	Determine level of customer specificity	Identify engagement customers
changed and been adapted each time, it has” (#8)									
"…how do we use central engineering to help us develop reliability growth plans, to develop maintenance optimisation, to bring on new initiatives?" (#9)	✓								
"…you either decide that you are going to keep that knowledge and that becomes competitive advantage or you can sell that data and somehow what that data has told you to a customer" (#9)				✓					
"…we've thought about the sales proposition" (#9)						✓			
“…what are the competences and capabilities that can be brought to bear and what’s the maturity of those?” (#10)	✓								

Paper 5

Clayton, R.J., Backhouse, C.J., Dani, S., Lovell, J. 2011, “A process model for developing integrated product-service offerings”, *Proceedings of the 18th Annual European Operations Management Association (EurOMA) Conference*, Cambridge University

A process model for developing integrated product-service offerings

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Abstract

Manufacturers are increasingly seeing the benefits of adopting a servitization strategy, however, literature reports that they face challenges developing new product-service offerings. Although a number of approaches have been proposed, they fail to distinguish the characteristics of products and service, they are typically sequential and exhibit variations in the level of detail proposed. Overcoming these knowledge gaps, a new development process model is proposed, consisting of 19 distinct processes. The process model was tested and recommendations for improvements are reported.

Keywords: Product-service system (PSS), product-service development, process model

1 Introduction

Driven by the highly cyclical nature of their increasingly commoditised product offerings, many capital goods manufacturers are seeing the benefits of exploiting their large installed based by offering services (Wise & Baumgartner 1999, Olivia & Kallenberg 2003). The transition to offering integrated product-service systems (PSSs) is known as servitization (Vandermerwe & Rada 1988, Baines *et al.* 2009).

Previous research has reported that manufacturers face three challenges adopting a servitization strategy: service development, organisational strategy and organisational transformation (Baines *et al.* 2009). Whilst there has been some research identifying how manufacturers can create integrated product-service offerings (Alonso-Rasgado *et al.* 2004, Pawar *et al.* 2009), this is largely anecdotal and does not propose formal processes for their development.

Yet, research outside of the servitization field has reported that “it seems to be worthwhile to explicitly organize the process of developing new services” (De Jong & Vermeulen 2003, p.844) with the most successful firms being those that have formal processes (Kelly & Storey 2000, Brentani 1991). This paper reports on the creation of a formal process for the development of integrated PSSs.

2 Literature review

Although limited research has been conducted within the servitization field to propose processes for developing integrated product-service offerings, the related PSS field is more mature in this area. However, although a PSS consists of both product and service elements, much of the PSS development literature does not make reference to either the new product or new service development literatures. Many authors argue for separate new product and service development approaches, claiming that the unique characteristics of services (intangibility, heterogeneity, inseparability and perishability) mean that their development is different from products (Kelly & Storey 2000, Ian Stuart 1998).

Given these inconsistencies a review of the product, service and product-service development literatures was conducted and three observations emerged:

2.1 The design stage for product elements is different from service elements

Early approaches to service development were based on the product development process reported by Booz, Allen & Hamilton (1982), proposing that service development was not different from product development. Scheuing & Johnson (1989) were the first to report a service development process different from products, identifying four distinct outputs from the design stage: service design, process design, system design and marketing programme design. Whilst the product development literature also proposes marketing programme design, other outputs include: product design and production development (Roozenburg & Eekels 1995). This difference emerges from the inseparability characteristic of services where production and consumption occur simultaneously (Lovelock & Gummesson 2004).

This difference is less well understood within the PSS development literature where the stages of the development process are broadly consistent with the stages of product development. However, whilst the distinction is not made clear at the stage-level, MEPSS (van Halen *et al.* 2005) proposes tools to model

- the resources providing the PSS;
- the user interaction with the PSS and delivery organisation; and
- the functionalities of the PSS.

These tools are attempts within MEPSS to encourage PSS development teams to design the service system, the service process and the service concept respectively. Whilst MEPSS proposes tools for considering the specific nature of services within the development process, it does not propose corresponding tools for considering products.

2.2 PSS development is typically sequential

Of the 11 reviewed PSS development processes, nine are presented as being sequential. However, both Brezet *et al.* (2001) and Engelhardt *et al.* (2003) propose dedicated evaluation stages in order to "guarantee a process of continuous improvement" (Brezet *et al.* 2001, p.17). Additionally, Kar (2010) proposes activities consistent with evaluation - e.g. analyse business case, gather feedback, monitor and provide support. The concept of assessing products and/or services whilst in-service in order to deliver incremental improvement is also reported by the cyclic PSS development process proposed by Mont (2001) and the cyclic service development processes proposed by Tax & Stuart (1997) and Johnson *et al.* (2000). Although represented as a cycle, these processes are essentially sequential where the output from the evaluation stage forms the input to the first stage of the next development process.

Recent research has reported that existing approaches do not reflect industrial practice - in addition to the incremental feedback loop linking the end of an evaluation stage with the first stage of the next development process, there is iteration between other stages within the PSS development process (Clayton *et al.* 2011). This suggests that the PSS development process is not sequential as reported by the majority of the existing literature.

2.3 Variations in the level of detail

Many of the processes proposed within the PSS development literature do not report specific activities that development teams have to execute in order to successfully complete the reported stages (e.g. Mont 2001). This reflects the early research within both the product and service development literatures where only the stages within the development processes were reported. However as the development processes proposed within the product and service literatures have become formalised, greater levels of detail have been reported.

The transition within the product and service development literatures towards being represented using formal process modelling techniques has not been reflected in the PSS development literature.

4 Research design

The observations presented in the previous section highlight that, although numerous processes for developing integrated PSSs have been proposed, they fail to

- take into consideration the characteristics of both the product and service elements within the design stage;
- they do not reflect industrial practice by enabling more iterative and incremental development; and
- no formal process modelling techniques have been used to represent the PSS development process.

The research presented within this paper was driven by a desire to fill these knowledge gaps by answering the following research question:

RQ: What does a formal product-service system development process model, that reflects industry practice, look like?

Addressing the research question involved the authors in three phases of research. During process model design, literature were analysed to specify the requirements for the PSS development process model. Process model development involved creating an initial version of the PSS development process model; representing it using a formal modelling language. Finally, process model testing involved evaluating the PSS development process model on an industrial application. The evaluation was conducted within a global transportation manufacturer (RailCo) in order to identify possible product-service offerings that could create a step change in its UK services business performance. 20 participants were involved in the evaluation (ranging from senior directors to mid-level managers) which was undertaken over the course of six full day and four half-day workshops. The results were used to refine the proposed PSS development process model.

5 Process model design

Requirements for the PSS development process model can be specified as:

5.1 Requirements for the process model structure

The purpose of identifying the requirements for modelling processes is to ensure that the process model is an effective representation of reality, efficiently created (Table 1).

5.2 Requirements for the content of the model

Work by Clayton *et al.* (2011) has reported that the PSS development process followed by industry consists of project initiation, analysis, idea generation and selection, design, production, articulate the value proposition, prototype, implementation and evaluation. In addition, Clayton *et al.* (2011) reports the high level of iteration between the phases, suggesting that PSS development is nonlinear.

Table 1: Process modelling requirements (Holt 2009)

Requirement	Description
Complete information	The process model must represent the required level of detail
Realistic	The processes modelled must reflect the practices executed in reality
Partitioning	Related processes must be grouped within the process model
Process iteration	The process model must describe how processes are carried out and re-used
Complexity and interactions	Relationships between elements at all levels within the process model must be visualised
Traceability	It must be possible to trace all artefacts back to the original project requirements
Tailoring	The generic process model must allow specialisation
Multiple views	To gain a full understanding of the process it must be represented from multiple perspectives

Complementing these findings, Baines *et al.* (2009) argues that the design of services requires manufacturers to take greater account of competition from outside their traditional domain, such as from their own suppliers, distributors and customers; consider the risk of performing activities previously undertaken by customers, where marginal risk incurred might outweigh the profit potential; and develop communication strategies that describe the value proposition to the customer and their role in value co-creation.

Given these findings, the PSS development process model must be made up of distinct processes that fulfil these reported requirements.

5.3 Requirements for the process modelling technique

The choice of modelling language must fulfil the requirements identified in the previous sections and be a formal modelling language (Table 2).

Table 2: Choice of modelling language

Language	Description	Fulfil reqts	Formal
Flowcharts	A schematic representation of algorithms or processes	N	N
Business process modelling notion (BPMN)	A general process modelling language	N	N
Integrated definition methods (IDEF)	A family of modelling languages including IDEF3 for business process modelling	N	Y

Language	Description	Fulfil reqts	Formal
Systems modelling language (SysML)	A domain-specific modelling language for systems engineering that is defined as a profile of UML (Unified Modelling Language - a general purpose modelling language that is the standard for specifying software intensive systems)	Y	Y

Based on the analysis, the SysML was chosen as an appropriate modelling language and implemented within Atego™ Artisan Studio©.

6 Process model development

The PSS development process model consists of seven different views; represented using a number of diagrams within the SysML (Table 3).

Table 3: Seven views of the PSS development process model

View	Description	SysML representation
Requirements	Specifies the overall aims of the processes within the process model	Use case
Stakeholder	Represents the classification of the different types of stakeholder role involved in the process	Block definition diagram
Process structure	Shows a high-level representation of the basic structure of, and the terminology used throughout, the process model	Block definition diagram
Process content	A set of diagrams that show the activities and artefacts of each process	Block definition diagram
Process behaviour	Describes the behaviour of each process, documenting the order of execution of activities	Activity diagram
Process instance	A set of diagrams that represent the execution of individual processes	Sequence diagram
Information	Identify the key artefacts from the process model and their inter-relationships	Block definition diagram

The PSS development process model consists of 56 diagrams, representing the seven views. The initial PSS development process model consists of 19 distinct processes arranged around two process groups: management and PSS development (Figure 1).

