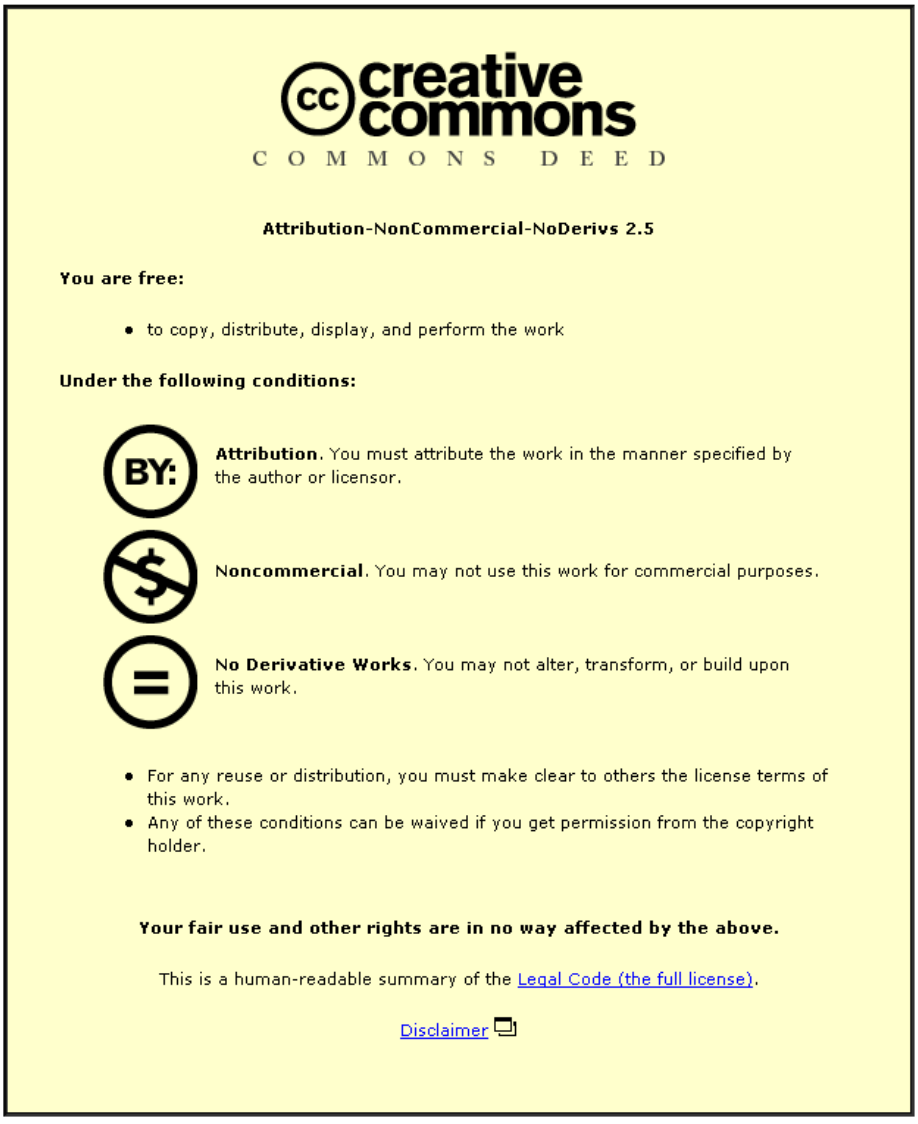

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Evaluating existing approaches to product-service system design: A comparison with industrial practice

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

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 servtization 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).

Take in Figure (1)

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).

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)

Type of PSS	Definition
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 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).

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).

Take in Figure (2).

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).

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

Inputs	Phase	Outputs
- 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*

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.

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).

Take in Figure (3).

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).

Take in Figure (4).

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*								
Sales literature			■					
Sales strategy			■					
Service offering		■						
Service offering in principle		■						
Size of addressable market*								

Output codes:	Project plan	PSS Concept	Sales strategy	Business case	Requirements set	Detailed offering	Value proposition to customer	Successful test
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

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*
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*						■						
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					■							

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*
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)

Inputs	Phase	Outputs
- 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.

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

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). 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).

Take in Figure (5).

