CRANFIELD UNIVERSITY

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SYSTEM-IN-USE METHODOLOGY:
A METHODOLOGY TO GENERATE CONCEPTUAL PSS (PRODUCT-SERVICE SYSTEMS) AND CONVENTIONAL DESIGNS USING SYSTEM-IN-USE DATA

SCHOOL OF ENGINEERING

PhD THESIS
Academic Year: 2009-2013

Supervisors: Dr Helen Lockett, Dr Jennifer Kingston, Dr Jeffrey Alcock
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This thesis is submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

ABSTRACT

Industries want to add value to their offerings but to do this, rather than just accepting customer requirements, they now need to know how their products and/or services have been embedded within their customer's process to achieve a goal that the customer has; any gaps within the process then present an opportunity for the provider to fill these gaps.

The System-In-Use (SIU) Methodology presented in this thesis facilitates customer issues in "pulling" the supply chain into creating new solutions as well as the supply chain "pushing" new value propositions into improving customer processes. It does this by drawing on a detailed theory of value and capability which was developed as part of this research.

The method has been applied in five industries in processes encompassing high value-assets with very positive outcomes for each of the stakeholders involved: notably, three solutions have been adopted in industry for which a KT-Box award was granted by Cambridge University.

State of the art techniques have been devised for this method which should be fairly easily comprehensible to stakeholders across geographies. These methodologies systematically unpack the problem and solution space so that innovative solutions can be generated throughout the value chain; some of these are more conventional solutions, against which any generated Product-Service System solution can be evaluated. A set of Design Options generates solutions by considering changes to:

- The local or wider environment (examples are protecting the resources from negative effects from variables in the environment or petitioning local government for changes to roads)
- Decomposed parts of the of the offending resource (the resource that contributed most to the overall value loss) by considering addition, substitution, elimination or customisation of each part to generate solutions which can be instituted at different tiers in the value chain and, thus, improve Supply Chain Management.
- The overall business process
- The receiver or the market segment to ones where there would be no value gaps

The SIU Method can be applied quantitatively as well as qualitatively that allows for a speedy, general understanding and generation of solutions which also protects proprietary data.

Keywords: PSS Conceptual Design, Closed Loop Design, Business Model Innovation

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AHP	Analytical Hierarchy Process
AILU	Associated Laser Users
BOL	Beginning of Life
CAD	Computer Aided Design
CWS	Cold Water System
EOL	End of Life
EPSRC	Engineering and Physical Sciences Research Council
GM	General Manager
GT	Grounded Theory
HH:MM:SS	Hours, minutes, seconds
HVAC	Heating, Ventilation and Air Conditioning Systems
IHIP	Intangibility, Heterogeneity, Inseparability, *Perishability*
IPS^2	Industrial Product Service Systems
LCD	Liquid Crystal Display
LPHW	Low Pressure Hot Water
MCDM	Multi Criteria Decision Models
MOL	Middle of Life
MOT	Ministry of Transport test
OEE	Overall Equipment Effectiveness
OEM	Origin al Equipment Manufacturer
PC	Personal Computer
PIU	Product-in-use
PSS	Product Service Systems
SCM	Supply Chain Management
S-DL	Service Dominant Logic
SIU	System-in-Use
SMS	Short Message Service
TC	Time-Cycle
TUC	Trade Union Congress

1 Introduction

1.1 An Overview of the Subject Area

Globalisation and low cost economies now enable capital intensive and high-tech assets to be developed and purchased more cheaply. The established industrialised economies now question how they can contend with such staunch competition, particularly during such harsh economic times which some herald to be the start of a global shift which could, if not managed sufficiently, result in the longstanding industrialised nations losing any sort of competitive advantage.

What is required to foster new competitive advantage is a way to establish, quite finely, what it is that the customer is trying to achieve overall and to help those customers achieve that aim; rather than focussing solely upon the creation of products, manufacturers should now seek to add value by helping the customer to meet their overall objectives. Product-Service Systems (PSS) are one way that the provider can do this as, rather just provide products, the manufacturer provides products bundled with services which should more deeply satisfy customer needs.

To do this, attention has to be paid to how the customer engages with products and services within their use-contexts; that is, the specific resources, competences and environment that the customer has at their disposal to effect solutions to meet their needs. Furthermore, an understanding of the sacrifices that customers endure in realising a goal and how the provider could accommodate this burden in order for the customer to focus more time, energy and resources in building their core competences so as to achieve their goals more quickly and exactly also need to be considered and catered for. Besides satisfying customer's needs, this should also benefit the provider by engaging in long term, locked-in relationships and hence steady income streams. However, the mind of engineering designers tend to be product-centric and often misses the point that the customer is not in need of a product but is, in fact, in need of fulfilling a task which is unique to them and specific to their contextual demands and constraints as well as being unique to their business objectives.

It will be shown that there is a literature and industry gap regarding how customer needs as well as how customers use products within their use-context could be used to inform PSS Conceptual Design. This thesis will develop theory and then, based on this theory, construct a method to address those gaps.

The main groups benefiting from this research are manufacturers who wish to servitize, manufacturers who wish to improve their offerings and customers who wish their goals to be met more exactly.

1.2 Research Context and Scope

The context of this research is the utilisation of data from a system using a product or PSS in-use as well as the customer's aim in using that offering to generate solutions (these can be modifications to the existing system or entirely new solutions) - some of which may encompass new PSS Conceptual Designs in order to satisfy the customer's aim more closely. The scope and focus of this study is wide and covers capital intensive and technical PSS such as laser-cutting machines, buildings, aero engines and high-tech trucks. This research develops a method to generate initial PSS Conceptual designs using system-in-use data.

1.3 The Project Aim and Objective

This research is part of the wider multi-disciplinary, ESPRC/IMRC funded PSS Conceptual Design project. This project was formulated to develop novel contributions in the areas of a PSS conceptual design framework, PSS offering representation, PSS service network capability modelling and informing design with product-in-use knowledge.

The design of a Product-Service System (PSS) offering is a co-production process between the provider of the PSS, the suppliers (the service network) to that PSS and the customer who uses the PSS. Industrial PSS involves complex business to business relationships within a service network and has to consider capability to deliver that service over a long timeframe and across geographies. The conceptual design of technical or industrial PSS offerings is significantly more challenging than product design. Currently, conceptual design in practice is ad-hoc and lacks a systematic approach in considering the service network and customer capabilities and issues in the design process; service is often added after the product is designed, there is a lack of communication between after-sales and design teams and the designers' mind-set is still very product centric. The research has also identified a current lack of knowledge to trade-off between the physical (product) and non-physical (service) functionalities to create required customer value or reduce cost and opportunities for resource optimisation during the technical PSS design process. The aim of the research is to develop a formal methodology to the conceptual design of industrial PSS offerings considering the existing and potential service network capability and past knowledge from the use of similar provisions. The research was to answer "how could we better design technical PSS solutions that can be used over a long term period across various distant locations?" The main objectives of the research were:

1. To develop a framework that will support the design of technical PSS
2. To explore and improve the role that service networks play in the design of PSS and then the support of PSS delivery so that their capability can be considered more fully at the design phase
3. To establish how the customer's knowledge of using PSS can be captured and fed back into future designs of PSS.

This research load was divided into three sections (Figure 1.1) and then allocated to three researchers:

1. Mehmet Cakkol (this researcher's aim was to develop understanding as to how the Service Network can contribute to PSS Conceptual Design),
2. Dr Gokula Annamalai Vasantha (this researcher's aim was the design of a framework for PSS Conceptual Design)
3. The author of this thesis, Romana Hussain. The aim here was to develop a framework to inform PSS Conceptual Design with data from a product-in-use.

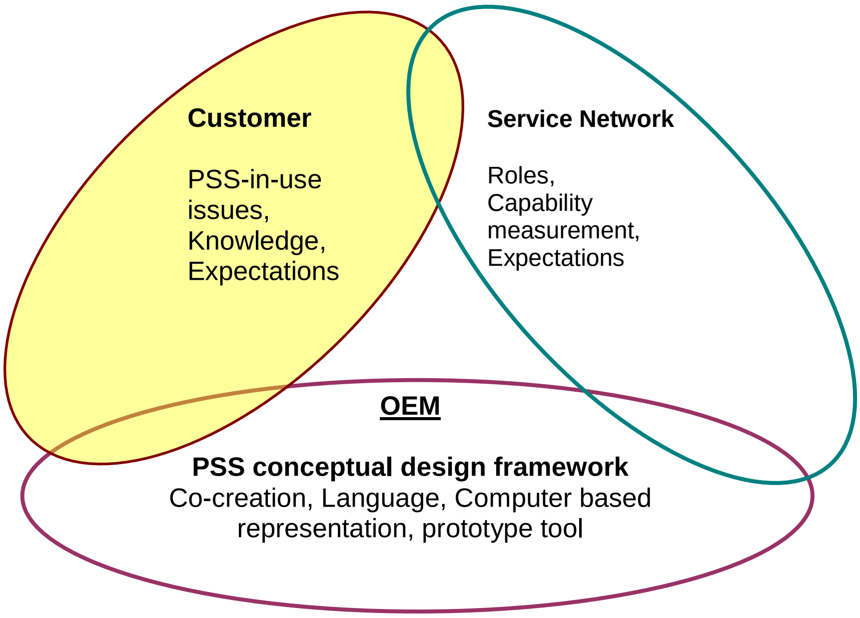

Figure 1.1: The Research areas in the PSS Conceptual Design Project

1.4 The Collaborators

For reasons of confidentiality, the collaborators have been anonymised. They are listed below:

1. A firm of HVAC (Heating, Ventilation and Air Conditioning Systems) systems consultants which are based in Kingston, Milton Keynes. This company can be regarded as a servitization enabler - they can help to support building product-service systems (such as hospitals, apartment complexes and office blocks which are leased or rented out). They can support these high value, technical product-service systems by establishing a pleasant climate in the building for tenants or lease-holders and by reducing the energy bills of the HVAC systems: this would make the occupation of the building more comfortable and affordable for its tenants. A core service that the company offers is the rationalisation of HVAC systems so that large energy savings can be made on existing heating and ventilation systems: by using sensors, trouble spots can be identified as can HVAC systems which may be working in opposition to each other– addressing these issues can result in huge energy savings. For this service, they offer a functional result; that is, the creation of a pleasant building (or floor) climate at a much lower

energy cost. A business model that they offer is one where they will accept a rolling percentage of the energy savings that they've instituted. This business model represents a "win-win-win" where the building users benefit from a pleasant climate, managers are able to cater for users but at lower costs, the company receives a percentage of the savings and (because less energy is being used) there is also a reduction in carbon emission.

2. A British multinational defence, security and aerospace company which has its headquarters in London. It has operations worldwide and is amongst the world's largest defence contractors. In 2008, 95% of the company's total sales were military related and the company plays important roles in military aircraft production. The company also manufactures many Land Vehicles and Armaments and it also has naval projects of submarines and surface ships.
3. A multinational aerospace and transportation company which provides Infomated trains and that became involved in British Rail's Research and Development facilities after privatisation.
4. A company which specialises in the development of Infomated modular, low carbon fuel cell systems for their blue chip partners and their global mass markets. It has over 300 staff and operates globally with offices in the USA, Europe and Asia. This company delivers efficient and clean energy technology for the global consumer electronics, automotive and stationary power markets. It manufacturers products from compact energy packs for mobile devices to power-trains for zero-emission vehicles and stationary power units for the always-on infrastructure.
5. One of the world's largest suppliers of machine tools and a world market and technology leader in the area of industrial lasers. It has 56 operating subsidiaries, across Europe, America and in Asia. Their product range includes laser marking systems, laser systems for cutting and welding two-dimensional and three-dimensional parts and carbon dioxide laser and lamp-and diode-pumped solid-state lasers. Theses lasers are in the automotive industry, medical technology, sheet metal fabrication and electronics and photovoltaic industries.

6. A leading, global supplier of precision photonic components and subsystems to OEM’s in the Medical, Industrial, Scientific and Microelectronics markets. Their solutions include laser sources, scanning and beam delivery products and precision motion control products. They collaborate with OEM customers to adapt their component and subsystem technologies to deliver highly differentiated performances in a wide range of applications. This company manufactures high performance lasers which are used in science and industry and drive a wide variety of industrial applications from semiconductor manufacturing to complex marking and precision drilling.
7. A global technology and innovation company which has its headquarters in the USA. It has around half a million employees and has clients in 170 countries and is the largest technology and consulting employer in the world. This company offers a wide range of technology and consulting services from a broad portfolio of middleware for collaboration, predictive analytics, software development and systems management as well as and advanced servers and supercomputers.
8. This company is a laser cutting and welding job shop as well as a laser system and process consultancy. It started trading in 1984 and currently employs 45 staff.
9. This company has been one of the leading laser cutting, water jet cutting and laser welding job shops in the South of England since 1987. This company specialises in laser cutting and water jet cutting materials such as stainless steel, mild steel, aluminium, titanium, brass, acrylic, wood, ply and MDF.
10. This company provides laser profiling, scanning and CAD services. SSC's core facility is laser cutting mild and stainless steel, brass and aluminium. Their laser cutting machines can handle sheet materials up to 3,000mm long, 1,500mm wide and 25mm thick.
11. Dr Fuad Sufian is an Associate Professor at Sana’a University in Yemen in civil engineering and architecture. He is also a consultant civil engineer and a freelance property developer.
12. An authorised distributor for a programmable and fully interactive virtual reality driving simulator.

13. This is a company which produces high-technology and capital-intensive industrial trucks - these are offered as a use-oriented PSS. The trucks are equipped with sensors that monitor how the trucks are being driven; harsh braking, for example, can (with time) damage the asset and lead to a higher maintenance burden. To reduce poor driving that has been detected, the company directs drivers that have committed driving faults to be re-trained.
14. A leading Transport Management Solutions provider specialising in Vehicle Tracking and Telematics, Transport Management and Planning and Proof of Delivery systems. This company employs about 160 staff with skills in software and hardware development, logistics consultancy and business analysis, project management, implementation, training and support. This company's customers are global and their systems are deployed across hundreds of fleets comprising of tens of thousands of heavy and light commercial vehicles.
15. This company is a first tier supplier to the global aviation industry. It is a leading manufacturer of highly complex composite, metallic aero structures and engine products. Its customers are from the military and civil markets. They employ approximately 12,000 people in more than 35 facilities across 4 continents.
16. This company designs, engineers and manufactures components and sub-assemblies for aircraft engine turbines. It supplies all of the major aero engine manufacturers and has positions on most major civil aerospace platforms.
17. This retail outlet stocks a wide range of electrical appliances, particularly those for kitchens.
18. This is an electrical retailer in the United Kingdom and Ireland. It specialises in selling household appliances. It has 295 superstores and 73 high street stores.

1.5 Thesis Structure and Summary

This Section presents the structure of this thesis and the succession of activities leading to the achievement of the research aim.

Chapter 1 gave an overview of the research context and the incentive for this study. It described the PSS Conceptual Design project and its objectives. The main aim of this research was also presented which is to develop a framework to utilise data from a product-in-use or PSS-in-use to inform PSS Conceptual Design. The thesis structure is also in this Chapter.

Chapter 2 is explores and analyses literature which is relevant to this research and identifies the research gaps. This helps to define the objectives which will eventually fulfil the overall research aim.

Chapter 3 presents the aim and objectives of this study. The research methodology is also presented which was developed after a thorough analysis of the available approaches and strategies. The nature of the objectives and the available resources to this study were the constraining factors of the selection of an approach and the strategy for this research.

Chapter 4 presents a basic framework to utilise data from a product or PSS in use to inform PSS Conceptual Design. This is based on a three-year, qualitative study across many industries that develop capital intensive, technical and infomated PSS. It also presents the industry gap. The member checking of the study is also presented here.

Chapter 5 presents how the basic framework was refined into a method that is industry specific. This refinement was achieved by conducting an in-depth study of a firm that utilises system-in-use data to inform low-cost PSS Conceptual Design. The refined method is then triangulated with the literature and then ontology for capability is developed to further refine the method.

Chapter 6 presents how the framework was further refined, extended and genericised into the System-in-Use Methodology; this was accomplished by triangulation with the literature. The decision to create a Workbook for user support of the Methodology is also presented.

Chapter 7 presents the validations of the developed System-in-Use Methodology. Various types of application of the Methodology to an array of industries and purposes are presented.

The Final Chapter, Chapter 8, discusses the research findings with regards to their applicability and generalizability. The main research contributions are stated, along with the limitations, the future research directions and the overall conclusions demonstrating how the objectives and the aim have been met.

2 Literature Review

2.1 Introduction

In Chapter 1, the research area and the aim of this study was presented. This Chapter reviews the literature associated with the context and research areas related to this study to uncover any research gaps and thus develop a better understanding of the area under investigation. The areas of the literature review include:

- The PSS Concept, Product-Service Systems and the Service Paradox which are discussed in Section 2.2
- The types and classifications of PSS which are discussed in Section 2.3
- PSS Conceptual Design which is discussed in Section 2.4
- Views of Products and Services which are outlined in Section 2.5
- The Nature of Product-Service Systems is discussed in Section 2.6
- How System-in-Use data could be used to influence PSS Conceptual Design which is outlined in Section 2.7
- An overview of PSS Design Methodologies which is given in Section 2.8
- The requirements of a framework to inform PSS Conceptual Design with Product-in-Use Data which is summarised in Section 2.9

2.2 The PSS Concept

PSS originated in Scandinavia in the late 1990s and can be described as a marketable set of products and services which jointly can fulfill a user's needs. The product to service ratio can vary, either in terms of function fulfillment or economic value (Mont, 2002). Baines et al. (2007) conducted an extensive state-of-the-art literature review on PSS and the following definitions reference this work. Additionally, PSS tries to reach the goals of sustainable development'. ELIMA (2005) has described PSS as a system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models. Due to the type of products studied, this research is to do with industrial PSS (IPS^2) (Roy and Cheruvu, 2009) which have the following characteristics:

- Consists of a physical product core (such as a laser system) which is enhanced and customized by a mainly non-physical service shell (such as training, maintenance and disposal)
- Is capital intensive and with a significant physical PSS core,
- Focuses on industrial applications (Aurich et. al., 2006a).

Servitization, of which PSS is a particular form (Baines, 2007), is the transition of manufacturers from offering solely products to offering product-service concepts to gain competitive advantage (Matthyssens and Vandenbempt, 2008). The concept of Servitization was introduced by Vandermerwe and Rada in the late 1980s (Neely, 2008). Governments now tend to contract for capability rather than buying products (Ministry of Defense, 2005).

The Service paradox: It has been stated that servitized organisations are mostly less profitable than purely manufacturing ones because the average labour costs are higher, the investment made to servitize and the net assets of the servitized firms (Neely, 2008). Gebauer et al. (2005) surveyed over thirty manufacturers to explore why investments in servitization rarely pay back which is a paradox. This appears to be due to the organisation's lack of familiarity with service delivery and the reluctance of customers to share knowledge of their processes and the performance of products. For these reasons, managers of manufacturing organisations are often unwilling to servitize as investments in production are regarded as less of a risk than those in services. However, this could be overcome by raising service awareness, understanding the risks involved in developing services and understanding the economic potential of services (Gebauer et al., 2005).

2.3 Types and Classifications of PSS

The types of PSS are outlined by Tukker (2004):

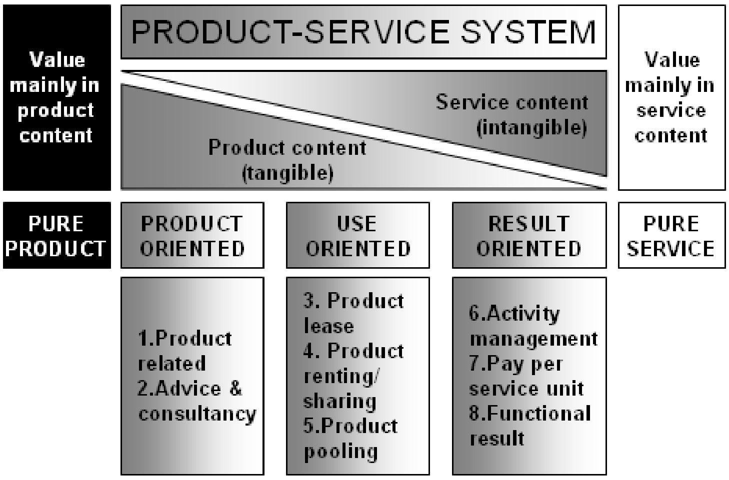

Figure 2.1: PSS Categories (Tukker and Tischer, 2004)

Figure 2.1 shows how PSS can be divided into three main PSS categories (product-orientated, use-orientated and result-orientated) and eight basic subcategories (Tukker and Tischner, 2006; Baines et al. 2007) which are discussed below:

- **Product-oriented PSS**

  This is the traditional sale of a product but embracing additional services. Here, the customer has ownership of the product. Two types of product-oriented PSS have been identified as:

  - *Product-related service:* The provider not only offers a product and also provides services related to that product such as warranty, maintenance, monitoring, consumables' management, repair, upgrades and/or recycling.

  - *Advice and consultancy:* Examples of such advice can be that the customer receives advice with regards to the most suitable product for that customer, advice on efficient product use and/or obtains staff training.

- **Use-oriented PSS**

  This is sale of the use or availability of a product. Here, the provider holds the property rights of the product and is responsible for its condition. Three types of use-oriented services have been identified:

  - *Product lease:* The lessee pays for the use of the product and has an exclusive access to it. Although the total that the customer will pay is usually more than if the customer had bought the product, there is no lump-sum to pay at the start of using the product and also no expenses regarding maintaining or replacing the product. A risk for the provider can be that the misuse of the product by the customer can lead to increased maintenance costs or even product replacement.
  - *Product renting or sharing:* Although this is similar to leasing, the customer does not have sole access to the product and purchases its use for a period of time.
  - *Product pooling:* This is similar to renting and sharing although the customers here can use this product virtually on-demand.

- **Result-oriented PSS**

  This is the sale of the result or capability of a product. Two types of result-oriented PSS have been identified:

  - *Activity management/outsourcing:* An organization outsources an activity to a third party company.
  - *Pay per service unit:* The customer pays for either the time a product is used or for each service unit provided by that product. This mean less risk for the customer as they only pay for when the product works as intended.

The impetus behind the PSS concept is the development of sustainable production and consumption as well as increased competitiveness by meeting customer’s needs and increasing revenue for providers. Besides manufacturing and service companies, the concept may also be beneficial for consumers and the environment (Mont, 2002):

- *Manufacturing companies:* PSS can improve relationships with customers due to increased interaction and information gathering regarding customer preferences. Furthermore, PSS can enable companies to provide a customized service to their customers. This can help to open new markets and increase profit margins (Aurich et al., 2006a).
- *Service companies:* PSS can help to diversify services whilst maintaining quality levels and thus help to protect market share.
- *Consumers:* Consumers can enjoy a wider variety of services without having the responsibilities of product ownership.
- *For the environment:* With PSS, the total amount of products produced could be reduced which would result in less resources being used and less waste.

2.4 PSS Conceptual Design

Maussang et al (2009) referred to the preliminary design phase in PSS as conceptual design and they stated that here different solutions should be considered and compared with each other. Kimita et al (2009) assert that the conceptual stage consists of customer values and features of the offering and Isaksson et al. (2009) extends this by stating that customer interactions (needs) should come together with the provider's competences to develop conceptual solutions. They also state that the whole conceptual offering should be modelled and simulated (Isaksson et al. 2009). Within the field of Competitive Design, Sisodia (2007) describes external integrity as being the meeting of user expectations and actual experience and he defines internal integrity as being whether a product functions well as a system. These terms would appear to map to PSS Conceptual design (external integrity) and PSS Design (internal integrity). At the PSS Conceptual Design level, there could be totally different types of offering which could satisfy the functional needs of the user. For example, a service could easily replace a product and this is actually an aim for environmental PSS Design which is a strategy for dematerialization (Mont, 2002). However, the Design stage deals with how the implementation of the selected offering can be designed so that the offering will perform well.

Ericson et al (2009) state that initiation of product development is hazy as information is sparse at this stage. They also state that the difficulty from the outset for the developers is to understand what they should design, how it should perform, for whom and under what circumstances (Ericson et al., 2009). It is here that relevant marketing research data is required as it should provide insights and direction as to what certain potential customers value.

Although these definitions are useful, more understanding of the PSS Conceptual Design Process is required as, in practice, it is ad-hoc and lacks a systematic approach (Alonso-Rasgado et al, 2006).

2.5 Views of Products and Services

Within the service literature, there has been much debate as to what distinguishes goods from services. This debate is particularly relevant to PSS as the impetus here is to find ways to combine goods and services into solutions which will deeply satisfy customer needs. Moreover, as manufacturing companies can tend to be product-centric, an understanding of what is significant about services in relation to products could help to change the mind-set of manufacturers to become more embracing of services.

The IHIP View: The traditional "textbook‟ view on services has tended to revolve around the IHIP characteristics (Lovelock and Gummesson, 2004) that is, that services are Intangible, Heterogeneous, Inseparable and Perishable. These characteristics tend to describe how the *form* of services differs from that of products rather than what is significant about products and services. These characteristics are:

- *Intangibility* - Services lack the tactile quality of goods
- *Heterogeneity* - Unlike goods, services cannot be standardized
- *Inseparability* - Unlike goods, services are simultaneously produced and consumed.
- *Perishability* - Services cannot be produced ahead of time and inventoried.

However, services such as training can be quite well standardised and primed ahead of time. Furthermore, using the IHIP view it would appear that, as services and products are so utterly different, a service would never be able to replace a product. Moreover, this model fails to tell us what is significant about services or, indeed, products.

Service Dominant Logic (S-D Logic): Vargo and Lusch (2004a) defined service as:

> *"...the application of specialized competences (knowledge and skills) through deeds, processes, and performances for the benefit of another entity or the entity itself."*

They also have stated that:

> *"Goods are a distribution mechanism for service provision."* (Vargo and Lusch, 2004a)

In the PSS engineering literature, Kato and Shimomura (2008) show agreement with Vargo and Lusch by stating that (particularly with the growth of technology) services are delivered by not only humans but also products; this assertion underpins their method of extended service blueprinting which allows products and services to be depicted similarly. Such understanding would appear to be consistent with how customers naturally perceive goods and services: we are used to hearing people in general use phrases such as, "*My car serves its purpose.",* or, "*My computer has served me well*." As far as the customer is concerned, products and services exist to serve their needs, that is, both products and services offer a service to them and they often have little interest in how they are created. Furthermore, because these assertions inform us as to what is common between goods and services, they also explain how within the Sustainability Model of PSS a service can replace a good:

> *"...traditional material intensive ways of product utilisation are replaced by the possibility to fulfil consumers' needs through the provision of more dematerialised services."(Mont, 2002)*

For commercially orientated PSS, such understanding of the commonality between products and services helps us at the start of design during the Conceptual Design phase as a trade-off can be made between the design of products and services on the grounds of function fulfilment against economic value (Mont, 2002). Furthermore, if goods are a way of providing service, then for manufacturers who want to servitize, the message of how to do this becomes clearer: rather than add services, manufacturers should endeavour to extend the level and type of *service* that they are already providing through their goods. Here, the core competences which are used to provide goods could also be used to provide services. This is an important starting point for a strategy to servitize as manufacturers could avoid stepping outside of their core competences. To sum up, at the PSS Conceptual Design stage, it is *service* (the serving of customer needs - capability) that is the focus rather than the *form* of how that *service* is delivered as this is the concern of product and services engineering.

2.6 The Nature of Product-Service Systems (PSS)

A definition of PSS will be deconstructed to see how this term relates to users and then how users relate to products will be examined later. A definition of PSS is offered by Baines et al (2007): '*A PSS is an integrated product and service offering that delivers value in use.*' Vargo and Lusch (2004a) define the term 'value in use' as *'…a customer's outcome that is served directly through the product/service consumption.*' Tukker and Tischner (2006) stated that the same product can satisfy different functions for different customers at different times and that this is central to the development of a new PSS as product function should be designed to meet the customer's deeper (functional) needs: '*the need behind the need'* (Tukker and Tischner, 2006). Thus, customer functional needs are fulfilled by value in use and this notion lies at the heart of Product Service Systems.

Morelli (2006) stated that a PSS is created through a value co-production process where all of the stakeholders offer suggestions as to the form of a PSS and how it can meet the needs of the customer. Co-production can help the value proposition to be more aligned to customer needs (Vargo and Lusch, 2004b). It has been stated that it is the interactivity between the customer and the provider with regards to defining the customer's needs which can lead to solutions which are more apposite for the customer (Davis and Manrodt, 1996). This is an important idea as customers integrate products and services into a system to accomplish a goal they have – this is a value-creating system (Ng et al, 2012). Value creating systems consist of value propositions and customer resources which are integrated together within the customer's use context (Ng et al, 2012). The components of value creating systems can be examined further:

- ***Use context:*** the environment in which the value creating system is embedded (Ng, 2012).
- ***Resources:*** Value creating system make use of resources and these resources can be classified as being either operant or operand resources. Operant resources are resources which act (follow a process) to change other resources to create benefit – produce an outcome (Vargo and Lusch 2004a); for example, a firm's capability to assemble components is an operant resource. Operand resources are resources which must be acted upon to be beneficial; examples are natural resources and other generally static matter (Vargo and Lusch 2004a).

Ng et al. (2012) further state that the links suggested by current research between value-in-use and resources require elaboration on their relationship in order to enable this value co-creation. This point is extremely pertinent to this research as the whole point of PSS design is the development of resources so that the customer can experience value in use.

The notion of value creating systems appears to map to the definition of capability which is a set of individual business processes that are connected to customer needs (Stalk et al, 1992) and this, in turn, also appears to map to the definition of service as offered by Service-Dominant Logic (SD-L) which is defined as the application of specialized competences (knowledge and skills) through deeds, processes, and performances for the benefit of another entity or the entity itself (Vargo and Lusch, 2004a). These definitions are below:

- ***Value creating systems*** – these are value propositions and customer resources which are integrated together within the customer's use situations (Ng et al, 2012).

- ***Capability*** - Stalk et al. (1992) define capability as a set of individual business processes that are connected to customer needs and state that a capability is strategic only when it begins and ends with the customer.
- ***SD-L Service*** - service here is defined as the application of specialized competences (knowledge and skills) through deeds, processes, and performances for the benefit of another entity or the entity itself (Vargo and Lusch, 2004a).
- ***Cocreation:*** any value creating system is co-created by various stakeholders (such as providers and customers) as each has proffered their resources to this system (Vargo & Lusch, 2004a).

Gronroos has stated "*Only during consumption, realised value in the form of value-in-use is created*." (Gronroos, 2008) which is notion also echoed by Vargo and Lusch (2004a). Thus, for any value proposition to be used, the customer has to have the means (their own resources which are integrated into their own value creating system with the value proposition) to do that. Therefore, *value in use* could be restated as *the customer accomplishing a task (achieving a goal)*. This occurs through co-creation (using the resources provided by each of the stakeholders such as the customer and provider); any given value proposition will only ever be one part of the customer's value creating system and it can only ever help to support that value creating system. The end-user's system is a value creation system (this is because its output is used directly in consumption). Although the subsystems within it are systems in their own right, they can only be described as value supporting systems. This is because they have to be integrated with the customer's other resources in the customer's environment for value in use to be delivered.

Ajaujo and Spring (2006) point out that although service relationships should be managed carefully with customers, that this should also be the case for new and complex products. The arrival of sensor technology means that a level of responsiveness can now be afforded through a product which was hitherto only ever seen with services. GrÖnroos (2008) states that such responsiveness by the provider allows for more value in use to be created. Vargo and Lusch (2004b) have stated that it is service that is bought even when a tangible product is offered; this now becomes even more evident with the advent of such Infomated products. Tomiyama et al (2004) defined a service as a set of activities that delivers service contents through service channels from service providers to service receivers in a service environment, and generates values for service receivers; here these authors have the same view that *service* (serving needs) can be delivered by products or services.

All organisations are resource integrators as, using their knowledge and skills, they transmute resources into value propositions; it is through this process that the resources of one system contribute to the co-creation of value between that and other systems (Vargo and Lusch, 2004a). This notion is echoed by Ng et al (2012) who assert that goods and service have a nested relationship and that an understanding of value creating systems can help to re-evaluate and inform the design of the supply chain (Ng et al, 2012). Therefore, as a system is composed of subsystems which are systems in their own right, value creating systems are recursive. This could be depicted as in Figure 2.2.

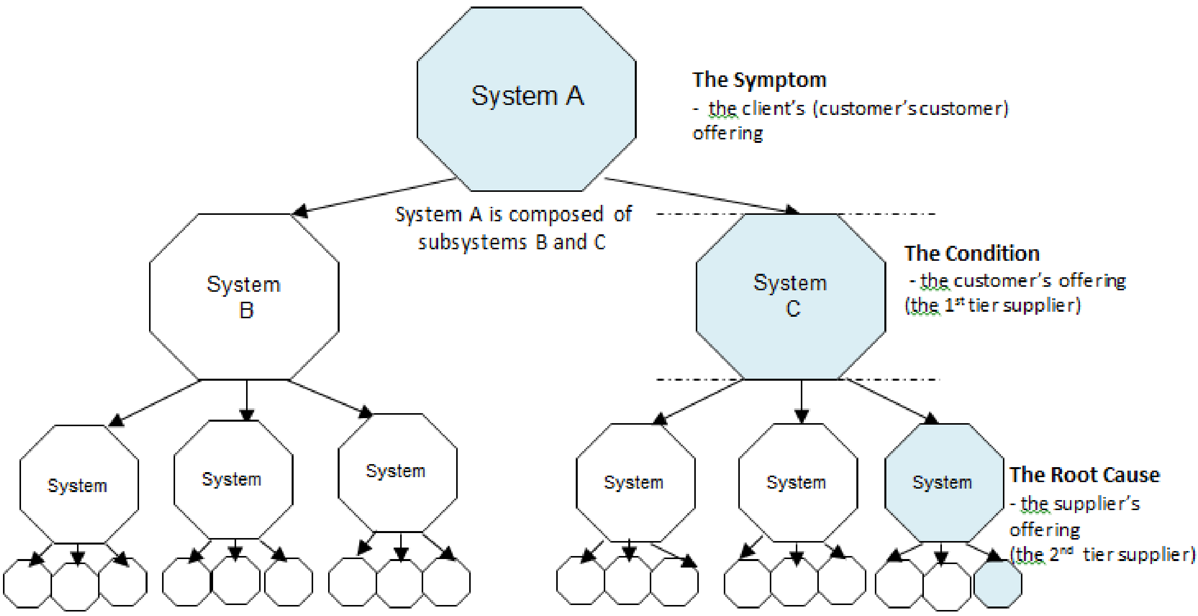

Figure 2.2: The System Recursion Tree

2.7 How System-in-Use Data could be used to influence PSS Conceptual Design

System-in-Use Data Compared to Requirements: If, as Ericson et al (2009) state, that people are often not aware of their needs and that their needs are usually embedded in their routines and actions, then how they actually interact with the world around them (including products) could be more indicative of what their underlying needs may be than anything they might say. For this reason, methods which aim to capture voiced customer demands in a way that can be useful for engineering such as QFD, (Akao, 1994) if employed this way, can fall short. Furthermore, capturing requirements for products and services assumes that the process in which they will be used requires no redesign.

Closing the Design Loop: Information is sparse at the start of design (Ericson, 2009) and, although there is much design information at the product Beginning of Life (BOL), it tapers off after this stage. Infomated products allow data to be collected and fed back to inform design with regards to modes of use, operational data and also how and when the product is decommissioned (Jun, 2007). Such information can be collected at the middle of life (MOL) and the end of life (EOL) of products and so encourages a life-cycle approach as the product (from beginning to end of life) can be continually evaluated (Ericson, 2009). The possibility for closing this loop so closely is a relatively recent event which is due to the emergence of new sensor technologies (Jun, 2007). Earlier measures to provide some closing of the design loop was provided by methods such as prototyping, field data analysis and task analysis although Infomated products can further facilitate the collection of such data.

A PSS offering is typically a system of products, services, infrastructure and supporting networks (Mont, 2001). Maussang et al (2009) state that PSS design differs markedly from conventional product development because with PSS the organisation of the whole system has to be taken into account. For the PSS offering, a trade off between the design of products and services can be made here on the grounds of function fulfilment against economic value (Mont 2002). As the user will integrate the offering into their systems (Matzen, 2005), the PSS offering should be designed and continually adjusted to be as integratable as possible so as to achieve maximum value in use. Feedback from how a product is meeting the user's functional needs can facilitate the creation of service to fill any gaps as they arise or allow for the next generation of the product to be redesigned to fulfil the user's needs more closely (Goh, 2009). Traditional user testing may not always reveal shortfalls between the product and the user needs as that would depend on exactly how the product performed after it had been integrated into the user's systems (Ajaujo, Spring, 2006).

With regards to systems integration of products, Ajaujo and Spring state:

> *"If it is true that intangibles cannot be assessed and tested in advance, it is equally true that for many complex products the process of installation and appropriation into the user's value system involves a lot more than the product itself." (Ajaujo, Spring, 2006)*

Therefore, the efficacy of the product could only truly be touched upon after the product had been integrated, attuned and familiarized by users. This has lead Isaksson et al. (2009) to comment that the development of PSS involves increased involvement in the customers' business processes into which the product will be embedded.

Infomated system-in-use data and qualitative data from users and customers could inform PSS Conceptual Design as to deficiencies in the original value proposition or deficiencies which have since arisen due to changing user needs. These gaps could then be designed for by producing services to fill the gaps or by designing the next generation of product to meet user needs more closely (Yang et al, 2009). Each generation of the offering could then be considered to be a form of prototype which is helpful when attempting to extract more comprehensive user needs as prototypes can help users express their needs in a more structured way (Ericson, 2009). Alternatively, as there are several theories on how to prepare a common "platform" and exchangeable modules in a product (Sakao, 2009), a modular design would allow for the upgrading of a product by switching modules; this way, the selected replacement module would deliver the required functionality and performance required by individual customers.