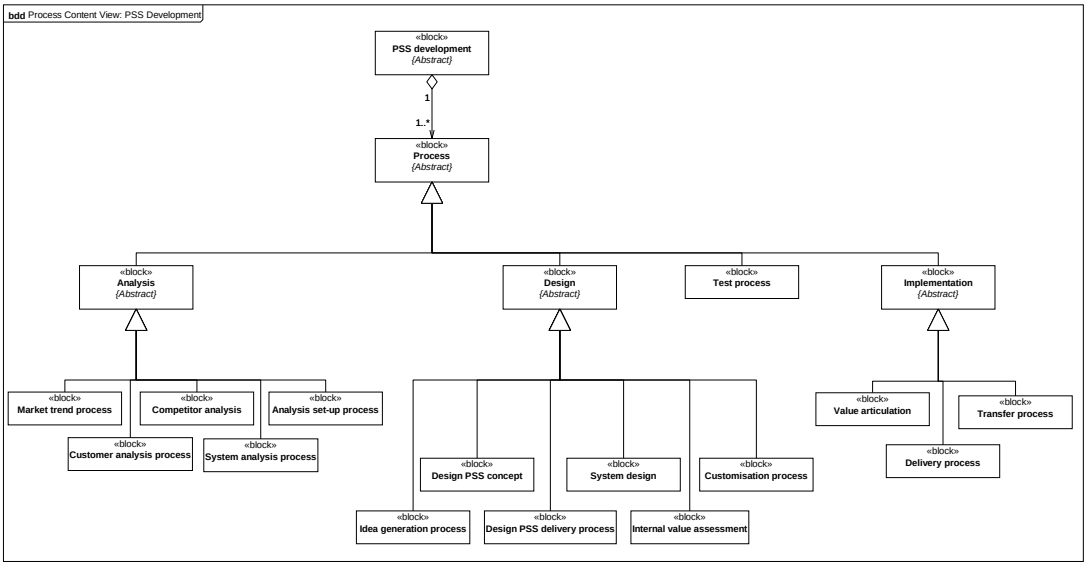

Figure 1: Process content view for PSS development process group

Each process is made up of activities, artefacts and roles. Activities are executed by roles and produce or consume artefacts (Figure 2). In the process behaviour views, swim lanes represent the roles responsible for each process. Each swim lane is responsible for the activities within it and the order of execution of the activities is shown. Artefacts are either produced (shown as inputs into activities) or consumed (shown as outputs from activities) and typically take the form of information.

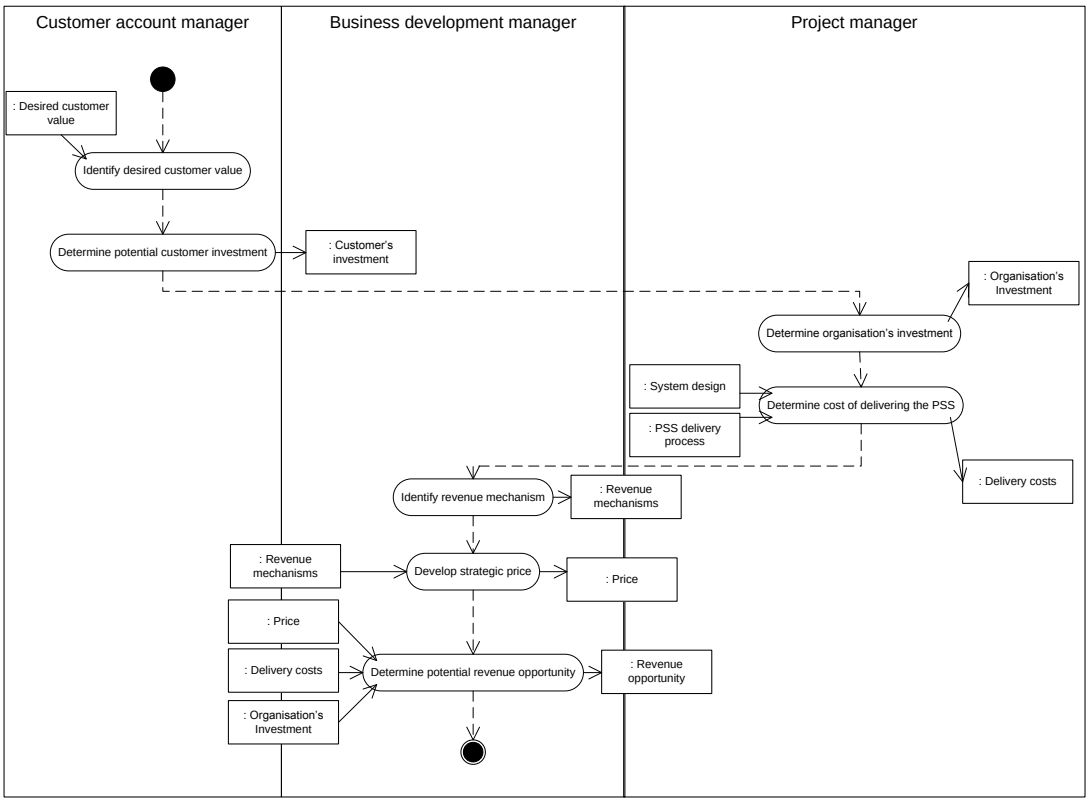

Figure 2: Process behaviour diagram for internal value assessment process

The processes within the process model are combined during a PSS development project. This combination can be linear, reflecting existing PSS development processes reported by the literature, or nonlinear; where variation depends on internal and external constraints imposed on the PSS development project.

7 Process model testing

The process model was evaluated through its application to a new product-service development project within the UK division of a global transportation manufacturer (RailCo).

Reflecting previous research, the actual PSS development process is highly iterative and nonlinear – represented by the re-use of a number of processes (Figure 3).

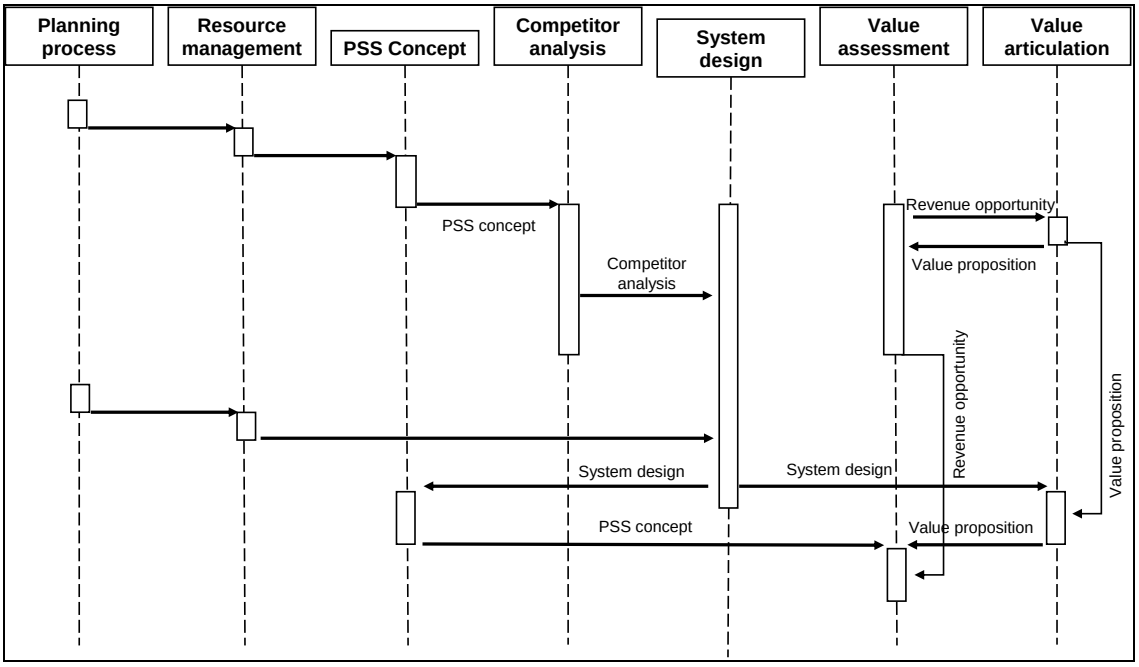

Figure 3: Example process instance view from application in RailCo

During process model testing not all activities were completed, or artefacts produced (e.g. Figure 4 where activities or artefact in bold were not executed or produced).

Of the 19 processes within the process model, six were not executed: market trend analysis, design PSS delivery process, customisation process, delivery process, transfer process and gate review process. In addition, a number of activities within the processes were not completed including: determine what the opportunity is worth to customer (customer analysis process), define service quality measures (design PSS concept process) and design service system for variations in deliver (system design process).

The testing also identified an activity performed by RailCo's that is not represented in the PSS development process model: risk analysis.

Findings indicate that the PSS development process model should include a risk analysis process similar to that reported by Baines *et al.* (2009). When applying the processes within the process model organisations are able to re-use processes, however, they do not necessarily

execute all of the activities within each process. Where organisations choose not to complete all activities, they need to be aware of the impact of this. The information view potentially offers a mechanism for providing this awareness, showing how the absence of artefacts may hinder the creation further artefacts.

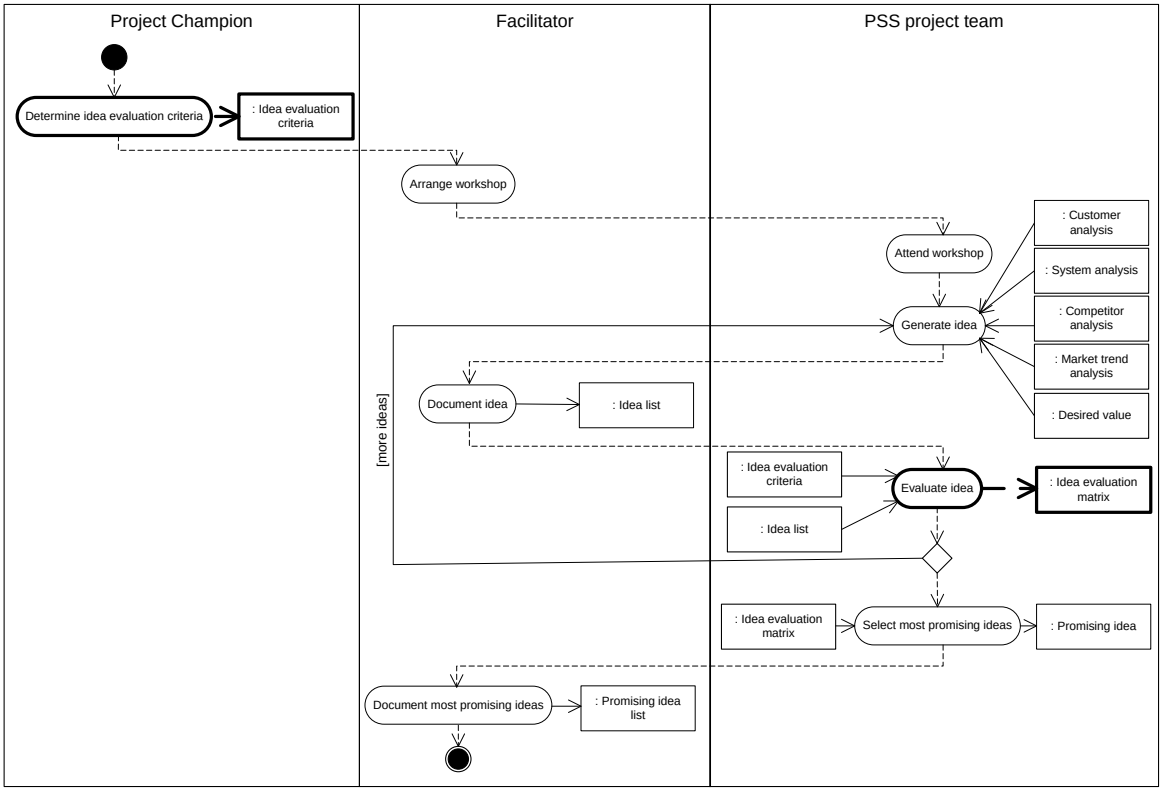

Figure 4: Process behaviour view from idea generation process within application in RailCo

8 Conclusion

The research reported within this paper has proposed a new approach to the creation of integrated product-service offerings: the PSS development process model. Existing approaches to PSS development

- fail to recognise that the design stage for product elements is different from service elements;
- report PSS development as sequential; and
- report variations in the level of detail within the proposed approaches.