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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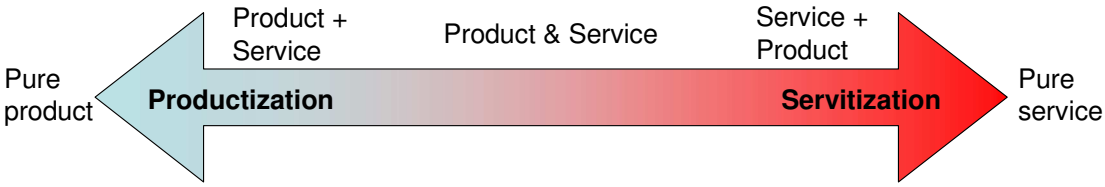

Figure 1: Product-service continuum

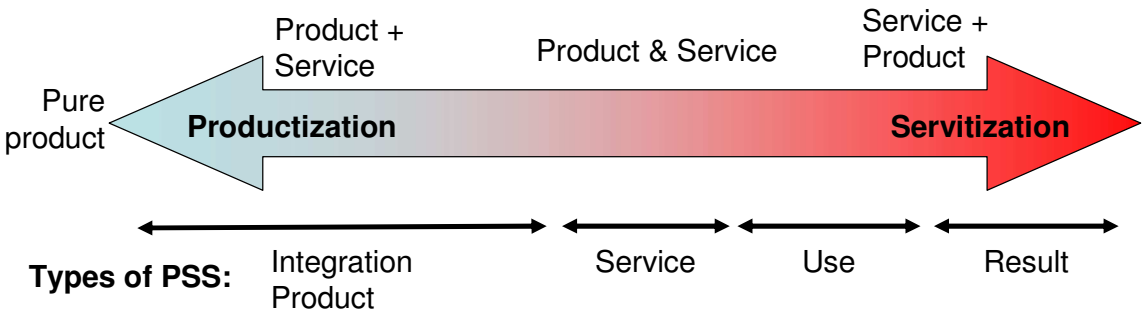

Figure 2: Continuum of product-service offerings