For capital-intensive, industrial and technical PSS development, the use of past knowledge is important to reduce the whole life cost. Whist work has been conducted in the area of informing design with service feature information, there are currently few references in the PSS literature to utilising feedback from PSS in-use to support PSS design.

Yang et al (2009) propose a methodology and tools for real realising Product Service Systems for consumer products. Using this methodology, the collection and processing of life-cycle data from sensors within a consumer product can result in the following types of product-related and use-related:

- Remote Diagnostics
- Remote Monitoring
- Rental and Sharing
- Analysis of Use Pattern
- End-of-Life Treatment

However, although such data can indicate the use patterns and the performance of the product, it cannot indicate *why* the product was used in that way, the overall goal of using that product or the resources, abilities and environment that the user has to have to make use of the product. This is because the impact of the environment and other resources used with the product to achieve an aim are not monitored. To sum up, this methodology provides little insight into the '*needs behind the needs*' and this is the goal of PSS Design. Furthermore, as methods such as FMEA tend to be applied to the failure of products and now services (Carlson, 2012), if the customer's concern is that of achieving a goal, then it is the failure of that aim that should be the focal point of design rather than solely any individual resource (that may be one amongst many) that was merely a means to an end.

Within the PSS literature in general, there has been much reference to using product-in-use data for design although how to accomplish this appears to be lacking:

- Mont (2002) highlights the potential benefits that can be achieved by learning from a PSS in-use but does not propose how the benefits can be achieved.

- Aurich (2006a) identifies "information procurement" as a key service function of a PSS which he defines as:

  '…*providing the manufacturer with customer information from product usage such as experiences, expectations or suggestions*.'

  He proposes a concept for life cycle oriented design of technical PSS but does not appear to incorporate the information procurement aspects in the concept.
- In the wider engineering literature there is a substantial body of research relating to collecting and analysing product usage data. This literature covers health monitoring, prognostics and other information collection methods that can be used to acquire feedback about a product in use (Boller, 2000; Chang, 2006; Hoske, 2006; Wang et al., 2007). However the emphasis is mainly on maintenance and the avoidance of service interruption rather than closing the loop back to design.

Furthermore, approaches to Service such as Service Dominant Logic, IHIP qualities and Unified Process Theory lack a framework with the specificity of knowledge, practices, solutions, general problems and scope that is required by a specialised discipline such as PSS (Wild, 2010). Likewise, although Value Engineering can be useful for understanding systems and can deal with the substitution of materials and methods, it lacks specificity to the concerns of PSS (Sakao et al., 2007); for example, the term ''value'' in Value Engineering is defined as function over economic cost whereas within PSS and Service Engineering (as defined by Sakao and Shimomura), the concern of value lies with the value-in-use that the customer experiences (Sakao et al, 2007). For example, any potential function that a product may afford can only be realised if the receiver has the requisite competences, resources and environment to realise that function and the value of that product will be determined by the degree it helps to accomplish that receiver's goals as compared to other products or services. Therefore, the use-context (Ng, 2012) has to be taken into account for PSS Conceptual Design.

What is required is an approach which is a problem-solving and has solution generation strategies that result in integrated PSS Concepts.

2.8 PSS Design Methodologies

From the designer's perspective, designing a PSS is a challenge as an extension of his traditional know-how into new domains is required as the designer has to consider and synthesise solutions springing from the comparison of different opinions and different customer needs (Morelli, 2003). As PSS has been defined as an integrated product and service system (Baines et al., 2007), this would suggest that an integrated development approach for both products and services is required. In product-service design, there are three main approaches (Aurich and Fuchs, 2004). These approaches are presented in Figure 2.3.

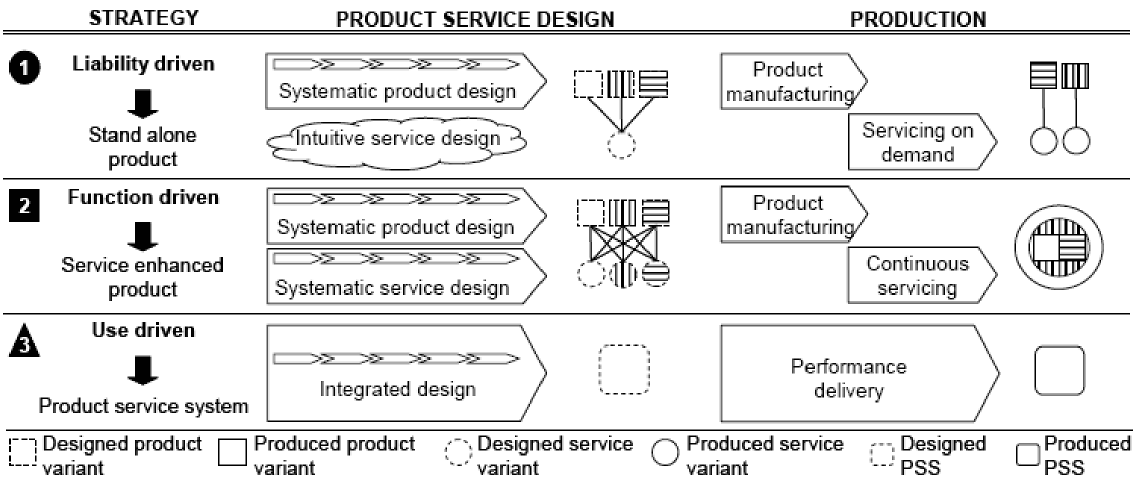

Figure 2.3 : Product-service design strategies (Aurich and Fuchs, 2004)

1. ***Liability Driven:*** This approach derives from the traditional view of manufacturing firms whose core competencies are the development and production of products. Here, although the product design processes are extremely structured, any service design process which may exist tends to be very intuitive and largely liability oriented. Any services which are offered tend to ensure product function.
2. ***Function Driven:*** This approach has a goal of offering service enhanced products. The systematic design of products is geared towards the development of product variants which are each supported by systematically designed service packages. Here, products and services are not regarded as

distinct entities but are combined according to customer requirements. This approach is termed 'function driven' as, although the main focus is still the physical product, its function is accomplished through services. Manufacturing companies often adopt this approach although their overall aim is an integrated product and service design process.

3. ***Use Driven:*** This approach aims to offer a customised solution to each customer. Here, the offering is designed so that services elements are integrated into the product design process resulting in a 'use driven' offering. Such design specification would cover a description of the physical product core with its main functions as well as a description of the customer requirements regarding the product, production processes, operator qualifications, related logistics and financing options (Aurich et al., 2004).

In practice, product design is usually performed by technical staff and service design is usually carried out by marketing and distribution personnel (Aurich et al., 2006a). However, for integrated PSS design, a common understanding of the offering to be designed and its elements is required. There are many PSS Design Methodologies and approaches. An overview of several is provided below:

- ***PSS Design*** (Maussang et al. 2009): assists engineers in jointly developing of physical products and interacting services to generate more value.
- ***Methodology for Product Service System*** (MEPSS, 2004): this is a five phase methodology developed by the European Commission under the 5th Framework Programme, to enable the European industry to develop PSS. The MEPSS toolkit was made available via a handbook and on the website www.mepss.nl.
- ***Service CAD*** (Tomiyama, 2001; Komoto and Tomiyama, 2009): this is a method which is used to design business models that increase ecoefficiency from a systems perspective.
- ***Fast-track Total Care design process*** (Alonso-Rasgado et al., 2004; Alonso-Rasgado and Thompson, 2006): This develops innovative offerings which

consist of hardware and services integrated to provide a complete functional performance.

- ***Integrated product and service design processes*** (Aurich et al, 2006a; Aurich et al, 2006b): this utilises the interrelations between physical products and non-physical services and the development of corresponding design processes.
- ***Service Model Service Explorer*** (Sakao and Shimomura, 2007; Shimomura et al. 2008; Kimita et al. 2009): This concentrates on service engineering to design products which have enhanced services.
- **Heterogeneous IPS² concept modelling** (Meier and Massberg, 2004; Welp et al. 2008; Sadek and Theiss, 2010): This is a model based approach of diffuse borders between products and services that generates heterogeneous Industrial Product-Service Systems conceptual designs.

Welp et al. (2008) have stated that currently there are no integrated approaches that facilitate PSS designers in generating PSS concepts. Komoto and Tomiyama (2009) have stated that the theories and methodologies for PSS are insubstantial and lack specifity. Likewise, a review of PSS Design Methodologies (Annamalai Vasantha et al, 2012) revealed that the field of PSS design is at an initial stage of development and substantial research is required to develop a practical PSS design methodology. They claim that the two major challenges facing PSS today are the development of ontology and systematic modelling approaches emphasizing co-creation. Furthermore, they state that the definition of the context needs to be improved, the positioning of stakeholders and that the monitoring of the use phase along with utilising the customer's experiences, desires and interactions are not considered sufficiently in the proposed methodologies. They also state that several major deficiencies in PSS Design Methodologies are:

- Detailed requirement lists tend not to be generated which means that added value, innovation, risks, uncertainties and cost reduction of PSS cannot be sufficiently modelled. Also, methodologies should accommodate the evolving of customer requirements.

- The roles, responsibilities and capabilities of the stakeholders in co-designing PSS offerings are not clearly defined in the methodologies.
- The significance of co-creation between stakeholders is only touched upon whereas there is a need to know how to implement it.
- The Integration of products and services is considered detailed steps of how to achieve this are not mentioned.
- The process to design innovative business models is not often detailed.
- The impact of business models on product and service design is not considered.
- How PSS design processes should differ for different types of PSS are not discussed.
- The evaluation of PSS offerings requires more research and should be conducted with a long-term view to consider related risks and uncertainties.

Sakao et al. (2009) have stated that although user involvement methods can facilitate feedback of information to successfully operationally adapt offerings, this is not currently reflected in existing PSS-development methodologies.

Furthermore, and quite crucially, the current PSS Design Methodologies tend not to evaluate PSS-based solutions against other more conventional solutions. The danger here is that the provider could invest a great deal of time and money into the development of the PSS then find that, before the PSS is marketed, that the customer has already solved the issue in a simpler, more conventional way.

Table 2.1 summarises and compares eight state of the art PSS design methodologies. They are compared by each method's PSS definition, aim, first step, PSS variables, PSS design representation technique and how each evaluates PSS designs. The criteria for selecting these particular methodologies are that they are in the PSS domain and they are detailed methodologies that have been applied to industrial cases. The rightmost column of the table lists the changes that would be required of the methodologies if they were to utilise system-in-use data and compares these elements against the aforementioned PSS methodologies.

Table 2.1: A comparison of state-of-the-art PSS design methodologies and changes required of them to utilise system-in-use data

Characteristics of the methods	Komoto and Tomiyama (2008, 2009)	Shimomura et al. (2007, 2008, 2009)	Maussang et al. (2009)	Alonso-Rasgado et al. (2004, 2006)	CHANGES REQUIRED TO THE METHODS TO UTILISE SYSTEM-IN-USE DATA
PSS definition	A set of services in the life cycle of products, whose characteristics are customized with respect to the services	Service/product engineering as a discipline seeking to increase the value of artefacts by focusing on service	PSS are composed of physical objects and service units that relate to each other	Total care products as integrated systems comprising of hardware and support services	To relate PSS to value creating systems.
Aim	Support the design and analysis of integration of services with a product life cycle and the identification of the characteristics of products	Focuses on service engineering to design products with a higher added value from enhanced services	Assists engineers in the joint development of physical products and interacting services to generate more added value	Develop innovative offerings consisting of hardware and services integrated to provide complete functional performance	To increase value in use to the customer whilst the provider avoids the services paradox.
The first step	Define goal(s) and quality as specified by product users	Define the state change of the receiver	Customer expectations, needs and specifications involved in the whole life cycle	Business ambitions of the client	Identify the customer's value-creating system with which there is an issue and elicit the ideal scene from the stakeholder with the issue.
PSS variables	Stakeholders in a product life cycle and the activities (e.g. production, use and services)	RSP, sequential chain of agents, relationships among RSPs, function, entity and attribute parameters	External functional representation, specifications of the physical elements	Customer's business needs, business solutions, clearer view of the hardware and/or services	Parameterise the value-creating system and the elements that it is composed of.
PSS design representation technique	A graph description based on service formulation	Business process markup language, service blueprint	Scenarios and FBD	No representation technique is mentioned	Representation that can depict value-creating systems and show co-creation (each stakeholders' contribution)
Evaluation of PSS designs	Life cycle simulation considering multi-objectives (e.g. economic and environmental)	AHP, Dematel and Petri nets (discrete event simulation)	No evaluation approach proposed	Business case validation and evaluation of alternatives	A scheme that can be easily used by all stakeholders which allows: • The solutions to be rated as to how they have addressed the issue and • A comprehensive range of solutions (conventional and PSS) to be evaluated against each other

2.9 Requirements of a Framework to Inform PSS Conceptual Design with System-in-Use Data

In this Section, the literature is drawn upon to elicit the constructs which are required for a framework to utilise system-in-use data to inform PSS Conceptual Design.

- **System Depiction and Decomposition**

Ng et al. (2012) have stated that, as the provider's value proposition is merely one part of the customer's value creating system, the provider needs to visualise their offering as an integral part of that customer's system so that it can be ascertained how that value proposition contributes to fulfilling the customer's task. Also, allowing identified receiver problems (experiences) (Aurich et. al., 2006) to be charted as a process (Ericson et al, 2009) (in which a product or PSS is embedded) will help to reveal the business ambitions of the customer (Alonso-Rasgado, 2004). This will also allow the designer (and customer) to see exactly where in the process value is lost as well as which aspect and under which circumstances so that this value loss can be designed out or minimised. Many representation techniques which are used to represent processes involving products and services have been discussed in the PSS literature. These include extended Service Blueprinting, UML, Functional Analysis, BPMN, SysML and SADT. However, the primary concern in PSS modelling is to co-create conceptual models that can be shared and understood by all stakeholders (Annamalai Vasantha, 2012). At the PSS Conceptual Design stage, this is particularly crucial as a great deal of interaction will take place between the provider, customers and suppliers.

As, in effect, the customer (by using products and services) is providing a service to themselves to achieve their objectives, Service Blueprinting (Shostack, 1982) could be a suitable technique which is also easily understood. Ng et el. (2012) propose that S-D Logic can be operationalized by redrawing the attributes of a provider's value proposition so that it is associated with the use and context to which the customer will apply it. They argue that this shows how the resources of the customer and providers are integrated. Here, Service Blueprinting would allow the provider's value proposition to be visualised as part of the customer's value creating and show the process of how a goal (that is, value in use) is attained. Furthermore, Service Blueprinting (as it utilises a flowchart technique) is easy to understand for most stakeholders who could, for capital-intensive PSS, be spread around the world. In addition to this, with Service Blueprinting, lines of visibility and interaction within the method also help to distinguish the roles and responsibilities of the stakeholders.

Extended Service Blueprinting is a modelling method which describes a service process which consists of service activities and product behaviours (Hara et al, 2011; Shimomura et al,2009), and so, for processes in which the issues are more heavily related to detailed product operation, this may be a more suitable method. Furthermore, Service Blueprinting (simple or extended) also allows for decomposition as the product or service elements can be blueprinted in their own right.

Concepts from Service-Dominant Logic may also be useful for developing decomposition techniques. Operant resources are resources which act (follow a process) to change other resources (Vargo and Lusch 2004a) to create a benefit (an outcome). Conversely, operand resources are resources which must be acted upon to be beneficial; examples are natural resources and other generally static matter (Vargo and Lusch 2004a).

- **Gap Analysis**

Aurich et al. (2006), recommend that how the system deviates from customer expectations should be analysed and Kimita et al (2009) also propose that designers require procedures that can analyse customer satisfaction as an outcome of product features which will allow quantitative assessment of satisfaction provided by the offering; the gaps would reveal the value loss to the customer and, moreover, such encoding is easily understandable by the provider.

Gap Analysis is the comparison of two views of a system (Cadle, 2010); it is used for internal evaluation to identify performance deficiencies and fine-tuning a process rather than for long term planning. It allows the performance of a system to be compared with what is required of the system. Gaps in an existing system could mean that either the requirements of the system have not been fully met or that the requirements have changed.

Kontoya and Somerville (1998) define requirements as

'…*descriptions of how the system should behave, application domain information, constraints on the system's operation, or specifications of a system property or attribute. Sometimes they are constraints on the development process of the system*'.

These aspects would appear to map to: the process within a system, the competences and resources within that process, the environment and uses to which the system is subjected to and the required parameters of the system, respectively. As Alexander and Stevens (2002) describe requirement as '…*a statement of need, something that some class of user or other stakeholder wants*', this suggests that, ideally, any PSS Conceptual Design framework should be designed to accommodate any stakeholder with any process issue. Five typical approaches have been described by Rios et al. (2006) which includes ECSS-E-10A (1996), Hooks and Farry (2001), Robertson and Robertson (1999), Kontoya and Somerville (1998) and Pahl and Beitz (1988). These have some overlap with the dimensions of value for services within the context of PSS which have been proposed by Toossi (2012) such as reliability and availability which should be particularly useful for this research.

Thus, the use of Gap Analysis could be used to determine the loss of value in a system, that is, the deviation of a system from customer needs; any gaps within that system then present an opportunity for the provider to fill those gaps with enhanced offerings.

- **System Parameters**

In order to perform Gap Analysis on a system, it would need to be parameterised so that how it behaved can be measured against customer needs. As Mont (2002) has suggested that to develop PSS offerings, a trade-off between the design of products and services could be made on the grounds of function fulfilment against that of economic value, functionality and cost could be two parameters.

Overall equipment effectiveness (OEE) (Hansen, 2005) is a concept which is utilized in a lean manufacturing implementation. Although it usually measures the effectiveness of a machine centre or a process line, it can also be applied to other operations. The formula for the lean manufacturing OEE is:

OEE = Availability X Productivity X Quality.

In this formula, what actually happened when the product or the process was running is compared against how it was expected to run. Availability (Annamali Vasantha et al, 2011) is also discussed in the PSS literature and this could indicate the times that the system can be operational (the availability – the times that it can work). Thus, Availability could be another further parameter. Quality here would also appear to map to functionality. The responsiveness of the system (how quickly the capability is achieved) can also be an issue for customers (Toossi, 2012) and so this could be another parameter.

- **Design Options**

Possible design options should recognise that the value proposition is distinct from its exchange value and facilitate the value proposition in being aligned with the customer's value creating processes so that a better fit is achieved and more value can be contributed (Ng et al, 2012). The Design Options should suggest what could be changed but not specifically how that change can be made; it is for the designer of any given capability to use the specialist knowledge of their domain to apply the Design Options. Any given system shows synergistic properties; that is, the properties and behaviour of the arrangement are more than the sum of the individual resources (Spohrer et al., 2008). This should be respected by the Design Options making generic recommendations but not making suggestions that are specific to the principles and practices of any given engineering discipline. Vargo and Lusch (2004a) state that other entities (potential customers) that could benefit more from competences that a provider has should be identified and so this should be an option that a PSS framework offers.

- **Solution Assessment**

Along with suggestions from the customer as to how the system could be changed to address the identified gaps, a scheme is also required to evaluate the suggestions akin to that proposed by Pahl and Beitz [24]. Analytic Hierarchy Process (AHP) (Saaty, 1980) is a popular Multi Criteria Decision Model (MCDM) which facilitates the user in solving decision problems based on both quantitative and qualitative decision criteria. It is also able to handle multiple, conflicting objectives whilst accommodating the different perspectives of decision stakeholders. This could be useful if one proposed solution satisfied one set of customer needs and if another satisfied another set of customer needs; it could also be useful if different proposals were favoured by different stakeholders.

The Weighted Objectives Method (Cross, 2008), is an evaluation method for comparing design concepts based on the overall value for each design concept; it allows the scores of all criteria (such as various customer needs) to be aggregated into an overall value for each design alternative. However, when considering initial possible solutions, it may be difficult for the customer to assign an exact score to each criterion. However, a Rating Scale such as the Likert Scale (Burns, 2008) would allow the customer to indicate the degree to which they expect that a proposed solution could meet their needs and this could be a simple way that customers could rapidly evaluate solutions.

- **Consider the Whole Value Chain**

For a method to consider the whole value chain in order to improve a given value creating system, each of the various systems whose outputs contributed to the value creating system in question would need to be inspected in turn so that the full problem-space and then solution-space can be examined. Thus, each stakeholder's contribution would need to be evaluated and, to address any system shortfall, the various value creating systems that have interacted would need to be conceptually readjusted to ascertain which system(s) and which adjustment(s) could help to close any gap. That is, it should be possible for a gap within a system to be addressed at different tiers in the value chain; this means that the method should not only be able to be applied to the system where an issue has been identified but also to a constituent subsystem from a supplier as well as to the superordinate system of the client in which it is embedded – this procedure should be able to be repeated continually.

- **Qualitative and Quantitative**

This sharing of intellectual property is an important concern and represents a risk that some customers may be reluctant to enter. However, Isaksson et al. (2009) states that emphasis on value-driven development may be the way to mitigate these risks although such a change in mind-set for all stakeholders is a challenge for PSS design. This framework should enable any focal company in the value chain to depict and suggest changes to the systems of their suppliers (and supplier's suppliers) and customers (and customers of customers), without necessarily having very detailed knowledge of their customer's or supplier's exact systems and whilst not divulging the exact nature of their own core capabilities. This way, innovation and competitive advantage can be fostered by each company whilst retaining their proprietary knowledge as such data relating to core capabilities which cannot always be disclosed. Furthermore, even if such data were available, collecting data on multiple supply chain tiers would be a huge challenge (Giunipero, 2008). For these reasons, the framework should be allow partial, qualitative data that a particular stakeholder may have with regards to a value chain to be used as a starting point to explore the problem-space and solution-space of that value chain.

2.10 Summary and Research Gap

- The main research gaps that are relevant to this study are:
    - Although the potential benefits that can be achieved by learning from a product or PSS-in-use have been outlined, it has not been fully proposed how these benefits can be achieved.
    - In the wider engineering literature there is a substantial body of research which relates to collecting and analyzing product usage data. However, this covers health monitoring, prognostics and other information collection methods that can be used to acquire feedback about a product-in-use where the emphasis is mainly on maintenance and the avoidance of service interruption rather than closing the loop back to design.
    - Although user involvement methods could facilitate the feedback of knowledge to successfully operationally adapt offerings, this is not currently reflected in existing PSS-development methodologies.
    - There is a lack of available structured methodologies for eliciting and structuring data from a product or PSS in the field to inform PSS Conceptual Design.
    - There is a lack of focus on the requirements of data from a product or PSS in the field for PSS Conceptual design, particularly in the case of complex, technical, high value products or PSS.
    - There is a lack of an in-depth study into the mapping between product-in-use or PSS-in-use knowledge and PSS Conceptual Design requirements.
    - PSS Design Methodologies are currently at a fairly rudimentary stage of development and the PSS Conceptual Design Stage is not well defined.

The next Chapter describes the aims and objectives of this research based on identified gaps in the literature.

3 Research Objectives and Methodology

3.1 Introduction

The purpose of this Chapter is to present the rationale of the research strategy and to outline the research methodology that has been followed to achieve the aim and objectives of this study.

3.2 Research Aim and Objectives

The aim of this research study as stated in Chapter 1 is:

To develop a method which uses data from a product- or PSS-in-use to:

- provide customised/ upgrade options for the PSS customer
- develop new, initial PSS Conceptual designs

The literature review in Chapter 2 identified the current research trends and challenging areas within the domain.

As a result, the following objectives were defined in order to fulfil the aim of this study. The research objectives can be summarised as:

1. To understand the current practice and state-of-the-art in using system-in-use knowledge from a system in which a product or PSS is embedded to inform PSS Conceptual Design.
2. Identify terminologies used in practice to define PSS.
3. To develop a representation for a system in which a product or PSS is embedded that can be used by designers to improve PSS Conceptual Design.
4. To identify the system-in-use knowledge (in which a product or PSS is embedded) required by designers at the PSS Conceptual Design stage.
5. To develop an effective methodology to use system-in-use knowledge to create initial PSS Conceptual designs.

6. To validate the methodology using detailed case studies.

In the next section, the available research strategies are reviewed and then how this study's research methodology was developed is presented.

3.3 Research Methodology development

This section outlines various alternative approaches which could be used to conduct this proposed research. The perspective of the research is firstly outlined, a research strategy is then chosen, and then issues regarding the data collection techniques used are considered.

3.3.1 Research Context

An outline of the context of this research is required so that the research methodology can be appropriately constructed.

This research is focussed upon the interaction between data from a system-in-use in which a product or PSS is embedded and PSS Conceptual Design. The scope of the study is to determine how such knowledge from technical, high value products or PSS can be used to create initial PSS Conceptual Designs and to identify the links between the two. The factors defining this research's context were the gaps identified within the overall domain of this study and those reported by the collaborating organisations (available industrial support).

3.3.2 Qualitative and Quantitative Approach

The two distinct approaches to research design are quantitative and qualitative research (Gummesson, 1991); these are also referred to as fixed or flexible designs (Robson, 2002; Johnson and Harris, 2002).

A quantitative approach always involves the numerical analysis of data (Johnson and Harris, 2002) and is rigorously specified before the main data collection stage. Typically, quantitative research takes place in a controlled environment so that the experimental conditions are under control, and the researcher is 'detached' so that there is minimal influence on the research findings (Robson, 2002).

For qualitative research, Johnson and Harris (2002) state that the data is collected in the form of words and observations rather than numerically and a qualitative approach is chosen when the phenomena of interest requires an exploration of detailed, in-depth data (Robson, 2002). In contrast to the controlled environment of the quantitative approach, the research here is conducted in a 'natural setting' (Creswell, 1998). The term 'flexible design' (Robson, 2002) refers to the fact that the research questions and ideas evolve during the course of the research.

Although it is not usual to undertake qualitative and quantitative research at the same time it is possible for a study to be divided into phases where either qualitative or quantitative approaches can be adopted. The foremost difference between qualitative and quantitative research is that the first approach tends to rely on few variables and many cases whereas the second approach involves many variables and a few cases (Creswell, 1998). Accordingly, it is difficult to adopt a quantitative approach for the study of a social or natural setting as there are many variables which cannot be controlled by the researcher.

A qualitative approach was adopted for this study as the overall topic called for further exploration in order to generate ideas and meet the research objectives. Furthermore, the topic required an in-depth study by interviewing and observing individuals at their places of work and not in a controlled environment.

3.3.3 Research purpose

The research objectives and the research context have been presented and so the next step in research methodology design is the selection of a suitable research strategy.

Prior to this selection, the purpose of the research has to be determined as this will help to clarify which research strategy is the most appropriate for the nature of the research. The purpose of research can be exploratory, descriptive, and/or explanatory (Robson, 2002). Considering the aim, objectives and the perspective of this research, its overall purpose could be best characterised as exploratory which is usually linked to a qualitative approach (Creswell, 1998; Robson, 2002).

3.3.4 Research Strategy Selection

Robson (2002) has outlined three suitable strategies for qualitative inquiry as *ethnographic study, case study* and *grounded theory study* (Table 3.1).

Qualitative Research Strategy	Definition	Usual Features
Case study	Detailed, in-depth knowledge development regarding one or several related cases.	Single case selection Study of the case within its context Use of various data collection techniques, such as observation and interviews.
Grounded theory study	Endeavours to generate theory based on collected data.	Can apply to a wide range of phenomena Mostly interview-based Provides extensive recommendations for data analysis and theory generation.
Ethnographic study	Endeavours to capture analyse and interpret how a group, organisation or community live and experience the world.	Selection of a group, organization or community Observation Researcher involvement in the situation

Table 3.1: Overview of the Qualitative Research Strategies as Outlined by Robson (2002)

Similarly, Creswell (1998) concluded that there are five qualitative design research strategies, namely, phenomenology, grounded theory, biography, ethnography and case study: these are compared in Table 3.2.

The factors which were considered for this selection and the eventual detailed research design were the context of the research, the available data collection methods, the involvement of the collaborating organisations and the access to comprehensive data from a product-in-use or a system-in-use in which a product or PSS is embedded.

Grounded Theory Study

The literature review revealed that using product-in-use knowledge to inform PSS Conceptual Design is an understudied area. In studies where theory is nascent, the Methodological Fit Model (Edmondson et al., 2007) suggests that, as there can be no certainty with regards to the issues that may emerge from any data collected, the hypothesizing of explicit relationships between variables should be avoided. For this reason, semi-structured, exploratory interviews were firstly used for this research with the aim of obtaining detailed data from the interviews from which major themes could be drawn: the purpose was to uncover the AS-IS situation as to how companies which provide capital-intensive, technical and industrial PSS use product-in-use knowledge for PSS Conceptual Design. A case study approach was then adopted as case studies are linked to exploratory work (Gummesson, 1991; Robson, 2002) which is the nature of this study.

	Phenomenology	Grounded theory	Case study	Biography	Ethnography
Focus	To identify phenomena through how they are perceived by actors in a situation.	Development of a theory which is grounded in data collected from the field	Development of an extensive analysis of one or many cases	Investigation of an individual's life	Description and interpretation of a cultural and social group
Discipline of origin	Psychology, Philosophy, Sociology	Sociology	Sociology, Political Sciences	Psychology, Sociology, Anthropology, History	Sociology Anthropology,
Data collection	Lengthy interviews with up to 10 individuals	Interviews with 20-30 individuals to provide an extensive basis for categories and to detail a theory	Multiple sources such as interviews, observations, documents, archival records, artefact s	Mostly interviews and archival records	Mostly observations, interviews, Sometimes artefacts
Data analysis	Meanings, Statements, Themes	Open Coding, Axial Coding, Selective Coding, Conditional Matrix	Description, Themes, Claims	Stories, Meanings, Historical reports	Analysis, Interpretation Description,
Narrative form	Description of the meaning of the experience to the individuals	Theory or theoretical model	In-depth study of one or more cases	Description of an individual's life	Description of the cultural group behaviour

Table 3.2: Comparison of the five qualitative research strategies as outlined by Creswell (1998)

Case Study

The objectives of case study research are to create a description, understanding, prediction or control of a phenomenon (Woodside and Wilson, 2003). A case study is a form of analysis where one or several units are studied in-depth in order to clarify a broader class of units (Gerring and McDermott, 2007). These units may consist of any phenomena as long as each unit is fairly well confined and positioned at the same level of analysis as the primary assumption. The data collection methods used during case studies can include archival material, interviews, questionnaires, artefacts and observations and the data collected can be qualitative, quantitative or combination of the two (Eisenhardt, 1989).

The researcher's presence and predilections can alter the research setting, how respondents react and can bias what data is collected and how it is interpreted. Hence, these possible risks need to be identified so that they can be circumvented as much as possible in order to establish the validity and generalisability of the study. This is presented in the following section.

Validity, Reliability and Generalisability

The validity and generalizability of the study will determine how trustworthy it is. The accuracy and correctness of a qualitative study will determine its validity (Robson, 2002). There are several main challenges to validity (Robson, 2002) and these can be minimised or eliminated if they are addressed in advance:

Researcher bias: this relates to the preconceptions that may influence the researcher in their selection of interviewees and interview questions.

Respondent bias: this relates to how the respondents react to the researcher. For example, respondents may modify their answers or conceal information in an attempt to please the researcher.

Reactivity: this relates to the way that the researcher's presence may influence the case study location.

Several strategies have been developed to minimise these challenges (Creswell, 1998; Robson, 2002):

Audit trail: recording all of the activities and events during the course of the research.

Prolonged involvement: here, the researcher spends time at the research location in an attempt to establish relationships with the participants and to understand their concerns, activities and culture. However, it could be possible that prolonged involvement could compromise the researcher's objectivity.

Respondent validation: here, conclusions drawn from the research are fed back to the informants to check the validity of the researcher's conclusions.

Negative case analysis: This involves searching for and discussing parts of the data that can challenge the patterns that have emerged from previous data. This process can refine the research.

Triangulation: the use of other methods and information sources to "cross examine" the conclusions of the initial research.

Peer debriefing and support: here, the researcher works with one or more colleagues who are more detached from the direction of the study. The peers examine the researcher's methodology, transcripts and final report in order to offer feedback to ensure validity.

Within a qualitative research context, reliability is concerned with the reliability of the methods and practices used so that there can be a replicability of results. For this to occur, the research strategy and data collection methods should be structured and consistent. Nevertheless, even if the study is reliable this does not necessarily mean that it is valid (Robson, 2002).

Generalisability relates to the general applicability of a research study's results to other situations and times (Maxwell, 2002; Robson, 2002). Within qualitative research, the two types of generalisability are internal and external. Internal generalisability relates to the degree to which the findings apply to the community which was studied. However, external generalisability relates to the degree to which the findings apply beyond that group, setting, context or time. Generally, external generalisability is perceived as being more difficult to achieve within a qualitative research context as the findings tend to be specific to the individuals or settings studied.

Bias Reduction

The qualitative research approach relies upon the researcher's participation or observation of events and eventually their interpretation and so, to reduce bias, the following activities were conducted:

Keeping an audit trail: all the activities that were conducted were recorded throughout the course of the research. This meant that notes were taken and that interviews were recorded wherever possible.

Debriefing peers: the notes, recordings, data collected and findings were presented to peers during regular discussion groups that the research project held or through conference and journal papers.

Triangulation: this occurred with the use of different data collection methods such as interviews, observations and respondent validation.

Literature Review: the state-of-the-art literature in the domain was used to contribute towards theory generation and idea creation with regards to the *System-In-Use* Methodology.

Prolonged involvement in the case study setting: this helped the researcher to gain a detailed understanding of the aims, practices and the challenged faced by the participants. As this could increase researcher bias, a decision was made to have a wide and varied number of validation case studies so that the theory and *System-In-Use* Methodology generated could be assessed for this.

3.4 Research Methodology Followed in this Thesis

The consideration of widely accepted approaches in the literature formed the rationale for the selection of the research approach, its design and strategy. The proposed research methodology is represented in Figure 3.1 and it is divided into three main stages which are *the research approach, data collection and idea creation* and then *data analysis and validation*.

Although the framework will utilise quantitative data, a quantitative research approach was not adopted. This is because, as it will be shown in Chapter 3, although data is routinely collected from capital-intensive products in the field, how this could relate to PSS Conceptual Design was largely unknown. The links between what data should be collected, how it could indicate customer issues and how it could inform PSS Conceptual Design had to be established. For this reason, a qualitative approach was adopted.

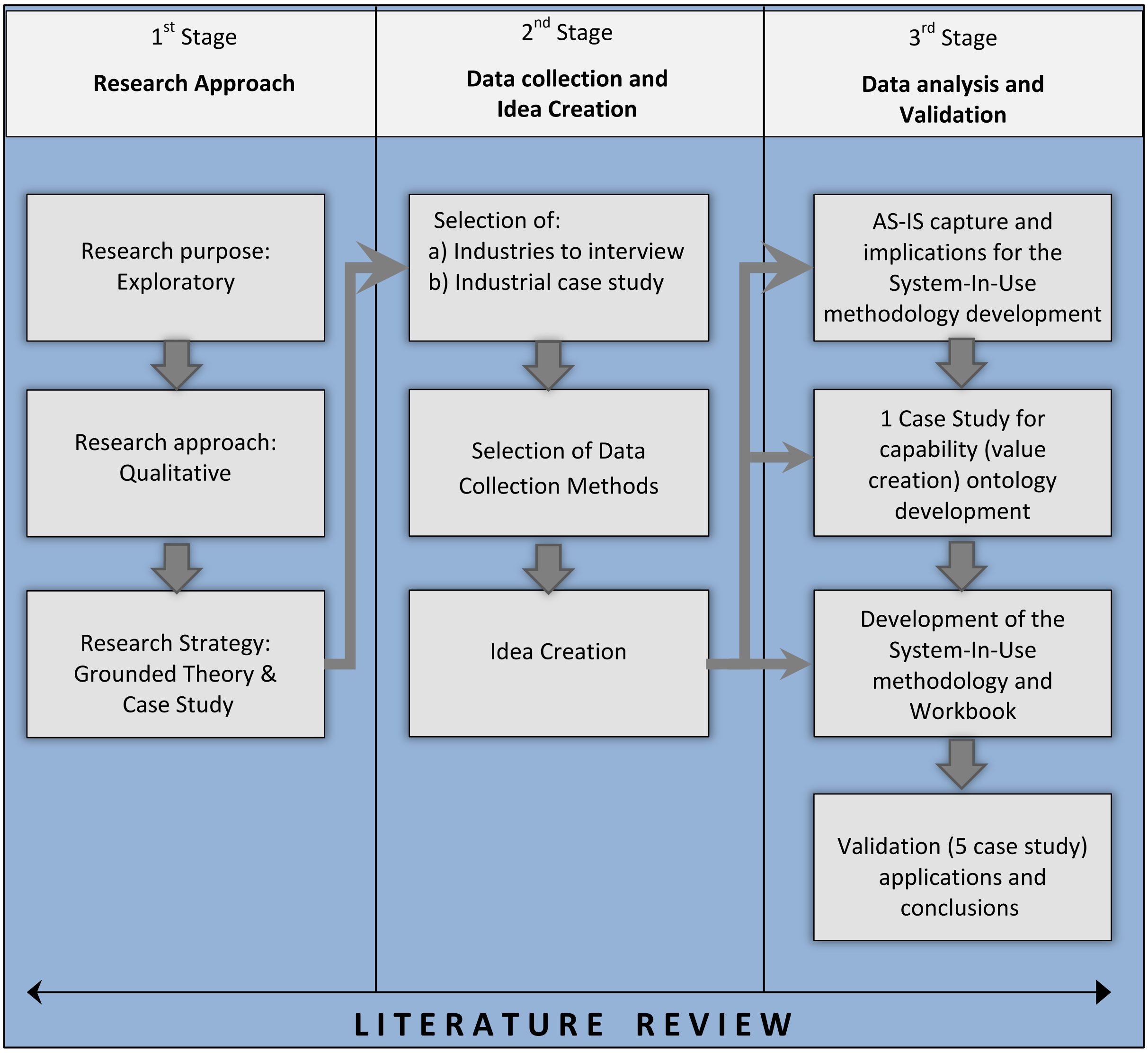

Figure 3.1: Design of Thesis Research Methodology

The literature was reviewed throughout the course of this research to establish the theoretical basis of the research issues and the general direction of this research.