The PSS development process model overcomes these weaknesses, proposing a representation of PSS development using a multi-view approach implemented in the SysML.

To assess the PSS develop process model, it was evaluated during application to a new product-service development project within the UK division of a global transportation manufacturer. The findings indicate that the process model needs amending to include a risk analysis process.

Additionally, the process model enables organisations to represent their PSS development processes in an iterative and nonlinear manner, through the concept of process re-use. Finally, the testing determined that organisations do not complete all activities within each process or create all artefacts.

Given that the research has been evaluated using one case study, further research is needed to: verify that the processes proposed are applicable in alternative scenarios and validate that the PSS development process model can be used to create PSSs in more cases. Additionally, further research is also needed to evaluate whether the activities not completed, and artefacts not produced, are detrimental to the quality of the resulting PSS and whether the PSS development process model delivers more value to organisations than existing approaches.

Acknowledgements

This paper would not have been possible without the financial support given by the UK government via EPSRC and industrial sponsors. Neither would it have been possible without the support of the industrialists who were involved in the process modelling and testing phase. The authors thank them for their time, knowledge and invaluable insights. The authors would also like to thank Atego™ for the free use of their software and for their time advising the researchers.

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Appendix IV – PSS Development Workbook

The following pages contain screenshots from the PSS Development Workbook.

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Driven by the highly cyclical nature of their increasing commoditised product offerings, many capital goods manufacturers are transitioning from producing products to providing integrated **product-service systems (PSSs)** in a process known as **servitization**.

Whilst evidence suggests that organisations pursuing formal approaches to new product-service development are more likely to be successful that those pursuing informal or ad hoc approaches (de Brentani 1991, Kelly & Storey 2000), few tools or methods exist to aid servitized organisations in their PSS development endeavours.

This **workbook**, the result of a four-year Engineering Doctorate research programme investigating product-service system development across numerous industries, describes a formal approach to aid servitized manufacturers conduct their PSS development.

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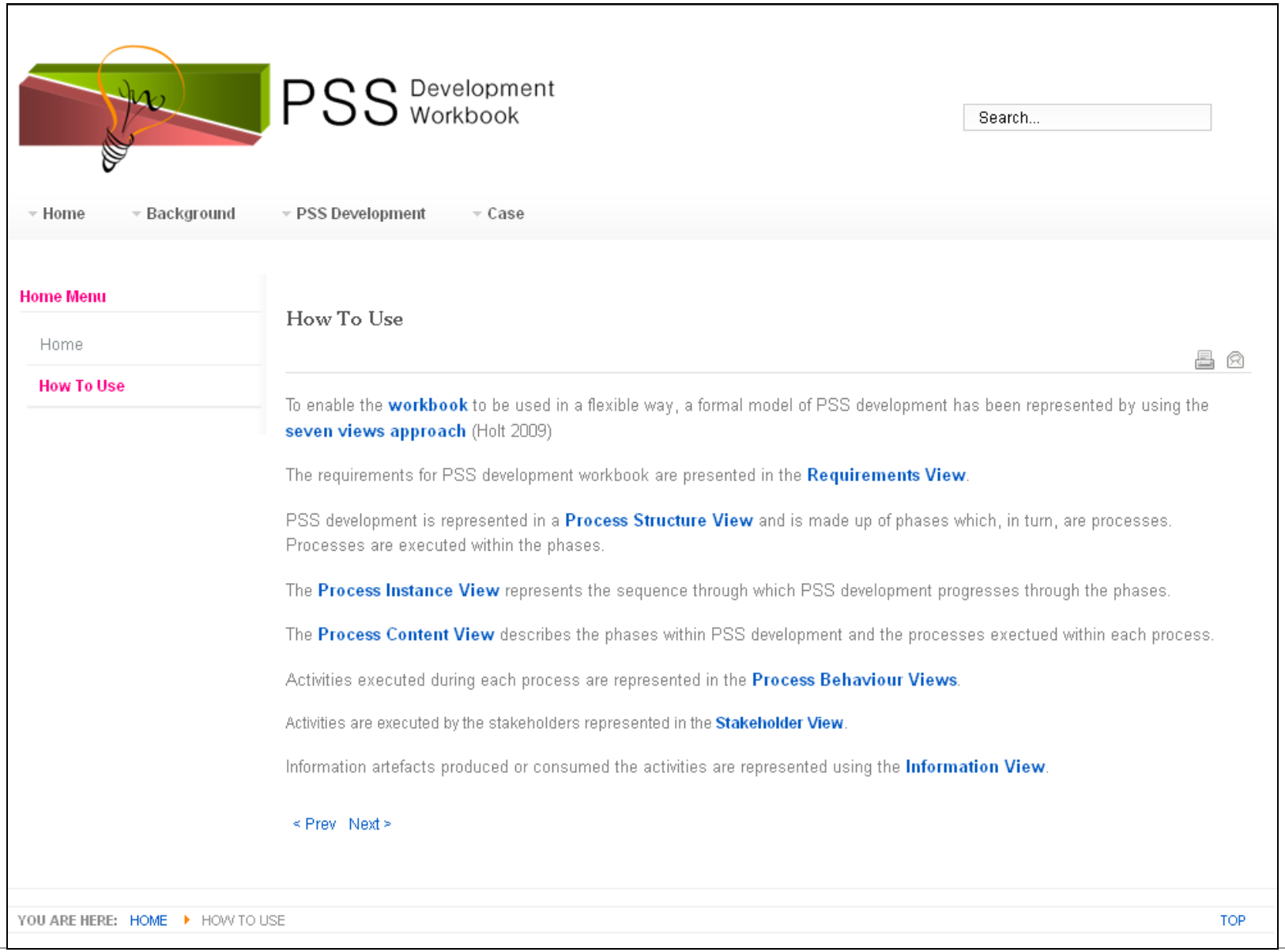
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To enable the workbook to be used in a flexible way, a formal model of PSS development has been represented by using the seven views approach (Holt 2009)
The requirements for PSS development workbook are presented in the Requirements View.
PSS development is represented in a Process Structure View and is made up of phases which, in turn, are processes. Processes are executed within the phases.
The Process Instance View represents the sequence through which PSS development progresses through the phases.
The Process Content View describes the phases within PSS development and the processes exectued within each process.
Activities executed during each process are represented in the Process Behaviour Views.
Activities are executed by the stakeholders represented in the Stakeholder View.
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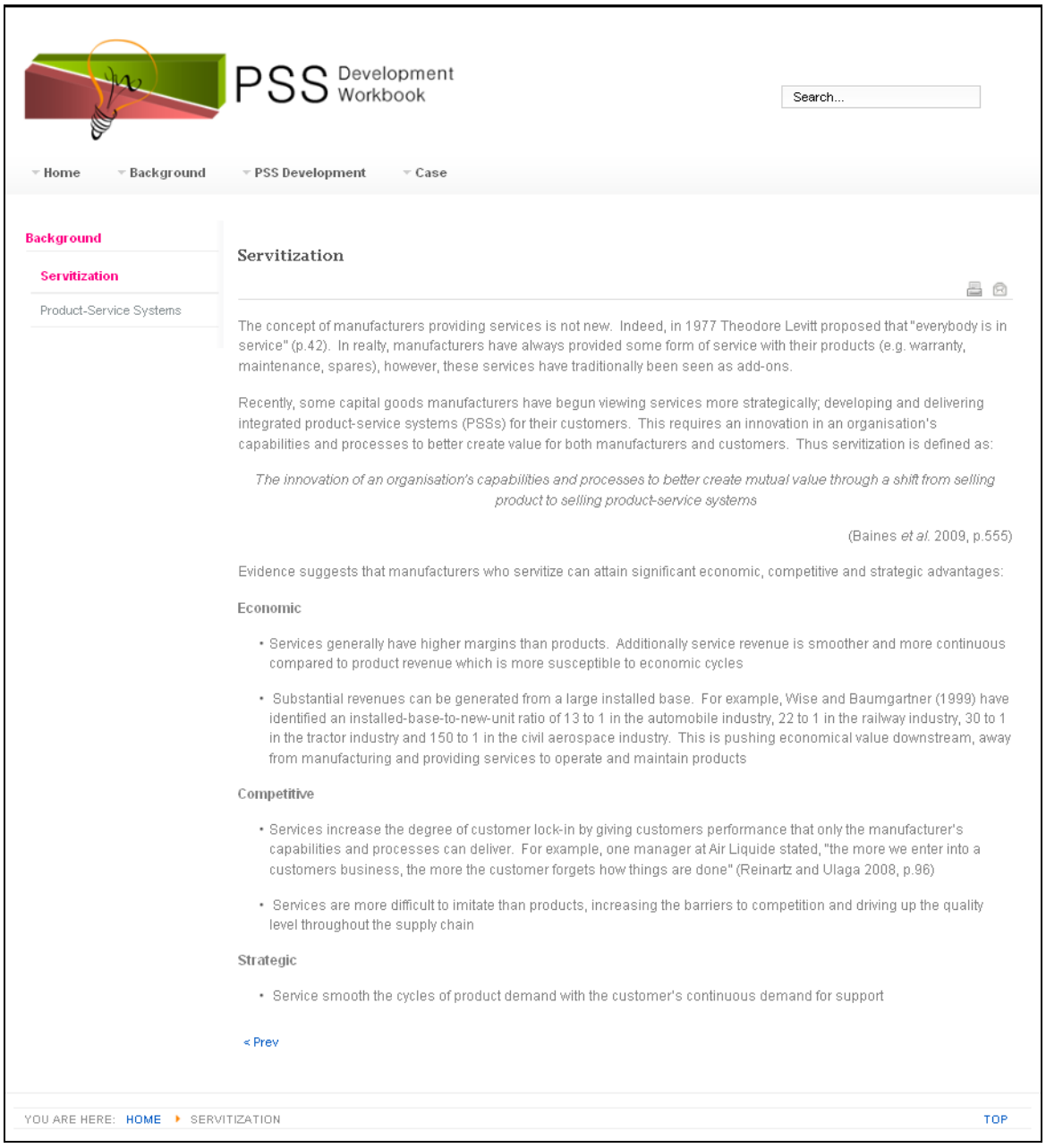
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Servitization
The concept of manufacturers providing services is not new. Indeed, in 1977 Theodore Levitt proposed that "everybody is in service" (p.42). In realty, manufacturers have always provided some form of service with their products (e.g. warranty, maintenance, spares), however, these services have traditionally been seen as add-ons.
Recently, some capital goods manufacturers have begun viewing services more strategically; developing and delivering integrated product-service systems (PSSs) for their customers. This requires an innovation in an organisation's capabilities and processes to better create value for both manufacturers and customers. Thus servitization is defined as:
The innovation of an organisation's capabilities and processes to better create mutual value through a shift from selling product to selling product-service systems
(Baines et al. 2009, p.555)
Evidence suggests that manufacturers who servitize can attain significant economic, competitive and strategic advantages:
Economic
Services generally have higher margins than products. Additionally service revenue is smoother and more continuous compared to product revenue which is more susceptible to economic cycles
Substantial revenues can be generated from a large installed base. For example, Wise and Baumgartner (1999) have identified an installed-base-to-new-unit ratio of 13 to 1 in the automobile industry, 22 to 1 in the railway industry, 30 to 1 in the tractor industry and 150 to 1 in the civil aerospace industry. This is pushing economical value downstream, away from manufacturing and providing services to operate and maintain products
Competitive
Services increase the degree of customer lock-in by giving customers performance that only the manufacturer's capabilities and processes can deliver. For example, one manager at Air Liquide stated, "the more we enter into a customers business, the more the customer forgets how things are done" (Reinartz and Ulaga 2008, p.96)
Services are more difficult to imitate than products, increasing the barriers to competition and driving up the quality level throughout the supply chain
Strategic
Service smooth the cycles of product demand with the customer's continuous demand for support
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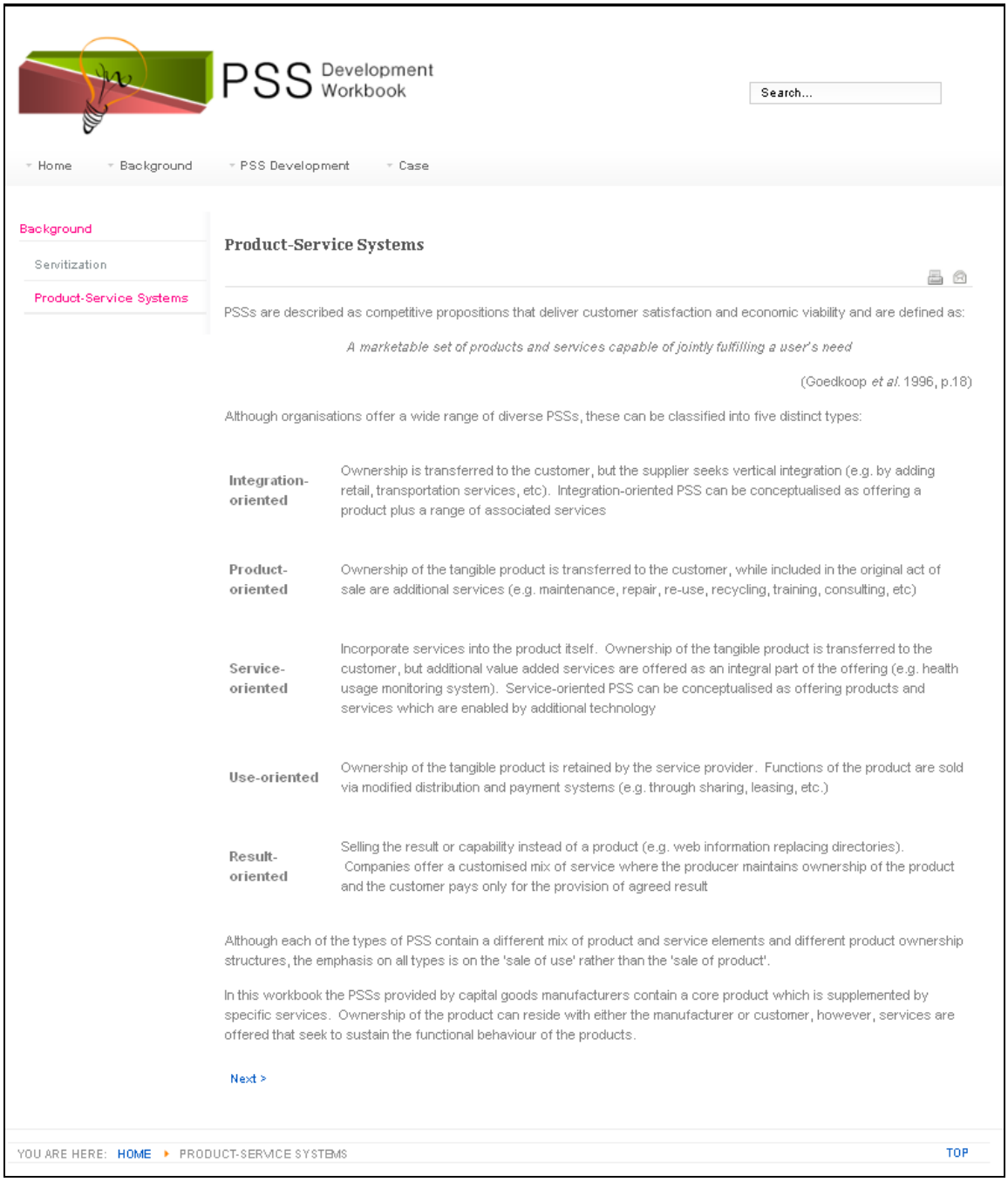
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Product-Service Systems
PSSs are described as competitive propositions that deliver customer satisfaction and economic viability and are defined as:
A marketable set of products and services capable of jointly fulfilling a user's need
(Goedkoop et al. 1996, p.18)
Although organisations offer a wide range of diverse PSSs, these can be classified into five distinct types:
Integration-oriented
Ownership is transferred to the customer, but the supplier seeks vertical integration (e.g. by adding retail, transportation services, etc). Integration-oriented PSS can be conceptualised as offering a product plus a range of associated services
Product-oriented
Ownership of the tangible product is transferred to the customer, while included in the original act of sale are additional services (e.g. maintenance, repair, re-use, recycling, training, consulting, etc)
Service-oriented
Incorporate services into the product itself. Ownership of the tangible product is transferred to the customer, but additional value added services are offered as an integral part of the offering (e.g. health usage monitoring system). Service-oriented PSS can be conceptualised as offering products and services which are enabled by additional technology
Use-oriented
Ownership of the tangible product is retained by the service provider. Functions of the product are sold via modified distribution and payment systems (e.g. through sharing, leasing, etc.)
Result-oriented
Selling the result or capability instead of a product (e.g. web information replacing directories). Companies offer a customised mix of service where the producer maintains ownership of the product and the customer pays only for the provision of agreed result
Although each of the types of PSS contain a different mix of product and service elements and different product ownership structures, the emphasis on all types is on the 'sale of use' rather than the 'sale of product'.
In this workbook the PSSs provided by capital goods manufacturers contain a core product which is supplemented by specific services. Ownership of the product can reside with either the manufacturer or customer, however, services are offered that seek to sustain the functional behaviour of the products.
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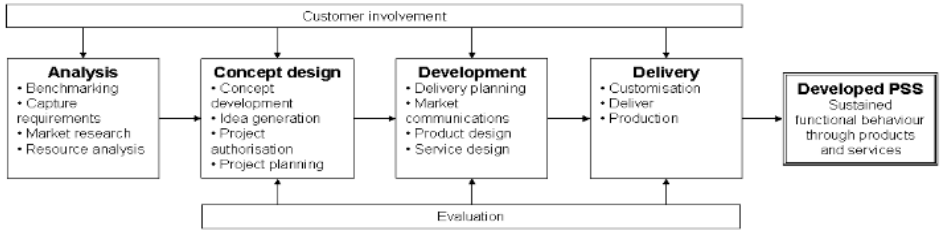
PSS Development