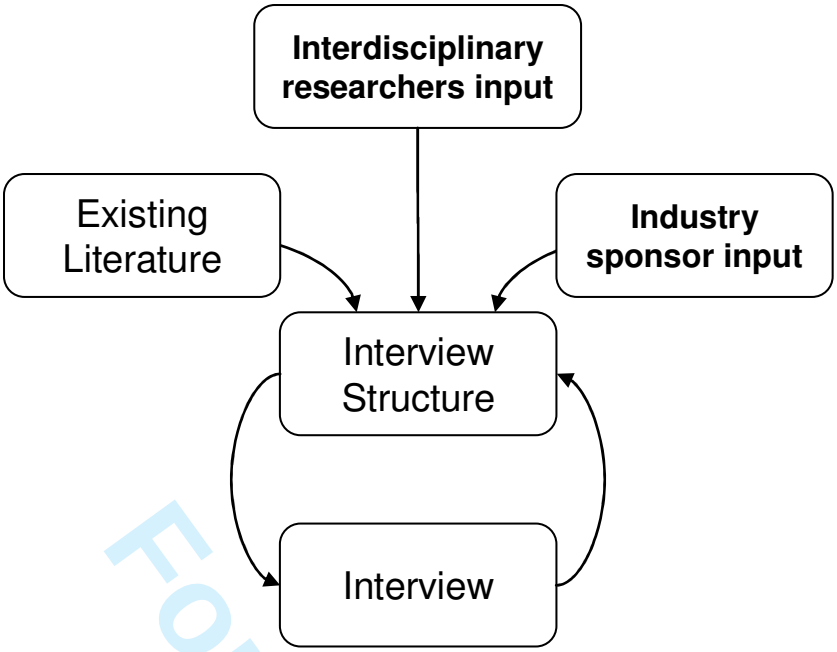

Figure 3: Interview data collection instrument development

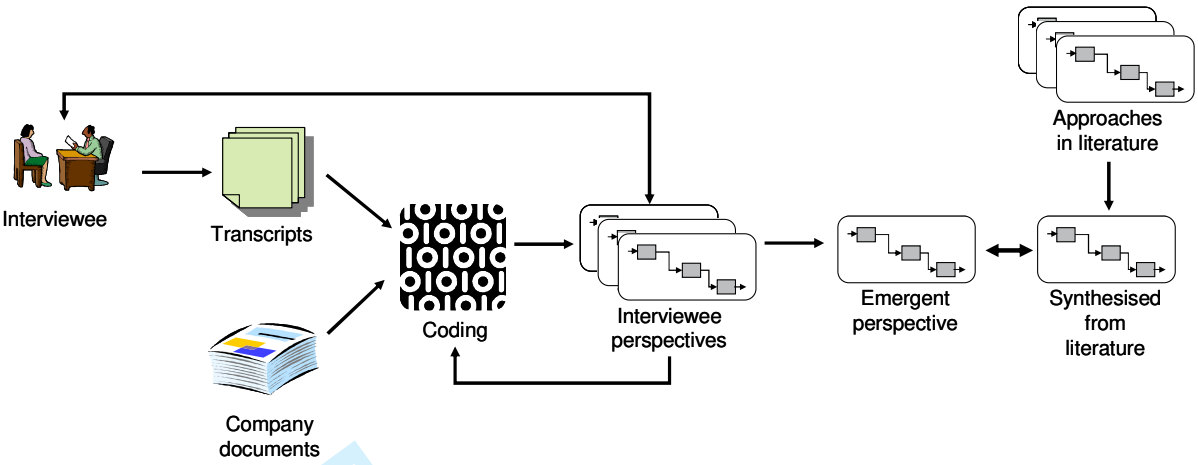

Figure 4: Data collection and analysis protocol

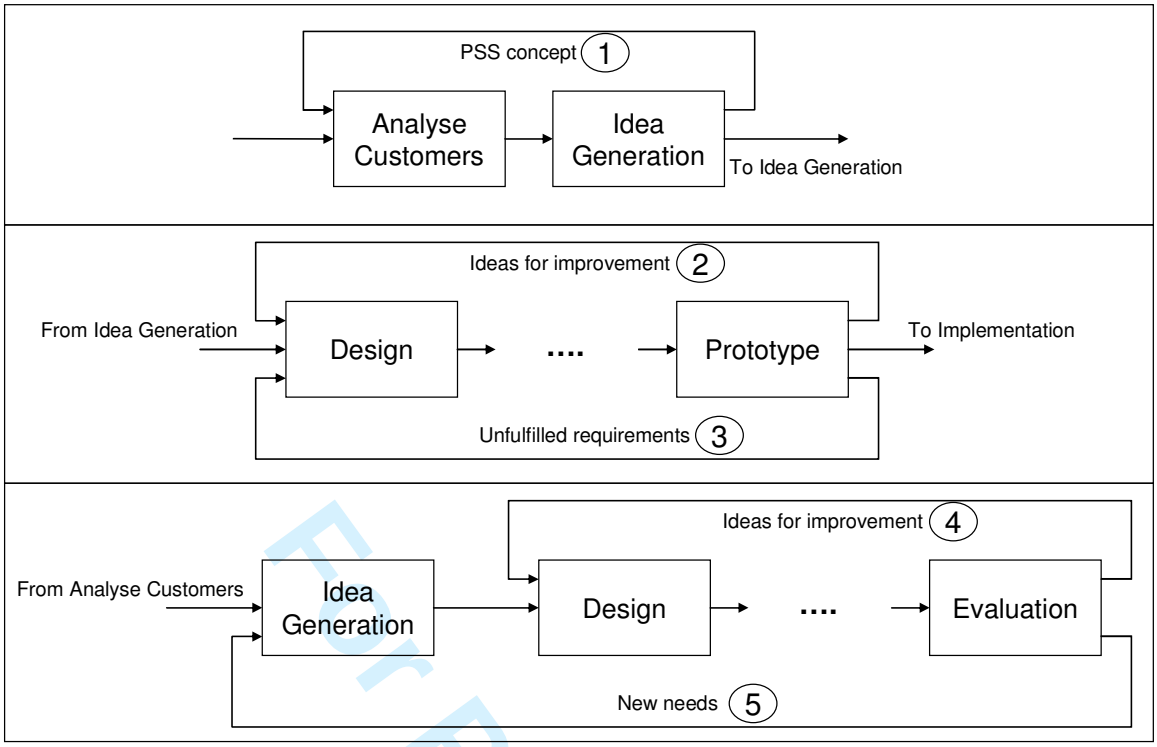

Figure 5: Summary of the feedback loops in RailCo's PSS design process