- **The First Stage**: is concerned with the review and selection of an appropriate research strategy. The research objectives required the research purpose to be defined as exploratory. A qualitative approach was then chosen and then the most suitable research strategy was selected to be a Grounded Theory Study followed by a Case Study.
- **The Second Stage:** relates to the selection of suitable data collection methods in order to clarify research issues and generate theory and ideas as to how these

could be resolved. To increase the validity of this study, the aforementioned Bias Reduction approaches were used. The selection of the interviewees for the Grounded Theory Study and the Case Study selection were based on their suitability for this research, the availability and accessibility of the collaborating industrial partners and the general resources for this research.

- **The Third Stage:** relates to the development and validation of the proposed System-In-Use methodology.
    - *AS-IS capture and implications for the System-In-Use Methodology development:* The findings of the interviews revealed that senior management in industries which produce capital-intensive, technical PSS did not know how to use product-in-use knowledge to inform PSS Conceptual Design. Nevertheless, some direction was forthcoming as to how this data collection could be widened (to become system-in-use knowledge) and some suggestions were offered as to how this could be used.
    - *Case Study for capability (value creation) ontology development:* This was a case study of a company which collects system-in-use data to actually influence PSS Design; the company does not supply capital intensive PSS but does provide a functional result. By combining this case study's findings and the findings from the literature, a representation for capability (ontology) was developed.
    - *Development of the System-In-Use Methodology and Workbook:* The *System-In-Use* Methodology was developed from the ontology as well as the findings from the literature and industry. A Workbook was also created which won funding for its knowledge transfer from academia to industry.
    - *Validation and conclusions:* Four case studies were conducted with the collaborating companies in order to validate the *System-In-Use* Methodology (which uses system-in-use knowledge to generate initial PSS Conceptual Designs). The first case study was conducted with a

laser job shop: this was to assess the validity of the System-In-Use Methodology (how it met the research objectives). The second with an aero engine and component manufacturer, the third with a truck provider and their technology provider and the fourth was with an HVAC (Heating, Ventilation and Air Conditioning) Consultancy and an expert Civil Engineer; these took place exercise the various paths in the *System-In-Use* Methodology and to prove its potential generalisability to industries in general. The research conclusions, limitations, and areas for future research are presented in Chapter 8.

3.5 Summary and Key Observations

The aim and objectives of this research study were presented in this chapter, the research context was established and the various qualitative and quantitative approaches were described. A qualitative approach was selected due to the exploratory nature of this study and a Grounded Theory Study and a Case Study strategy was chosen from the various research strategies described. The issues of validity, reliability and generalisability were also discussed. Finally, the research methodology followed in this study was presented and each of its three stages have been described in detail along with actions to minimise any bias that may threaten the validity and generalisability of this study.

The next chapter focuses on the AS-IS situation of using knowledge from a product or system-in-use in industries which produce capital-intensive, technical PSS.

4 Investigation of the Current Practice in Industry Producing Capital-Intensive PSS

4.1 Introduction

The literature review revealed that using data from a product-in-use or PSS-in-use to inform PSS Conceptual Design is an understudied area. In studies where theory is nascent, such as the use of data from a product-in-use or PSS-in-use to inform PSS Conceptual Design, the Methodological Fit Model (Edmondson et al., 2007) suggests that, as there can be no certainty with regards to the issues that may emerge from any data collected, the hypothesizing of explicit relationships between variables should be avoided. For this reason, grounded theory research methodology was used where semi-structured, exploratory interviews were conducted with the aim of obtaining detailed data from which major themes could be drawn.

4.2 Grounded Theory

Grounded Theory (GT) (Charmaz 2006; Glaser 1992; Glaser and Strauss 1967) is a suitable research methodology when the objective is to develop theory. It is applied here to interviews from respondents who provide industrial, capital intensive, technical and infomated PSS in order to generate theory as to how data from a product-in-use or PSS-in-use could be used to influence PSS Conceptual Design. This investigation generated some basic ideas as to what is required of a framework to utilise data from a product-in-use or PSS-in-use to inform PSS Conceptual Design and also highlighted the need for a deeper, theoretical understanding of PSS and value-in-use. Although this investigation was conducted as the PSS Conceptual Design Research team (as outlined in Chapter 1), only the parts of this overall investigation for which the author was responsible and which are pertinent to this particular research are reported here. Over a three year period, this investigation interviewed thirty-seven respondents in ten industries and generated 65 hours of recorded interviews.

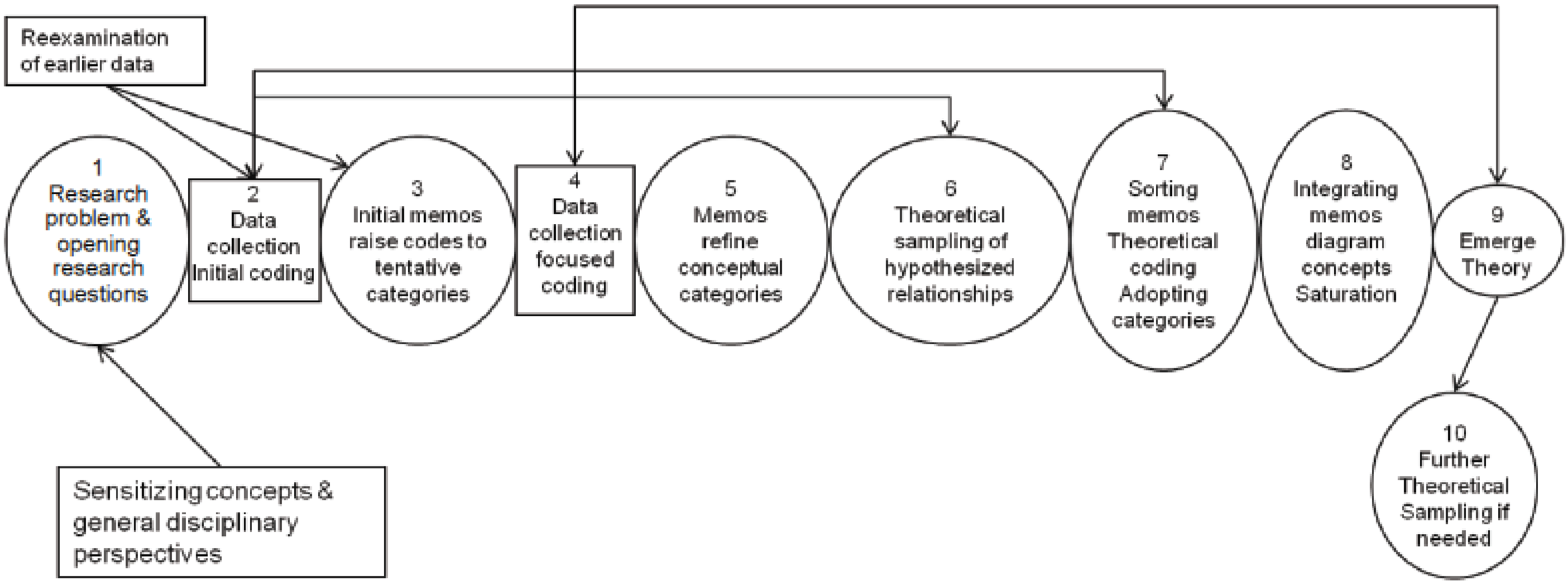

Figure 4.1: The Grounded Theory Process (Randall et al., 2010)

GT provides a methodology which is based on an inductive and pattern searching technique which is used for conducting in-depth investigations within and across organizations (Charmaz 2006; Glaser 1992; Glaser and Strauss 1967). By investigating the respondents' understanding, GT can identify key variables and relate them (Glaser and Strauss 1967; Hunt 1992) without introducing the bias of existing theoretical structures (Charmaz 2006). The usefulness of GT is in its ability to offer a structured procedure of investigation to a relatively unknown area.

Figure 4.1 (Randall et al., 2010) depicts this and this investigation employed several iterations of the body of this process.

The analytical process of GT is called constant comparison which emphasizes the "discovery of what concepts and hypotheses are relevant for the area that one wishes to research" (Glaser and Strauss 1967). These comparisons involve interviews which aim to identify themes and then test whether these themes remain consistent in subsequent or previous interviews (Charmaz 2006; Glaser and Strauss 1967).

4.3 Methodology

The first step involved was for the three researchers to meet with three senior academics who have applied expertise in engineering design and PSS to focus the research problem, discuss the initial research aim and qualify the initial sample and to also create an interview protocol. For the author's research, this was deemed to be:

Research Aim: To develop a framework to utilise system-in-use or PSS-in-use data to inform PSS Conceptual Design to:

- support customised/ upgrade options for the PSS customer
- develop new PSS system designs

Research Question: What are the antecedents, processes and outcomes of that framework?

During this phase, the sample as well as the participants were also identified by reviewing archival material, emails and previous contact relating to the business, responsibilities and expertise of each of the potential participants and their company.

The interview questions asked by the three researchers are detailed in Appendix A - section 4 details the questions which were asked by the author; only the answers to the author's question are reported in this thesis.

– these are the questions that the author asked. A pilot interview was held with three senior academics who have applied expertise in engineering design and PSS to ensure that the research aim and interview questions had clarity and pertinence to this study and the respondents. The initial focus of the interviews was agreed to be availability contracts (as this is a high form of PSS) and maintenance as this is the remedy for as well as a cause of unavailability. At the beginning of each interview, the aims of the research (as previously outlined) were presented. Due to reasons of industry confidentially, it was agreed that it would not be possible to conduct in-depth studies in any one organisation and so cross-sectoral interviews were decided upon which would allow for common themes across industries to be ascertained. All of the potential participants selected were senior managers in roles which encompassed engineering and/or business development who have knowledge of PSS and maintenance in companies producing industrial, capital-intensive, technical and infomated PSS and each had at least five years' experience in their role. Although it could be the case that junior managers could have more up-to-date academic knowledge of PSS, a decision was made to interview senior managers. This is because senior managers are primarily responsible for the formulation and/or execution of business strategy (such as a strategy to servitize) and for the development and execution of PSS Concepts within their company. Senior managers with at least five years' experience in their role would also be expected to possess a deep, as well as broad, knowledge of their operating areas. Many participants were contacted with regards to this study and the six companies that showed interest in the research aims had (See Table 4.1) semi-structured interviews conducted with them in order to gain a broad understanding of current practices and challenges across industry. Each interview was recorded and then later transcribed. These companies are in Table 4.1.

Provider ID	Industry	Interviewee	No. Of Interviewees	Time (hrs)
PlaneCo	Defence Aerospace	Senior Managers	2	3.0
RailCo	Rail Transportation	Senior Managers	3	6.0
TruckCo	Commercial Trucks	Senior Managers	5	7.0
LandCo	Defence Land Systems	Senior Manager	1	3.0
AeroCo	Aerospace	Senior Managers	4	4.5
NavalCo	Defence Surface Ships	Senior Managers	2	4.5
		Totals	**17**	**28**

Table 4.1: **The initial sample used for the creation of initial antecedents and categories**

Although an interview protocol was developed and used as the basis for the interviews, due to the open-ended nature of the interviews, the questions were not necessarily asked in order. The participant interviews (steps two and four) were conducted over a period of three years. The transcripts of the interviews and the secondary data sources were systematically analysed and coded using a grounded approach with no a priori definitional codes (Yin, 2003). This enabled key themes and categories to be formulated (Easterby-Smith, 2008). Each of the related codes from each document (the primary and secondary data sources) were then listed and the findings were then categorized under emerging themes. From the constant comparison that took place, initial categories and more focused follow-on coding emerged (step 3). From the findings, a report was created which was circulated to the respondents and then the initial categories and codes were presented at a conference in Germany on industrial PSS (Hussain et al., 2011). From the feedback received from the respondents and the insights generated from academics at the conference, the report was revised and re-circulated to the respondents and then new interviews were conducted (Table 4.2) with new participants (step four); this facilitated constant comparison. Previous interviews were also re-examined in the light of the new insights that had emerged.

Provider ID	Industry	Interviewee	No. Of Interviewees	Time (hrs)
TruckCo	Commercial Trucks	Senior Managers	2	2
AeroEngineCo	Aerospace Engines	Senior Managers	5	13
FuelCo	High-Tech Fuel Cell Provider	Senior Manager	1	2
		Totals	**8**	**17**

Table 4.2: The second round of interviews used for the emergence of theoretical coding

The memos (step three and five) documented how a particular concept, category or relationship was arrived at and also record how relationships evolved in subsequent interviews as well as the rationale behind the emerged variables (Charmaz 2006). The memos also noted questions for further interviews and documented the emergence of theoretical coding (step five). In contrast to statistical validity, GT is concerned with theory validation (Cho and Trent 2006) which it achieves through theoretical sampling (step six) which is a process that tests previously identified relationships in a new sample (Table 4.3). At these interviews, no further themes emerge and no further issues were identified regarding a category of data.

Provider ID	Industry	Interviewee	No. Of Interviewees	Time (hrs)
TruckCo	Commercial Trucks	Senior Managers	3	3
Fuel Co	High-Tech Energy	Senior Manager	1	1
AeroCo	Aerospace	Senior Managers	4	10
LaserCo	Laser Technology OEM	Senior Manager	1	2
LaserSysCo	Laser Systems	Senior Manager	2	2
ComputerCo	Computerised Solutions	Senior Manager	1	2
		Totals	**12**	**20**

Table 4.3: The third round of interviews used to test the theoretical coding that emerged

Through categories being proposed, the subsequent relating of them to each another and then testing those relationships in subsequent interviews, theoretical sampling and constant comparison elevated the codes into theoretical categories (step seven) (Charmaz 2006). The theoretical categories were then related into an emerging theoretical structure (step eight) (Charmaz 2006).

The relationships were formulated and then tested which lead to saturation which is associated with validity in qualitative research (Cho and Trent 2006); here, new data was gathered until no further insights were generated, no further themes emerged and no further issues are identified regarding a category of data (Bowen 2008). This saturation resulted in the emergence of theory (step nine) which is a basic framework to utilise system-in-use data for PSS Conceptual Design. The framework (See Figure 4.2) which emerged was related back to the respondents

4.4 Antecedents

Six categories of antecedents emerged: *Problem Identification, Determine the Type and Extent of the Problem, Data Collection, Fault Location, Compare different instances of the Process, Asset and Subsystems* and, lastly, *Inform PSS Conceptual Redesign*. The antecedents influence the source, type and amount of data required and how that data could be analysed to inform PSS Conceptual Design; that is, the antecedents indicate the elements that a framework to utilise product-in-use or PSS-in-use data should have to influence PSS Conceptual Design. A discussion of each of the antecedents and their associated codes follow.

Problem Identification Antecedent and Codes: Several respondents suggested that it should be the extent to which the customer achieves an aim by using a product, rather than how a product functions, that should be considered by PSS Conceptual Design. Different respondents suggested that different parts of the system in which an asset is embedded (rather than just the asset or PSS itself) should also be identified as the problem space (See **Table 4.4**).

Category: Problem Identification Identify the customer's system (this is the process and environment) in which an asset or PSS is embedded. This will show how the customer is trying to achieve a goal; this reveals their functional needs. The reported problem should be an issue with the customer's overall goal (that is, the meeting of their functional needs) rather than just an issue with an asset (requirements).	
Code 1: The aim of PSS Conceptual Design should be the accomplishment of the customer's goal.	The aim of PSS Conceptual Design should be the improvement of the degree to which a customer's goal is accomplished rather than just the improvement of an asset.
Code 2: Identify all of the elements which impact upon the customer's overall goal.	There is a drive to identify, along with the asset or PSS in question, elements of the use context (such as the environment) and other systems which may have little bearing on the main asset or PSS but which may impact upon the customer's overall goal.

Table 4.4: Problem Identification Antecedent and Codes

Category: Determination of the Type and Extent of the Problem Determine the type and extent of the issue using gap analysis to find the difference between what the customer wanted to achieve and what actually happened.	
Code 1: Monitor the customer's mission	There is a desire to monitor the customer's overall mission rather than just asset performance.
Code 2: Find the difference between what the customer wanted to be achieved and what actually happened.	There is a desire to assess the degree to which the customer's mission (for which a given asset or PSS was used) was fulfilled. This will determine the type and extent of the issue.

Table 4.5: Determination of the Type and Extent of the Problem Antecedent and Codes

Determination of the Type and Extent of the Problem Antecedent and Codes: The type and extent of any reported problem could be determined using gap analysis which is the difference between what was desired and what actually happened (**Table 4.5**) when the customer was attempting to achieve their goal.

Data Collection Antecedent and Codes:

Different respondents suggested collecting data from different parts of the system which could be used to influence PSS Conceptual Design (See Table 4.6):

Category: ***Data Collection*** The asset (or PSS) and other assets and systems (along with their subsystems), the environment and the type of use the asset was put to should be monitored.	
Code 1: Monitor other assets and systems used (besides just the asset or PSS) to achieve the customer's goal.	There is a need to monitor other systems (besides just the asset or PSS) which may have little bearing on the main asset but which may impact upon the customer's mission. This is particularly the case for assets which operate in unison such as fleets. However, this data tends not be collected.
Code 2: Monitor the subsystems and components of the asset.	Subsystems are currently monitored to trigger maintenance but it this is not currently used systematically to influence PSS Conceptual Design.
Code 3: Monitor the type of use that the asset was put to.	There is a desire to monitor the type of use that the asset was put to but this tends not to occur.
Code 4: Monitor the environment.	There is a need to monitor any environmental variables that could impact upon the customer's mission. Such monitoring could help to determine the environmental conditions under which failures for an asset occur. However, this data tends not be collected and that which is collected tends not to be analysed in this way.

Table 4.6: Data Collection Antecedent and Codes

Fault Location Antecedent and Codes: Most of the respondents stated that the relationship between the performance of the asset (and its subsystems and components) and failures in the customer's mission should be established (Table 4.7).

Category: ***Fault Location*** Determine the part of the system (and its subsystems and components) which contributed most to the failure of the customer's mission. This could be determined by applying gap analysis to that part of the system which is the difference between how an expert would expect the sub-system to perform and what actually happened. Alternatively, this could be determined by the degree to which that part of the system contributed to the failure of the mission.	
Code 1: Determine the relationship between the performance of an asset and the failure in the customer's mission.	The relationship between the performance of an asset and the failure in the customer's mission will help to determine the contributing factors to any failures in a customer's overall mission. However, data that is collected for from assets tends not to be analysed in this way.
Code 2: Determine the relationship between a subsystem's or component's behaviour and the failure in that system	There are many assets for which data regarding subsystems and components is currently collected. However, this tends to be used to trigger maintenance services rather than being used to determine the relationship between a subsystem's or component's behaviour and the failure in that system.
Code3: Determination of the difference between the expected operation of an asset (as determined by an expert) and how it actually behaved.	There are assets which are monitored so that the difference between the desired operation of an asset (as stipulated by the provider) and what actually happened can be determined. However, this is performed so that asset misuse can trigger training rather than being used as an indicator that the asset may have contributed to the failure of the customer's overall goal.

Table 4.7: Fault Location Antecedent and Codes

Compare Different Instances of the Process, Asset and Subsystems Antecedent and Codes: Several respondents suggested comparing the process, asset and subsystems to those in different environments and put to different uses to see if they performed differently.

Category: A comparison of the process, asset and subsystems in different local and wider environments should allow the assessment of how a variable in one environment affects a particular process as compared to when that variable is absent or reduced.	
Code 1: Find the difference of an asset's (or subsystem's or component's) performance in one environment as compared to its performance in another. This will help to identify environmental variables that may impact upon it.	Assets and subsystems can behave differently in different environments. Comparing their performance under different circumstances can reveal which environmental variables impact upon various parts of the asset or subsystem. However, this tends not be done.
Code 2: Find the difference of performance for an asset used in one way as compared that when that asset is used in another way.	Monitoring how different types of asset use impact upon the long-term performance of the asset can help to determine which types of use limit the performance or damage the asset. It also could be used to discover which type of use contributed to the failure of the customer's mission. However, this tends not to be performed.

Table 4.8: Compare Different Instances of the Process, Asset and Subsystems Antecedent and Codes

Inform PSS Conceptual Design Antecedent and Codes: All respondents stated that they did not know how data collected from an asset or PSS in the field and any other part of the customer's system could be used to inform PSS Conceptual Design so that designs can be generated to address the customer's issue.

Category: Process the data to inform PSS Conceptual Design so that designs can be generated to address the customer's issue which are: • customised/ upgrade options for the PSS customer • new PSS system designs	
Code 1: How to process the data to generate PSS Conceptual Designs was unknown.	How to process the data to generate PSS Conceptual Designs was unknown.

Table 4.9: Inform PSS Conceptual Design Antecedent and Codes

4.5 Results: The Proposed Framework

How to utilise data from a product-in-use or PSS-in-use data to inform PSS Conceptual Design is unknown; this was the unanimous verdict of all respondents and across all industries throughout the course of this investigation. As one respondent commented:

> *"Although we collect a great deal of data from assets in the field, we don't know how to use this for PSS Conceptual Design; we refer to this data as shelf-ware."*

Although the constructs, processes and expected outcomes of a framework to utilise product-in-use data for PSS Conceptual Design were unknown, some suggestions were made as to the general antecedents of using product-in-use data to inform PSS Conceptual Design. These antecedents were used to create a basic framework of how product-in-use or PSS-in-use data could inform PSS Conceptual Design (See Figure 4.2). This Framework (See Figure 4.2) has the following steps:

1. **Problem Identification** - The reported problem should be an issue with the customer's overall goal (that is, the meeting of their functional needs) rather than just an issue with an asset (requirements). From this, chart the customer's system (this is the process and environment) in which the asset or PSS is embedded. This will show how the customer is trying to achieve a goal and thus reveals their functional needs. There were no suggestions as to how this could be depicted.
2. **Determine the Type and Extent of the Problem** - Determine the type and extent of the issue using gap analysis to find the difference between what the customer wanted to achieve and what actually happened. This would determine the degree to which a goal is being met rather than just how an asset performs. There was little indication as to the exact types and categories of data to collect.
3. **Fault Location** - Determine the part of the system (and its subsystems and components) which contributed most to the failure of the customer's mission. This could be determined by applying gap analysis to that part of the system which is the difference between how an expert would expect the sub-system to perform and what actually happened. Alternatively, this could be determined by the degree

to which that part of the system contributed to the failure of the mission. The exact types and categories of data to collect were unresolved.

4. **Compare different instances of the Process, Asset and Subsystems** - A comparison of the process, asset and subsystems in different local and wider environments should allow the assessment of how a variable in one environment affects a particular process as compared to when that variable is absent or reduced. However, the exact types and categories of data to collect were unresolved.
5. **Inform PSS Conceptual Redesign** - Process the data to inform PSS Conceptual Design so that designs can be generated to address the customer's issue which are:
   - customised/ upgrade options for the PSS customer
   - new PSS system designs

   However, how to actually process the data to generate PSS Conceptual Designs was unknown.

4.6 Respondent Validation

Flint et al. (2002) advise researchers to evaluate that the data, analysis and the emerged theory fit with the environment as interpreted by experts (Flint et al., 2002). The framework was presented to a firm of HVAC (Heating, Ventilation and Air Conditioning) consultants which, although they produce low cost PSS, they use system-in-use data to inform PSS Conceptual Design. They stated that the framework appeared to be comprehensive and to follow the general steps that they take although, in practice, they tend to rely on intuition and their considerable knowledge and expertise of their domain area rather than a systematised method.

Framework	Deficiencies in the Framework
Problem Identification Identify the customer's system (this is the process and environment) in which an asset or PSS is embedded. This will show how the customer is trying to achieve a goal; this reveals their functional needs. The reported problem should be an issue with the customer's overall goal (that is, the meeting of their functional needs) rather than just an issue with an asset (requirements).	How this could be depicted was not forthcoming
⇓	
Determine the Type and Extent of the Problem Determine the type and extent of the issue using gap analysis to find the difference between what the customer wanted to achieve and what actually happened. This would determine the degree to which a goal is being met rather than just how an asset performs.	The exact types and categories of data to collect were unresolved
⇓	
Fault Location Determine the part of the system (and its subsystems and components) which contributed most to the failure of the customer's mission. This could be determined by applying gap analysis to that part of the system which is the difference between how an expert would expect the sub-system to perform and what actually happened. Alternatively, this could be determined by the degree to which that part of the system contributed to the failure of the mission.	This is already used in some industries to trigger existing services such as maintenance. However, it is not used to inform PSS Conceptual Design. The exact types and categories of data to collect were unresolved.
⇓	
Compare different instances of the Process, Asset and Subsystems A comparison of the process, asset and subsystems in different local and wider environments should allow the assessment of how a variable in one environment affects a particular process as compared to when that variable is absent or reduced.	However, the exact types and categories of data to collect was unresolved
⇓	
Inform PSS Conceptual Redesign Process the data to inform PSS Conceptual Design so that designs can be generated to address the customer's issue which are: • customised/ upgrade options for the PSS customer • new PSS system designs	How to process the data to generate PSS Conceptual Designs was unknown.

Figure 4.2: The emerged framework from the antecedents

4.7 Summary and Key Observations

In this chapter, the AS-IS situation in industry with regards to using product-in-use data from industrial, technical, infomated products and PSS to inform PSS Conceptual Design was explored. The interviews revealed, conclusively, that in industries producing capital-intensive PSS very little is truly known about how utilise data from a product-in-use or PSS-in-use could be utilised to inform PSS Conceptual Design and that PSS Conceptual Design in these industries tends to be ad-hoc and unsystematised. However, there does appear to be a need in industry to monitor the use patterns and context in which the asset is used along with other assets that are used to meet a goal; rather than just product-in-use data, the data that should be collected appears to be *system-in-use* data which would be the data collected from the whole system in which a product or PSS had been embedded. Here, the fulfilment of the customer's goal or mission should be the primary concern of the provider. Knowledge of the customer's business operation times, the required performances and the customer's resources that are required to achieve a goal all need to be gleaned along with precise information as to how the asset or PSS performs under various contexts. For higher PSS models, this is particularly important because, as the customer will not own the asset, they will not be able to heavily integrate or modify the asset to tailor it to their exact needs.

Some suggestions as to how a method could start to be developed were elicited but exactly what data to collect and what this would indicate for PSS Conceptual Design was not forthcoming. The main requirements for the creation of a method to utilise product-in-use data for PSS Conceptual Design appeared to be:

- The definition of the problem space as the process in which the asset or PSS is embedded (rather than just a consideration of the asset or PSS), all of the elements within the process (such as other products and services) and any events that occurred or environmental impacts; it is the accomplishment of the customer's goal that is of primary importance rather than the requirements of any individual product or PSS.

- Contextual monitoring (of environmental variables which impact upon the asset, the process in which the asset is embedded along with other assets and systems in that process and the use purposes to which the asset is employed) is required which, currently, tends not to be conducted. If all of the variables that could affect availability could be ascertained and then monitored and compared across assets in different circumstances, it then becomes more possible to discover the circumstances that lead to asset, subsystem and even mission failure. Analysis across data sets of assets employed for different use purposes and in different environments could help to identify possible causes of failure in differing contexts.
- The monitoring of, not just the asset or PSS, but also subsystems and components within it so that it can be ascertained which part of the asset may have contributed to any failure in the customer's mission. A method is required to build-up precise knowledge over time of the performance of the asset (and other systems used to accomplish a goal) under various circumstances and the part of the asset which had the fault. This is extremely important for the creation of availability contracts. The framework should allow a fault tree to be constructed which would show how the fault is built up and the location the source of the fault.

Despite the emergence of a basic framework, the exact sources and types of data to be collected, how the data relates to PSS Conceptual Design and then how that data should be processed to inform PSS Conceptual Design need to be defined. This highlighted the need for a deeper, theoretical understanding of PSS and value-in-use (how the customer's goal is being met). The next chapter addresses this by performing a longitudinal study with a company that does use system-in-use data to influence their low-cost PSS Conceptual Designs. Although this company does not produce capital-intensive PSS, the PSS they deliver is technical, infomated and supports their clients who do produce capital intensive PSS. How this company uses system-in-use data to inform PSS Conceptual Design is studied to gain more insight as to the refinement of the framework.

5 Framework Refinement

5.1 Introduction

The previous Chapter outlined the AS-IS situation of how data from a product- or PSS-in-use is used by industries producing capital-intensive, industrial and technical assets to inform PSS Conceptual Design. There was no general or systematised method to accomplish this or, indeed, any real understanding of how this could be accomplished. Nevertheless, from the investigation that was conducted, theory was generated (from findings across many industries) from which the basis of a framework was developed.

In this Chapter, the framework is refined based on the expertise of a low-cost PSS provider which uses system-in-use data to inform PSS Conceptual Design. To achieve this, interviews and an ethnographic research approach was adopted. This company then evaluated the resultant, refined method. The findings resulted in several reconceptualizations of key terms within PSS.

At this point, the requirement was to refine the basic framework developed in the previous Chapter. To do this, the following had to be determined:

- a way to depict the customer's system
- the system elements and the data should be collected from them
- how can the degree of value in use delivered (how the customer's goal is being met) can be determined from the system-in-use data
- how the part of the system that contributed most to that system not meeting the customer's goal from the system-in-use data could be determined
- how PSS Conceptual Design can be informed by the gap in value in use and the part of the system that contributed most to that gap in order to support customised/ upgrade options for the PSS customer and develop new PSS system designs

Although the company in this study does not offer a capital-intensive PSS, they do offer a technical, high level (a result-orientated business model) PSS. This is a Heating, Ventilation and Air-Conditioning (HVAC) Consultancy firm; in the previous Chapter, they stated that the framework appeared to be comprehensive and to follow the general steps that they take although, in practice, they tend to rely on intuition and their considerable knowledge and expertise of their domain area rather than a systematised method.

5.1.1 HVAC Consulting Company Study

The HVAC Consulting Company has a staff of five people and tends to have very close contact with their clients and their client's use context and users. Besides using system in use data to inform low-cost PSS Conceptual Design, they were also selected for this study for the following reasons:

- ***Support of Capital Intensive PSS:*** This company supports their clients in providing capital intensive, technical and industrial PSS. For example, their clients can be property developers who lease or rent office space, warehouses or buildings to hospitals. The HVAC Consultants can reduce heating and cooling costs of a building and ensure a pleasant climate; this is important for the building provider as, if the building is too costly to heat and cool and/or if the building climate is unpleasant, then the customers of the building may choose another building provider. Therefore, although the HVAC Consultants are a separate company, by partnering with/supporting property developers, they jointly offer a capital-intensive, infomated and technical PSS; the HVAC Consultants could quite easily have been a department within the property developer's company.
- ***Functional Result Business Model:***

  Description: A core service that the HVAC Consultants offer is the rationalisation of HVAC systems so that large energy savings can be made on existing heating and ventilation systems: by using sensors, trouble spots can be identified and parts of the HVAC system which may be working in opposition to each other can be identified – addressing these issues can result in huge energy savings. For this service, they offer a functional result; that is, the creation of a pleasant building (or floor) climate at a much lower energy cost. A business model that they offer is one where they will accept a rolling percentage of the energy savings that they've instituted. This business model could be described as a "win-win-win" where the building users benefit from a pleasant climate, managers are able to cater for users but at lower costs, the HVAC Consultants receive a percentage of the energy savings and (because less energy is being used) there is also a reduction in carbon emission and so there is also an environmental win.

5.2 Methodology

To refine the framework, efforts were made to capture the expertise of the HVAC Consultants; the data were collected as below. All of the data collection described in this Chapter was conducted by the author.

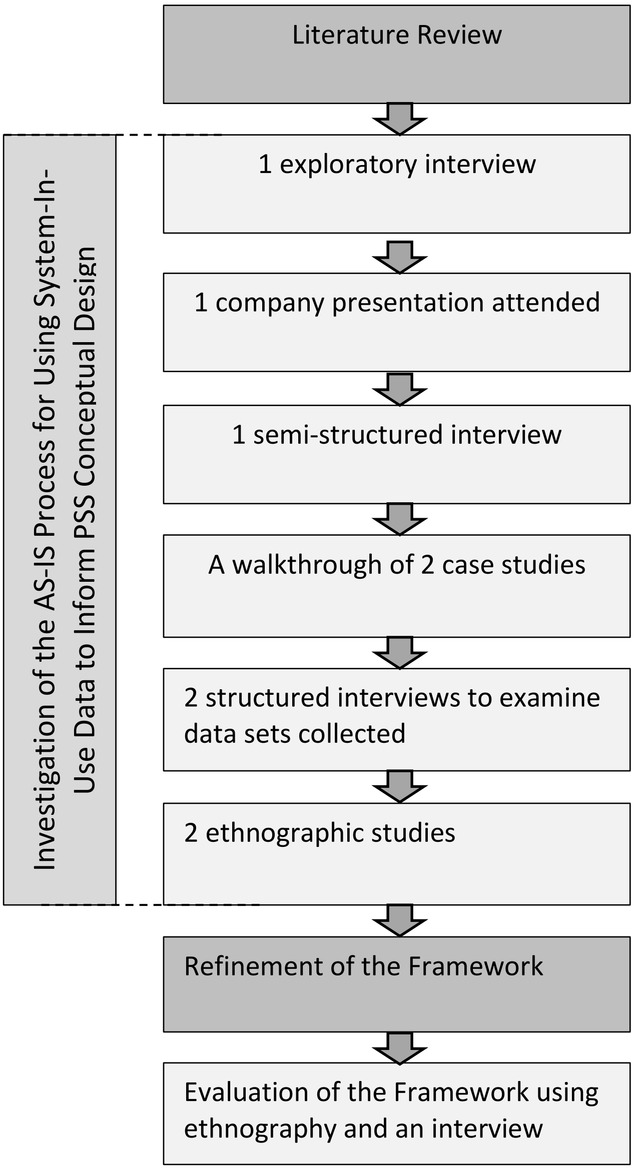

Figure 5.1: Methodology to refine the framework and develop ontology

1. A literature review on themes related to the study had been conducted before the investigation at the company. Where possible case studies to be used for validation were identified.
2. An exploratory interview was conducted which covered the general business of the HVAC company and how it could relate to this research. A company presentation was given which detailed the company's business. A semi-structured interview was then held where the three researchers asked questions (Appendix C – section 4 details the questions which were asked by the author). Only the answers

to the author's questions are reported in this thesis.

3. An interview was conducted where the consultants 'walked through' two HVAC systems that they had improved.
4. Two interviews were held where the consultants explained two different data sets that were collected from two different HVAC systems they had improved (see Appendix B for an anonymised sample data set).
5. Two ethnographic studies were held were the consultants were watched as to how they go about assessing an HVAC system based on customer and user complaints and, from that, how conceptual solutions are generated.

The flow chart (See Figure 5.1) details the steps that the author took during this research. The paler grey colours in the flowchart depict when there was interaction with the HVAC Consulting Company. The interviews that were held were semi-structured, face-to-face interviews. During these interviews, the research questions (outlined at the beginning of this Chapter) were asked and the HVAC Consultants were asked to evaluate the framework by applying it to example case studies.

The participants for this investigation are outlined in Table 5.2 and the type of study they participated in is shown in Table 5.1.

TYPE OF RESEARCH	No. Of Interviewees	Time (hrs)
An exploratory interview was conducted where the aims of this research were firstly presented and then the general business of the HVAC company was explored.	2	2
A company presentation was attended which detailed the company's business.	2	2
A semi-structured interview was then held where further details were gleaned as to how the company derives their business models and conducts their business.	3	1.5
An interview where the consultants 'walked through' two HVAC systems that they had improved.	2	2
Two interviews were held where the consultants explained two different data sets that were collected from two different HVAC systems they had improved.	2, 3	2 x 1.5
Two ethnographic studies were held were the consultants were watched as to how they go about assessing an HVAC system based on customer and user complaints and, from that, how conceptual solutions are generated	3, 3	4
Evaluation of the Framework using ethnography and an interview	2, 3	3.5 + 1
	Total	**19**

Table 5.1: Summary of the types of study that the participants had participated in.

Participants	Years of experience
Managing Director	9 years' experience in HVAC systems
Technical Director	15 years' experience in HVAC consulting
HVAC Consultant	5 years' experience in HVAC consulting

Table 5.2: The participants from the HVAC Company

5.3 Antecedents

From the investigation as to how the HVAC Consultants use System-In-Use data to influence PSS Conceptual Design, seven categories of antecedents emerged: *The Problem Definition Antecedent and Codes, Depiction of the Customer's System, The System Elements and the Data to Collect from Each, Measuring Value in Use of the Customer's System, Locating the Value in Use Loss within the Customer's System, Reducing the Gap within the Process to Improve Value in Use, Changing Other System Elements to Improve Value in Use.* The antecedents state the source and type of data required from an identified process (in which a product or PSS is embedded) and how that data is utilised to generate PSS Conceptual Designs and other system changes which will improve value-in-use. Antecedents and their associated codes follow:

1. The Problem Definition Antecedent and Codes:

Category: The issue is quantified and the system (in which there is an issue) is determined.
Code 1: Quantify the issue: a) Determine which parameter the issue could refer to (the parameters are: cost, the temperature, the time it takes for a temperature to be reached and the times the desired temperature can be available) and determine the issue's units. Collect data to quantify the issue. This will then help to either confirm or debunk the reported issue. b) ***The Severity of the Issue:*** Check with other stakeholders to determine if they are aware or have experienced this issue and how important they believe it to be. This will help to determine how many stakeholders are affected by the issue and its importance to the stakeholders.
Code 2: Determine the scope of the system: Collect data on when the issue arises and how long it lasts. Note any events or changes and the time they occur in that environment when the issue is present. Then compare these changes and events to when the issue arises – this will help to determine the scope of the system to be investigated and gauge the frequency of the issue.