This workbook, the result of a four-year Engineering Doctorate research programme conducted through Loughborough University, presents an approach to developing PSSs by captial goods manufacturers.

PSS development is defined as:

An overall approach to creating products and services that, when integrated, are capable of fulfilling customers' needs and delivering sustained functional performance

PSS development consists of four phases which describe the state of the PSS during any stage of its development. Within each phases a number of processes are executed which consist of a number of interrelated or interacting activities which transforms inputs into outputs.



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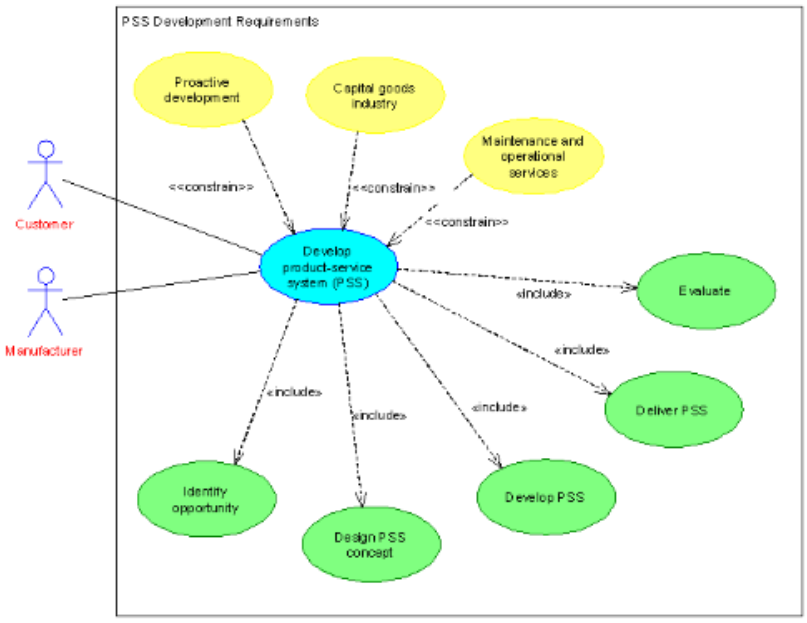
Requirements View

The aim of this workbook is to provide guidance to aid manufacturers and customers to co-develop PSSs.

The requirements view provides an understanding of the things that need to be done to develop PSSs and the things that need to be managed:



Requirements View

Once it has been decided to develop a PSS it is necessary to first perform some analysis to identify potential opportunities before designing and developing PSS concepts. Once developed, the PSS is co-delivered. During all of this, evaluation is conducted to ensure that the evolving PSS is technically feasible and economically viable.

The advice provided in this workbook is principally aimed at proactive PSS development of maintenance and operational services in the capital goods industry.

Proactive PSS Development

Research has determined that PSSs can be triggered by: an organisation proactively seeking to offer PSSs; customer's demanding PSSs; the imitation of competitors whom already deliver PSSs; or pressure to increase the perceived value of an offering. The PSS development approach is likely to be contingent upon what triggers the need for development.

This workbook focuses on PSS development that is proactive where the servitized manufacturer seeks to develop PSSs to fulfill unexpressed needs that are not currently being fulfilled by competitors' PSSs.

Maintenance and Operational Services

Although a number of servitization strategies have been proposed, this workbook focuses on developing PSSs that deliver sustained functional performance through products and services. Therefore only servitization strategies that include maintenance and operational services are considered (e.g. Rolls-Royce's "Power by the Hour"™). Other strategies, such as professional services (e.g. IBM's transition to business solutions provider) are not considered.

Capital Goods Industry

The advice provided in this workbook is principally aimed at capital goods manufacturers sell products and services in industrial markets to customers who use them in the production of other products and service (i.e. business-to-business). PSSs provided within consumer markets are not considered.

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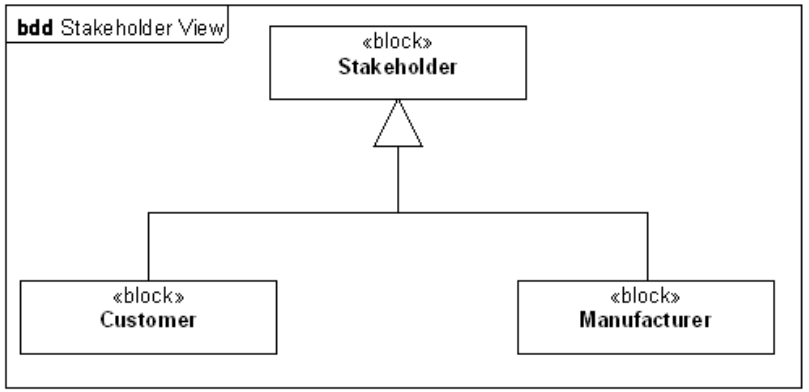
Stakeholder View

Although a large number of stakeholders are required to successfully develop and deliver PSSs, at a high level PSSs are co-developed and co-delivered by manufacturers and customers:



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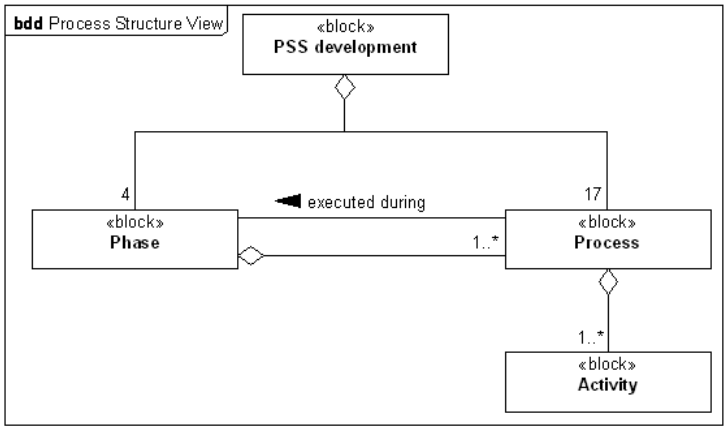
Process Structure View

The model of PSS development presented in this workbook is made up of phases and processes. Processes, in turn, are made up of activities. Phases are a period within the development lifecycle of the PSS that refers to the state of the PSS at any point during its development. Processes are a set of interrelated or interacting activities which transforms inputs into outputs. Activity are a set of actions that consume time and resources and whose performance is necessary to achieve, or contribute towards, the development of PSSs



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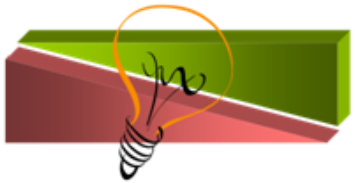

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Process Content View

The process content views can be interrogated in two ways through either the phase library or the process library.

Phase Library

The phase library shows the actual content of PSS development in terms of the phases. Each phase can be further investigated to reveal the related processes that are executed during each phase. These processes can be interrogated to show that actual content, in terms of activities, that are executed by the development teams.

Process Library

The process library shows all of the processes that are executed during PSS development. These are represented unrelated to the phases. The processes can be interrogated to show the actual content, in terms of activities, that are executed by development teams.

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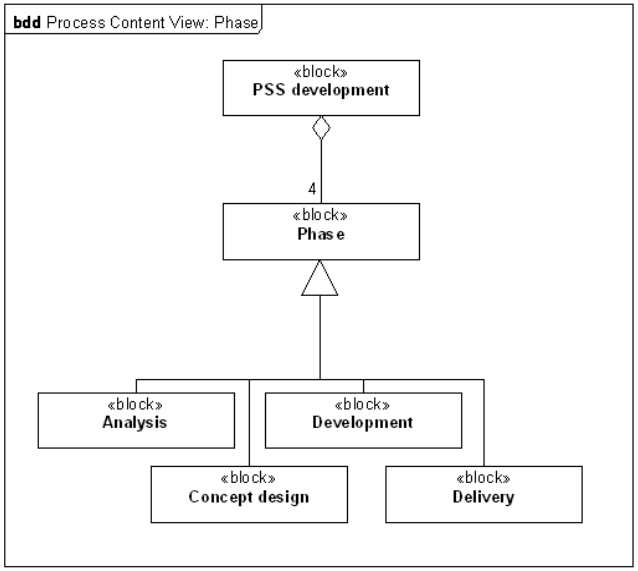
Process Content View: Phase

PSS development is made up of four phases:



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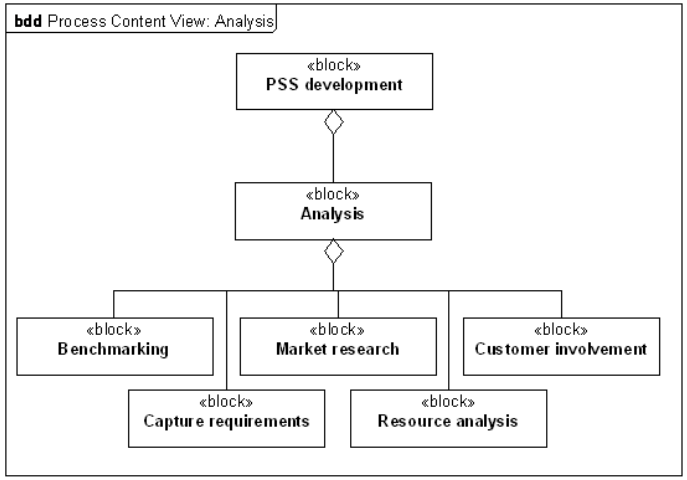
Process Content View: Analysis

Analysis refers to building an understanding of the manufacturer's customers, its installed base, competitors and internal organisation in order to identify a first set of objectives and requirements for a PSS concept. Analysis is performed continuously to identify customer's latent needs (i.e. those needs that customers have not articulated but could be fulfilled through PSSs)

During the development of PSSs, four processes are executed during the Analysis phase:



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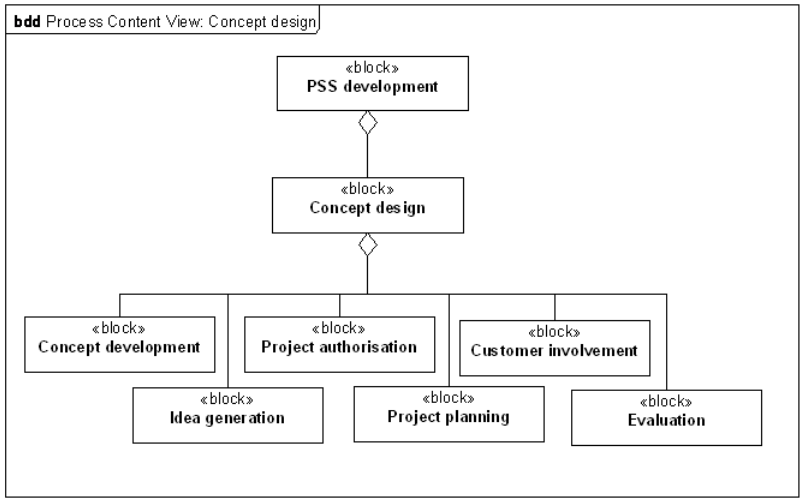
Process Content View: Concept Design

Concept design refers to the generation, evaluation and selection of potential PSS ideas and the development of the most promising ideas into PSS concepts that will fulfill customer's needs. Within concept design, projects are authorised and plans are created to further develop the most promising and viable PSS concepts.

During the development of PSSs, six processes are executed during the Concept Design phase:



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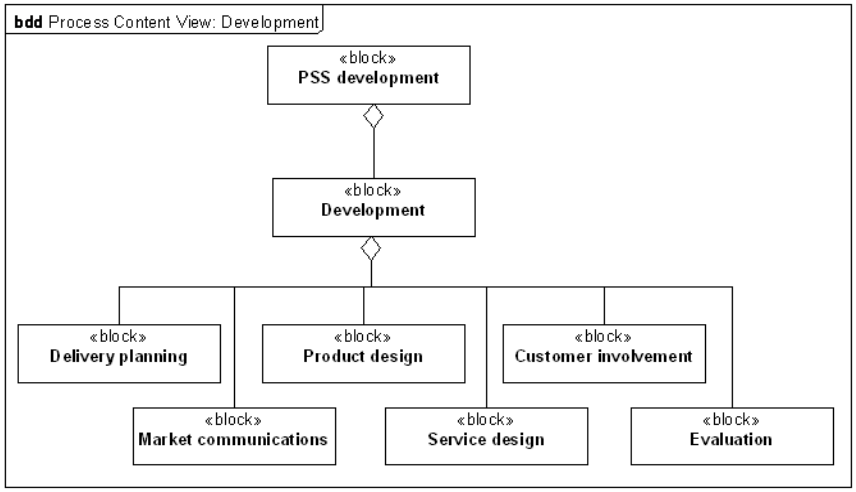
Process Content View: Development

Development is concerned with transforming the PSS concepts into viable, marketable PSS offerings. During development all product elements are developed concurrently with the service elements and preparations are made for delivery.

During PSS development, six processes are executed during the Development phase:



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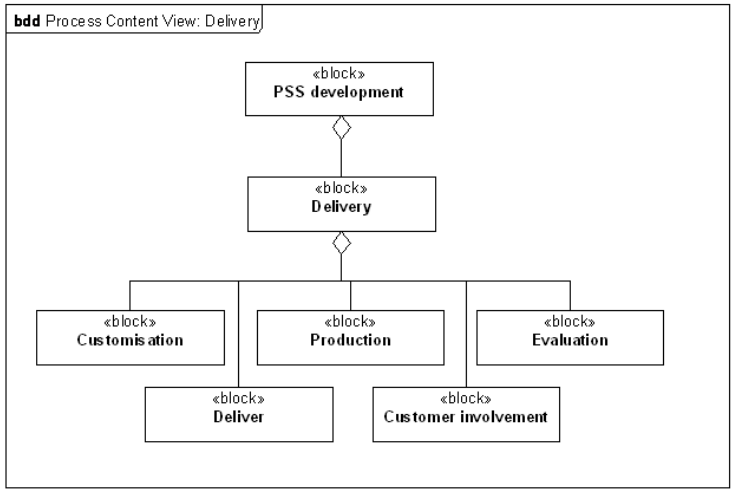
Process Content View: Delivery

Delivery is concerned with producing the product elements and making all necessary preparations to execute the service elements. The delivery phase can be applied with one customer specifically, principally to test and prototype the PSS, before the PSS is delivered to customers in the wider market. Delivery is ongoing, ensuring that the PSS's functional behaviour is sustained over time.