Table 5.3: The depiction of the problem definition antecedent

2. Depiction of the Customer's System Antecedent and Codes:

Category: The system is depicted by a floor plan.
Code 1: Floor Plan A Floor Plan which shows all of the system elements and the actual temperature of each.

Table 5.4: The depiction of the customer's system antecedent

3. Measuring Value in Use of the Customer's System Antecedent and Codes:

Category: To indicate the degree to which the system has met the customer's needs, the difference between the desired system parameters and the actual system parameters is reckoned.
Code 1: The difference between the desired and actual overall system parameters This is the difference between the desired system parameters (elicited from the customer and the users of the area of the building in question) and the actual system parameters (elicited from temperature sensors recording data against time in the area of the building in question).

Table 5.5: Measuring value in use of the customer's system antecedent

4. Locating the Value in Use Loss within the Customer's System:

Category: To indicate the location of the issue in the system, for each sub-system, can be reckoned by either the difference between the desired sub-system parameters and the actual sub-system parameters or by the amount that a subsystem's parameter contributed to the overall system's gaps.
Code 1: The difference between the desired and actual system parameters for each sub-system The location of that value loss within the customer's system was gauged in one of two ways: • the difference between the expected parameters of a subsystem (as gauged by an expert of that type of process and subsystem) and what had actually happened (elicited from temperature sensors recording data against time in the area of the building in question). • The degree to which an actual parameter of a subsystem (elicited from temperature sensors recording data against time) contributed to the gaps in the overall system.

Table 5.6: Locating the value in use loss within the customer's system antecedent

5. The System Elements and the Data to Collect from Each Antecedent and Codes:

Category: The system elements are: the process (and all of its resources) to achieve a customer's goal and the environment (local and wider); these give the system's parameters. For the process, the data to be collected is the temperature, the time it takes a set temperature to be reached, the periods of time that the set temperature cannot be achieved and, lastly, the cost. For the environment, the data to be collected are those from any variables in the environment that impact upon the process.

Code 1: All sub-systems in the process, the temperature produced by each against time

Every device (sub-system) that is integrated into a process to achieve a customer's goal of a pleasant climate is a system element. The data to be collected from each of these elements in the process are:

a) The temperature level (in units of °C). This can be collected with temperature sensors.
b) The length of time it takes for a certain temperature to be reached (in units of HH:MM:SS). The date and time is recorded against the temperature readings. From this data, the length of time for a certain temperature to be reached can be calculated.
c) The times the sub-system can be operational (the availability – the times that it can work) (in units of DD/MM/YY and HH:MM:SS).
d) The cost (in units of £00.0000). This data can be determined by taking the cost of using a device for the length of time that it is used.

Code 2: The local environment and any factors that could impact upon the process

The local environment (the immediate vicinity around the process) is also a system element. Examples of variables in the local environment that could impact upon the process and its outcome are draughts, heat from computers and the presence of people in that vicinity. The data to be collected is the degree to which any variables in the local environment impact upon the system parameters. This data can be gleaned by comparing the same (or a similar) process in different local environments (either quantitatively by using data collected from system parameters or by using the heuristic judgement of experts) to assess how a variable in one environment affects a particular process as compared to when that variable is absent or reduced.

Code 3: The wider environment and any actors that could impact upon the process

The wider environment (the vicinity around the local environment) is also a system element. Examples of variables in the wider environment that could impact upon the process and its outcome are shade from a tree just outside of the building and heat from the sun. This data can be gleaned by comparing the same process and local environment in different wider environments (either quantitatively by using data collected from system parameters or by using the heuristic judgement of experts) to assess how a variable in one environment affects a particular process as compared to when that variable is absent or reduced.

Table 5.7: The system elements and the data to collect antecedent

6. Reducing the Gap within the Process to Improve Value in Use:

Category: After the provider has examined the process in which their offering has been embedded, the offending part of the process can be considered for redesign to increase the value in use of the customer's system; this can be a customisation/upgrade or a new offering design. Any modifications recommended may not necessarily be to that provider's offering; the changes recommended can be to other products and/or services, to the customer's system's environment or to the receiver of that capability. The HVAC Company then presents and discusses the solutions which they believe are feasible with the customer and users.

Code 1: Consider substitution of the offending subsystem

The offending part of the system: substitution: Consider substituting that part of the system that has been found to have contributed most to the overall system issue.

Examples:

- If a space is colder than desired and a particular heater has been found to be not fully working, then that heater could be substituted for another heater which works.
- If a space is warmer than desired and a particular fan has been found to be not fully working, then a fan could be substituted for another fan which works.

Code 2: Consider an addition to the offending subsystem

The offending part of the system: addition: Consider an addition to that part of the system that has been found to have contributed most to the overall system issue.

Examples:

- If a space is colder than desired, then a heater could be added to that space.
- If a space is warmer than desired, then a fan could be added to that space.

Code 3: Consider customisation of the offending subsystem

The offending part of the system: customisation: Consider customising that part of the system that has been found to have contributed most to the overall system issue.

Examples:

- If a space is colder than desired and a particular heater has been found to have been set to a low temperature, then that setting could be increased.
- If a space is colder than desired and leaving the door open has contributed to this, then the users could be instructed to close the door or it could be adjusted to close automatically.

Code 4: Consider elimination of the offending subsystem

The offending part of the system: Elimination: Consider eliminating that part of the system that has been found to have contributed most to the overall system issue.

Examples:

- If a space is used for storage and the heating comes on automatically although the customer wishes to reduce energy bills, removing the heaters in that space should be considered.

Table 5.8: Reducing the gap within the process to improve value in use antecedent

7. Changing Other System Elements to Improve Value in Use:

Category: Besides modification of the offending part of the process, to increase value in use of the overall system, other changes to the system can be made. These are modifications to the local and wider environment, changing the receiver of the system and a complete redesign of the system. Such recommendations would be a service that the provider offers. The HVAC Company then presents and discusses the solutions which they believe to be feasible with the customer and users.
Code 1: Consider a change to the local environment ***Local Environment**:* Consider changes to the local environment. Examples: • If a window has not been insulated, then this could cause a draught or make that space colder than required. Here, rather than just change the HVAC system to produce, for example, more heat to meet customer requirements, a change to the local environment (such as insulating a draughty window) should be considered. • If there is a crack in the wall, then that could contribute to that space becoming colder than required. Here, rather than just change the HVAC system to produce, for example, more heat to meet customer requirements, filling the crack should be considered.
Code 2: Consider a change to the wider environment ***Wider Environment:*** Consider a change to the wider environment: Examples: • If that area of the building is in shade (by, for example, the presence of a tree), then that could contribute to that space (the area of the building under investigation) being colder than required. Here, rather than just change the HVAC system to produce, for example, more heat to meet customer requirements, a change to the wider environment (such as to remove the tree outside of the building) should be considered. • If that area of the building is sun-facing, then that could contribute to that space becoming too hot. Here, rather than just change the HVAC system to produce, for example, cooler air to meet customer requirements, a change to the wider environment (such as placing barriers such as bill boards to the outside of the building) are considered.
Code 3: Consider changing the receiver ***The Receiver (the beneficiary of the system):*** Consider changing the receiver when developing a solution. Examples: • If that area of the building is uncomfortable for the users then consider moving those building users to another area of the building where they will be more comfortable and let other users (who find that area comfortable) move in. • If that area of the building costs too much to heat and/or cool for the customer, consider moving the users to another part of the building and using that space for a use which will not be affected by the natural temperature of that space (for example, storage).
Code 4: Consider a redesign of the whole system ***The Whole System:*** Consider changing the whole system (rather than just one part) when developing a solution. If a given HVAC system produces undesirable results, then consider changing that whole system for a new one which can meet user and customer requirements more easily. Examples: • Changing an old fashioned radiator system to under floor heating can be a more comfortable way to heat a space for users. • Changing an old fan coil unit system to a solar powered heating and cooling system could reduce energy costs in the long term.

Table 5.9: Changing other system elements to improve value in use antecedent

5.4 Refinement of the Framework

The antecedents did not produce any changes to the framework but did refine the framework (See Table 5.10). How each step refined the framework follows:

1. ***Problem Identification*** – a way to depict the system was determined: the HVAC consultants check with other stakeholders so as to gauge a reported issue's importance and then use four parameters to quantify that issue. A floor plan is used to depict the system.
2. ***Determine the Type and Extent of the Problem –***the degree of value in use delivered was determined: the difference in parameters between what the customer desired and the way the system actually behaved gives the value gap.
3. ***Fault Location*** - The system elements and the data that should be collected was determined as well as which part of the system contributed most to the value gap: each of the devices in the HVAC process and the environment are system elements. Gap analysis (as above) is applied in turn to each element in the system.
4. ***Compare Different Instances of the Process*** - a comparison of the system in question is made by the HVAC consultants to other similar systems either quantitatively or by using their experience. This helps them to determine environmental variables that may have adversely affected the system and it also helps them to generate solutions.
5. ***PSS Conceptual Design*** - How PSS Conceptual Design can be informed by the gap in value in use and the part of the system that contributed most to that gap was determined: the HVAC Consultants consider changes to the offending part of the system to increase the value in use. These are substitution, addition, elimination and customisation. Besides modification of the offending part of the process, to increase the value in use of the overall system, other changes to the system can be made. These are modifications to the local and wider environment, changing the receiver of the system and a complete redesign of the process. Such recommendations are a service that the Consultants offer.

Problem Identification

Identify the process used to achieve a goal (along with its environment and the stakeholders) in which an issue has arisen. The reported problem should be an issue with the customer's overall goal (that is, the meeting of their functional needs) rather than just an issue with an asset (requirements).

The HVAC Consultants quantify the issue and determine the customer's system - a floor plan depicts this.

Determine the Type and Extent of the Problem

The type and extent of any reported problem could be determined using gap analysis (the difference between what the customer desired and what actually happened). The reported problem should be an issue with the customer's overall goal (their functional needs) rather than just an issue with an asset (requirements).

The HVAC Consultants use the following procedure: the desired overall system parameters are gleaned from the customers and users of the building. The actual system parameters are taken using temperature sensors. The parameters are:

a) The temperature (in units of °C). This is collected with temperature sensors.

b) The length of time it takes for a certain temperature to be reached (in units of HH:MM:SS). The date and time is recorded against the temperature readings. From this data, the length of time for a certain temperature to be reached can be calculated.

c) The times the process can be operational (the availability – the times that it can work) (in units of DD/MM/YY and HH:MM:SS).

d) The cost (in units of £00.0000). This data can be determined by adding up the cost of running all of the subsystems being used for the length of time that they are used.

Fault Location

This is the determination of the part of the system which contributed most to the issue. This could also be determined by applying gap analysis to the various subsystems which is the difference between how an expert would expect the sub-system to perform and what actually happened.

The HVAC Consultants use the same parameters as in *Determine the Type and Extent of the Problem*. For the environment, data is collected from any variables in the environment that impact upon the process.

Compare Different Instances of the Process

A comparison of the process in different local and wider environments will allow the assessment of how a variable in one environment affects a particular process as compared to when that variable is absent or reduced. Comparing different subsystems and process arrangements that are used to meet the same goal can also help to generate solutions.

The HVAC Consultants achieve this either quantitatively by using data collected from system parameters and/or by using their heuristic judgement.

PSS Conceptual Redesign

Process the data to inform PSS Conceptual Design which could then generate designs to address the customer's issue by:

- supporting customised/ upgrade options for the PSS customer
- developing new PSS system designs

The HVAC Consultants consider changes to the offending part of the system to increase the value in use. These are substitution, addition, elimination and customisation; these can be a customisation/upgrade or a new offering design. Besides modification of the offending part of the process, to increase the value in use of the overall system, other changes to the system can be made. These are modifications to the local and wider environment, changing the receiver of the system and a complete redesign of the system. Such recommendations would be a service that the Consultants offer.

Table 5.10: How the antecedents relate to and refine the framework

5.5 Evaluation of the Framework by Observation

The resultant framework was evaluated by observing how the HVAC Consultants use system-in-use data to develop PSS Conceptual Designs and observing if any of the steps that they followed differed from the framework.

The following case study shows how HVAC Consultants were called to a customer's premises because the customer wanted to reduce their HVAC energy bills as they regarded these bills as being very high. The researcher took notes whilst the HVAC Consultants conducted their business at the premises and the steps that were followed were then transcribed.

The HVAC system in the customer's premises used fan coil units which are devices that poll the air and, depending on their settings (the desired temperature that the air should be) the fan coil units will heat or cool the air around it. Sensors can be used around each fan coil unit to poll the air temperature around it. The fan coil unit receives hot or cold water from a central plant, and removes heat from or adds heat to the air through heat transfer. The actual temperature of the Low Pressure Hot Water (LPHW) and Cold Water System (CWS) can also be polled by temperature sensors. Fan coil units have dampers which are designed to let a degree of supply air pass into the space; the percentage at which the damper is opened will also be polled. Appendix B is an anonymised data set which shows the data (the temperatures) which are collected by sensors from each element in an HVAC system.

5.5.1 The Results of the Observation

1. Problem Identification

In this case study, the problem that the client stated is an issue with the cost of their heating bills which they wanted to reduce by at least 15%. A basic floor plan of the space in the building which is under investigation (Appendix D) is created. The position of the Low Pressure Hot Water (LPHW), Cold Water System (CWS) and Supply Air is depicted. The space is conceptually divided into Zones each of which has two or more fan coil units and these are also depicted on that floor plan. User behaviour which can affect the temperature of the area (the main outcome of the process) is looked for. An example of such behaviour would be propping doors or windows open and, if this is found, it is mentally noted but not depicted. This is the same situation for "trouble spots" such as hot air collecting at the ceiling (rather than being circulated where it is needed) or draughts from doors; temperature sensors were placed at these positions to see if this was the case. Besides observing the local environment, the wider environment is also checked for any variables which may affect the process. In this case study, no such problems were found in the local or wider environment.

2. Determine the Type and Extent of the Problem

The HVAC Consultants used the following procedure: In this case study there are five zones so, in effect, there are five customer systems to be investigated. For each zone, the users specified the same desired desk-level temperature of 21-23°C. For each zone, the customer and users specified the desired length of time for the desired temperature to be reached as half an hour before people entered the building. The desired times that the system should be available (that is, could work) was specified (across all zones) as, at least, 8am to 6pm. The customer wanted to significantly reduce the energy that the HVAC system used and so reduce his energy bills. This information was used to populate the desired overall system parameters. These were then compared with the actual system parameters which were the same for each zone:

1) The desk-level temperature level (21-23 °C). This was collected with temperature sensors.
2) The length of time it takes for the desired temperature to be reached (this took 30 minutes). The temperature sensors record the date and time against the temperature readings. From this data, the length of time for the desired temperature to be reached was calculated.
3) The times the HVAC system can be operational (the availability - times that the HVAC system can work) was established as being (with very rare exceptions) 24 hours per day.
4) The cost of the energy. This was established from the energy bills.

The comparison revealed that (besides the issue of cost), the system met all of the customer's and user's expectations. Based on their experience of HVAC systems, the HVAC Consultants did believe the energy bills to be much higher than they needed to be.

3. Fault Location

For each zone, the desired parameters for each device were stipulated by the HVAC engineers as, based on their expertise, they are aware of how each device should ideally operate in order to produce a desired temperature for a set space. Using temperature sensors, the actual temperature produced by the devices, the times they could work and the length of time it took for the devices to produce the desired effect were established; they all met the desired parameters with two exceptions: firstly, the cost of operating the fan coil units. In this case study, it was found that the fan coil units were operational a great deal of time and that this constant operation of the units (to maintain the temperature as specified by the customer and user) would be costly – this gave the location of the gap within the system. Secondly, one fan coil unit was found to be faulty.

The exact parameters are not reported here as this is proprietary information and specific to the core competences of the HVAC Consulting firm.

4. Compare different instances of the process

Based on their experience of other similar systems, the HVAC consultants knew that the units did not need to be constantly operating in order to maintain a desired temperature. When attempting to achieve a set temperature within an area, a fan-coil unit can slightly overshoot the desired temperature. This can then trigger a nearby fan-coil unit to start cooling the air which can mean that the temperature becomes too low which, in turn, triggers the other unit to start heating the air again and so forth. This constant "battling" between units is very energy hungry.

5. PSS Conceptual Redesign

For the fan coil unit which was faulty, HVAC Consultants replaced this with a new unit. The unit was old and so there seemed little point in repairing it (that is, customising it). The addition of a new unit could have been made but, as there was a space for the old unit, replacement seemed to be a better option. It could have been the case that this fan coil unit could simply have been eliminated but the HVAC Consultants believed that the system required it. There appeared to be no changes that could have been made to the receivers or to the local or wider environment to address the issue of the faulty fan coil unit.

As for the fan coil units, the units were customised: they can be set to poll the air temperature at wider intervals which will greatly reduce this 'battling'. This can result in huge energy savings being made whilst still maintaining the desired temperature. The HVAC Consultants conducted an experiment where they recalibrated the fan-coil units to poll the air at wider intervals (whilst maintaining the desired temperature). They took temperature readings of the zones and, although the units operated far less frequently, the desired temperature was still maintained. From their experience with HVAC systems, the HVACs consultants were aware that huge energy savings should be made. The exact details of this procedure are not reported here as this is proprietary information and specific to the core competences of the HVAC Consulting firm. For this case study, the HVAC Consultants did not believe that any other changes to the process (other than customisation of the fan coil units) or changes to the receivers or to local or wider environment would be able to match the huge energy savings that the re-calibration of the fan-coil units would afford.

They then set the units back to what they previously were and offered their customer a functional result: they offered their service initially for free (the replacement of a fan coil unit and the calibration of the fan-coil units) but with a rolling percentage on any energy savings that the customer would make over a set period of time. This way, the HVAC consultants share the risk with their customers; if no savings are made, then the HVAC consultants will not be paid. The HVAC consultants, if commissioned, will then place temperature sensors within that area so that they can constantly remotely monitor it; these are the 'eyes' and the 'ears' of the HVAC Consultants in the system and any unexpected readings can then flag to them that they should re-inspect that building.

5.5.2 Conclusions on the Evaluation of the Framework

An evaluation session was held with the three HVAC Consultants. They were shown how the framework appeared to be followed during the case study observation. They agreed that framework contained all of the steps in their procedure. They did see any omissions or additions for the framework or how the observation was written up. They also stated that they were not able, at that moment in time, to suggest any improvements to the framework.

5.6 Conclusions on the Interviews and Observation

The framework was refined by the longitudinal study of the HVAC Consultant as it determined:

- A way to depict the customer's system **-** *The HVAC Consultants use floor plans.*
- The system elements and the data should be collected from them - *The HVAC Consultants consider all of the sub-capabilities which are integrated together into a process to meet a customer's goal as system elements. The data they collect from each sub-capability are:*
    - *The temperature level (in units of °C). This can be collected with temperature sensors.*
    - *The length of time it takes for a certain temperature to be reached (in units of HH:MM:SS). The date and time is recorded against the temperature readings. From this data, the length of time for a certain temperature to be reached can be calculated.*
    - *The times the sub-system can be operational (the availability – the times that it can work) (in units of DD/MM/YY and HH:MM:SS).*
    - *The cost (in units of £00.0000). This data can be determined by taking the cost of a device being used for the length of time that it is used.*

  They also consider the local and wider environments as system elements and look for variables within them that may impact upon the process (that is, affect the parameter values of any subsystem).

- How the degree of value in use delivered (how the customer's goal is being met) can be determined from the system-in-use data **-** *The HVAC Consultants measure this as the difference between the actual system parameters and those specified by the customer and user.*
- How the part of the system that contributed most to that system not meeting the customer's goal from the system-in-use data could be determined - *For each subsystem, the location of the value loss within the customer's system is gauged by the HVAC Consultants in one of two ways:*
  - *the difference between the expected parameters (the same parameters as in the answer to Research Question 2) of a subsystem (as gauged by an expert of that type of process and subsystem) and what had actually happened (elicited from temperature sensors recording data against time in the area of the building in question).*
  - *by how much an actual parameter of a subsystem (elicited from temperature sensors recording data against time in the area of the building in question) contributed to the gaps in the overall system.*

  Those subsystems which have the largest gaps indicate that it is those subsystems where value is lost.
- How PSS Conceptual Design can be informed by the gap in value in use and the part of the system that contributed most to that gap in order to support customised/ upgrade options for the PSS customer and develop new PSS system designs - *The HVAC Consultants consider changes to the offending part of the system to increase the value in use. These possible changes are substitution, addition, elimination and customisation; these can be a customisation/upgrade or a new offering design. Besides modification of the offending part of the process, to increase the value in use of the overall system, other changes to the system can be made. These are modifications to the local and wider environment, changing the receiver of the system or a complete redesign of the system.*

5.7 Discussion of the Findings from the Interviews and Observation

1. **The Framework:** the general steps in the framework were followed by the HVAC Consultants during their process of using system-in-use data to develop PSS Conceptual Designs.
2. **System Depiction:** The HVAC consultants depict the system using a floor plan although they tend not to depict possible sources of faults (such as variables in the environment or user behaviour) which could impact upon the process but make a mental note of it. This seems to work well for the HVAC Consultants; they are a very small company (of five people) producing low-cost PSS and they tend to work alone rather than partner with any other firms and so a more deliberate method of sharing information between stakeholders is not required. However, this may not be the case for large industries producing capital-intensive PSS as they may require information to be shared with many stakeholders and across many internal divisions and other companies. Therefore, other types of system depiction which are more generic and apply equally well across all industries should be considered.
3. **The Parameters of the Overall System and its Sub-capabilities:** The parameters used by the HVAC Consultants could be genericized to apply across all industries.
4. **The Evaluation of the Solutions:** The HVAC Company presents the solutions which they believe to be feasible to be discussed with the customer and users and this tends to be a fairly informal procedure. However, other industries may benefit from this process being more structured.
5. **System-in-use data vs. Product-in-use data:** From the ethnographic study that was performed, there was a confirmation that it should not be product-in-use data that is used to inform PSS Conceptual Design but, rather, it should be system-in-use data that is used.
6. **Integration of the Product and Service:** there tends to be little concern as to whether the product and the service are integrated together; the main concern appears to be whether the product and service can be integrated into the customer's system.

7. **PSS Conceptual Design:** Not all of the designs generated were PSS Designs. This is beneficial as it allows for any PSS design to be evaluated against other more conventional changes which could improve the customer's value in use.

5.8 Summary and Key Observations

In this Chapter, the framework has been refined based on the expertise of a low-cost PSS provider which uses system-in-use data to inform PSS Conceptual Design. This allowed the system elements to be defined, determined the types of data to collect, determined how the data can be used to indicate the value loss in a customer's system and then the location of the gap within that system. Furthermore, rather than simply informing PSS Conceptual Design, the refined framework now allows first-cut, conceptual designs to be generated which can then be evaluated by the customers, users and providers. The solutions that are acceptable can then be developed and considered further. In this Chapter, the framework was also applied and evaluated. This framework, although more refined, would appear to be consistent with the initial framework proposed from the literature review in Chapter 2.

It is important to note that the services that the HVAC Consultants provide could easily have been offered by building providers. For example, such a provider could offer an office building for lease or rent and either have the energy use included or help the customer to reduce their bills so that they would not be tempted to leave the building if they thought their bills were too high.

At this stage, the framework (if it could be genericized) appeared to also be applicable to high-value PSS Conceptual Design. However, this would require validation, as will be shown in subsequent Chapters. Also, several key reconceptualizations were developed and observations made which are particularly pertinent to this research:

- **The primary unit of observation and unit of analysis for PSS Conceptual Design:**
  - **The unit of observation proposed in the literature and industry: *The Value Proposition (the Product or PSS).*** The literature and industry stress a need to close the design loop by feeding product-in-use data into PSS Conceptual

Design. However, the term suggests that the provider's product offering or PSS is the primary unit of observation (and perhaps analysis) for PSS Conceptual design.

   - **The proposed unit of observation: *The Value Creating System.*** The customer is not actually in need of a product but is, in fact, in need of fulfilling a task which is unique to their business operations and specific to their contextual demands, resources, competences and constraints; to meet a goal they have, customers integrate value propositions and their own resources into a value creating system that is situated within their environment (Ng et al., 2012). It is this value-creating system that should be the primary unit of observation (Hussain, 2012) and this should also be the primary unit of analysis rather than the provider's value proposition. Observing and collecting data from the customer's system should inform the provider as to the degree to which that value creating system meets the customer's functional needs.

- **Integration in PSS Conceptual Design:**
  Rather than the concern of the provider being that the product and service of their PSS be integrated together (as emphasised by the extant PSS literature), the concern should be that those product and service elements are integratable into the *customer's value creating system* and support it. The service and product which may be offered may not necessarily be related.
- **The Starting Point for PSS Design:** The design process starts with the customer. Throughout the ages, customers have designed their own value-creating systems and then sourced, evaluated, integrated and attuned various value propositions with their own resources to suit their own environments in order to implement the conceptual systems that they initially conceived. These customers then operate, maintain and make improvements to that system. Therefore, the idea of PSS Conceptual Design (the envisaging of a system to achieve a goal and then implementing it according to what resources are available) is not new and this has been traditionally in the hands of the customer who is, essentially, a designer. However, in order to offer value propositions that more closely help to achieve

customer goals, servitizing providers need to either appropriate part of or assist those roles of the customer in order to help to design and implement systems which deliver more value in use. Thus, PSS Conceptual Design should start with the customer's value creating system and not just the design of individual products and/or services.

- **Design Options for PSS Conceptual Design:** If the customer's value creating system is regarded as the design space (that is, the problem-space and the solution-space), then each of the elements of that system can then be considered in turn for redesign in order to ascertain which change would improve value in use.

The next Chapter genericizes and further refines the framework so that it can become a method that is applicable across industry. The framework will now be referred to as the SIU (System-In-Use) Framework. A generic method of system depiction, generic parameters that should apply to any capability, a technique for decomposition, a refinement of design options and a technique for initial solution assessment are developed next.

6 Development of the Framework into a Method

6.1 Introduction

Chapter 5 refined the framework into an industry-specific (HVAC) framework – the SIU (System-In-Use) framework; this was the result of an in-depth investigation of a single company that uses system-in-use data to inform PSS Conceptual Design. In this Chapter, the literature is drawn upon to triangulate the identified Framework constructs as well as genericize the framework into a method, the System-In-Use Method, so that it is applicable across industry. The rationale to produce a Workbook is also outlined.

6.2 Methodology

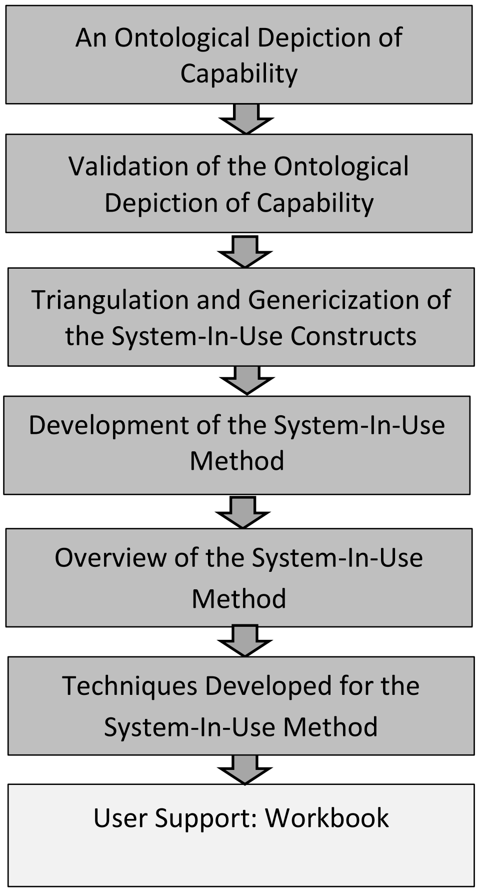

Figure 6.1: Methodology to Develop the SIU Method

1. The first step was to develop an ontological depiction of capability.
2. The above depiction of capability was subsequently validated by the HVAC Consultants.
3. The literature was then reviewed to triangulate, refine and genericize the System-In-Use constructs.
4. From the findings from the literature, the SIU Framework was developed into a generic SIU Method.
5. The steps of the SIU Method were then fully detailed.
6. The techniques that the SIU Method use were then refined.
7. Meetings were then held with various experts in the field as to how the SIU Method could be supported. This was to decide as to whether a software tool or Workbook would be the best option to support the user of the SIU Method.

6.3 Development of the SIU Method

6.3.1 An Ontological Depiction of Capability

Ontology facilitates unambiguous communication, the formulation of standards and semantic-alignment efforts as well as future industrial information infrastructures (Schlenoff et al., 1999; Annamalai Vasantha et al, 2011). Using the findings from the literature, ontology was developed (See Figure 6.2) which shows the operant resource and operand resource as well as the process the operand uses change the operand. This was required to depict the elements in a capability so that it could be fully revealed which factors give rise to capability and where within a capability a problem could arise. Although these aspects were not mentioned in any way during any of the interviews with industry, they could help to further unravel the nature of capability and, thus, enhance the SIU Method. For example, the previous interviews with industry revealed that a way of conceptually decomposing the asset was required for fault finding. However, for the SIU Method, such a technique should be able to also apply to services. The operand and operant concept could provide the basis for such a technique.

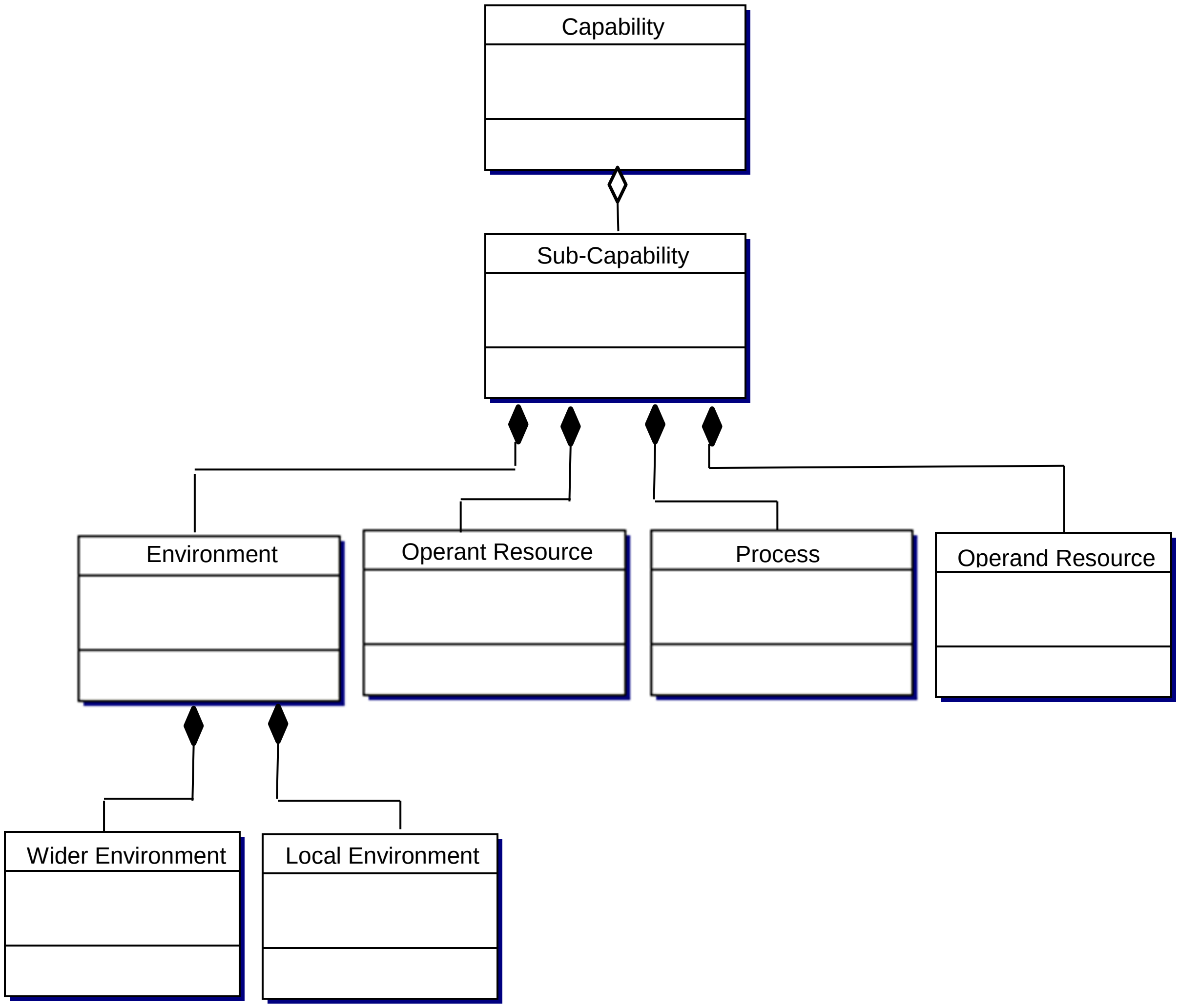

Figure 6.2: Capability class structure

6.3.2 Validation of the Ontological Depiction

This section describes the validation of the ontological description of capability. The author conducted it with the collaborating HVAC Consultants. They appear to consider the system-in-use rather than the product-in-use or the PSS-in-use when developing conceptual solutions. This understanding of how value is created and how it can be improved upon could be the reason why they are able to share the risk with clients in offering higher-level PSS business models.

The validation took place through a workshop, which lasted for two hours. Two scenarios were described, and in each case a demonstration was given to indicate the how the ontological description of capability can be used to help:

1. Assess the effectiveness of a given capability
2. Generate possible conceptual solutions

The workshop started with the author giving a short presentation about the research and the achievements at that stage. During the presentation, a scenario of usage for the ontology was described (Appendix E).

The Questions and Results of the Ontological Validation

	Questions	Answers from the HVAC Consultants
1	Is this ontological description of capability your understanding of how capability (say, an HVAC capability) is constructed? Rate this on a scale of 1 to 10.	"We have never thought about an HVAC system this way but this is useful. Yes, we look at all aspects of the system but have never depicted it this way. It prompts you not to forget about considering a change to each part of the system – this can be rated as 10."
2	Is there anything that is missing or that should be changed?	"There does not appear to be anything missing."
3	Is this ontological description of capability useful in assessing HVAC capabilities and generating solutions? Rate this on a scale of 1 to 10.	"It could be useful for us to check that we have examined all of the possibilities. Rating = 10."
4	How would you enhance this ontological description of capability?	"It seems to be complete."

Table 5.9: The questions and results of the ontological validation

6.3.3 Genericisation of the SIU Framework Constructs

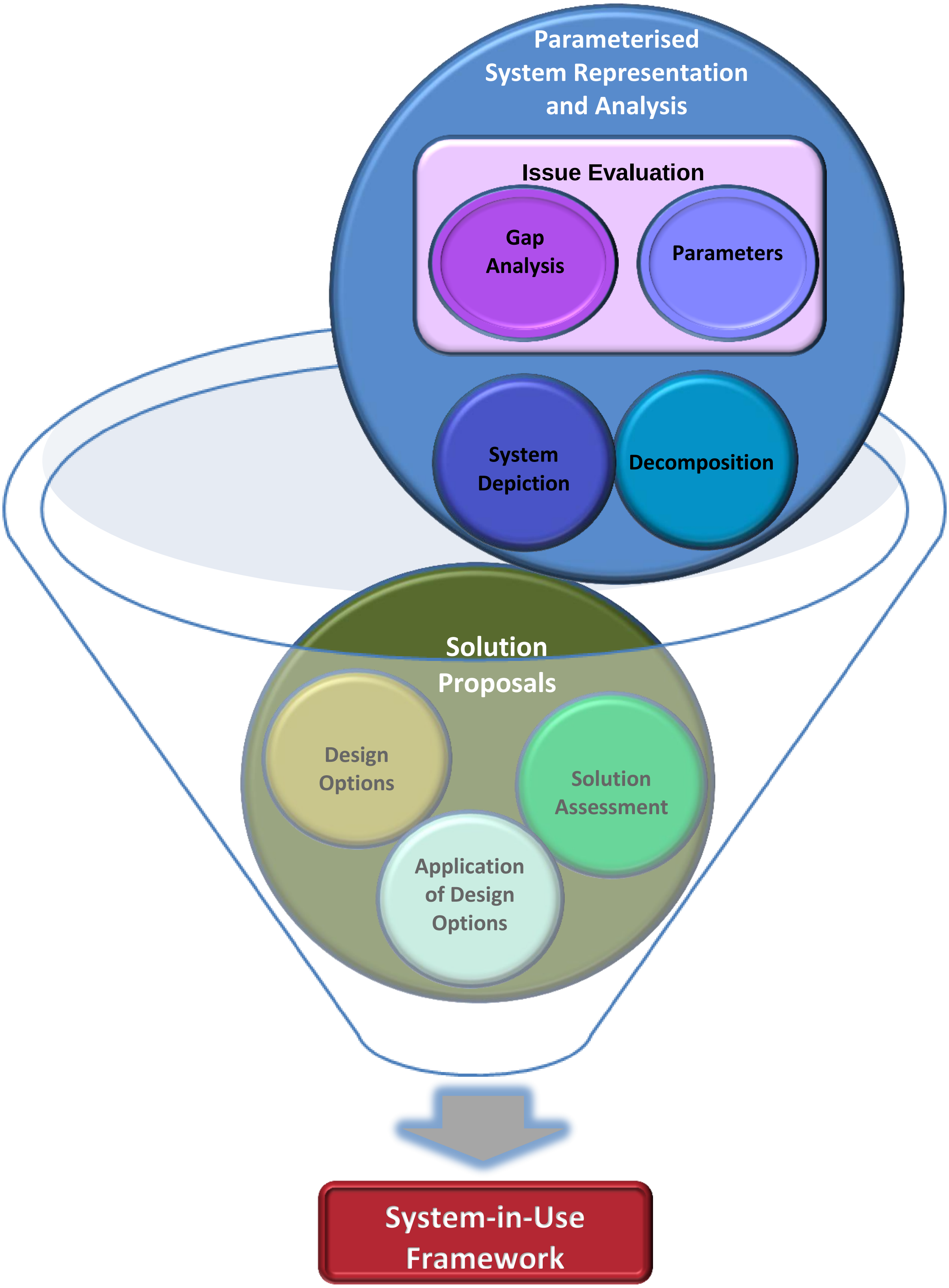

Figure 6.3: The Author's System-in-Use Framework Constructs

From this research, the System-In-Use constructs (See Figure 6.3) have been identified to be:

1. ***Parameterised System Representation and Analysis***
    - System Depiction
    - Issue Evaluation
        - Gap analysis
        - Parameters
    - Decomposition
2. ***Solution Proposals***
    - Design Options
    - Solution assessment
    - The Application of Design Options

Each construct is now triangulated, refined and genericised in turn:

1. System depiction

The HVAC Consultants depict the system using a floor plan and they tend to make mental notes of processes and the location of gaps therein as well as the roles and responsibilities of the stakeholders. Although this may be adequate for a very small company dealing with low-cost PSS, for large providers of capital-intensive PSS, a more deliberate method of sharing information between stakeholders and across many internal divisions and other companies would be required for PSS development.