During PSS development, five processes are executed during the Delivery phase:



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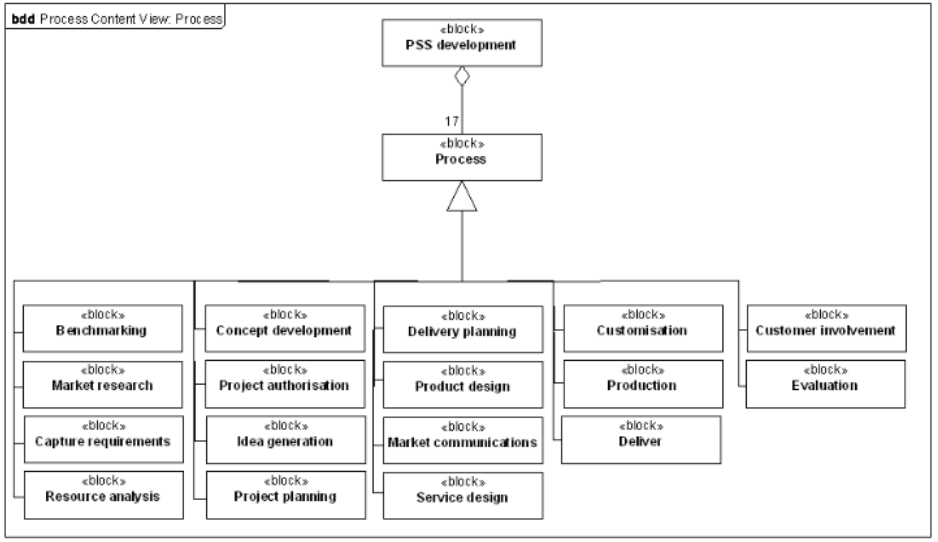
Process Content View: Process

PSS development is made up of seventeen processes:



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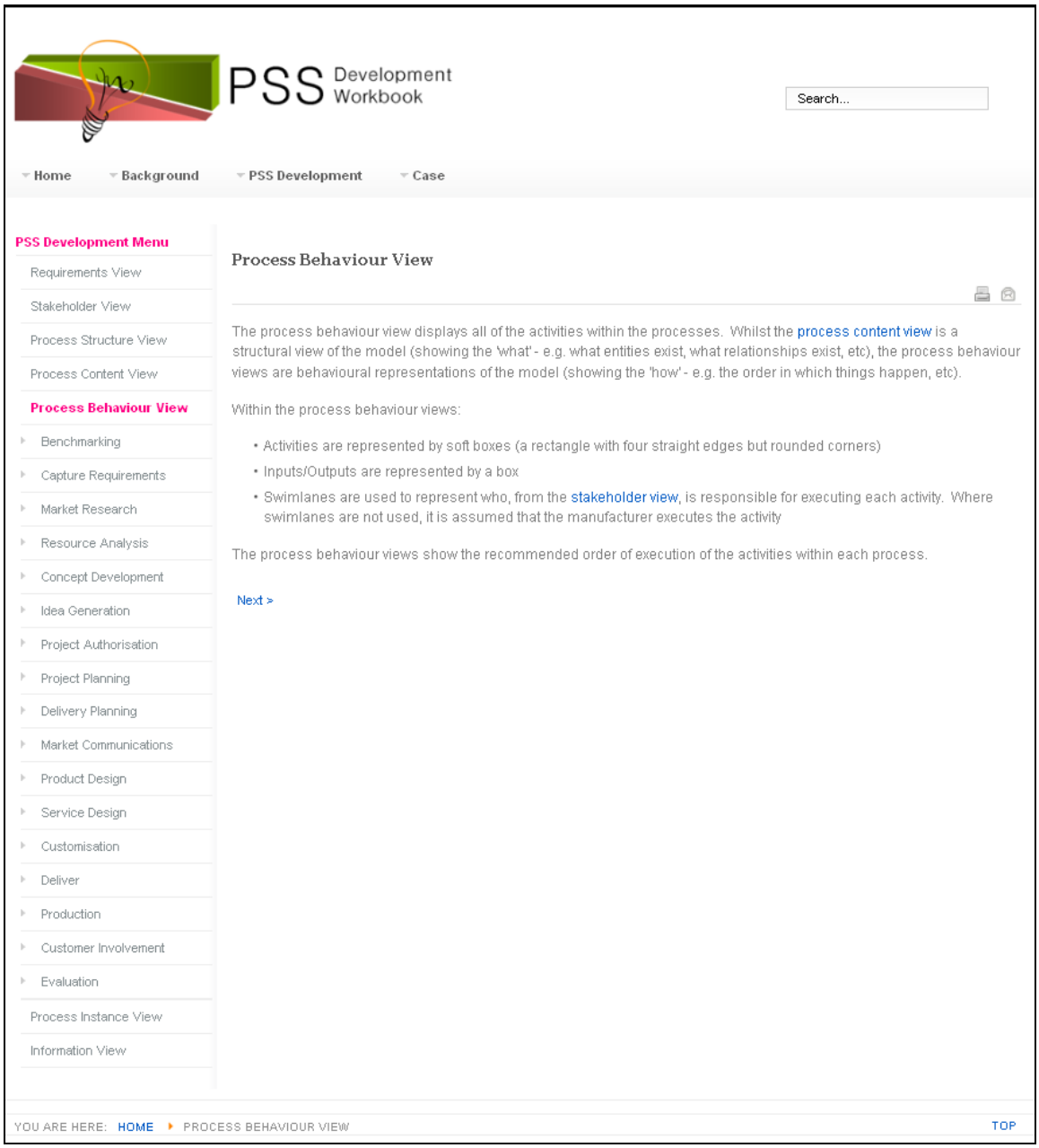
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The process behaviour view displays all of the activities within the processes. Whilst the process content view is a structural view of the model (showing the 'what' - e.g. what entities exist, what relationships exist, etc), the process behaviour views are behavioural representations of the model (showing the 'how' - e.g. the order in which things happen, etc).
Within the process behaviour views:
• Activities are represented by soft boxes (a rectangle with four straight edges but rounded corners)
• Inputs/Outputs are represented by a box
• Swimlanes are used to represent who, from the stakeholder view, is responsible for executing each activity. Where swimlanes are not used, it is assumed that the manufacturer executes the activity
The process behaviour views show the recommended order of execution of the activities within each process.
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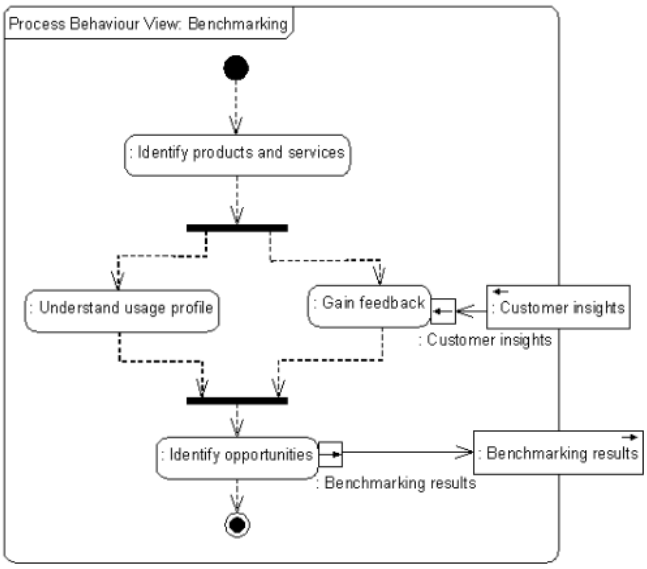
Process Behaviour View: Benchmarking

Benchmarking refers to the identification and analysis of existing products and services in order to understand their usage profile and gain customer's feedback. Based on the results of these analyses, opportunities to deliver new PSSs are identified.



During benchmarking, the customer insights (gained during the execution of the customer involvement process) are used to help gain feedback on existing products and services. Based on this analysis, opportunities for new PSSs are identified and documented in the benchmarking report.

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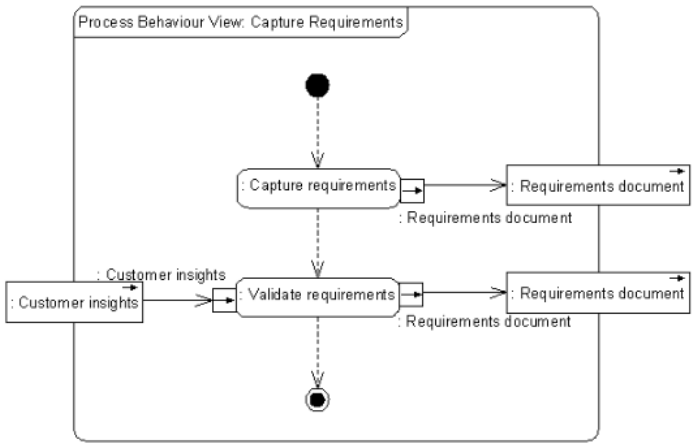
Process Behaviour View: Capture Requirements

During the Capture Requirements process the requirements that describe the functionality that the PSS should deliver is documented and validated with customers.



During capture requirements the requirements describing the functionality that the PSS should delivered as documented in the requirements document. Using customer insight (gained from the customer involvement process), the requirements are validated and the requirements document updated.

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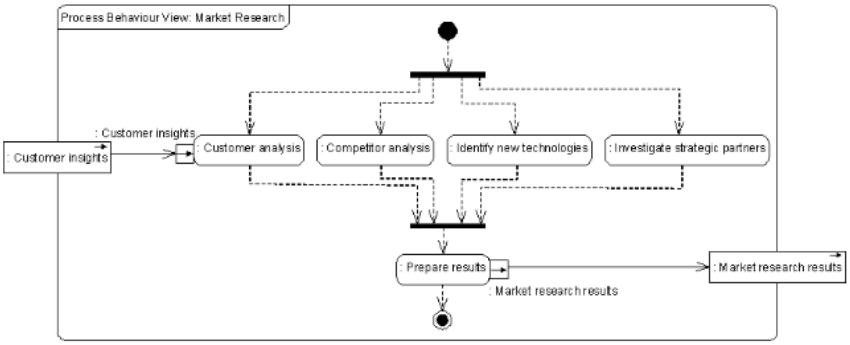
Process Behaviour View: Market Research

Market research is an ongoing process to identify customer needs as well as monitor competitive activities, staying on top of industry events, analysis new business opportunities and searching out strategic alliance partners.



During market research, customer insights (gained from the customer involvement process) are used to help perform customer analysis. The results of all of the analyses exectued during the process are documented in the market research report.

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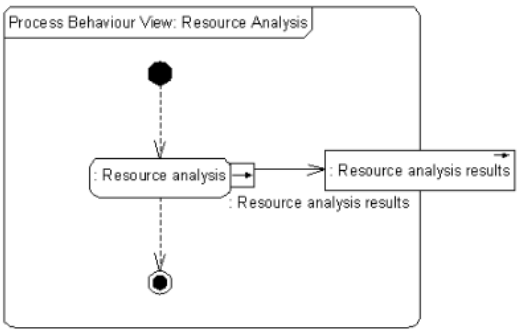
Process Behaviour View: Resource Analysis

During Resource Analysis assessments are conducted to determine what the tangible and intangible assets currently exist that the manufacturer has access to which could be suitable for development into new PSSs.



The results of the resource analysis activity are documented in the resource analysis report.

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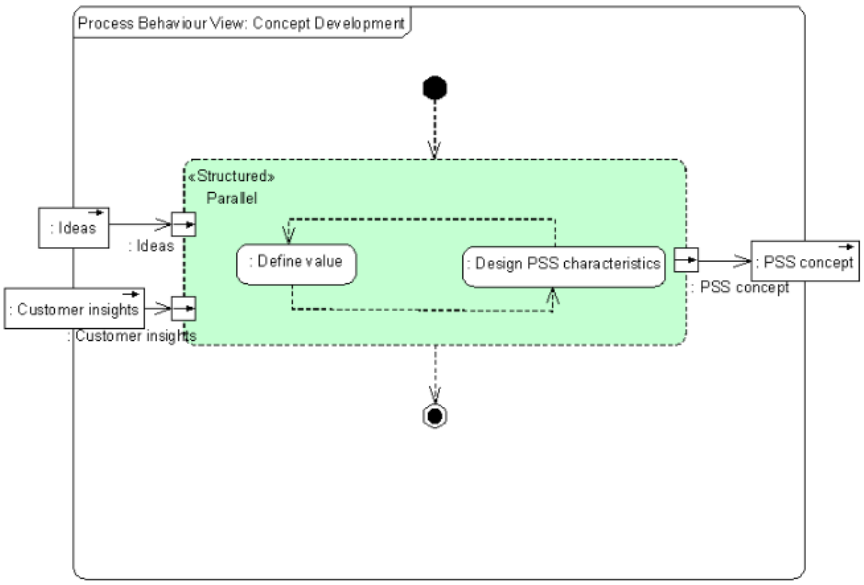
Process Behaviour View: Concept Development

The concept development process identify

- the total benefits that customers are likely to receive from the PSS and an estimate of what these benefits might be worth to customers; and
- the form of the services and the characteristics of the products required to enable the services to be delivered:



During the concept development process, the ideas (gained from the idea generation process) and customer insight (gained from the customer involvement process) are synthesised and a PSS concept is generated and documented.

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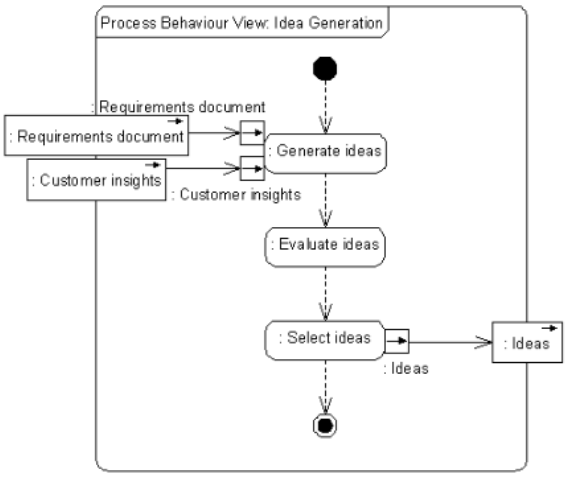
Process Behaviour View: Idea Generation

During the Idea Generation process, potential PSS ideas and created. This are subsequently evaluated and screened and identify the most promising PSS ideas for fulfilling customer needs:



The requirements document (created during the capture requirements process) and customer insights (gained during the customer involvement process) are used as triggers to generate ideas on potential new PSSs. The most promising ideas are documented.

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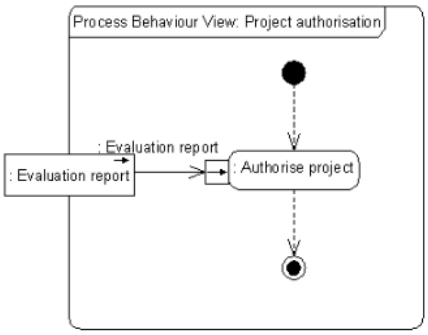
Process Behaviour View: Project Authorisation

During the project authorisation process the most viable PSS concepts are approved for further development by the manufacturer:



Projects are authorised based on the information provided in the evaluation report (created during the evaluation process).

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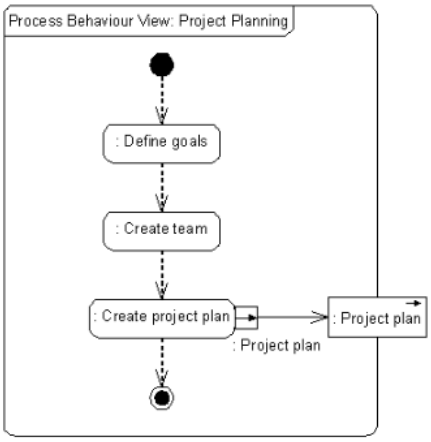
Process Behaviour View: Project Planning

During Project Planning the goals for the evolving PSS concept are specified and project plans and schedules are created. A team is assembled to progress the development towards a deliverable solution:



The results of this process are documented in a project plan.

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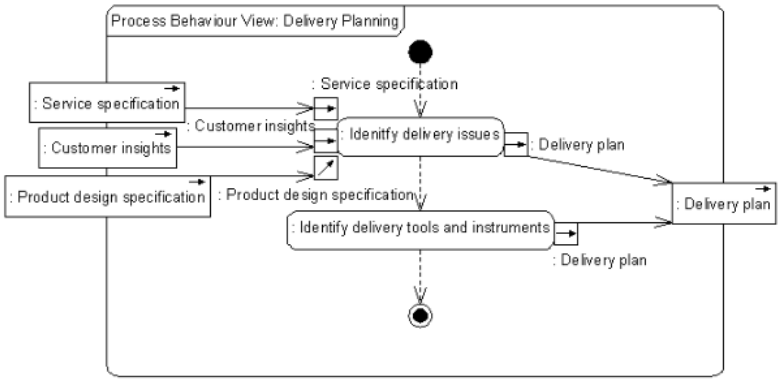
Process Behaviour View: Delivery Planning

Delivery Planning is concerned with providing guidelines for delivering the PSS, identifying potential obstacles and specifiying tools and technologies that might aid in Delivery:



During delivery planning the service specification (created in the service design process) and product specification (created during the product design process) are synthesised with customer insights (gained from the customer involvement process) to identify any potential delivery issues. These are documented and incorporated into the delivery plan.

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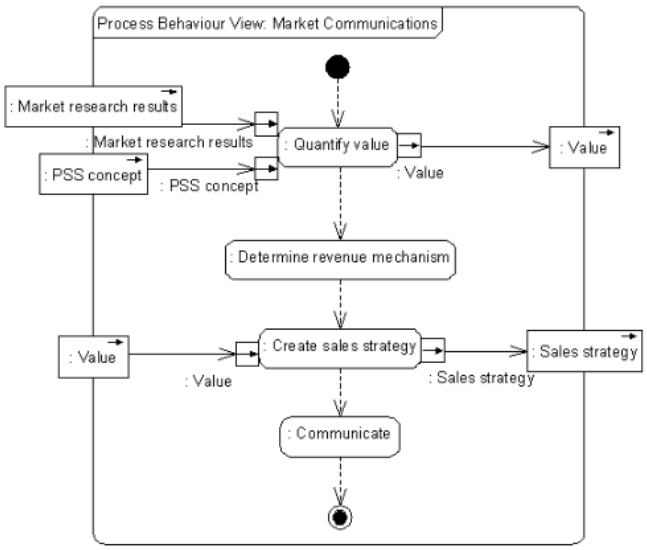
Process Behaviour View: Market Communications

Market Communications is concerned with creating and implementing a strategy to communicate the value of the PSS to existing and potential customers:



The market research results (reported in the market research process) and the PSS concept (created in the concept development process) are analysed to identify how customers will perceive the value of the PSS. This is documented in a value statement. The perceived value is used to inform the sales strategy for each customer.

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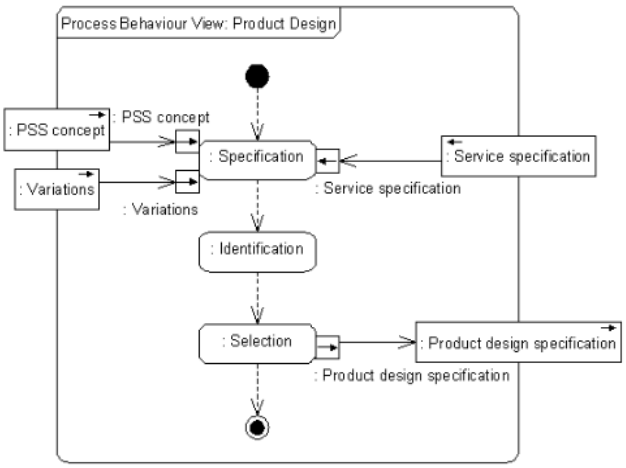
Process Behaviour View: Product design

The Product Design process refers to the identification, selection and specification of the technical components required to enable the PSS to be delivered:



During the product design process, the PSS concept (created in the concept development process), service specification (created in the service design process) and variations (identified in the customisation process) are used to determine the product elements needed to deliver the service elements. These are documented in the product design specification.

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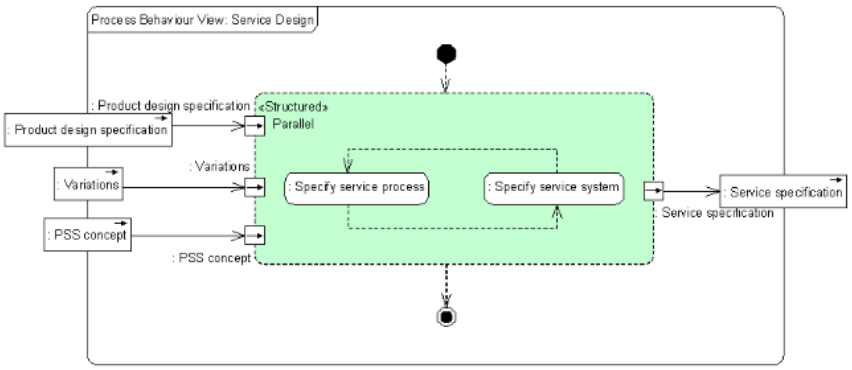
Process Behaviour View: Service Design

The Service Design process concerns the co-design of the service process and service system between the manufacturer and customer:



During the service design process, the PSS concept (create in the concept development process), the product design specification (created in the product design process) and any variations (identified in the customisation process) are used to specify how the service elements will be co-delivered. This is documented in the service design specification.