As discussed in the literature review (Chapter 2), Service Blueprinting (simple and extended) could be used for system depiction. However, a means to depict the environment in which a system is located would have to be added.

The definition of the system should be corroborated, where possible, by other experts in that particular process, other stakeholders and with archival material. The HVAC Consultants (whose expertise the SIU Method draws upon) tended not to corroborate system depictions that they devised; they have considerable expertise in HVAC systems and the systems they engage with are small so they are able to test the system limits with sensors. Nevertheless, for large systems, especially ones that can spread across many internal divisions or geographical locations, the SIU Method should explicitly state that the system definition should be corroborated with other sources.

2. Issue Evaluation

If the method were to be a solely quantitative method then, for the provider to apply it, their customer's process would have to be transparent to them at, sometimes, quite a detailed level. However, this sharing of business information and trust between stakeholders is absent in many industries. However, if the method, in essence, could be simple enough for a knowledgeable customer to apply it to their own processes; the suggestions from the Proposals Matrix could then be shared with the provider. Although it would be more informative for the provider to have access to detailed existing process depictions and detailed data from that process, at least suggestions to improve value-in-use would be a step forward. Nevertheless, the method should also allow partial and qualitative information which a provider may know about a customer's process to be utilised. This would mean that the system parameters and gaps should be able to be described both qualitatively as well as able to be defined quantitatively.

a. Identification and Development of Generic Parameters for the Method

In the previous Chapter, parameters were specified which were specific to the systems (and also to the subsystems) that the HVAC Consultants collected data to indicate:

I. the value loss of a customer's system which was gauged as the difference between:
   - the actual parameters of the overall system and
   - the parameters desired by the customer

II. the location of the value loss within the customer's system – this was gauged in one of two ways:

- The difference between the expected parameters of a subsystem (as gauged by an expert of that type of process and subsystem) and what had actually happened.
- By how much an actual parameter of a subsystem contributed to the gaps in the overall system.

However, in order for the SIU Method to apply across many industries, these parameters would need to be triangulated with the literature and be genericised.

With regards to genericising the parameters, functionality (Mont, 2002) would appear to map to the HVAC Consultants business-specific parameter of temperature and economic value (Mont, 2002) would appear to map to their parameter of cost. The responsiveness of the system (how quickly the capability is achieved) (Toossi, 2012) can be an issue for customers (Toossi, 2012) and this appears to map to the HVAC Consultants business-specific parameter of the length of time it takes for a certain temperature to be reached. Availability (Annamali Vasantha et al, 2011) is discussed in the PSS literature and this appears to map to the HVAC Consultants business-specific parameter of the times the system or sub-system can be operational (the availability – the times that it can work).

In the OEE, Availability measures the percentage of time that the asset was running compared to the available time. This would appear to map to the Time-Cycle in the SIU Method parameters. Performance measures the running speed of the asset compared to its maximum capability. Quality measures the number of parts within tolerance produced compared to the total number of parts made. This would appear to map to Range in the SIU Method parameters.

For the purposes of this research (and for brevity) these parameters have been renamed. The mapping of the generic parameters gleaned from the literature with those of the HVAC Consultants along with how these are termed for this research is summarised in Table 6.1:

	HVAC Consultants Parameters	The Generic Parameters Gleaned from Literature	The Nomenclature for Parameters for this Research
1	The temperature level	Function fulfilment (Mont, 2002).	**Range:** this describes the level of an effect
2	The length of time it takes for a certain temperature to be reached	Responsiveness (Toossi, 2012).	**Span:** this describes the length of time it takes for an effect to be reached.
3	The times the system or sub-system can be operational (the availability – the times that it can work)	Availability (Annamali Vasantha et al, 2011)	**Time Cycle (TC):** this describes the times an effect can be operational
4	The cost	Economic fulfilment (Mont, 2002)	**Cost:** the monetary cost of an effect

Table 6.1: Genericization of the Parameters used by the HVAC Consultants

b. Gap Analysis

As discussed in the literature review (Chapter 2), gap analysis can indicate the severity of the issue.

3. Design Options

In the previous Chapter, design options were developed based on the HVAC Consultants understanding of system elements and how each element can be considered in turn for redesign to improve value in use. With regards to the offending part of the process (that which contributed most to value loss), replacement (substitution) would be a natural change to consider as would addition, elimination or customisation. This is also the case for the consideration of a new conceptual design of the whole process to achieve the same aim.

When dealing with the receivers of a system within a firm, the HVAC Consultants consider changing the receiver who experienced issues with the system with another who is quite happy with that system. This reduces or removes the gaps as the capability is offered to other receivers or market segments where the gaps do not occur; this is another Design Option that can be used. This could then mean that the provider could focus solely on market segments (or receivers) where they would provide most benefit and so further hone their competences which should lead to increased specialization. Alternatively, the provider could partner with a company that can fill the gaps more closely. In S-D Logic, the removal of resistances that can negatively impact a process is deemed necessary and this could involve lobbying for new laws (Vargo et al., 2010). Therefore, the design option which considers changes to the wider environment should be amended to reflect this. With regards to the local environment, if an environmental variable is reducing the performance of the process, then the part of the process that is affected could be enveloped against the effect of that variable or that variable could be removed.

Rather than just relying on past performance and known solutions, the Design Options, force each of the elements that make up a capability to be considered in turn; this allows previously unexamined factors to be considered for redesign and this should foster innovation.

4. Decomposition: Operand and Operant Resources

For the offending part of a process to be redesigned, the generic elements that can be considered in that subsystem are: the operand resource, the operant resource (Vargo and Lusch 2004a) and the way (the process) that the operant resource acted upon the operand resource to produce an outcome. This means that any subsystem can be decomposed into its operand resource, process and operand resource. Furthermore, as systems are recursive, that is, nested (Ng et al, 2012) each of these subsystems are systems in their own right which can also be parameterised and also decomposed further. This is pertinent for the development of this method. Functional decomposition modelling could help identify products and services within a PSS (Becker et al, 2008) and identify the stakeholders for each so that other supplier tiers can be explored for solutions.

5. Solution Assessment

As the scope of this research is to inform PSS Conceptual Design rather than to produce refined solutions; only proposed solutions which do not appear to be much of an improvement and/or which the customer abhors should be rejected. Other proposed solutions which appear to satisfy customer needs the most and which the customer is amenable to should be refined and *then* evaluated stringently against each other and against customer needs. However, the production of a developed, stringently evaluated PSS solution is outside of the scope of this research. Therefore, as discussed in the literature review (Chapter 2), a simple evaluation method such as a Likert Scale For the development of the SIU framework, could be a suitable way for customers to evaluate alternatives.

6.3.4 Adaptation of the SIU Framework into a Method

To genericize the SIU constructs, using the findings from the literature, the following adaptions to the SIU constructs are made:

1. **System Depiction:** Service Blueprinting (simple or extended) will be used. However, the environments in which the system is located will also be shown as will the parameters of the system. This type of environment-specific, parameterised Service Blueprinting will now be referred to as Enhanced Service Blueprinting. The system depiction should be corroborated by other sources.

2. **System and Subsystem Parameters:** These have now been termed:
   a) **Range:** this describes the level of an effect
   b) **Span:** this describes the length of time it takes for an effect to be reached.
   c) **Time Cycle (TC):** this describes the times an effect can be operational
   d) **Cost:** the monetary cost of an effect

3. **Gap Analysis**: The value loss *of* a system is determined by the difference in the actual parameters and the desired parameters of the overall system. The value loss *within* the system is indicated by either:
   a. The difference between the expected parameters of a subsystem (as gauged by an expert of that type of process and subsystem) and what had actually happened.
   b. By how much an actual parameter of a subsystem contributed to the gaps in the overall system.

4. **Decomposition:** Service Blueprinting facilitates this. Furthermore, the decomposition of any sub-capability into its operand resource, operant resource and the process that operand uses also facilitates further decomposition.

5. **Solution Assessment:** A Likert Scale is to be used so that stakeholders can indicate the degree to which they expect a proposal to close the gaps. The pre-coded responses to be used are: "High", "Medium", "Low" or, if the design option appears not to apply, "N/A". For options which make the gap bigger, a "↑" symbol can be stipulated and for options which do not change the gaps, a "0" can be given.

6. **Design Options:** These can be used to generate new designs by considering changes to various parts of the system (Figure 6.4).
    a. Changes that can be considered to the overall system:
        i. The environment (local and wider)
        ii. A completely new conceptual process
        iii. Changing the receiver to one whose needs are met by the system.
    b. Changes that can be considered to the part of the system which contributed most to value loss:
        i. Substitution
        ii. Customisation
        iii. Elimination
        iv. Addition

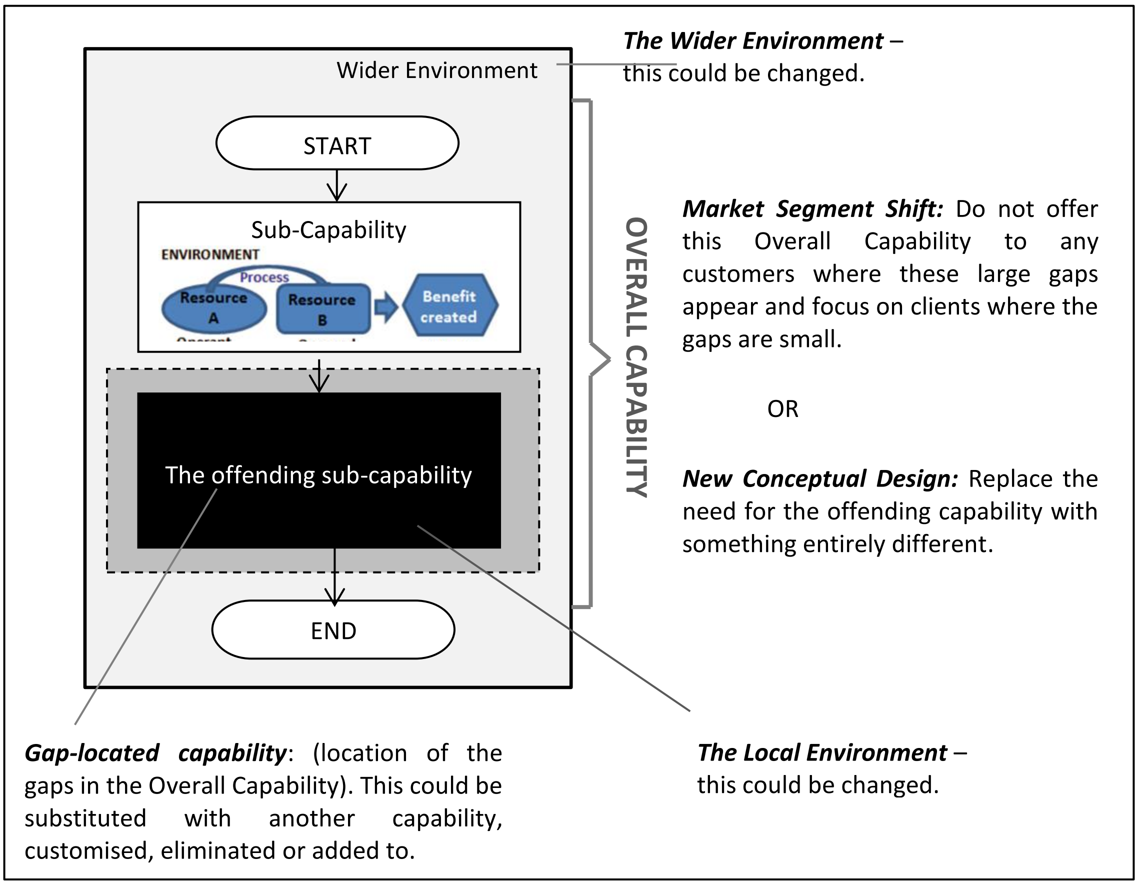

Figure 6.4: The elements in a capability that can be changed

6.4 The System-In-Use (SIU) Method

6.4.1 The Overview of the SIU Method

Using the findings from the literature in Section 6.3.1, the framework is refined into a method (next) which generates prototype Conceptual PSS Designs by utilising System-In-Use data. A detailed description of the Steps is listed after the overview of the method and the techniques that the SIU Method uses are charted in Section 6.4.2 .

Overview of the SIU Method

Start: The user of the method will start applying the method at the end-user's value-creating system (Supplier Tier = 0). In practice, this may not be possible as the focal company may have very little knowledge of the end-user. However, the method can still be applied by starting with the customer level that the user of the method does have knowledge about.

1. **Problem Definition** - Determines the issue and the system in which the issue arose. This is depicted.

2. **Determine the Gaps in the Overall Capability** - Defines the type and extent of the issue. This can be performed quantitatively or qualitatively[1].

3. **Determine the Gap-Located Capabilities within the System** - Determines where the issue lies within the system. This can be performed quantitatively or qualitatively.

4. **Corroborate the System Definition** – Where possible, consult with other relevant stakeholders, experts and archival material as to the legitimacy of the system depiction.

5. **Operant-Operand Decomposition of the Gap-Located Capability** – This decomposes the issue within the system for further exploration

6. **Determine the Stakeholders** –suppliers of elements of the system, its customers and users as well as those who impact upon or are impacted by the system in other ways (such as legally, socially or environmentally)

7. **Comparison of Similar Capabilities** - Aids possible solution generation

8. **Propose Solutions** - Considers changes to the offending part of the system, its environment, receiver and the whole system. Solutions generated are then evaluated.

9. **Next Tier?:** There could be an operand or operant resource or process that the operand used which has contributed to the Gap-Located Capability that could have the Proposals Matrix (and its design options) applied to it. The resultant Proposals Matrix should then be presented to that particular supplier as it is that stakeholder that has the expertise to fully correct and evaluate any possible solutions in that Matrix.

10. Increase the Tier by 1: A methodological check to ensure that the value chain is considered systematically and then the creation of the Service Blueprint for this Tier.

11. Next Gap-Located Capability? - If the issue has found to lie in more than one part of the system, then this gap can similarly be explored and solutions generated and evaluated.

12. Rate and Select Solutions: Rather than rate and select solutions for all of the Proposal Matrices that have been generated - this allows solutions to be compared across Matrices.

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[1] If quantitative data is not available then the heuristic judgment of experts can be used.

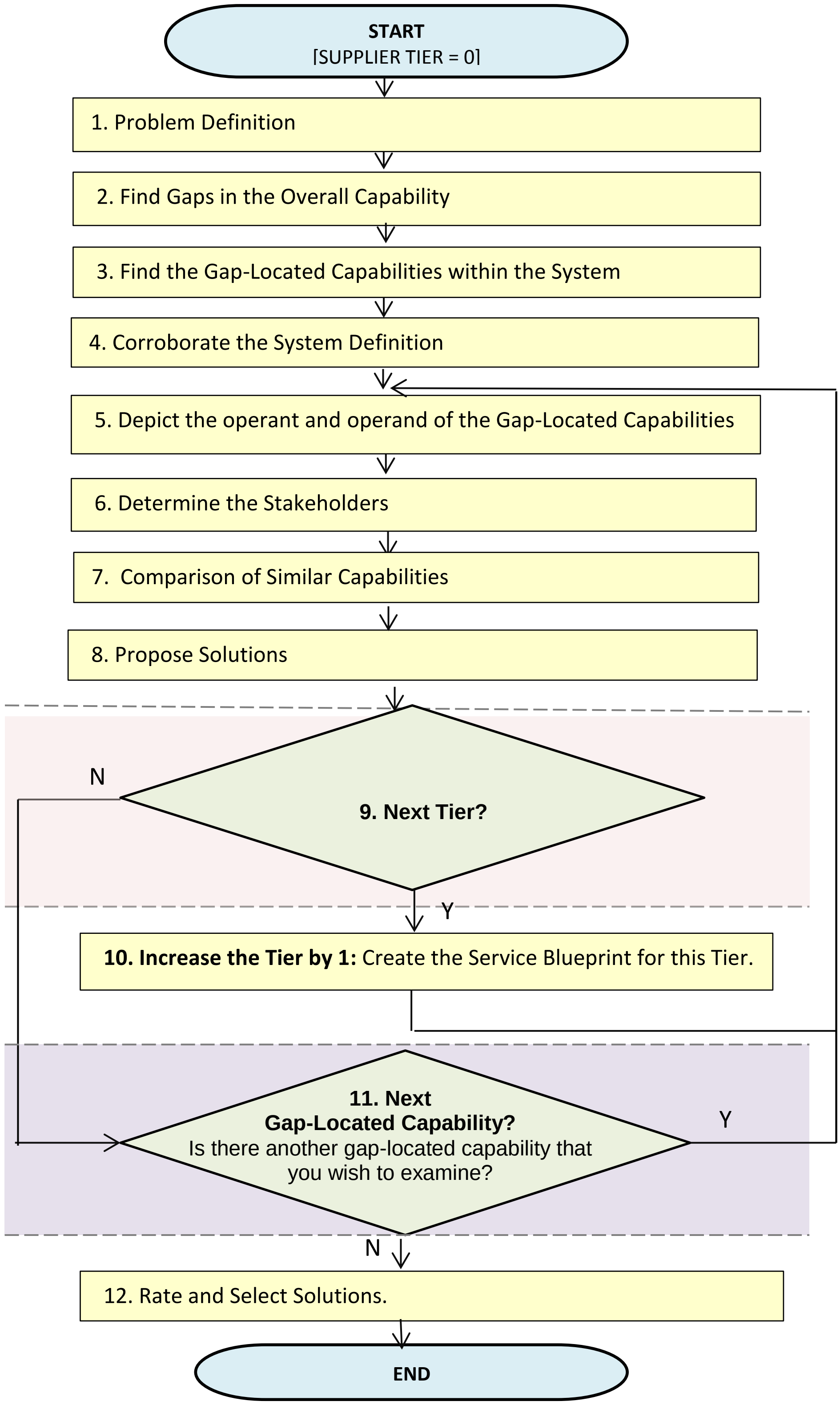


Figure 6.5 : The SIU Method Steps

Detailed Steps of the SIU Method

START: At the start, the Supplier Tier is set to 0 – this is the receiver (or the Tier nearest to the receiver) that the applier of the method can collect data from or has knowledge of. The parameters to collect data for are in Section 6.4.2.

STEP 1: Problem Definition

For any capability in which there is dissatisfaction, start with the end-users capability (or, if little is known about this, start with the capability *nearest* to the end-user from which data can be collected or there is knowledge).

a) **Define the Issue:**

i. ***If there is quantitative data available then:***

1. ***Quantify the Issue:*** Determine which parameter the issue could refer to (such as cost, range, span or TC) and determine that issue's units. Collect data to quantify the issue and other parameters. This will then help to either confirm or debunk the reported issue.

ELSE

2. ***Gauge the Extent of the Issue:*** Describe how important the issue is.

ii. ***The Severity of the Issue:*** Check with other stakeholders to determine if they are aware or have experienced this issue and how important they believe it to be. This will help to determine how many stakeholders are affected by the issue and its importance to the stakeholders.

b) ***Determine the scope of the system:*** collect data on when the issue arises and how long it lasts. Note and describe any events or changes and the time they occurred in that environment when the issue was present. Then compare these changes and events to when the issue arises – this will help to determine the scope of the system to be investigated and gauge the frequency of the issue.

c) ***Depict the System:***

i. ***If Detailed Systems Analysis has been performed:*** For simplicity, Service Blueprinting could be used or, if detailed product operation is a concern, then Extended Service Blueprinting could be used instead. Label the environments that each of the capabilities is located in. A possible data sources is systems analysis .

ELSE

ii. ***Use the Heuristic Judgment of Available Experts:*** create a basic Service Blueprint of the capability based on the partial information which is known by the applier. If possible, label the environments that each sub-capability is located in. Service Blueprinting could be used or, if detailed product operation is a concern, then Extended Service Blueprinting could be used. Examples of possible data sources are interviews with the receivers and owners of the process.

STEP 2. Determine the Gaps in the Overall Capability - *This defines the type and extent of the issue. Examples of possible data sources are interviews with the receivers and owners of the process, data from sensors and the systems analysis of the process. Add the gaps to the Service Blueprint.*

a) If there is quantitative data available then:

I. ***Define the Desired Overall Capability Parameter Values***: Determine what ideally should have happened for there not to have been dissatisfaction. This indicates the level and type of performance that is required for the receiver's goal to be accomplished satisfactorily.

II. ***Determine the Actual Overall Capability Parameter Values:*** Collect data on what really happened in the capability in question.

III. ***Find the Overall Capability Parameter Gaps:*** This is the difference between what actually happened and what should have happened – this is the gap between the actual and desired capability.

ELSE

b) **Describe the Desired Overall Capability Parameters:** Describe the gaps of the

Overall Capability.

STEP 3. Determine the Gap-Located Capabilities within the System:

I. If there is quantitative data available then:

a) ***Define the Actual Sub-Capability Parameter Values****:* Find the actual parameter values for each of the sub-capabilities in the capability. This indicates how each sub-capability actually behaved.

b) ***Determine the Gaps within the Capability:*** This can be accomplished in one of two ways:

I. By Expert Assessment:

- Define the Desired Sub-Capability Parameter Values: To do this, an expert in that process and the sub-capability in question can state the parameters of how the sub-capability should have behaved in order for the gaps not to be present in the overall capability.
- Find the Actual Sub-Capability Parameter Values: this is how each sub-capability actually behaved. Examples of data sources are sensors and in-service records.
- Determine the Sub-Capability Parameter Gaps: Determine which sub-capabilities of the system contributed most to the issue by finding the difference between the actual sub-capability parameter values and the desired sub-capability parameter values.

II. Gap Contribution to the Overall System:

- Find the Actual Sub-Capability Parameter Values: this is how each sub-capability actually behaved. Examples of data sources are sensors and in-service records.
- Gauge the proportion to which a sub-capability's parameter has contributed to the same parameter in the gap of the overall capability.

ELSE

II **Describe the Gap-Located Capabilities within the Capability:** Describe where the gaps within the capability(s) are estimated to be situated (which sub-capability(s)).

The sub-capability(s) with the largest gap(s) become the Gap-Located Capability(s). Add this to the Service Blueprint. For large gaps, decompose the sub-capability by creating a more detailed blueprint of it and, again, find the gaps. This can be repeated until the lowest level of decomposition is reached. The sub-capability(s) with the largest gap(s) become the Gap-Located Capability(s). Add this to the Service Blueprint.

STEP 4. Corroborate the System Definition: Where possible, consult with other relevant stakeholders, experts and archival material as to the legitimacy of the system depiction.

STEP 5. Operand-Operant Decomposition of the Gap-Located Capability: Each Gap-Located Capability can then be decomposed into its constituent parts of: operant resource, the operand resource and the process by which the operant resource changes the operand resource. If there are several large Gap-Located Capabilities then, rather than decompose each one, they could be grouped and an Operand-Operant Diagram could be created to show the relationships between them; this will allow a common solution to be found later.

STEP 6. Determine the Stakeholders: Define the stakeholders responsible for each part of the Gap-Located Capability.

STEP 7. Comparison of Similar Capabilities To help determine if different environments or types of use could be the cause of the gaps and to help generate possible solutions, comparisons can be made (if such data or knowledge is available) to other similar capabilities where the gaps do not appear or where the gaps are reduced.

STEP 8. Propose Solutions: With the assistance of relevant stakeholders and experts (if available), apply the third Design Option (Changes Regarding the Offending Capability) in the Proposals Matrix to the operant, operand and operant's process in the largest Gap-Located Capability. Then apply the first, second and fourth Design Options to the Overall Capability. Each of the solutions could be stated as a question for the stakeholders to answer.

STEP 9. Next Tier?: If desired, another supplier Tier could be explored. There could be an operant resource, operand resource or process that the operant uses which has contributed to the Gap-Located Capability that could be decomposed further and then the Proposals Matrix could be applied to it. The resultant Proposals Matrix can eventually (outside the scope of this research) be presented to that particular supplier as it is that stakeholder who would have the expertise to fully correct and evaluate any possible solutions.

STEP 10. Increase the Tier by 1: A methodological check to ensure that the value chain is considered systematically and creation of the Service Blueprint for this Tier.

STEP 11. Next Gap-Located Capability?: If there is more than one Gap-Located Capability, then this can be examined similarly; this then becomes the largest Gap–Located Capability to examine.

STEP 12. Rate and Select Solutions: Each solution can then be estimated by the applier as to the extent that it should close the gaps (as High, Medium or Low). If a solution cannot be generated for that type of redesign then "N/A" (Not Applicable) is stated. For options which make the gap bigger, a "↑" symbol can be stipulated and for options which do not change the gaps, a "0" can be given. The solutions can then be shared with the stakeholders.

6.4.2 Techniques used by the SIU Method

1. System Depiction: Service Blueprinting (simple or Extended) will be used. However, the environments in which the system is located will also be shown as will the parameters of the system. This type of environment-specific, parameterised service blueprinting will now be referred to as Enhanced Service Blueprinting.

2. Capability Parameterisation (System and Subsystem Parameters and Gap Analysis):

Examples of how the data could be collected: from sensors or in-service records. The overall capability is parameterised as actual and desired parameters. The difference between the actual overall capability parameters and the desired overall capability parameters give the overall capability parameter gaps. See Figure 6.6 for an example (a package-delivery capability).

ACTUAL OVERALL CAPABILITY PARAMETER VALUES	DESIRED OVERALL CAPABILITY PARAMETER VALUES	OVERALL CAPABILITY PARAMETER GAPS
Span: 3 days	**Span:** 1 day	**Span:** 2 days
Cost: £20	**Cost:** £15	**Cost:** £5
TC: 98%	**TC:** 99%	**TC:** 1%
Range: Delivery of packages under 15kg	**Range:** Delivery of packages under 15kg	**Range:** None

Figure 6.6: An example of the parameters for an Overall Capability for Delivering Packages

Each sub-capability is parameterised similarly. Determining the gaps within the system can be accomplished in one of two ways:

b) **By Expert Assessment:**

Define the Desired Sub-Capability Parameter Values: For each sub-capability, define the desired parameter values for each of the sub-capabilities in the system. To do this, an expert in that process and sub-capability could state the parameters of how the sub-capability should have behaved in order for the gaps not to be present in the overall capability.

c) **Gap Contribution to the Overall System:**

For any given parameter gap in the overall capability, gauge the proportion to which each sub-capability's corresponding parameter has contributed to it. The parameters and examples of units that could be used are in Table 6.2.

	Parameter Types	Examples of units that could be used
1	**Range:** this describes the level of an effect	This depends on what the capability is. Examples are temperature and weight.
2	**Span:** this describes the length of time it takes for an effect to be reached.	This could be expressed in minutes, hours, days, weeks, months or years.
3	**Time Cycle (TC):** this describes the times an effect can be operational for use.	This could be expressed as a percentage of time or the days of the week or hours that the effect can be available.
4	**Cost**: the monetary cost of an effect	Pounds, pennies or fractions of a penny could be used.

Table 6.2: Parameters in the SIU Method and examples of units that could be used

3. Operand-Operant Diagrams

Service Blueprinting (simple and Extended) facilitates decomposition as each sub-capability (product or service) in any blueprint can then be blueprinted in its own right to reveal its internal operation. In addition to this, any sub-capability can be decomposed into its operand resource, operant resource the process that operand uses and the environment: this allows for how an effect was created to be examined. For a Gap-Located Capability, an Operand-Operant Diagram can be created which is a new technique which has been devised for the SIU Method. The elements of the diagram are shown in Figure 6.7:

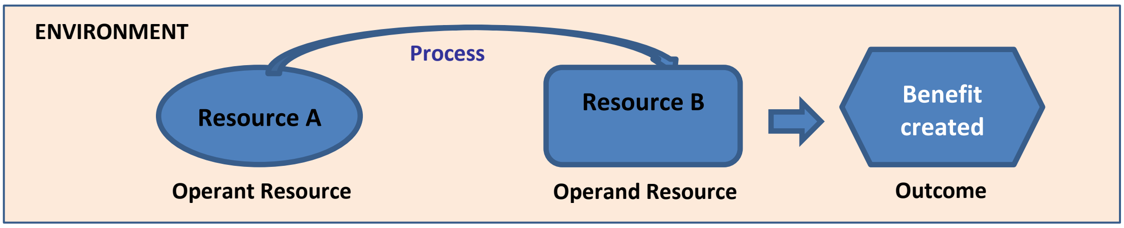


Figure 6.7: An Operant-Operand Decomposition Diagram

4. The Application of Design Options and Solution Assessment

The Proposals Matrix (Table 6.4) is also a new technique that has been devised for the SIU Method. It allows the Design Options in Table 6.3 (a new construct which has also been devised for the SIU Method) to be applied to the system so that new designs can be generated which close the gaps.

Table 6.3: The Design Options

Types of Generic Change
1) NEW CONCEPTUAL DESIGN Basically replace the need for the whole capability with something entirely different (a new process) to meet the same goal (the overall aim) - a new Conceptual design.
2) MARKET SEGMENT/RECEIVER SHIFT Do not offer this Overall Capability to any market segment or receiver where these large gaps appear and focus on markets or receivers where the gaps are small; this should lead to increased specialization for the capability provider. Alternatively, partner with a provider that can fill the gaps more closely.
3) CHANGES REGARDING THE OFFENDING CAPABILITY : **The operant(s), operand(s) and the operant's process(es) within the gap-located capability can each (or any combination thereof) be considered for redesign in the following ways:**
a) SUBSTITUTE - Find substitutes that could reduce or remove the gaps for the offending capability.
b) ELIMINATE - Simply remove the offending capability and do not replace it with anything. However, there could be ramifications for other phases in the lifecycle or for higher or lower capabilities in which this capability is embedded.
c) ADDITION - Add a capability alongside the offending capability to reduce or remove the gaps.
d) CUSTOMISE - Modify the offending capability so that the gaps will be reduced or removed.
4) ENVIRONMENTAL CHANGE
a) CHANGE LOCAL ENVIRONMENT - Change the environment around the offending capability. If an affecting environmental variable is reducing the performance of the capability then that capability could be enveloped to protect it from this variable or that variable could be removed.
b) CHANGE WIDER ENVIRONMENT - Make changes to the wider environment which could close the gaps. This could involve petitioning local government to reduce or remove the affecting variable. If constraints such as standards, policies or regulations are contributing to the gaps and if there are no processes which the capability would adversely affect if the constraints were removed, then this could suggest that these constraints should be questioned.

For each parameter gap in the Gap-Located Capability, a column can be added to the Matrix stating the parameter: in the example Proposals Matrix (Table 6.4), there are two parameters gaps in the Overall Capability. Option 3 (*Changes Regarding the Offending Capability*) is applied to the Gap-Located Capability which contributed most to value loss and Options 1, 2 and 4 apply to the overall process. Each element in the capability to which design options are to be applied are in the left-hand Column of the Proposals Matrix in Table 6.4. A full description of the Design Options for the Proposals Matrix are listed in Table 6.3.

To appraise the solutions, "High", "Medium" or "Low" or, if the design option appears not to apply, "N/A" can be stipulated. For options which make the gap bigger, a "↑" symbol can be stipulated and for options which do not change the gaps, a "0" can be given. The solutions that close the gaps the most and which are acceptable can then be ringed or highlighted.

Types of Generic Change for the Use Phase	RATING		Application to this Case
	Overall Parameter gap 1 decrease	Overall Parameter gap 1 decrease	
1) NEW CONCEPTUAL DESIGN			
2) MARKET SEGMENT/ RECEIVER SHIFT			
3) CHANGES REGARDING THE OFFENDING CAPABILITY			
a) SUBSTITUTE			
b) ELIMINATE			
c) ADDITION			
d) CUSTOMISE			
4) ENVIRONMENTAL CHANGE			
a) CHANGE LOCAL ENVIRONMENT			
b) CHANGE WIDER ENVIRONMENT			

Table 6.4: The Proposals Matrix

6.5 Support for the User of the SIU Method

6.5.1 Comparison of the Usefulness of a Tool against a Workbook

The original intention of this research was to develop a framework to utilise data from a product-in-use or PSS-in-use and then to develop a tool which would direct the user of the tool through the framework steps and perform background processing of the quantitative data. However, during the course of this research, the research aims changed considerably:

- Rather than product-in-use data, from the research that was conducted, it became clear that it is system-in-use data which indicates the degree of value-in-use that the receiver obtains. Because of this, it is system depiction, parameterisation, decomposition and the heuristic judgement of experts to apply design options which are the cornerstones of the SIU method. However, originally, it was expected that extensive processing would be required of quantitative data and that the results of this would be mapped to various PSS designs. However, the SIU Method performs the very simple data processing of finding the difference between parameters.
- Rather than processing quantitative data and mapping that to PSS types, the SIU Method facilitates the consideration of redesigning any and all of the elements in the customer's value creating system. This allows simple conventional changes to be evaluated against any PSS suggestions. Significantly, it has emerged that PSS Conceptual Design is essentially process design. Here, the customer's value creating system is redesigned which may generate basic product and service specifications, some of which could be offered by the provider.

These points were raised in three workshops, each of which lasted for an hour, which were held as to the opinion of academic and industry experts who were familiar with this work and who had expressed an interest in having their colleagues instructed in the method and applying the SIU Method at their place of work. Each was asked as to how the development of a tool could support a user of the SIU Method. The participants in the separate workshops with the author were:

- *Workshop 1:* A senior academic in PSS and engineering.
- *Workshop 2:* Two senior managers from the afore-mentioned HVAC Consulting Company.
- *Workshop 3*: A senior academic in PSS and aero engines, who is also employed as an engineering specialist within aero engine firms that provide capital-intensive, industrial and technical PSS

There was consensus that, at this stage, a software tool would not add anything to the usability of the method: the steps were reasonably straight forward and the calculations were simple. Furthermore the techniques used were basically flowcharting techniques (Service Blueprinting), a simple decomposition technique (Operand-Operant Diagrams), form filling (the Proposals Matrix) and simple rating (the Likert Scale which is used in solution assessment). Each suggested that a workbook would be the greatest support to the user of the SIU method where the method background and steps could be clearly explained in a user-friendly way. For the form of the workbook, the consensus was that the workbook should follow the general format of a user manual and use a case study to illustrate the SIU Method. It was agreed that the structure of the workbook should contain an overview of PSS, PSS Conceptual Design and an overview of the SIU Method and its techniques.

6.5.2 Workbook Development

The SIU Method and the Workbook that was produced is validated in Chapter 7. The first draft of the workbook had the SIU Method illustrated by reference to the laser job shop case study (Section 7.2). The Workbook was firstly applied to a domestic heating issue (See Chapter 7) by an English teacher (a non-technologist) who had little prior knowledge of PSS; this was done to assess the usability of the workbook by someone who had very little knowledge of PSS or engineering. The Workbook was then applied by an expert civil engineer who also had little prior knowledge PSS. The HVAC Consultants were also asked for their opinion of the workbook (See Chapter 7) and, based on their feedback, the Workbook was revised. This was then presented back to each of these validators. There were three such cycles of revision to the workbook.

When the fourth version of the workbook was produced and presented to the validators, no further amendments or revisions were made.

An award from Cambridge University's KT-BOX was won for the Workbook's industrial applicability.

The current version of the workbook is appended (Appendix F) and the final version is to be released shortly as a Kindle book on amazon.co.uk.

6.6 Summary and Key Observations

In this Chapter, it was shown how the SIU Framework was refined and genericized into the SIU Method by triangulation with reviewed literature. This Chapter also presented the rationale behind the development of the SIU Methodology as a workbook.

- **Section 6.3** showed how the SIU Framework which was developed in Chapter 3 and then refined in Chapter 4 was genericized and refined into the SIU Method by a review and triangulation with the literature.
- **Section 6.4** showed the resultant structure of the SIU method along with the techniques it uses. Some of these are new techniques which were developed specifically for this method. These new techniques are:
    - ***Capability Parameterisation***: this is accomplished by using the generic parameters of range, span, Time-Cycle (TC) and cost.
    - ***Enhanced Service Blueprinting:*** here, Service Blueprinting (simple or Extended) is made environment-specific and parameterised
    - ***Operand-Operant Diagrams***: these allow a sub-capability to be decomposed into its operand and operant resources as well as the process that the operand uses.
    - ***The Design Options:*** these allow various changes to the part of the capability which contributed most to the overall gaps to be considered as well as changes to the capability's environment (local or wider) along with changing the receiver of the capability and changing the whole capability.

  - ***The Proposals Matrix:*** this allows the design options to be applied, the expected reduction in gaps to be rated and the acceptability of the proposal to be stated.
- **Section 6.5.2** discusses how the decision to produce a Workbook was arrived at.