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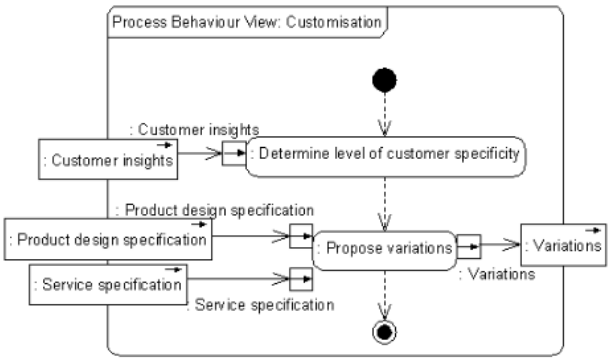
Process Behaviour View: Customisation

During the Customisation process the product and/or service elements of the PSS are tailored to specific customers' businesses:



Customer insights (gained from the customer involvement process) are used to determine the extent to which the PSS will need tailoring. Variations are proposed to the product design specification (created in the product design process) and service specification (created in the service design process) and are documented in the variations report.

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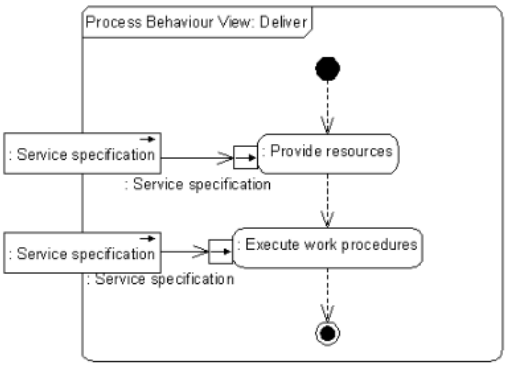
Process Behaviour View: Deliver

During the Deliver process both the manufacturer's and customers' staffs are executing the agreed work procedures/service process:



The PSS is co-delivered in line with the service specification (created in the service design process).

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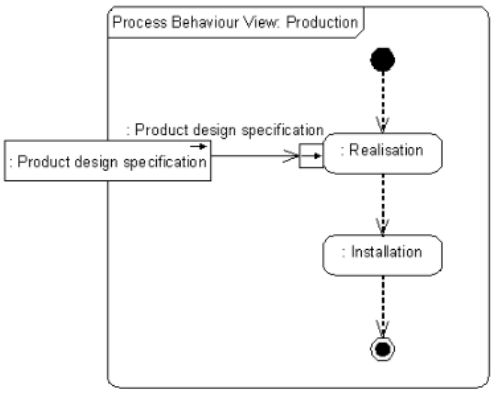
Process Behaviour View: Production

During the Production process the product elements that are needed to enable the PSS realised and installed:



During this process, the product elements are realised in line with the product design specification (created in the product design process).

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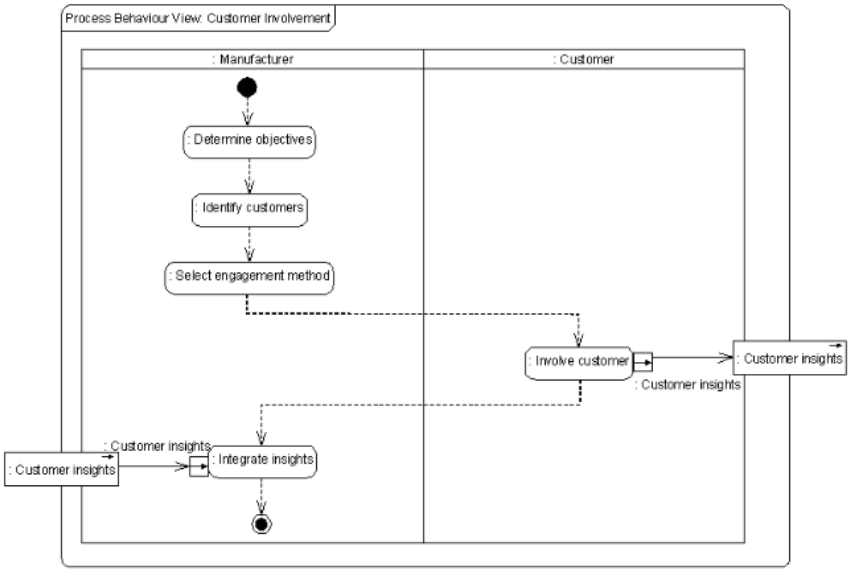
Process Behaviour View: Customer Involvement

During the Customer Involvement process customers are engaged in dialogue to identify their needs and co-design and co-produce the PSS:



Involving customer during the co-development and co-delivery of PSSs will lead to insights that are documented in the customer insights report. These insights are then integrated into PSS development.

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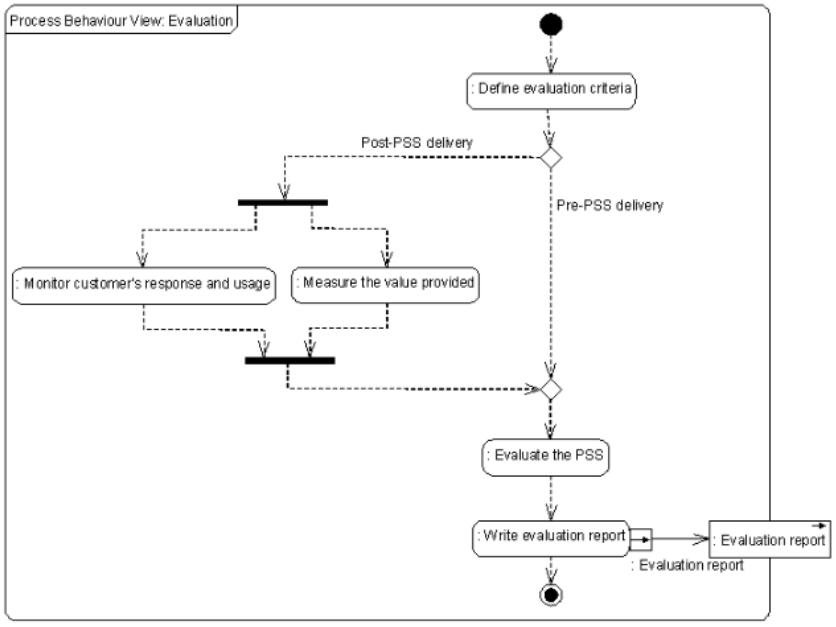
Process Behaviour View: Evaluation

The Evaluation process occurs throughout PSS development and is ongoing during Delivery. During development Evaluation is primarily concerned with making an assessment of the PSS concept to determine its technical and financial feasibility. Once the PSS is being delivered, Evaluation is ongoing to monitor customers' use of the PSS in order to ensure the required functional behaviour is sustained:



The results of the evaluation process are documented in the evaluation report.

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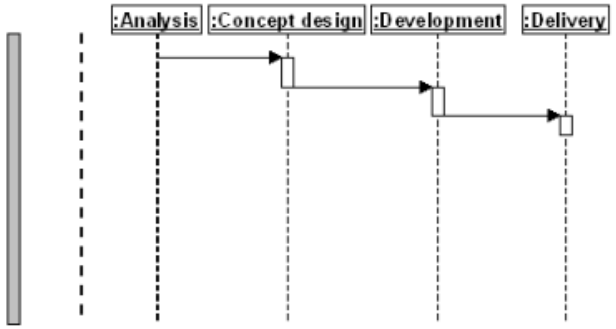
Process Instance View

The Process Instance View prescribes the sequence of application of the phases:



With PSS development, analysis is the first phase to be completed. This is followed by concept design, development and then delivery.

The process instance view does not prescribe the sequence of application of the processes. This ensures that the processes can be executed in a flexible and iterative manner.

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Information View

During PSS development, ten distinct documents are created.

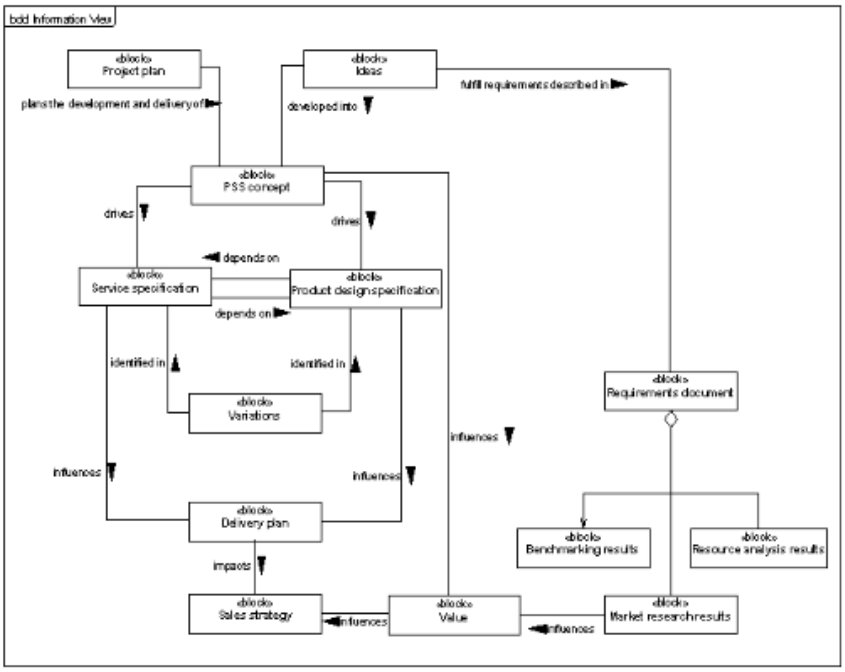
Resulting from the Analysis phase, the Requirements Document is made up of the results from the Market Research, Resource Analysis and Benchmarking processes.

During the Concept Design phase, a PSS Concept is developed from Ideas which in turn fulfill the requirements specified in the Requirements Document. A Project Plan is created to plan the development and delivery of the PSS Concept.

In the Development phase, the PSS Concept drives both the Service Specification and the Product Design Specification. These influence how the PSS concept will be delivered and the implications are recorded in the Delivery Plan. Value is influenced by what customers perceive to be important (recorded in the Market Research results) and the PSS Concept. The Sales Strategy is created which is influenced by the Value and the Delivery Plans.

During the Delivery phase, Variations are identified to the Service Specification and the Product Design Specification to ensure that the PSS is tailored to specific customers' businesses.

Any one document identified with the model of PSS development is related to all other documents as demonstrated by:



Where it is deemed unnecessary to create a document identified within this workbook, the information view provides a way of visualising the impact of this decision on PSS development.

The documents identified within this workbook could potentially take different forms. For example, if PSS development were proactive then a formal requirements document could be specified (e.g. in DOORS). However, if PSS development is in response to a customer request then the requirements document may be manifest in a tender document.

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