In the next Chapter, the SIU Method is applied to various case studies in different industries in order to exercise the paths of the method and to assess its effectiveness when applied quantitatively as well as qualitatively. Furthermore, detailed validation sessions with industrial experts will be presented to test the credibility of this research and, specifically, the usefulness of the SIU Methodology and the supporting Workbook.

7 Validation

7.1 Introduction

In Chapter 6, the author presented the development of the SIU methodology along with the techniques it uses and the decision to produce a Workbook. The purpose of this Chapter is to detail the validation sessions of the Workbook that took place at the concluding stage of this research.

Each of the validation sessions in this Chapter were accomplished by applying the SIU Method to case studies. These were used to exercise the different versions of the method (quantitative and qualitative), the different paths (iterations of tier analysis and solutions, iterations of gap analysis and solutions), the techniques that the Method uses and the usability of the Workbook (See Figure 7.1). The case studies allowed each Validator to apply the SIU Method to an issue they were familiar with in their domain area so that it could be evaluated as to whether the application of the method produces results that were more useful than how they would normally address the issue. To further test the usability of the Workbook, it was also applied by a non-technologist to a domestic heating issue they had.

For every validation, the author:

- Discussed one or more issues with each validator that they had with regards to satisfying an outcome that they desired. The author and validator then selected an issue and an appropriate version of the SIU Method to apply to that issue. The issue selected depended on the availability of data (that is, access to the process which gave rise to the issue or access to experts who had knowledge of the process) and the time estimated to conduct the validation.
- Instructed the validators as to the theory underpinning the SIU Methods as well as how to apply the SIU Methods
- Assisted the validators in applying the SIU Method and, afterwards, interviewed them as to the merits and demerits of the Method.

The types of validations and validators are summarised in the next table:

	Case Study	Validator(s)	The type of SIU Application	Paths in the Method
1	A laser-cutting (a component making) process.	MD of the laser job shop, AILU, HVAC	Quantitative "pull"	• 1 iteration of gap analysis
2	Aero engine value chain (encompassing the airline, aero engine, engine components and the material supplier)	Expert in aero engines and academic leader in PSS.	Qualitative, "pull"	• 2 Iterations of gap analysis and solutions • 4 Iterations of tier analysis and solutions
3	Domestic heating issue and building design	Non-technologist and no previous knowledge of PSS HVAC Experts with knowledge of PSS Expert civil engineer with no previous knowledge of PSS	Quantitative, "pull"	• 1 Iteration of gap analysis and solutions • 2 Iterations of tier analysis and solutions
4	Truck Driving Instruction	Expert in gathering customer requirements for technological solutions.	Qualitative, "push"	• 1 iteration of grouped gaps
5	Fault Reporting	Expert in gathering customer requirements for technological solutions.	Qualitative, "pull"	• Application of the Method to generate a solution • Application of the Method to refine a product

Table 7.1: The Validations, Validators and Type of Validation

After the Workbook had been applied, the Validators were interviewed with regards to the merits and demerits of the SIU Method. In Validation 1, the SIU Method was Evaluated. For Validations 2 to 5, the techniques the SIU Method uses and the Workbook was also validated. These five validations will now be presented in the following sections:

- Section 7.3 presents Evaluation 1
- Section 7.3 presents the Validation 2
- Section 7.4 presents Validation 3
- Section 7.5 presents Validation 4
- Section 7.6 presents Validation 5

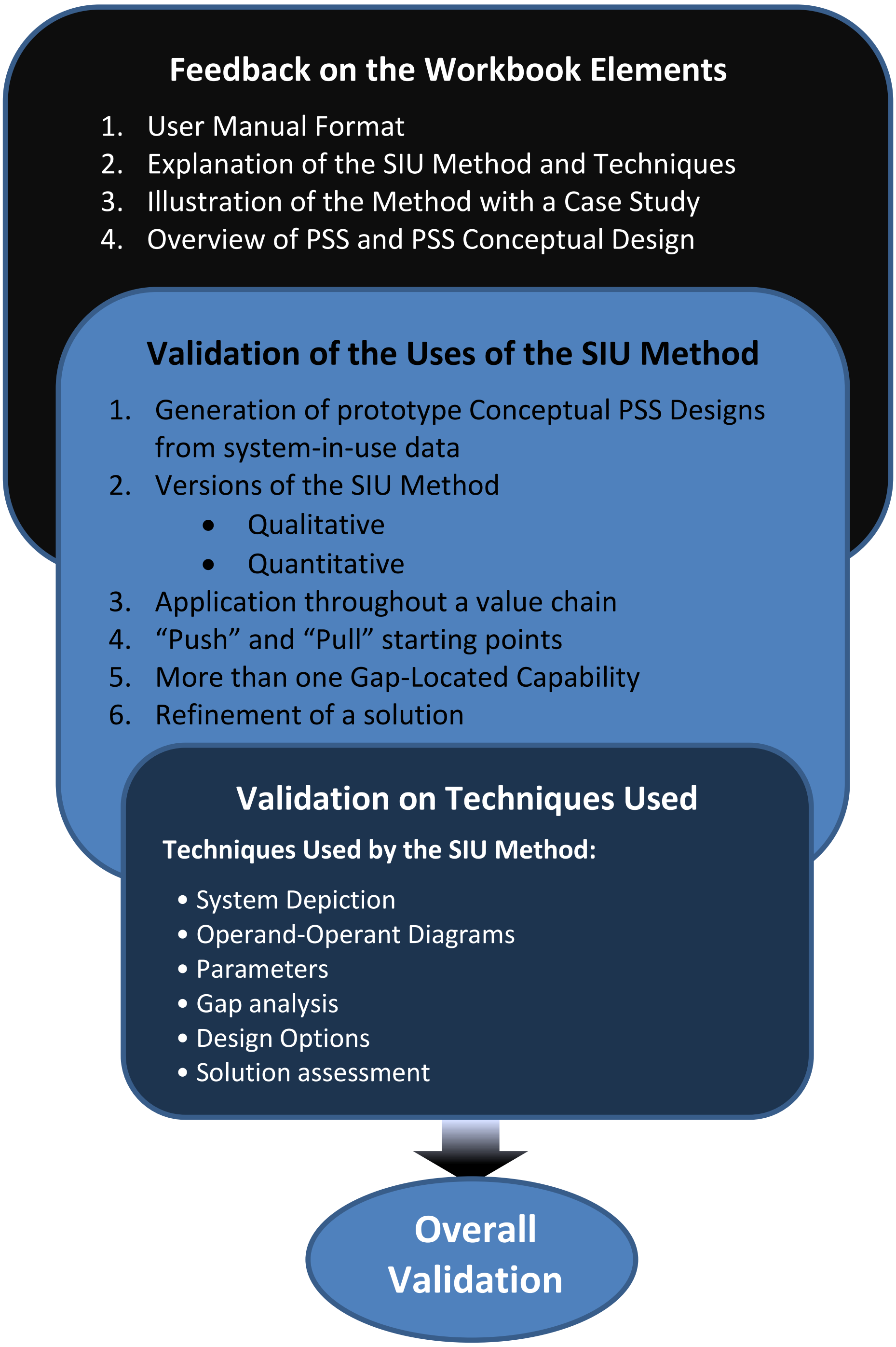


Figure 7.1: Elements of the Overall Validation

7.2 Validation 1: A Laser-Cutting Process

A Real-Time Application

7.2.1 Introduction

Laser systems are capital-intensive, technical and infomated industrial products. Typically, laser system OEMs integrate laser technology into a laser system which they then often offer as a PSS where the laser system is bundled with maintenance services. Laser job shops are essentially factories that use laser systems to laser-cut components for their clients. This value chain was explored to select a case study against which to validate the SIU Method:

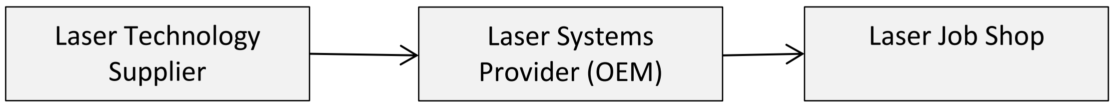


Figure 7.2: The Laser Systems Value Chain

To apply the proposed method, a case study with a laser job shop was conducted. The selected case study has been defined using a limited set of parameters to allow the process to be followed more easily. Although Extended Service Blueprinting could have been used for this case study, Service Blueprinting is used here to aid clarity and also because detailed product operation is not the issue in this particular case, as will be shown later.

The case study company is a laser job shop which provides laser cutting services to industry that, typically, comprise of the cutting and then a delivery service of metal component products based on their client's CAD drawings. The overall capability here is to provide laser cut parts quickly and at low cost. The reliability, speed, uptime and the ease of use of their series of laser cutting machines was extremely high and the bundled maintenance service was speedy and effective; certainly, the laser job shops, overall, were really quite satisfied with this. Nevertheless, from the interviews, it was apparent that some of this laser job shop's clients were unhappy with the length of time it took from instructing the job shop to the time that the parts were delivered. For these clients, the costs were also high which made the job shop uncompetitive. This was an issue because, from interviews with three laser job shops, it appears that laser-cut parts have been commoditised; generally, the capability to cut laser parts tends to be fairly uniform amongst the laser job shops and so, at the moment, it is just speed and cost that tends to differentiate the job shops.

7.2.2 Methodology

The first step involved meeting with a senior academic and expert in industrial laser systems who is involved with PSS projects who presented a summary of issues within the laser systems manufacturing industry as well as issues that their customers have. The type of evaluation of the SIU Method was discussed and it was decided that applying the SIU Method to a real, on-going case study in the laser manufacturing and/or laser user industries (rather than to an example scenario) should allow the overall Method to be tested more fully. During this phase, the samples as well as the participants were identified by reviewing archival material, emails and previous contact relating to the business, responsibilities and expertise of each of the potential participants and their company.

At each exploratory interview (below), the aims of the research (as presented in Chapter 3) and an overview of the SIU method (as in Chapter 6) were presented then a semi-structured, exploratory interview (See Appendix G and Appendix H for the interview questions) was conducted to discover their AS-IS practice for using field data to influence PSS Conceptual Design and to source possible case studies to apply the SIU Method to in order to assess the method’s merits and demerits. Each interview was recorded and then later transcribed.

The Methodology followed is outlined below:

1. A literature review on themes related to the study had been conducted before the investigation at the company. Where possible case studies to be used for validation were identified.
2. The author attended a one week course on the technical aspects of laser cutting and welding systems.
3. The open-day of a Laser System OEM (that provides product-related PSS) was then attended where an overview of the company was presented along with their laser systems.
4. Two exploratory interviews were then held at that company with a senior sales manager and a senior technology manager.
5. An exploratory interview was held with a senior sales manager at a laser technology supplier company (that provides product-related PSS).
6. Three separate meetings were then held with the managing directors of three different laser job shops who are customers of the Laser System OEM. At each job shop an exploratory interview was conducted and then the factory floor was visited so that a walkthrough of typical laser job shop processes could be conducted.
7. From the interviews, various case studies where there had been a customer issue had been detailed. From these, a case

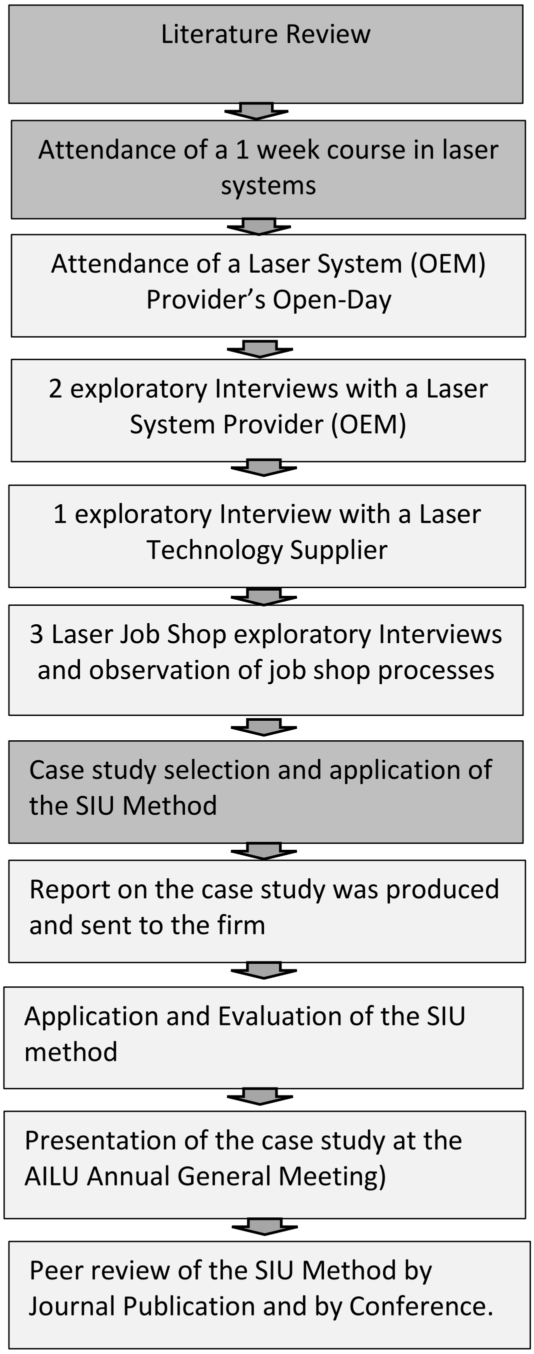


Figure 7.3: The steps followed to evaluate the SIU Methodology

study was selected which appeared to have more complexity than other case studies and for which the data relating to the case study had been made available. The researcher then applied the SIU Method to the case study.

8. A report was then created on the application of the SIU Method to the case study which was then sent to the managing director of the job shop concerned.
9. To evaluate the SIU method, Interviews (Appendix J) were then conducted with:
   I. The Managing director of the laser job-shop
   II. Two senior managers from the HVAC Consultants firm
   III. A respondent who, as well as being a senior and leading academic in PSS and aero engines, is also employed (for over fifteen years) as an engineering specialist within aero engine firms that provide capital-intensive, industrial and technical PSS.
10. The case study and how the SIU Method was applied to it was then presented at the AILU (Associated Industrial Laser Users) Annual General Meeting which is attended by representatives from laser job shops (including the three managing directors who had been interviewed) and the laser OEM that had been interviewed.
11. Peer review of the SIU Method also took place by Journal Publication and by Conference.

Participants	Years of experience
Senior Sales Manager (Laser Systems OEM)	8
Senior Technology Manager (Laser Systems OEM)	7
Senior Sales Manager (Laser Technology Provider)	6
Managing Director at Job Shop 1	18
Managing Director at Job Shop 2	15
Managing Director at Job Shop 3	11
Technical Director from the HVAC Consultants firm	15
HVAC Consultant from the HVAC Consultants firm	5
A senior engineering specialist within aero engine firms that provide capital-intensive, industrial and technical PSS.	8
A senior academic in PSS and management	6
A senior academic in PSS and engineering	5

Table 7.2: Job roles and years of experience of the interviewees

DATA COLLECTION and FEEDBACK	No. Of Interviewees	Time (hrs)
2 separate, exploratory interviews; each with a senior sales manager at a laser OEM.	1 + 1	1.5.+ 1.5
An exploratory interview with a senior sales manager at a laser technology supplier company.	1	2
3 Separate visits to 3 laser job shops	1 +1 + 1	3+3+4
Evaluation of the SIU Method with the Managing Director at Job Shop 3	1	1
Evaluation of the SIU Method with a senior engineering specialist within aero engine firms that provide capital-intensive, industrial and technical PSS.	1	1.5
Evaluation of the SIU Method with the Technical Director and the HVAC Consultant from the HVAC Consultants firm	2	2
Discussion with a senior academic in PSS and management regarding the refining the SIU Method	1	1
Workshop with a senior engineering specialist within aero engine firms that provide capital-intensive, industrial and technical PSS regarding the Workbook or tool creation	1	2
Workshop with the Technical Director and the HVAC Consultant from the HVAC Consultants firm regarding the Workbook or tool creation	2	1
Workshop with a senior academic in PSS and engineering regarding Workbook or tool creation	1	1
	Total	**24.5**

Table 7.3: Respondents and the time for data collection

7.2.3 Application of the SIU Method to a Laser Job-Shop Case Study

STEP 1: Problem Definition

This issue (that some of this laser job shop's clients were unhappy with the price of the components and length of time that it took from instructing the job shop to the time that the parts were delivered) had already been investigated and confirmed by the managing director of the laser job shop who also had scoped out the capability from which the issue had arisen. From the details of the issue and the process which were given by the managing director, a primary Service Blueprint for the laser cutting service (the overall capability) in which the PSS from the laser OEM (the laser machine and the corresponding maintenance service) is embedded was created (Figure 7.4).This was then parameterised as *span* (the length of time that it takes for the capability to be effected) and *cost* (the cost of the capability). See Figure 7.4 – the Blueprint.

STEP 2: Find the Overall Capability Parameter Gaps

a) *Define the desired overall capability parameter values* – For a particular client of the job shop, the desired span was 0.5 days with a cost of £700. See Figure 7.4 – the desired overall capability parameter values.

b) *Define the actual overall capability parameter values* – The time from when the job shop received the request for laser-cut parts until the time that the driver reported that the parts had been delivered. See Figure 7.4 – the actual overall capability parameter values.

c) *Find the overall capability parameter gaps* – The difference between the Desired Parameter Values and the Actual Parameter Values were then surmised as a difference in span of 1.5 days and a difference in cost of £300. See Figure 7.4 – the overall capability parameter gaps.

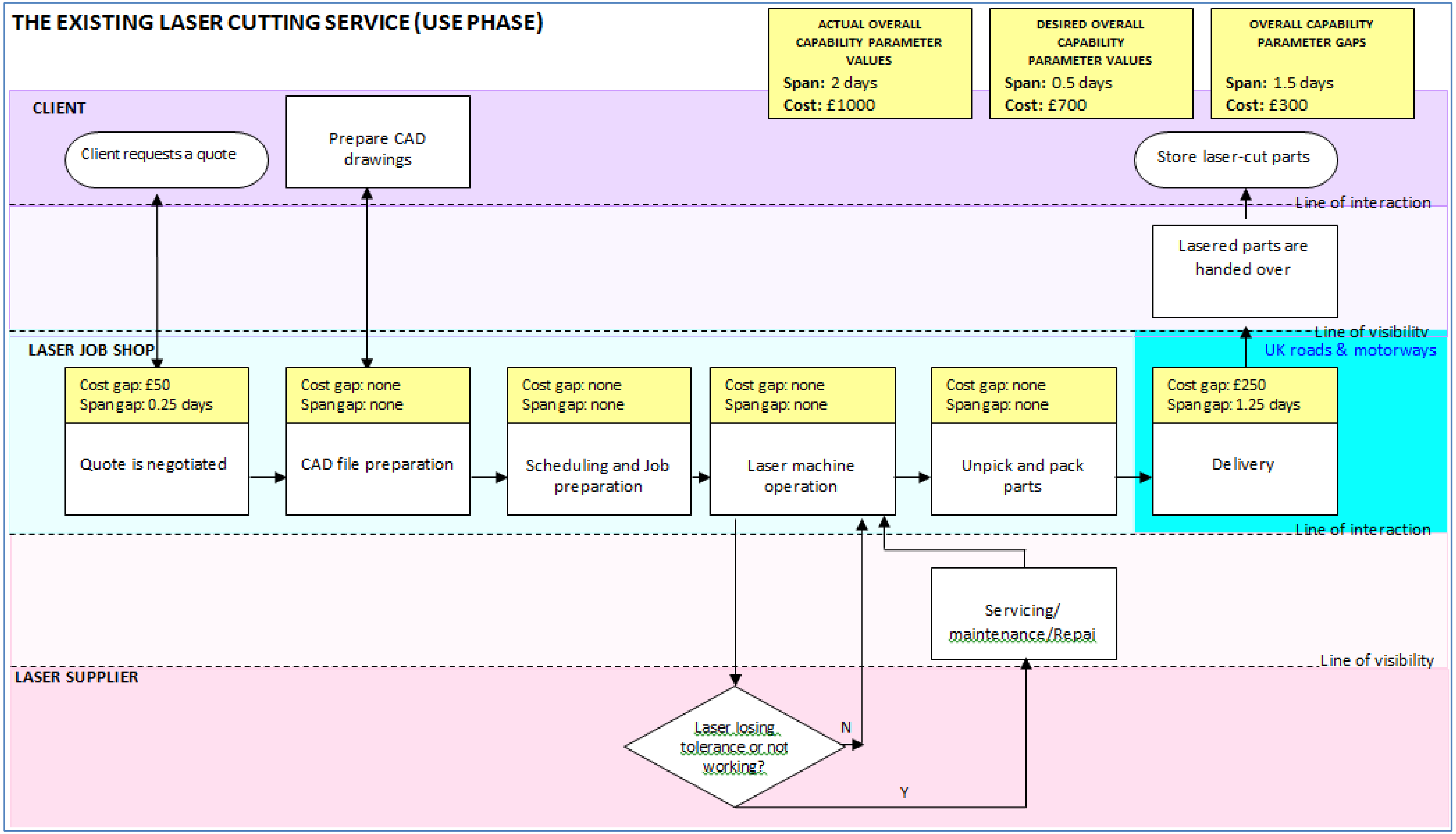


Figure 7.4: Blueprint for the current laser cutting service

STEP 3: Find the Gap-Located Capability(s) Within the System

a) *Define the desired sub-capability parameter values* – Each element in the capability (in the Service Blueprint) is a sub-capability and these were also similarly parameterised.

b) *Define the actual sub-capability parameter values* – For the parameter of span, the length of time that it takes for each sub-capability to complete was calculated from when it was started until the time it instructed the next sub-capability. For the parameter of cost, the cost of each sub-capability was estimated based on the plant, machinery and staff used for the duration of that capability in this instance.

c) *Find the sub-capability gaps* – Differences between each sub-capability's actual parameter values and its desired parameter values were reckoned – this gave the gaps for the sub-capabilities. See Figure 7.4 – the sub-capability parameters of cost and span. The proportion that each sub-capability gap contributed to the actual overall capability parameter gaps were then gauged. It was found that the sub-capability of "Delivery" contributed most of all – this gave the *gap-located* capability – the location of the gap within the capability.

d) *Service Blueprint Decomposition* – When the "Delivery" sub-capability was decomposed Figure 7.5 , it was seen that the size of the parameter values for *Travel to the customer* of span (the amount of time travelling) and cost dictated the size of the span and cost in the higher (the super-ordinate) capability of *Delivery of Lasered Parts*: this gave the *cause of the gap.*

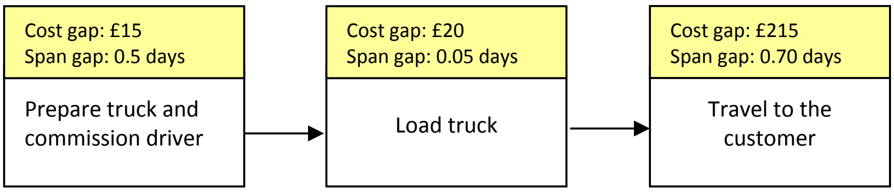


Figure 7.5: A decomposition of the sup-capability of delivery

For some of the clients of this laser cutting service, delivery took at least half of the total time (the span) and greatly increased costs. For example, although an order of laser-cut parts could be obtained, laser-cut and delivered all in one day for a reasonable price, this process could actually take two or more days if the client was situated a long way from the job shop. This long delivery distance also resulted in a much higher cost. When the Enhanced Service Blueprint was presented to the MD of the laser job shop, no discrepancies were found.

STEP 4: Corroborate the System Definition

The enhanced Service Blueprint was shown to the MD for him to corroborate the system definition.

STEP 5: Operand-Operant Decomposition of the Gap-Located Capability

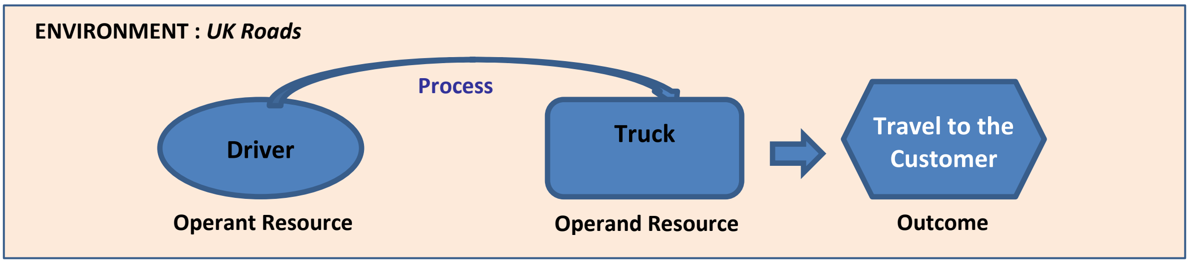


Figure 7.6: Operand-Operant Decomposition of the Travel to Customer Sub-Capability

STEP 6: Determine the Stakeholders

The stakeholders in the gap located capability are the:

- The MD of the laser job shop
- The drivers
- The customers

STEP 7: Compare the Capability to Other Similar Capabilities

The span of the delivery for these clients was also compared to the span of delivery to other clients where there were very small or no Overall Capability Gaps; all of these showed that these deliveries had a small amount of time and cost – these were local deliveries. Thus, the amount of kilometres between the customer and job shop showed direct proportionality to the size of the gaps in the overall capability.

STEP 8: Propose Solutions

• ***Apply the Proposals Matrix:*** From the gaps, a Proposal Matrix was constructed (Table 7.4). The first column postulates several generic ways that any capability can be changed by changing separate elements in the system. It is then for the job shop with perhaps the help of their provider and any relevant experts as well as their client to apply the generic recommendations to their unique situation (the last column in the Matrix - Table 7.4). Although statistical techniques could have been used to develop comparisons of the time and cost of travel as compared to the Overall Cost of the capability and hence pinpoint disproportionate time delays and costs due to deliveries, in this case this was achieved qualitatively from interviews with the job-shop.

• **Appraise the solutions** – These specific recommendations can then be evaluated and rated for the particular case in hand (Table 7.4– last column). From the Proposals Matrix, it was clear that, for clients who are far from the job shop, it was the great distance which caused the large gaps of time delay and cost. From the interviews, this job shop was keen to retain their larger clients, some of whom spend in excess of a million pounds per year on laser-cut parts. The job shop's concern was that these clients may either decide to use a more local job shop to eliminate the gaps regarding speed and cost or that, in the near future, there could be laser manufacturers who could offer their clients a new generation of machines that are more easily operable or that are bundled with operator services and offered on a pay-per-use (availability) basis, thus bypassing the need for a laser job-shop. At this stage, the proposals are evaluated to see which ones could be worth considering further. The degree to which each proposed solution is anticipated to close the gaps of span and cost are rated as high, medium or low and then to further refine and assess the potential solution (this part is outside of the scope of this research), the exact degree to which these gaps should actually close can then be ascertained by assessing the capability of all of the stakeholders to close these gaps. In the Proposals Matrix, the job shop rejected proposals 1 or 2 as both of these solutions were totally unacceptable to the job shop although both of these would completely close the gaps. Proposals 3b and 4a were accepted for further assessment of their acceptability as well as the capability of the stakeholders to effect them. Figure 7.7 offers a basic Service Blueprint for the strategy of putting a laser cutting machine onto the client's site. It can be seen that the line of visibility shifts so that the processes involved become more transparent to the client. It should be noted that this close partnering could actually be counter to the interests of the laser job-shop as, with time, such transparency could cultivate the client into devising their own services.

The PSS solution of installing a laser cutting machine on the customer's site introduces a new risk for the laser job shop; that is, that the job shop's knowledge and processes may become too transparent to the client. The alternative solution to set up a job shop in the vicinity of the client would help the job shop to protect their knowledge. The relative merits of these solutions will be discussed in the following section.

STEP 9: Next Tier?

There is no wish to examine an operant, operand or process belonging to a lower Tier.

STEP 11: Next Gap?

If there is more than one Gap-Located Capability, then the next largest one can be examined similarly, reiterating the method from Step 5; this then would then become the largest Gap –Located Capability to examine. In this case, there was only one Gap-Located Capability so the application of the SIU method ended here.

Generic Changes for the Use Phase	RATING		Application to this Case
	Span gap decrease	Cost gap decrease	
1) NEW CONCEPTUAL DESIGN	**High**	**High**	The clients could laser cut their own parts. This would totally remove the need for not just delivery but also the need of this client for the whole laser-cutting capability as currently supplied by the laser job shop. The job shop could receive a large remuneration at the initiation stage for installation and staff training and could be employed at the use phase as consultants. However, this would be far less than what they receive by supplying parts – not acceptable.
2) MARKET SEGMENT/ RECEIVER SHIFT	**High**	**High**	Faraway , smaller clients could be abandoned although large, important clients should be catered for. Partnering with other job shops local to the client could mean a huge loss in revenue and margins are already tight - not acceptable.
3) CHANGES REGARDING THE OFFENDING CAPABILITY			
a) SUBSTITUTE	**Low**	**Low**	***Operant Resource (Truck):*** Alternative methods of transport: There would still be a large time delay even if faster trucks were used. Planes or trains could be very costly and there would still be a time delay.
	Low	**Low**	***Operand (Driver):*** There would still be a large time delay even if more competent drivers could be sourced.
b) ELIMINATE	**High**	**High**	***Operant Resource (Truck), Operand (Driver), Operand's Process (Driving):*** Totally eliminate the need for delivery along with its associated costs and time delays. The job shop could place a laser cutting capability on the client's site. Nevertheless, there would be a large cost and a time delay in setting this up at the initiation phase of this solution.
c) ADDITION	**Low**	**Low**	***Operant (Truck):*** If road works held up the drivers, then an up-to-date satellite navigation system could help to speed up the journey. Current systems could be updated to provide a small improvement.
d) CUSTOMISE	**Low**	**Low**	***Operant Resource (Driver):*** There would still be a large time delay and cost even if the drivers were trained further.
	Low	**Low**	***Operant Resource (Truck):*** There would still be a considerable time delay and cost even if the trucks were made faster or more suitable for the terrain.
4) ENVIRONMENTAL CHANGE			
a) CHANGE LOCAL ENVIRONMENT	**High**	**High**	The only environmental variable that impacts upon this capability is distance. If this could be reduced or eliminated then the gaps would close; moving closer appears to be the only way to apply this. A laser cutting facility could be set up on or close to the customer's site. Either way, the initial cost to the job shop could be prohibitive although this could be offset if the laser machine was offered on a lease or pay-per-use basis.
b) CHANGE WIDER ENVIRONMENT	**N/A**	**N/A**	There are no reasons such as the road quality or lighting which could help the truck to travel faster. Not an issue here.

Table 7.4: Proposals Matrix – To Reduce the Span and Cost Gaps in Far Deliveries

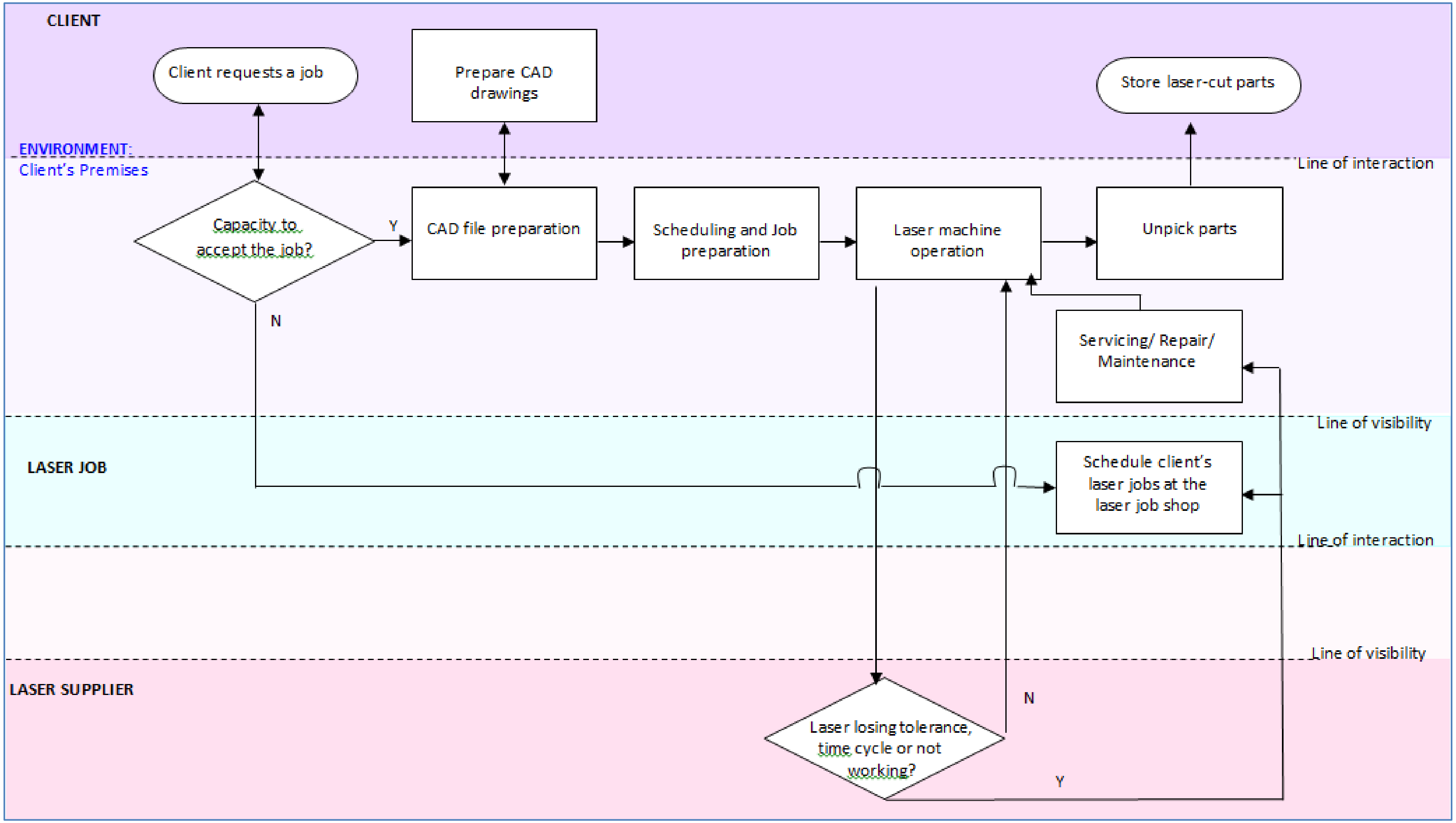


Figure 7.7: Blueprint - Shift the Capability to the Client's Premises

7.2.4 Discussion of Case Study Results

The laser case study has illustrated the importance of reviewing the customer's needs for PSS Conceptual Design. Even in this simple example where the main problem faced by the customer is delivery time and cost, the proposed solutions may significantly change the relationship between customer and provider and would have a significant impact on the provider's business model.

In this example, the application of the method has been instigated by the job shop, but the application of the method could just as easily have been instigated by the laser OEM to see if a different type of laser system PSS is now more suitable for the job shop. Either way, the outcomes of the method's application to the job shop's main process would be expected to be the same: that is, for the job shop to investigate the possibility of providing a laser-cutting PSS to their client or to set-up a laser-cutting service nearby this client and then (after the initiation phase had been considered at the PSS Conceptual Design stage) to see if the laser OEM could help to support the new solution.

The decision whether to provide a laser cutting capability on the customer site or local to the customer site would depend on the nature of the relationship of the client with the job shop and their future concerns. Furthermore, if a machine were to be placed on the client's premises, probably only one machine would be installed which could mean that at times of high demand or if the machine is not working that the laser job shop would have to make up this extra capacity (see Figure 7.7).

The proposals can be evaluated further to see if the stakeholders have the capability for the initiation of such solutions and to also ascertain if all of the stakeholders are amenable to them along with any changes in responsibility, roles and ownership. There would be a considerable cost and a time delay in setting up either of the proposed solutions at the initiation phase of this solution and this would have to be traded off against the expected benefits at the use phase. The provision of an on-site machine would require careful planning to ensure that the machine is used to capacity and that any overspill to the job shop occurs infrequently so that delivery delays and charges do not cause major capability gaps again. Here, collecting past performance data depicting loads over time as well as knowledge of the client's business strategy could help. Other considerations would be how the operators could be installed; experienced operators could be sent to the client or local people could be trained. Either way, there will be a lead time and a cost involved and supplies would also have to be considered. For the laser manufacturer, offering machines which are easier to operate, allow remote monitoring, offer dedicated laser-cutting processes and perhaps encompass or integrate more of the surrounding processes as well as having a smaller footprint could further facilitate such a solution. The laser manufacturer could consider a more modular design which would allow the laser machines to become dedicated to one or two processes so that many customers could be more easily served in a similar way. It could be possible for the manufacturer to offer the whole solution although this would probably involve the manufacturer stepping outside of its core competences; it is the laser jobs which have the expertise in understanding their client's needs as well as the processes to fulfil them. The business model could consist of a pay-per-use or a leased machine bundled with a process operation service from the job shop for a fixed period; here, the OEM would share the risk with the job shop and the capital investment of the job shop in installing machines near to or onto client's sites would be circumvented. As this could be a PSS where the manufacturer and the job shop are in partnership, it becomes clearer that the need of the job shop (to satisfy its clients) now becomes a need of the laser manufacturer. All of these are challenges for PSS Conceptual Design and simulation of any possible solutions at the use, initiation and end of life phases would help to pre-empt the appearance of any possible capability gaps. If it is found that a selected solution is, at that time, difficult to effect then other proposals from the matrix should be considered. Note that job shop could have stated to the OEM that they were having difficulty in getting their laser-cut parts to clients in time and that the OEM's response could have been to try to make the laser machines faster: whilst this effort would have been admirable, it would not have addressed this particular job shop's concerns. Similarly, product-in-use data could have indicated to the laser system provider that the job-shop's laser machines are operating near to capacity: this could have prompted the laser system manufacturer to provide machines with a higher capacity although the real need of the job shop is for smaller machines which they can then put on or near to their client's sites. This emphasises the need for a systems rather than a product-centric approach to the analysis and design of PSS solutions.

From the interviews with the laser systems providers, it was apparent that they were not keen to develop any other business models or lasers systems for the laser job shop market as they represent only a very small segment. Nevertheless, it was clear from the interviews in general that there are many other large companies who either have their own dedicated laser cutting processes or who send laser cutting work offshore where the machines used tend to be older and the processes less reliable. It could be the case that customised, process-dedicated laser cutters offered on an availability basis which are bundled with a process operation service could open up these other, larger markets.

Although laser cutting equipment OEMs are not currently offering higher PSS business models, the authors would claim that they are still in a process of servitising; this is because many of the sacrifices [9] that the receivers used to make in order for their overall tasks to be accomplished have now been appropriated by the laser machines. For example, over the past couple of decades, laser cutting systems have become more easily operable, more reliable and less expensive. This means that there has been a capability shift from the job shop processes and resources to the laser machine: much of the sub-capabilities that the job shops had to institute to meet an overall capability are not required to the degree they previously were.

This case study was conducted in 2010, at the end of 2011 the laser job shop had discussed the options with their clients, further assessed the solutions and installed rolled out the solution to several of their most important clients.

7.2.5 Evaluation of the Applied SIU Method

7.2.5.1 Expert Evaluation

An initial validation was performed to assess the merits and demerits of the proposed method (Appendix I). The case study was presented to the MD of the laser job-shop and then to two senior managers from the aforementioned HVAC Consultants firm mentioned in Chapter 5. All agreed that the application of the method seemed to produce reasonable results of which could then be refined to create PSS solutions that satisfy all of the stakeholders more closely. They also stated that the SIU Method provided a way to systematically explore the issue and then generate a wide range of possible solutions, some of which, without the Method, they doubted they would have thought of. All three respondents, at this stage, did not identify any omissions or failures in the method but urged for applications of the method to other differing capabilities, to exercise different parameters and to also to apply the method to large quantitative data sets from sensors.

7.2.5.2 Industry Evaluation

At a presentation of the case study at the AILU (Associated Industrial Laser Users Annual General Meeting), no amendments to the SIU Method, its techniques or to Workbook were suggested. However, an MD from a laser job shop suggested that the SIU Method should incorporate issue selection.

- ***FEEDBACK - Issue Selection:*** This suggestion was discussed at the meeting and it was generally agreed that the stakeholders of any capability have to define which issue is important to them and this will depend upon the nature of the capability, other pressing issues and the business strategy of the firms involved. Business strategy is a wide area encompassing many different theories and techniques; it is for senior managers to use their expertise to select which theories and techniques are most appropriate for their aims and capabilities to help them to define the issues that they need to address. This area would appear to be outside of the scope of this research which focusses upon utilising system-in-use data to generate conceptual PSS Designs. For this reason, this suggestion was not considered further.

7.2.5.3 Peer Review by Journal Publication

The application of the SIU Method to the laser job shop case study was published in May, 2012 in *Computers in in Industry, Product Service System Engineering: From Theory to Industrial Applications* (Hussain et al., 2012). Only ten papers out of a total of sixty which were submitted were selected for this special issue.

7.2.5.4 Peer Review by Conference

The analysis and emerged theory were also presented at a research summit held on 22nd February, 2012 by the Cranfield Management Research Institute to disseminate and discuss the research findings from a number of PSS research projects (including this research), which had been conducted over the course of the preceding years. The attendees were senior managers and engineers from industries delivering technical, capital intensive, infomated PSS as well as leading industrial PSS academic researchers. No further changes were recommended at this meeting.

7.2.6 Solution Adoption in Industry

The solution to install a laser cutting facility on or near to the sites of important clients was acted upon by the laser job shop in 2011. The solution has now been rolled out to several clients.

7.3 Validation 2: An Aero Engine Case Study

A Retrospective, Qualitative and Recursive Application

7.3.1 Case Study Introduction

A component manufacturer was informed that a component which they had supplied to an aero engine manufacturer was unacceptable because, as it was discoloured, the engine manufacturer's client (an airline) had rejected the engine. This component is an engine case. As the engine cases are positioned at the rear part of the engine, they are exposed to high temperature combustion gases. During operation, anomalies in the gas loads result in its discolouration which can indicate that the component could develop defects and so a thorough inspection of it may be warranted. In this case study, the component was manufactured using another technique other than that which is usually used; this manufacturing technique involved welding and heat treatment operations which caused the component to become discoloured although the functional performance and integrity of the component was not in question. Therefore, this issue (the rejection of the engine) would be a *symptom* of the component manufacturer having used a different fabrication process that produces discoloured components. Although a process could have been added to finish the surface which would produce a unified colouration – a kind of "polishing", there was no mention of desired colouration in the specification to the component manufacturer.

It was the component manufacturer which addressed this issue by introducing the polishing capability which would render the components the uniform background colour which the airline desired. However, there could have been other solutions which could have been proposed at different points in the value chain, considered and perhaps effected. What follows next is an application of the qualitative and recursive path through the SIU method which can consider different solutions at different tiers in the supply chain: this allows the possible problem space and solution space to be unfolded and evaluated.

There was a paucity of information with regards to why and who rejected the engine at the airline. However, this is a common problem within the value chains of many industries; the conversion of expectations into requirements which are then cascaded down multiple levels in the value chain is known for the loss of some contextual information and intent. Nevertheless, most companies will have a fair idea about the general capabilities of their customers and suppliers and some understanding of how those capabilities are arranged. Therefore, a heuristic method using general knowledge known about customers and suppliers which uses a common representation that can be understood by all stakeholders in a value chain could be useful in gaining a fuller picture of the problem space and then solution space. Such a method could be used to perform 'What if 'analysis and the results could be then used to prompt other stakeholders for their input and then win further support for more detailed analysis and solution generation.

Figure 7.8: The value chain in question

7.3.2 Methodology

1. A literature review on themes related to the study had been conducted before the investigation at the company. Where possible, case studies to be used for validation were identified.
2. There was a discussion with the potential validator (a senior manager in aerospace engineering as well as a senior academic in engineering and PSS) where he presented an overview of PSS research he was involved in and where the researcher presented an overview of the aims of this research and the current research stage of validating the emerged SIU method by application to case studies.

3. The company premises were visited where a 'walkthrough' of main processes were conducted with the potential validator.
4. Five exploratory interviews were conducted with five senior engineering managers in the aerospace company over the course of fifteen hours. At each exploratory interview, the aims of the research (as presented in Chapter 2) and an overview of the SIU method (as previously outlined in Chapter 6) was presented then a semi-structured, exploratory interview (See Appendix J for the questions) was conducted to discover their AS-IS practice for using field data to influence PSS Conceptual Design and then to source possible case studies to apply the SIU Method to in order to assess the method's merits and demerits. Each interview was recorded and then later transcribed and the findings were used for the investigation as described in Chapter 4.

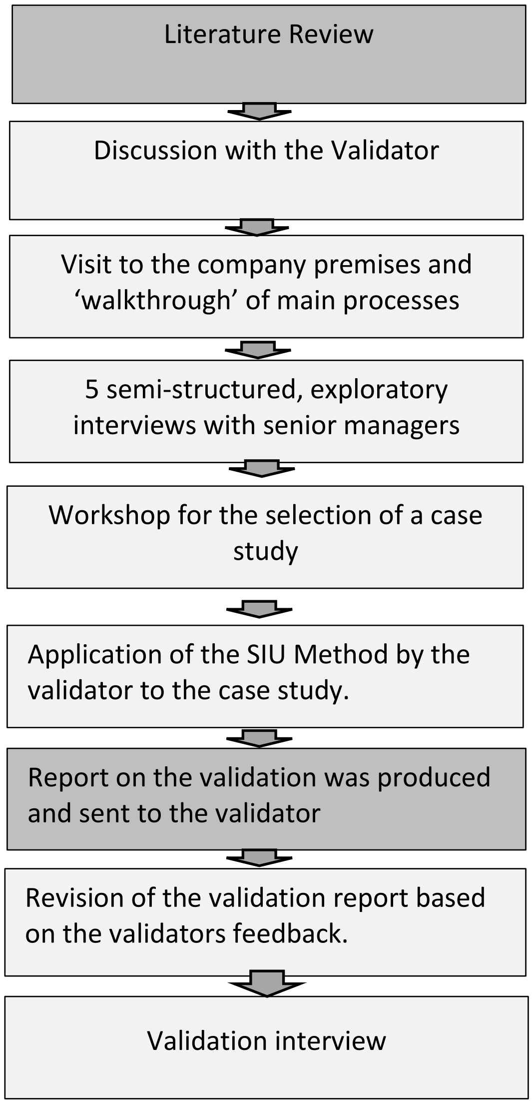


Figure 7.9: The Methodology for the validation with an aero engine case study

5. A workshop to explore possible case studies to validate the SIU method was held with the potential validator to assess various cases that had been elicited in the previous interviews. Any case study selected had to be a non-sensitive issue to the company where the sharing of case information outside the company would not compromise the proprietary knowledge of the company. A case study was selected where this was the case and where the issue had already been resolved; this would allow for evaluation of the SIU Method against the way that the company usually addresses such issues.

6. The SIU Method was then applied by the validator to the selected case study. Notes were taken by the researcher during this time.
7. A report on the validation (the application of the SIU Method) was produced and sent to the validator.
8. The report was revised in the light of the feedback from the validator.
9. The validator was then interviewed (Appendix L) with regards to the merits and demerits of the SIU Method.

Participants	Years of experience
Senior Specialist in Product Development	8
Chief Engineer	6
Strategy and Technology Manager in Advanced Engineering	5
Senior Engineering Specialist	7
Development of Technical Services	6

Table 7.5: Job roles and years of experience of the interviewees (Aero engine case study)

DATA COLLECTION	No. Of Interviewees	Time (hrs)
An exploratory interview was with the potential validator.	1	2
A 'walkthrough' of main processes at the company premises with the potential validator	1	2
Five separate semi-structured, exploratory interviews with five senior engineering managers.	5	15
A workshop to explore possible case studies with the potential validator.	1	3
The SIU Method was then applied by the validator to the selected case study. Notes were taken by the researcher during this time.	1	4
The validator was then interviewed with regards to merits and demerits of the SIU Method.	1	3
	Total	**20.5**

Table 7.6: Aero Engine Case Study: Data collection - number of interviewees and interview hours

7.3.3 Application of the Method

This is a retrospective application of the method and, as the issue has already been resolved, none of the new solutions generated here have actually been put forward to the airline or any of the other stakeholders. Nevertheless, applying this method to this issue does illustrate how innovative solutions can be generated. The application of the method has been initiated by the component supplier and is based on their general understanding of the capabilities in each company in the value chain. The method is applied from the component supplier's perspective; that is, it is the component supplier who is acting as the facilitator and is applying the method. Using the general and partial knowledge that the component supplier has about the airline, the method is firstly applied to a basic understanding of the airline's value creation system to reckon where the gaps could be that lead to the issue and then to gauge what sorts of solutions could be generated.

STEP 1: Problem Definition

The extent and importance of the issue had been determined by the component manufacturer: the interviews at the component manufacturer's revealed that this had been a very serious issue that had to be remedied as quickly as possible: the airline could have lost a great deal of revenue if any their planes were grounded and the aero engine manufacturer could also have lost revenue if their engines kept being rejected.

Whilst the aero engine manufacturer found the component acceptable, it was the aero engine manufacturer's customer (an airline) which rejected the engine and this was assumed by the component manufacturer to be due to the fact that the background colour of the component can be important for maintenance staff as changes in colour (from the component's natural colour to a new one) can be indicative of possible defects. Such a rejection of one or more engines would cost the airline a great deal if their planes were grounded. Nevertheless, as other airlines who had received the engine with the discoloured component had made no complaint, the component manufacturer and the aero engine manufacturer believed that this different natural colour of the component should have still allowed this airline's maintenance staff to conduct their activities as usual.

The aero engine was rejected in the delivery acceptance activity when it arrived at the airline. The exact procedure for not accepting the discoloured engine is not known in detail, although it is known that other engines which were not discoloured had been accepted by this airline. It is possible that the handling staff (who inspect incoming engines to make sure that the correct engine has been delivered) are responsible for the rejection simply because they believed that the component looked different; it is not inconceivable that the maintenance staff may not have found any issue with the colour of the component and not even have known that the aero engines had been rejected. Such deficiencies in communication flow are possible. Although this is speculation, a consideration of all possibilities (until further information is forthcoming) is useful; without doubt, the over-arching issue is that the customer's expectations were not explicitly turned into requirements and cascaded throughout the value chain and this is a common problem. Another possibility is that it could have been the maintenance staff who instructed the handling staff not to accept any engines with a component having such a discolouration; this particular airline may operate in different environments and may have different use purposes and types to other airlines which could mean that they need to distinguish different possible defect colourations (as compared to other airlines) from the component background colour. If this was the case, this airline (due to their unique use context and use patterns) may have had defect colours appearing which are indistinguishable from the new component background colour. As for the component manufacturer, previous to this incident, they would not have known that this airline preferred the component to be a certain colour.

Depict the capability of the airline (Figure 7.10): Service blueprinting (rather than extended service blueprinting) is used here, as detailed, internal product operation is not a consideration in this case. The gauged parameter gaps are shown, as is the general understanding of the airline's environments, which are labelled and demarcated with different colours.

STEP 2: Describe the Overall Capability Parameter Gaps

The Overall Capability Gap would be: *Failure to install and hence fly and maintain an aircraft.* The overall capability to install the engine, fly the aircraft and conduct routine maintenance failed. The actual parameters of span, time-cycle, range and cost of this process would all be totally outside of the expected parameters.

STEP 3: Find the Gap-Located Capability(s) Within the System

The component manufacturer had not been told exactly why and who at the airline issued the order to reject the aero engine; in fact, there is very rarely ever any sort of dialogue between the airline and the suppliers other than limited discourse between the component manufacturer and the engine manufacturer. The component manufacturer was merely told that the engine had been rejected by the airline because the component was discoloured although colouration had not been explicitly stated to the component manufacturer as an acceptance criterion. For this reason, the component manufacturer would have to suppose what could have happened.

As far as the component background colour is concerned, the desired parameters (however the airline expected them – although this is also unknown to the component manufacturer) of colouration for the component could have been set by one of two capabilities. This gives the possible gaps being at the sub-capabilities:

- *Component X colour in range?* could have been set for either of the reasons below:
  - Past component attributes: the usual colouration of the component was expected. This is likely to be a measure devised by the handling staff.
  - Maintenance Staff needs: the desired colouration could have been stipulated by the maintenance staff. Therefore, the parameters of this part of the handling capability could actually be dictated by those of the capability: *Have defect Colours in component x been detected?* and so the location of the gap could actually be here.
- *Have defect colours been detected in component x?* It could be the case the maintenance staff wanted the engine to be rejected because:
  - The component simply looked different and so the maintenance staff felt uncertain about being able to do their job.
  - For this particular airline (because of their use context), some defect colours could be indistinguishable from the components new background colouration. A structured and documented "walk-through" of the maintenance process where the maintenance staff along with the help of other domain specialists capture the requirements for maintenance could have meant that this

discolouration issue could have been avoided. However, if the issue arose because of variations in the use context, then the any requirements of the component may simply have become out of date.

As it is unknown which sub-capability is where the issue is situated, both will be considered to be possible Gap-Located capabilities and examined in the next section.

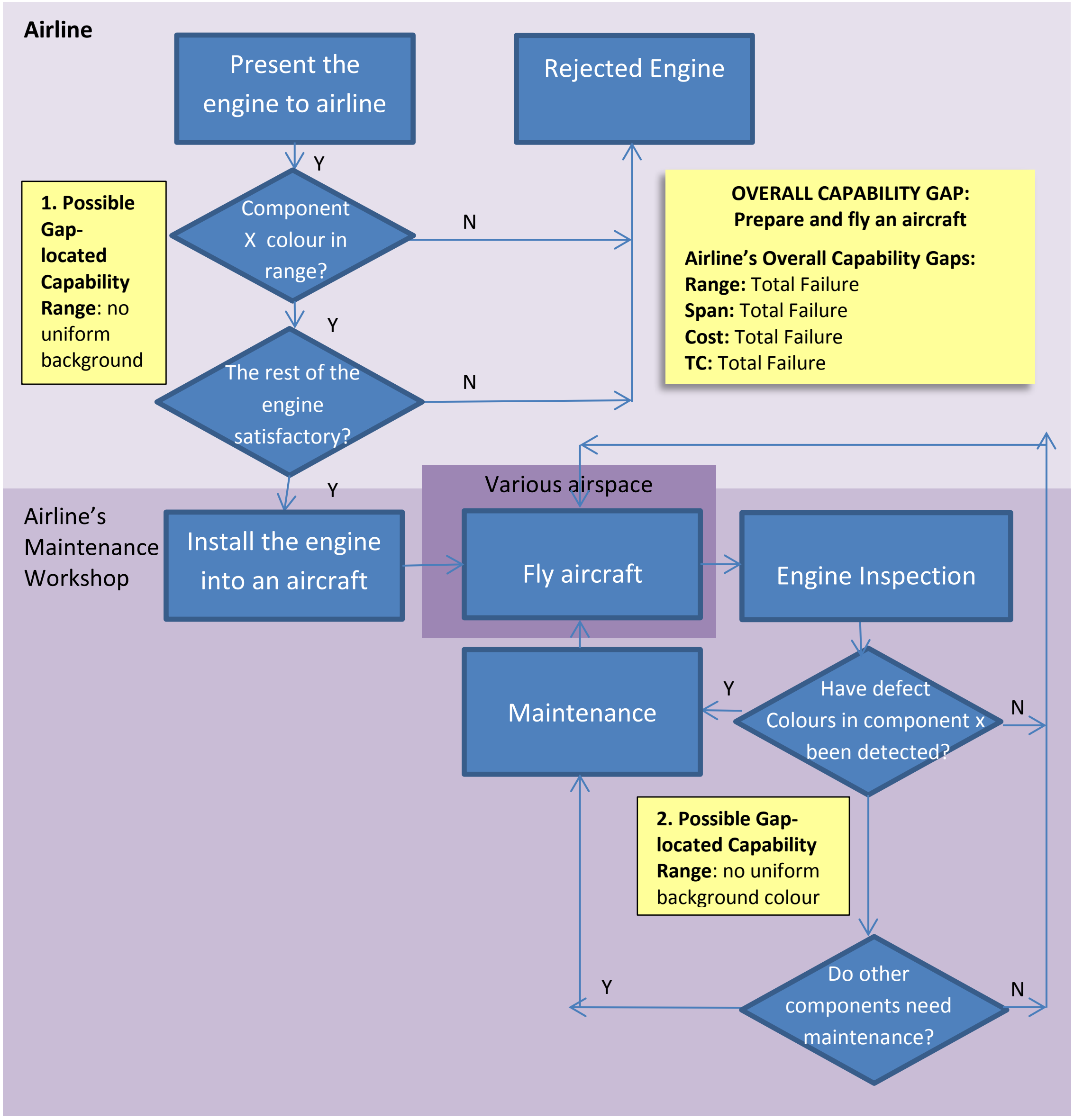


Figure 7.10: Basic depiction of the airline's and the aero engine manufacturer's capability

STEP 4: Corroborate the System Definition

The Expert Validator conferred with his colleagues as to the validity of the Enhanced Service Blueprint. The result was that all agreed that the system depiction appeared to meet their understanding of the airline's processes in which the issue arose.

STEP 5a: Operand-Operant Decomposition of a Gap-Located Capability

As it is unknown which capability is the Gap-Located Capability, both will be explored. The first (*Have defect colours been distinguished in component x?)* is explored here and the other possible Gap-Located Capability is examined later in STEP 11a. It could be the case that this particular airline may operate in different environments and may have different use purposes and types which could mean that they need to distinguish different colours (as compared to other airlines) from the component background. This capability is decomposed in an Operand-Operant Diagram (Figure 7.11).

Tier 0: *The Airline*

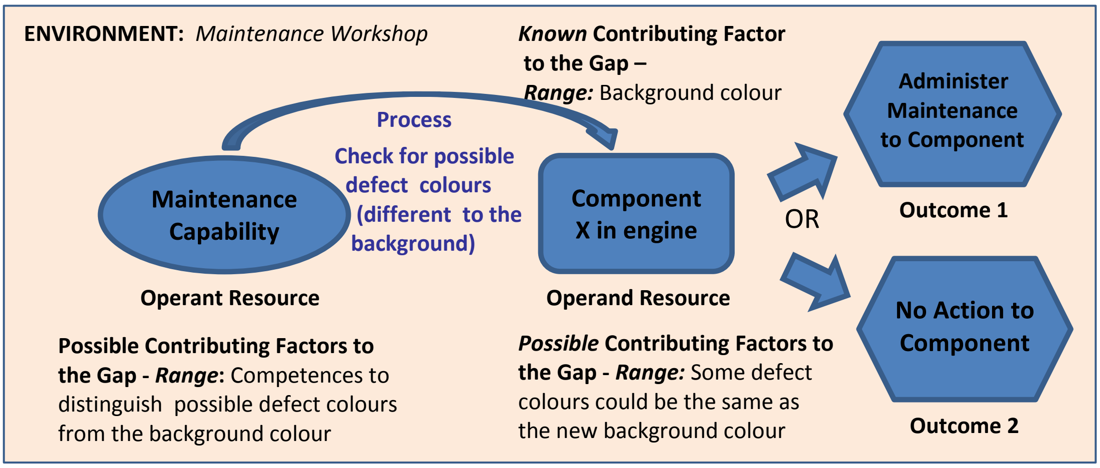


Figure 7.11: The Operand-Operant Diagram of the capability: *Have defect colours been distinguished in component x?*

STEP 6a: Determine the Stakeholders and Their General Roles

- It is the maintenance staff who are responsible for and own the capability to distinguish defect colours
- The component manufacturer is responsible for the component's form (and its colouration).

STEP 7a: Compare the Capability to Other Similar Capabilities

Uniformity of component colour: The gaps did not occur when the component was a uniform colour. Thus, one solution could be to reinstate the original fabrication process. It is also known that a "polishing" process could be added which would produce a unified colouration; therefore, this could be another solution.

STEP 8a: Propose Solutions

A Proposal Matrix has been completed (see Table 7.7) for this possible gap. For any new product development to occur, the maintenance process would have to be very carefully and fully captured as there are stringent regulations regarding flight worthiness that have to be adhered to. However, the suggested solutions in the Proposals Matrix (at this stage) are just ideas which, depending on the stakeholders concerns, could be worthy of further consideration.

STEP 9a: Next Tier?

For this capability, there is no part of the Operand-Operant Diagram to be explored further.

STEP 11a: Next Gap-Located Capability?

As mentioned previously in STEP 5, another possible Gap-Located Capability that should be examined is *Component X colour in range?*

STEP 5b: Operand-Operant Decomposition of a Gap-Located Capability

Another possible gap is that, as only this customer has rejected the engine, it is most likely that it is due to the airline staff simply being alarmed at the new component colouration. This could (at this stage) be presumed because all of the maintenance staff of other airlines have had no issue with the discolouration although it is supposed that their use contexts and use patterns are equally wide and varied. This is detailed in the Operand-Operant diagram (Figure 7.12).

Types of Generic Change	Decrease in gaps	DETECTION OF DEFECT COLOURS 
1) NEW CONCEPTUAL DESIGN		Could the component simply be replaced at scheduled maintenance checks before the component had aged or been used enough to develop any defects? The time and cost to replace a component would have to be compared against the time and cost to conduct defect assessment and maintenance. The aero engine manufacturer could help to support this by determining if a change in engine design could result in quick and easy component changes and the component supplier could help to determine if component recycling or remanufacture is a viable possibility.
2) CHANGES REGARDING THE DESIRED PARAMETER(S) OF THE GAP(S) OF THE OFFENDING CAPABILITY		
a) MARKET SEGMENT /RECEIVER SHIFT		If some types of air travel resulted in certain defect colours which were indistinguishable from the component, then could these flights (and the passengers that require them) be abandoned?
3) CHANGES REGARDING THE OFFENDING CAPABILITY:		
a) SUBSTITUTE		**Operant:** ***staff*** - If there were other maintenance operatives who would not feel disconcerted at such a background colour change, then could these operatives be used instead? However, this is not an option if the issue arose because certain defect colours are the same as the background colour.
		Operand: ***component*** **–** Could the same (or a different) engine supplier be instructed to supply components that are the expected colour?
		Process: Could another method for detecting possible defects be used rather than the method which checks colouration?
b) ELIMINATE		**Operand:** ***component,*** **Operant:** ***staff and*** **Process –** Could the engine manufacturer redesign the engine so that the component is not required?
c) ADDITION		**Operant:** ***staff*** **-** Could colour charts be created which would help the maintenance staff to distinguish the natural component colouration from new colours which appear with age and use? If so, this would change the staff job specification as they would not have to be able to distinguish possible defect colours from the background colours. However, this is not an option if the issue arose because some defect colours are the same as the background colour.
		Operant: ***staff*** **-** Could an electronic device be sourced or created which would help the maintenance staff to distinguish the natural component colouration from new colours which appear with age and use? The other stakeholders could be asked about this. This would change the job specification of the staff as they would not have to personally be able to distinguish possible defect colours from the background colours. However, this is not an option if the issue arose because some defect colours are the same as the background colour.
d) CUSTOMISE		**Operant:** ***staff*** **-** Could extra training be given to maintenance staff to assure and inform them with regards to detecting possible defects given the components current natural colouration? The stakeholders could be asked about this. However, this is not an option if the issue arose because some defect colours are the same as the background colour.
		Operant: ***staff*** – are vision checks adhered to?
		Operand: ***component*** – Could the airline install a polishing process to make the component a uniform background colour?
4) ENVIRONMENTAL CHANGE		
a) CHANGE LOCAL ENVIRONMENT		Could conditions such as the lighting in the maintenance workshop be causing difficulty with staff distinguishing colours?
b) CHANGE WIDER ENVIRONMENT	N/A	There would appear to be no changes that could be made to close this gap– is that the case?

Table 7.7: Treat the Symptoms - capability: *Have defect colours in component x been detected?*

Tier 0: ***The Airline***

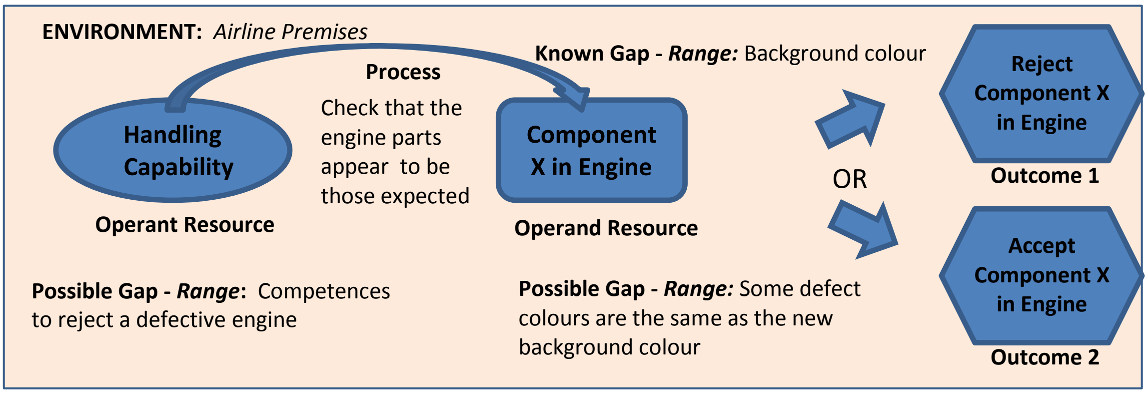


Figure 7.12: The Operant-Operand Diagram for the possible gap at the capability: *Component X colour in range?*

STEP 6b: Determine the Stakeholders and Their General Roles

- It is the handling staff who are responsible for rejecting supplies that appear not to be those expected.
- The component manufacturer is responsible for the component's form (and its colouration).

STEP 7b: Compare the Capability to Other Similar Capabilities

Uniformity of component colour: Again, as the gaps did not occur when the component was a uniform colour, reinstating the original component fabrication process or introducing a "polishing" process that is known to render components an acceptable, uniform colour.

STEP 8b: Propose Solutions

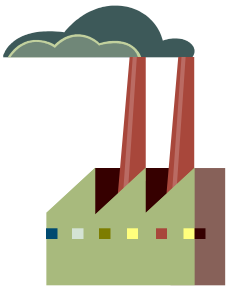
A Proposal Matrix has been completed (Table 7.8) for this possible gap.

Types of Generic Change	Decrease in gaps	ENGINE AND COMPONENT INSPECTION
1) NEW CONCEPTUAL DESIGN		Could quality control assurances and photographs of the parts be forwarded or emailed by the engine manufacturer which details how the engine meets its brief? If this could occur then all that the handling staff would have to do is to check that the photographs match the engine. However, this is not an option if the issue arose because some defect colours are the same as the background colour.
2) CHANGES REGARDING THE DESIRED PARAMETER(S) OF THE GAP(S) OF THE OFFENDING CAPABILITY		
a) MARKET SEGMENT /RECEIVER SHIFT		If some types of air travel resulted in certain defect colours which were indistinguishable from the component, then could these flights (and the passengers that require them) be abandoned?
3) CHANGES REGARDING THE OFFENDING CAPABILITY:		
a) SUBSTITUTE		**Operant: *staff*** – Could maintenance staff perform the check of the engine? If it is a question of the handling staff not knowing that the colouration of the component may be acceptable to maintenance staff then this could be a solution, particularly if a similar situation has arisen for other components. However, this is not an option if the issue arose because some defect colours are the same as the background colour.
		Process –Could the colour range that the staff have been using be substituted the with the new acceptable colour range? Stakeholders such as the engine and component manufacturer as well as the maintenance staff could advise on this. However, this is not an option if the issue arose because some defect colours are the same as the background colour.
		Operand: *component* – Could the same (or a different) engine supplier be instructed to ensure components are the expected colour?
b) ELIMINATE		**Process** – Could the staff be instructed not to check the colouration of the component? However, this is not an option if the issue arose because some defect colours are the same as the background colour.
		Operand: *component,* Operant: *staff and* Process – Could the engine manufacturer redesign the engine so that the component is not required?
c) ADDITION		**Operant: *staff*** - Could colour charts be created which would reassure the handling staff that the component colouration is acceptable? However, this is not an option if the issue arose because some defect colours are the same as the background colour.
d) CUSTOMISE		**Operant: *staff*** - Could staff be trained or informed that the colouration is acceptable? However, this is not an option if the issue arose because some defect colours are the same as the background colour.
		Operant: *staff* – are vision checks adhered to?
4) ENVIRONMENTAL CHANGE		
a) CHANGE LOCAL ENVIRONMENT	N/A	Could conditions such as the lighting in the maintenance workshop be causing difficulty with staff distinguishing colours?
b) CHANGE WIDER ENVIRONMENT	N/A	There would appear to be no wider environmental causes for this gap – is that the case?

Table 7.8: Treat the Symptoms - Possible gap-located capability: *Component X colour in range?*

STEP 9b: Next Tier

In the airline's Proposals Matrices, various solutions were outlined as to how the airline could change their capability, given their resources and environment; changes were outlined as to how the handling capability could be changed but what was of more interest to the Validator was how the maintenance staff's capability of detecting defects could be explored further. Although the airline can make changes to the maintenance staff and the process of inspection that their staff use, the airline has very little capability to make changes to the engine and/or component: for this reason, the component is now traced through the value chain from the aero engine manufacturer who integrates it into an engine, to the component manufacturer who fabricated it and then to the component's material supplier (Figure 7.2.5). By a recursive application of the method, the supplier tier being considered will have its capability drawn as part of its customer's capability so that it can be seen where that supplier's value proposition is in relation to the customer's gaps (the issue with their capability) and how it contributes to them. The SIU method will be applied to the capability of each particular firm in the value chain so that it can be determined what each specific firm could do to help to close the gaps.



STEP 9b: Increase the Tier by 1

Tier 1 (Condition 1): *The Aero Engine Manufacturer's Overall Capability*

Although the engine manufacturer has little control over the airline's maintenance, they are responsible the engine and the capability that created it. For the Service Blueprint, see the Value Chain Service Blueprint (Figure 7.14).

STEP 5c: Operand-Operant Decomposition of a Gap-Located Capability

See Figure 7.15.

STEP 6c: Determine the Stakeholders and Their General Roles

- It is the aero engine manufacturer who is responsible for and who owns the capability to integrate components into an engine.
- The component manufacturer is responsible for the component's form (along with its colouration).

STEP 7c: Compare the Capability to Other Similar Capabilities

None are known with any sort of certainty.

STEP 8c: Propose Solutions

See Table 7.9.

STEP 9c: Next Tier?

Yes, the component fabrication process is to be considered.

STEP 11c: Increase the Tier by 1

Tier 2 (Condition 2): *The Component Supplier's Overall Capability*

Existing Capability Depiction: See the Value Chain Service Blueprint (Figure 7.14).

STEP 5d: Operand-Operant Decomposition of a Gap-Located Capability

Depict the Operant and Operand Resource and the Process – See Figure 7.16.

STEP 6d: Determine the Stakeholders and Their General Roles

- The component manufacturer is responsible for the component's form (along with its colouration).
- It is the material supplier who is responsible for and who owns the capability to source and prepare the material.

STEP 7d: Compare the Capability to Other Similar Capabilities

None are known with any sort of certainty.

STEP 8d: Propose Solutions

See Table 7.10.

STEP 11d: Next Tier?

Yes, the material supplier's process is to be considered

STEP 12d: Increase the Tier by 1

Tier 3: *The Material Supplier's Overall Capability*

Existing Capability Depiction: See the Value Chain Service Blueprint (Figure 7.14).

STEP 5e: Operand-Operant Decomposition of a Gap-Located Capability

Depict the Operant and Operand Resource and the Process – Figure 7.17.

STEP 6e: Determine the Stakeholders and Their General Roles

- At this stage, it could be presumed that the material supplier is responsible for the sourcing and refining of the material.

STEP 7e: Compare the Capability to Other Similar Capabilities

None are known with any sort of certainty.

STEP 8e: Propose Solutions

See Table 7.11.

STEP 9e: Next Tier?

There is no further Tier to be considered.

STEP 11: Next Gap-Located Capability?

There are no other Possible Gap-Located Capabilities to explore.

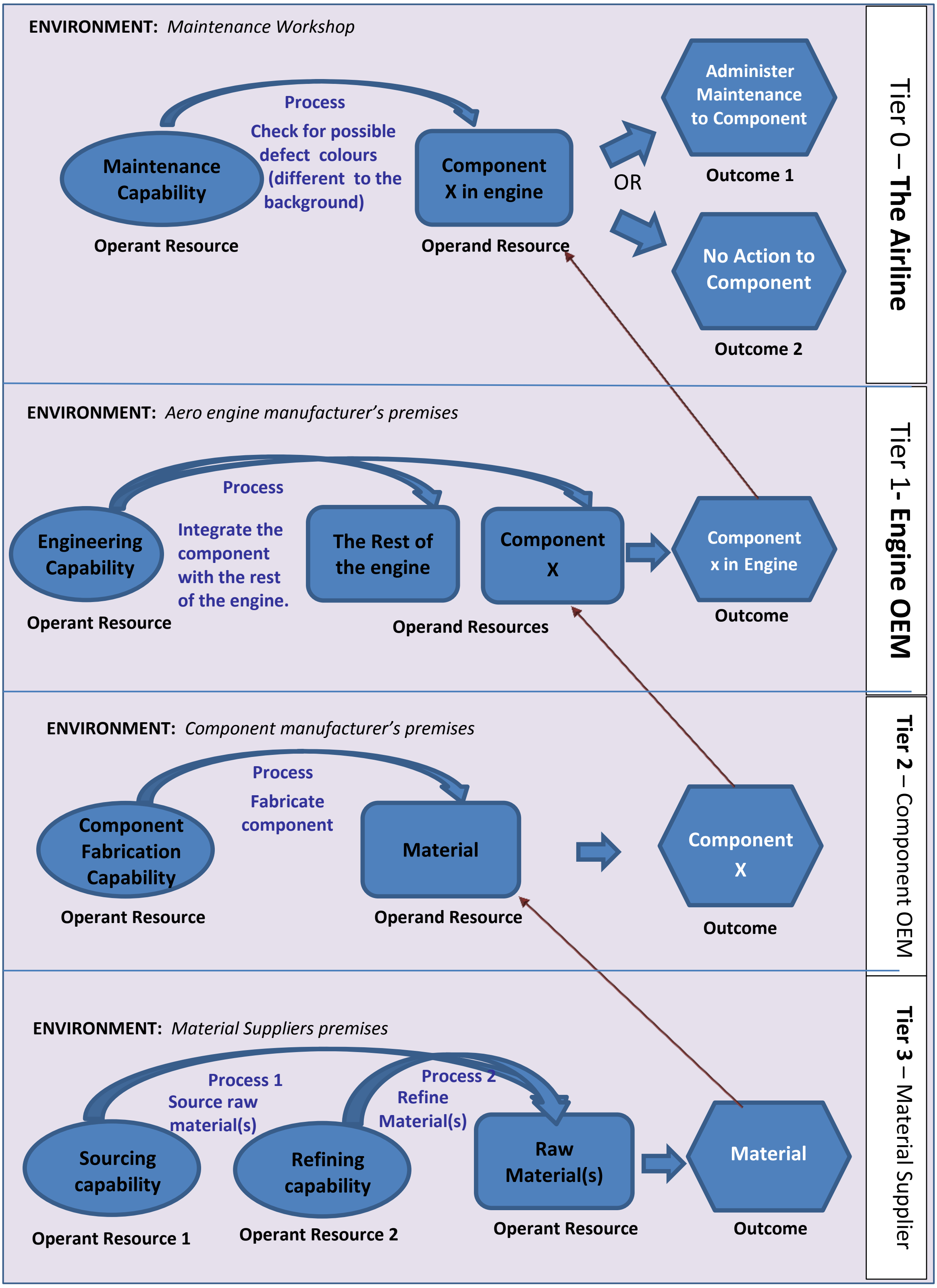


Figure 7.13: Operant-Operand Diagram of the nested capabilities within the aero engine incorporating the component

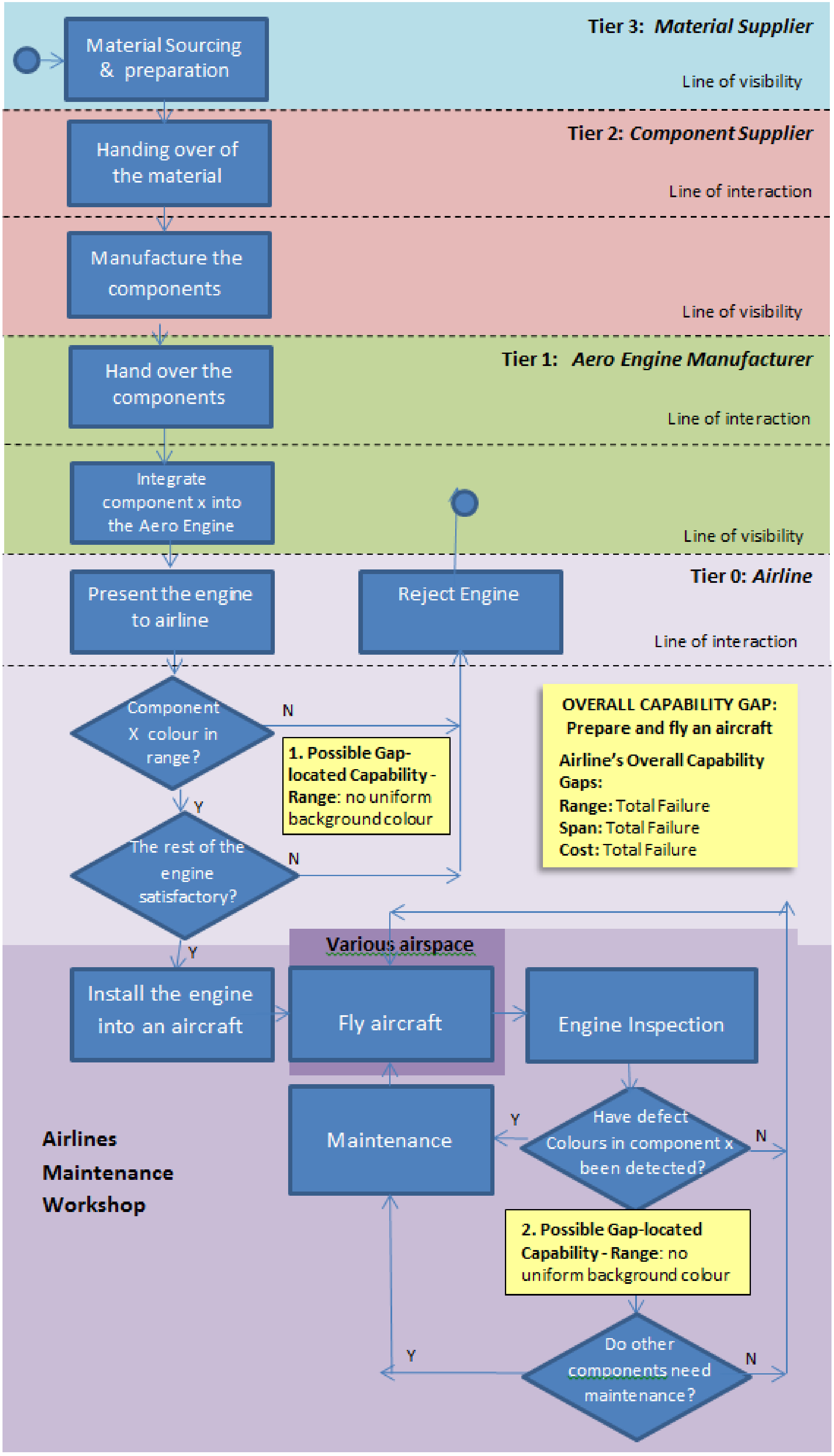


Figure 7.14: Value Chain Service Blueprint

Tier 1: *The Engine Manufacturer*

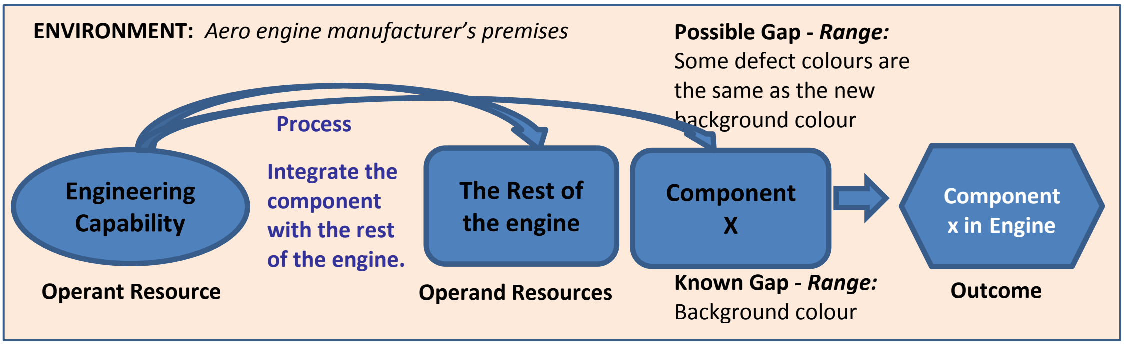


Figure 7.15: The Operant-Operand Diagram for the possible gap at the capability: *Integrate Component X into the Aero Engine*

Types of Generic Change	Decrease in gaps	AERO ENGINE MANUFACTURE
1) NEW CONCEPTUAL DESIGN		Could a change in engine design result in quick and easy component changes? The component supplier could help to determine if component recycling or remanufacture is a viable possibility. The component could simply be replaced at regular maintenance checks before the component had aged or been used enough to develop any defects. This becomes more feasible if component upgrades are expected because of advances in fabrication (the material supplier could also be consulted with regards to other materials and new composites) or changing user requirements. If the aero engine manufacturer is or wants to offer a PSS such as "power by the hour" (pay per use) then replacement rather than leaving defect detection to a third party could be less risky for the engine manufacturer. The time to replace a component would have to be compared against the time to conduct defect assessment and maintenance. The cost of regular replacement of components would also have to be assessed. This becomes more feasible if there are other capabilities which could also be improved by engine redesign.
2) CHANGES REGARDING THE DESIRED PARAMETER(S) OF THE GAP(S) OF THE OFFENDING CAPABILITY		
a) MARKET SEGMENT /RECEIVER SHIFT		This airline could be too important to abandon. Could the airline's expectations be changed by partnering with them by using the aero engine manufacturer's engineering capability to help provide a maintenance service for them?
3) CHANGES REGARDING THE OFFENDING CAPABILITY:		
a) SUBSTITUTE		**Operand: *component* –** Could the same (or a different) component supplier be instructed to ensure components are the expected colour?
b) ELIMINATE		**Operands: *component, rest of engine* Operant: *Engineering capability and* Process –** Could the engine be redesigned so the component is not required?
c) ADDITION		**Process:** Could the engine manufacturer add or use an existing polishing process they may have to make the component a uniform background colour?
d) CUSTOMISE		**Operant: *staff* -** Could extra training be given to the airline's maintenance staff to assure and inform them with regards to detecting possible defects given the components current natural colouration? The stakeholders could be asked about this. However, this is not an option if the issue arose because some defect colours are the same as the background colour.
4) ENVIRONMENTAL CHANGE		
a) CHANGE LOCAL ENVIRONMENT	N/A	There would appear to be no changes that could be made to the wider environment to close this gap – is that the case?
b) CHANGE WIDER ENVIRONMENT	N/A	There would appear to be no changes that could be made to the wider environment to close this gap – is that the case?

Table 7.9: Treat the Condition 1 - Possible gap-located capability: *Engine Manufacture*

Tier 2: *The Component Manufacturer*

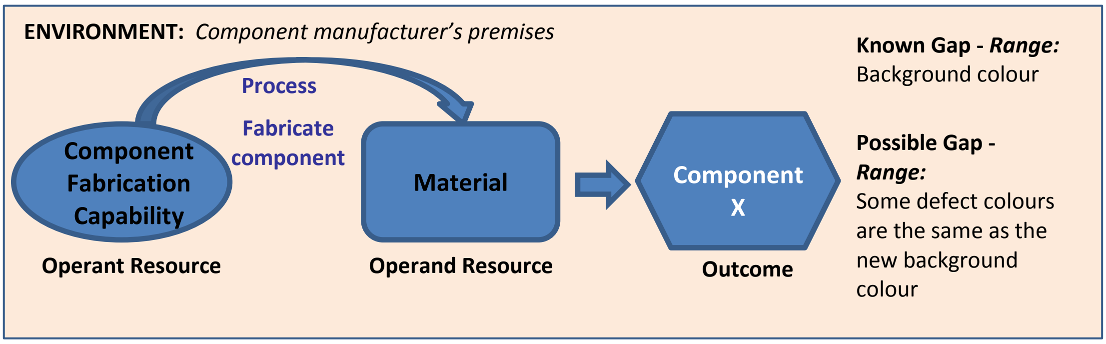


Figure 7.16: Operant-Operand Diagram for the capability: *Manufacture the components*

Types of Generic Change	Decrease in gaps	COMPONENT FABRICATION
1) NEW CONCEPTUAL DESIGN		If additive manufacturing was used rather than laser cutting or casting to create the components, would the discoloration issue not arise? What could be the ramifications for the engine manufacturer and airline?
2) CHANGES REGARDING THE DESIRED PARAMETER(S) OF THE GAP(S) OF THE OFFENDING CAPABILITY		
a) MARKET SEGMENT /RECEIVER SHIFT	N/A	The client (the aero engine manufacturer) could be too important to abandon – not an option here. Could partnering with another component manufacturer who could ensure that component does not become discoloured be an option?
3) CHANGES REGARDING THE OFFENDING CAPABILITY:		
a) SUBSTITUTE		**Operant: *Component Fabrication*, Operand: *Material* and process –** Could another fabrication process be used (such as the previous one) to produce a component of the expected colour?
b) ELIMINATE		**Operands: *component, rest of engine* Operant: *Engineering capability and* Process –** The only way to eliminate any of the manufacturing capability for the component appears to be a new engine design. The aero engine manufacturer could be consulted about this. However, this could be a prolonged and costly route unless there are other reasons for a new engine design. Although the component manufacturer would no longer make this component, there may be other components which are required.
c) ADDITION		**Process:** A process to polish the component so that it is uniformly the background colour which is expected by the airline.
d) CUSTOMISE		**Process -** Could the manufacturing process be changed so that no discolouration appears?
4) ENVIRONMENTAL CHANGE		
a) CHANGE LOCAL ENVIRONMENT		Are the there any local environmental reasons which could contribute to component discolouration?
b) CHANGE WIDER ENVIRONMENT		Are the there any wider environmental reasons which could contribute to component discolouration?

Table 7.10: Treat the Condition 2 - Possible gap-located capability: *Manufacture the Components*

Tier 3: ***The Material Supplier***

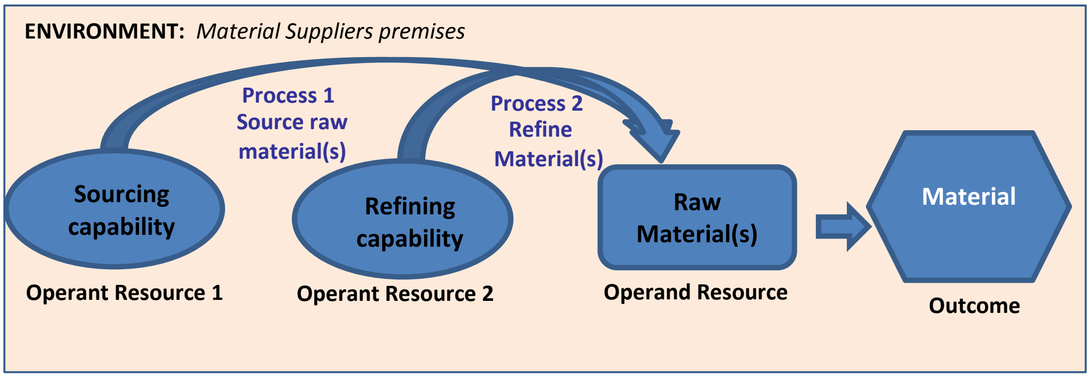


Figure 7.17: The Operant-Operand Diagram for the capability: ***Material Sourcing and Preparation***

Types of Generic Change	Decrease in gaps	SOURCING AND REFINING OF MATERIA
1) NEW CONCEPTUAL DESIGN		Could composites be supplied instead? What would be the ramifications for the other stakeholders?
2) CHANGES REGARDING THE DESIRED PARAMETER(S) OF THE GAP(S) OF THE OFFENDING CAPABILITY		
a) MARKET SEGMENT /RECEIVER SHIFT		The client (the component manufacturer) could be too important to abandon – probably not an option here. Could partnering with another material supplier who could ensure that material supplies do not become discoloured in the component manufacturer's current fabrication process or another fabrication process be an option?
3) CHANGES REGARDING THE OFFENDING CAPABILITY:		
a) SUBSTITUTE		**Operand:** ***Material*** – Could another material be used that does not become discoloured during the component manufacturer's fabrication process?
b) ELIMINATE		**Operand:** ***material*** **–** The only way to eliminate the need for any material would appear to be for a new engine design. The other stakeholders could be consulted about this. Although this material would no longer be supplied, there may be other materials which are required.
c) ADDITION		**Operand:** ***material:*** Could a process be added to the material preparation to prevent discolouration during manufacture?
d) CUSTOMISE		**Operand:** ***material*** – Could the material be treated in anyway so that discolouration will not happen during manufacture?
4) ENVIRONMENTAL CHANGE		
a) CHANGE LOCAL ENVIRONMENT		Are the there any local environmental reasons which could contribute to material becoming discoloured during manufacture?
b) CHANGE WIDER ENVIRONMENT		Are the there any wider environmental reasons which could contribute to material becoming discoloured during manufacture?

Table 7.11: Treat the Root Cause 2 - Possible gap-located capability: ***Material Sourcing and Preparation***

STEP 12: Rate and Select Solutions

The resultant Service Blueprints, Operand-Operant diagrams and the Proposals Matrices could then be shared with all of the stakeholders in the value chain. If necessary, the stakeholder can then make corrections to the Enhanced Service Blueprint, the Operand-Operant Diagram and the Proposals Matrix. If no corrections are necessary, then each supplier tier can simply answer the questions in the Proposals Matrix that are relevant to their tier. Each type of solution generated can then be estimated as to the extent that it should close the gaps (High, Medium and Low). If a solution cannot be generated for a particular type of redesign then “N/A” (Not Applicable) can be stated. The solutions are then accepted or rejected by the stakeholder in question – the accepted solution(s) can then be discussed with the other stakeholders.

The sharing of the outputs of the SIU Method with the stakeholders could then help to win further support for a more detailed analysis by the application of the quantitative SIU Method to each Tier: each company could apply the quantitative version of the SIU Method to their own capability and then, along with a basic service blueprint of their capability and where the shortfalls lay, share some of the possible solutions with the value chain; any sensitive information or detailed outputs of the SIU Method need not be shared with everyone. Any solutions which are accepted by the stakeholders can then be refined and evaluated and refined further. However, this stage is outside of the scope of this research.

7.3.4 Conclusions on the Application Results

As this is a retrospective application of the SIU Method and, as the issue has already been resolved, none of the new solutions generated here have actually been put forward to the airline or any of the other stakeholders. Nevertheless, applying the method to this issue does illustrate how innovative solutions can be generated. This application of the SIU Method is a type of What-if analysis which allows the problem-space and solution-space to be explored. In this case study, the solution space has been expanded by generating solutions at various levels of the value chain. It can be seen that a range of solutions, some being quite innovative, were generated throughout the value chain. As capabilities are nested, the SIU method can be used to treat the:

- *Symptoms:* at Supplier Tier level 0 - the Customer
- *Condition(s)*: at Supplier Tier levels 1 and 2 - the Aero Engine Manufacturer and the Component Manufacture
- *Root Cause(s)*: at Supplier Tier level 3 - the Material Supplier

Some of the solutions (such as the development of colour charts for the airline maintenance staff for defect detection) could be instituted very quickly and cheaply whilst other solutions suggest the development of a PSS (such as the component manufacturer or engine OEM also offering a supplementary training service to the airline's maintenance staff). Other solutions (such as engine redesign) could take much longer and be very expensive to develop. Nevertheless, such a change could be worthy of consideration if there are other reasons for engine redesign. Furthermore, some solutions encompass a change across several capabilities whilst others institute a change in just one.

The key benefits of this application of the SIU method are that:

- It forces a shift in mind set from product-centric thinking to systems thinking along with network based exploration,
- It acts as a communication channel in the value chain by sharing possible ideas to solve a specific issue,
- This task-centric approach applied throughout the value chain facilitates a deeper understanding of the issue and the generation of solutions,
- This method fosters an appreciation of the value proposition offered by each stakeholder in the value chain and underlines the importance of each of the resources which are committed to the realization of value-in-context.

7.3.5 Results

For eight years, the expert validator has been a Senior Company Specialist in Product Development at a company which is an industrial, capital intensive, technical and infomated PSS provider; it is a manufacturer of aero engine components and product-related services. The company is interested in methods which develop PSS. The previous ten years of his employment were as an engineering specialist at an aero engine and aero engine component manufacturer. The Expert Validator is also a senior, leading academic in servitization and industrial PSS.

Notes were taken during the validation session and these were written up by the author of this thesis and then presented back to the Expert Validator. Revisions suggested by the Expert Validator were then incorporated into this text; this happened several times until the Expert Validator deemed that no more revisions were necessary. The Expert Validator's responses to questions regarding the validation are detailed in Appendix L. To sum up the results of the validation, the SIU method was found to be complete and no changes to it or any of the techniques it uses were suggested. The method was found to be systematic, to foster innovation and to help suppliers understand how they contribute to the end customer's processes. However, the validator suggested that more detail on the method and the techniques it uses should be incorporated into the Workbook. Following these suggestions, the Workbook was subsequently revised.

7.3.6 Discussion of the Results

The validation has served as an example of a situation that:

1) Was not captured and expressed clearly using traditional requirements elicitation. However, (as use contexts and supply can change continually) this could point towards a need for constant data capture.
2) requires a deeper understanding of the end-user situation by several levels in the supply chain
3) Shows how a multi-level design process can be instituted.

The SIU Method enables any focal company in the value chain to depict and suggest changes to the capabilities of their suppliers (and supplier's suppliers) and customers (and customers of customers). The SIU Method allows innovative suggestions to be created at lower levels which could "push" higher capabilities into new solutions and, similarly, innovative suggestions could be created at higher levels which could "pull" lower capabilities into new solutions.

For the next stages of solution development, the solutions can be further evaluated and refined. Although the generation of refined PSS solutions are outside the scope of this research, this can be touched upon briefly here: the gaps with any new use-phase solutions could be found and filled using this method– this would offer a further level of refinement and evaluation can then again take place. Supplier capability, that is, the ability of the suppliers to meet new solutions could be determined by charting the gaps between the new solution and what various suppliers could offer: this may generate also new product and service requirements for the new solution. Furthermore, the SIU Method could be used to find any gaps in supplier capability and fill them.

The method could also be used to find and address gaps, not only in the use-phase, but also in the initiation, integration, attuning and end-of-life phases of the new solution. All of the stakeholders could then collectively assess the solutions. This would create further solution refinements.

The selection of any of these solutions would depend on the conditions and consequences of each as well as their acceptability to each of the stakeholders. However, even if some of the generated solutions are not feasible right now, a wide solution-space has been unfolded which always helps with decision-making and this could prompt the value chain towards more innovative solutions. Furthermore, in the future, some of these solutions could be feasible.

7.4 Validation 3: An Excessive Heat Issue

A Real-Time, Quantitative and Recursive (2 Tiers) Application

7.4.1 Introduction

The aim of this validation of the method is to assess how it can be applied by different stakeholders at different Tiers (Tier 0 is the tenant and Tier 1 is the civil engineer) and then to assess the merits and demerits of the SIU Method as compared to how professional, experienced consultants in that domain (HVAC Consultants) would have addressed the issue:

1) The first iteration of the SIU Method (in this case study) is applied by a non-technologist (Tier 0 - the tenant) who has little knowledge of PSS and engineering – this is to test the general usability of the Workbook and the SIU Method.
2) The second iteration of the SIU Method (in this case study) is applied by an expert civil engineer (Tier 1) who has little knowledge of PSS– this is to test the usability of the Workbook and the SIU Method for someone who is an engineer but not very familiar with PSS. This iteration is also conducted to assess how the SIU Method can inform building design.
3) The results of the application are then presented to HVAC consultants to assess the merits and demerits of the SIU Method as compared to how they would have addressed the issue.

A tenant of a housing association who was known to the researcher mentioned that his open plan kitchen-lounge became unbearably hot whilst he was cooking. The researcher then discussed this with the aforementioned HVAC Consultants and an expert civil engineer (who besides practicing in civil engineering is also a senior academic) and, as the tenant was amenable, it was decided to use this as a case study and for the tenant to follow the steps in the Workbook to apply the SIU Method. As the tenant was a non-technologist (he is an English teacher) and knew very little about PSS, the usability of the Workbook would be tested fully if he were to validate the Workbook and the SIU Method within. At the outset, the tenant's issue was expected to be contributed to by the design of the kitchen-lounge and so this presented another possible opportunity for validation by a building expert and also by the HVAC Consultants.

7.4.2 Methodology

The methodology that was followed for this validation is depicted in Figure 7.18. The paler grey colours depict data collection stages.

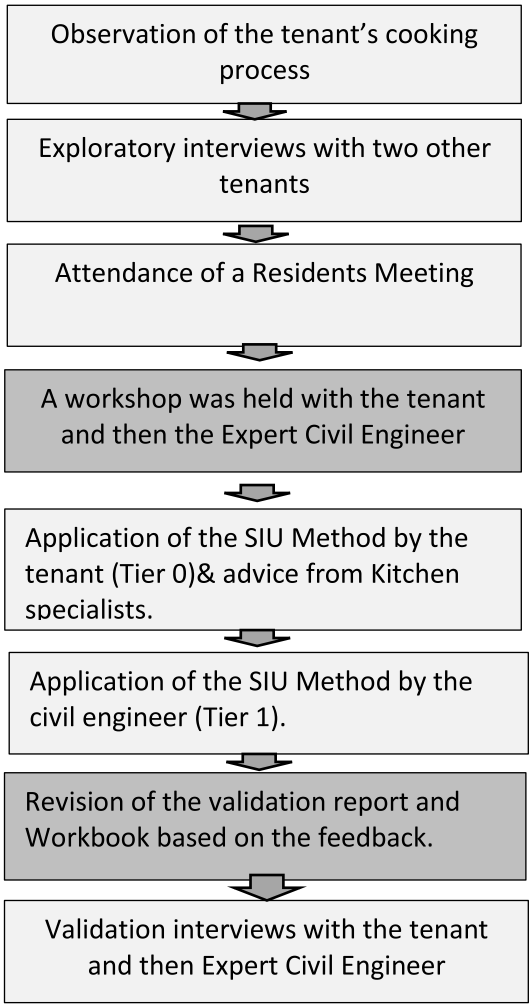


Figure 7.18: The methodology followed (Heat Issue Case Study)

1) The tenant was observed during the cooking of a meal and the kitchen-lounge did appear to become quite hot and the tenant did seem to be very uncomfortable.
2) Exploratory interviews were then held with two other tenants in that block of flats who also had very similar flats and they were asked if there were any problems when they cooked.
3) With the aforementioned tenants, the researcher attended a Residents Association meeting that is held periodically by the housing association.
4) The researcher held a two hour workshop with the tenant to cover PSS , the main ideas behind the SIU Method and to give some instruction with regards to Service Blueprinting. This was then repeated (this time by teleconference and email) with an Expert Civil Engineer.
5) At the Christmas holiday period of 2011 (as the researcher was available then to constantly observe the tenant and his environment), the tenant was then given temperature sensors and a thermometer as well the Workbook. He was asked to attempt to follow the steps in the Workbook and report any problems in following the steps to the researcher who would be present. The researcher took notes on

how the tenant applied the SIU Method and any problems that he had in following the Workbook. For solution generation, advice was sought from two kitchen appliance sales store managers from two nationwide kitchen specialist retail companies.

6) Using the results from the tenant's application, the second iteration of the body of the SIU Method was then performed by an Expert Civil Engineer who made notes regarding the application and the usability of the Workbook.
7) The notes that were taken were written up by the researcher. Also, based on the feedback regarding the usability of the Workbook, the Workbook was revised. The case study and revised Workbook were then presented back to the tenant and Expert Civil Engineer who made corrections. The corrected case study and Workbook were then presented back to the tenant and Expert Civil Engineer. There were three such cycles of revision to the workbook. When the fourth version of the Workbook and case study was produced and presented to the validators, no further amendments or revisions were made.
8) The tenant and then the Expert Civil Engineer were interviewed (the interview questions are in Appendix L) with regards to the merits and demerits of the SIU Method and the Workbook. The HVAC Consultants were also invited to attest to the credibility of this application of the SIU Method, the SIU Method itself and the usability of the Workbook (Appendix L). These validations were then written up by the researcher and presented back to the validators who made corrections and then approved the final, revised version.

Participants	Years of experience
3 Tenants	No experience in PSS or technology
An Expert Civil Engineer and Senior Academic	24 years in Civil Engineering
HVAC Technical Director	15 years' experience in HVAC consulting
HVAC Consultant	5 years' experience in HVAC consulting
Kitchen appliance sales store manager 1	6 years' experience in a managing that store
Kitchen appliance sales store manager 1	2 years' experience in a managing that store

Table 7.12: Job roles and years of experience of the respondents

DATA COLLECTION	No. Of Respondents	Time (hrs)
Observation of the tenant's cooking process	1	2
Exploratory interviews with two other tenants	2	2
Attendance of a Residents Meeting	2	3
The SIU Method was then applied by the tenant to the selected case study. Notes were taken by the researcher who was constantly present.	1	240
The SIU Method was then applied by the Expert Civil Engineer to the selected case study who also made notes.	1	4
3 separate Validation Interviews with: the tenant, the Expert Civil Engineer and then the HVAC Consultants	1, 1, 2	2, 3, 2
The validator was then interviewed with regards to merits and demerits of the SIU Method.	1	3
	Total	**261**

Table 7.13: How the data was collected against the number of interviewees and interview hours

7.4.3 Case Study Background

This field test shows how the SIU method can be used to support an existing product-service system: that is, improve its effectiveness.

A UK community housing association offers a product-service system (these are flats for rent which are maintained and periodically refurbished). Semi-structured interviews were held with three tenants who each have a one bedroom flat in a block of flats which is provided by this housing association. The flats are very similar in size and layout – each has an open-plan kitchen-lounge.

Semi-structured, exploratory interviews with the users (the tenants, each of whom had a serious medical condition) revealed one issue that, whilst cooking and just after, their kitchen-lounge would often become unbearably hot and that, even in the middle of winter, at least one window would have to be opened. This was a particularly serious issue for one tenant who stated that his illness meant that he had breathing problems and that when the kitchen-lounge became that hot that there were times that he felt dizzy. All of the tenants complained that they often got headaches and that they deemed the sometimes excessive heat in the kitchen-lounges to be a major contributing factor. Another issue that surfaced was that they believed their utility bills to be fairly high and that the energy used to cook contributed greatly to this.

The tenants have said that these unbearable temperatures only happen during and just after cooking – never at any other time. They also stated that this happens in all seasons. In summer, the tenants stated that the kitchen-lounges tend to be quite warm anyway, and so unbearable temperatures during cooking and just after are reached even more quickly.

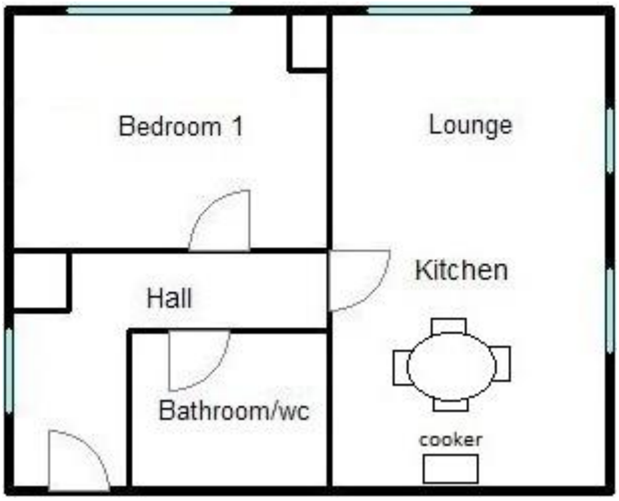


Figure 7.19: A floor plan of the field test flat

A particular flat was used for a field test of the SIU method – (see Figure 7.19). The dimensions of the kitchen-lounge are:

- **Height:** 2.4m (approximately 7ft 10½ in)
- **Width:** 3.5m (approximately 11ft 6¾ in)
- **Length:** 5.8m (approximately 19ft 1½ in)

The tenant of this flat is 6” 1’ (185.42cm) and so, when standing, the ceiling is only 1” 9 ½‘ (54.58cm) above him.

The flat is situated on the corner, ground floor of a block of flats. The bottom wall (against which the cooker rests) in the floor plan (Figure 7.21) is shared with an adjacent flat. The remaining three sides are exposed.

The issue to be investigated is that of cooking and its negative side effect (making the kitchen-lounge air unbearably hot) that has been reported. The next section details how the SIU Method was applied.

Problem Definition

Note: The steps were conducted by the tenant with the help of the author. It was important to:

1) ***Quantify the Issues:***
   - The actual temperature at which the tenants start to find the atmosphere unbearable. This will be used later as the Desired Overall Capability Parameter.
   - The extent to which cooking contributed to the tenants' bills – to determine if this was significant.
2) ***The System which gave rise to the Issues***: It was necessary to determine whether this "unbearable" temperature and above is only reached during and just after cooking – if "unbearable" temperatures were reached at other times then this would suggest that other factors contribute significantly to the high temperatures; that is, that they are not just to do with cooking and these other factors would require investigation. It was also important to determine where in the kitchen-lounge "unbearable temperatures" were reached.
   1. **Establishing the threshold of "unbearable temperatures":** In the field test flat, all of the windows and doors were closed and, using a standard thermometer, the ambient temperature was taken at the tenant's waist- level (this is also the tenants head height when he sits at the dining room table, which he stated is often where he sits) and around the kitchen-lounge – each corner and the centre of the room registered 23°C within 1°C. The tenant stated that he did not find this temperature uncomfortable. When the tenant started cooking, he was asked to state at what point he started to find the temperature wholly unbearable. At this point, thermometer readings taken were 25.5°C at the tenant's waist-level. At that point, thermometer readings were taken at the same level at various other points in the kitchen-lounge and the readings were

the same within 0.5°C. The temperature of the air at the tenant's head height when standing (which is 185cm) was then also taken in the same way – this was 27.6°C. Thus, the temperature at which the air starts to become "unbearable" is established to be 25.5°C at waist-level and at 27.6°C at head-level for that particular tenant.

2. **Establishing the cost of cooking**: To gauge this, a typical, high energy-use cooking session was studied along with a gas bill provided by the tenant – the tenant viewed this bill as being a fairly typical gas bill. This cooking session was the making of a roast chicken meal using the tenant's Creda Capri gas oven. All appliances that use gas (the boiler and heating) were turned off and a gas meter reading was taken. A chicken with potatoes and stuffing were placed in the oven at Gas Mark 6 for 55 minutes – half way through this cooking time, two gas rings were turned on at a middle heat for 20 minutes to boil vegetables. Then, the gas meter reading was taken again. From this, the amount of energy units used up and the resultant cost of the energy used was calculated in the following way:

a) *Reading the units:* the units are expressed in metric units - the last 3 digits (with a red border) which are displayed by the gas meter represent fractions of a unit. The readings were:
    - START 2025.847
    - FINISH 2026.066

This difference gave (0.218) as the amount of units used during this cooking session.

b) The metric units are then converted to kWh (the gas suppliers make this conversion so that so that their bills can be compared to electricity bills) in the following way (as presented on a bill dated 15th August 2009, by British Gas, the tenant's supplier):

metric units used		calorific value		volume correction		to convert to kWh		gas used in KWh
0.218	x	39.3965	x	1.02264	÷	3.6	=	**2.448**

Table 7.14: Conversion of the metric units to KWh

c) The cost of the units used for this cooking session are calculated as:
   a. On the tenant's gas bill, there are two tariffs: the first 646 kWh are priced at £0.06846 and the next 450.74 units are priced at £0.03275.
   b. The tenant's bill showed that he had used 1096.74 kWh. This would mean that 59% of his bill (646/1096.74*100) would be at the higher tariff and the remaining 41% would be at the lower tariff.
   c. These percentages with the tariffs above were used to cost the cooking session:
      i. 41% x 2.448 kWh x £0.03275 = £ 0.03287
      ii. 59% x 2.448 kWh x £0.06846 = £ 0.09888

The sum of these gave the total cost of cooking a whole roast dinner as £0.13

The tenant's bill showed that he had used 1096.74 kWh of gas over an 88 day period over from 19th May 2009 to 15th August 2009. Therefore 1096.7÷ 88 = 12.4625 kWh/day – this is the average kWh used each day. This would mean that the cooking of a roast meal (which the tenant did infrequently – he usually did not cook that much food or for that length of time) every day would only represent 19.6% (2.448÷12.4625 /100) of his total gas use that day.

The process was repeated over consecutive days using other types of cooking. These were:

a) Cooking food under the grill for 15 minutes: cost = £0.04p
b) Just using two rings on the hob for 20 minutes at a medium heat: cost = £0.06p
c) Baking a meal (just using the oven and not the rings) for 50 minutes at gas mark 6: cost = £0.07p

Figure 7.20: Extech SD200 unit

3. Establishing if "unbearable temperatures" are only reached during and just after cooking: To do this, Extech SD200 three channel temperature data loggers (temperature sensors, Figure 7.20) were put in place in this tenant's kitchen-lounge on the 20th December 2011. The sensors were to be there for over a week and so had to be placed at positions that were unobtrusive for the tenant (see Figure 7.21).

Sensor 1: was secured between the kitchen window and the sink, at the tenant's waist level when standing (this is 119cm from the floor) and this is also the tenant's head height when sitting at the dining table. This sensor was 190cm away from the centre of the cooker.

Sensor 2: at head-level by the cooker (185cm from the floor and 105cm from the centre of the cooker).

The sensors were set to record the temperature at these points every minute in degrees Centigrade. Alongside the temperature, the date, time, and the number of the reading were also automatically recorded.

Testing the Sensor units: before the tenant started cooking, it was ensured that the windows were kept closed along with the kitchen-lounge door and the front door. To test if the sensors were working, the readings were compared with that of a conventional thermometer: the readings were in agreement.

There was also a check to ensure that the temperature readings taken by the unit could be transferred to an Excel spread sheet on a PC.

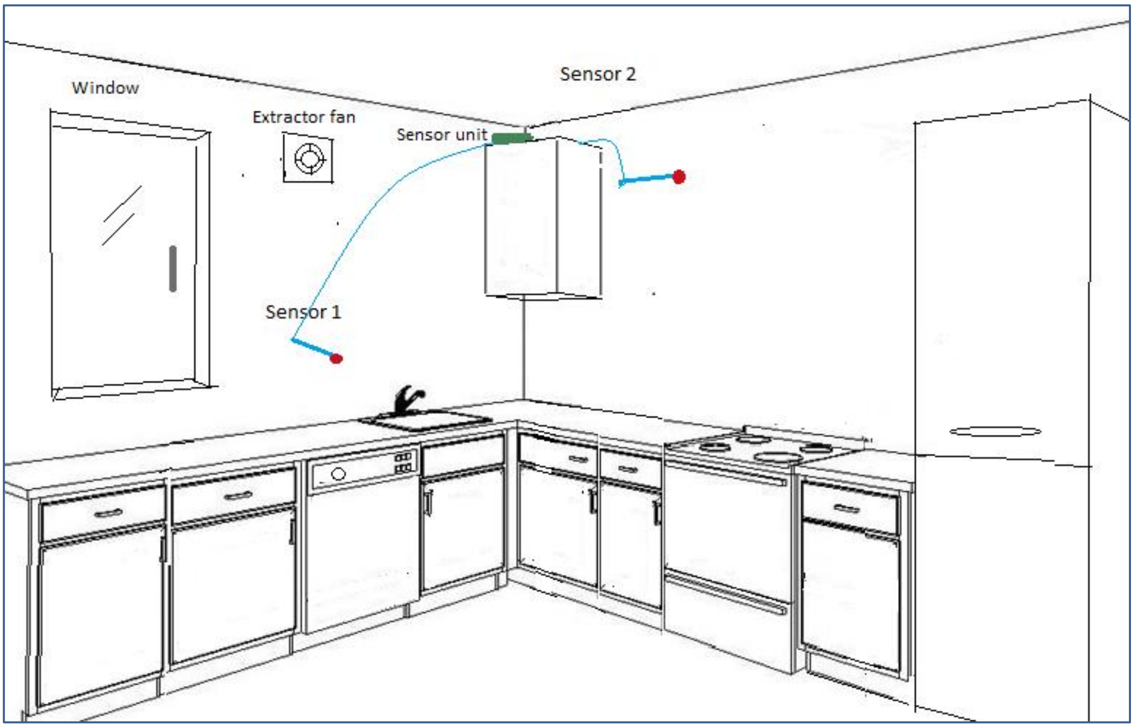


Figure 7.21: Layout of the kitchen area and the position of the sensors

Data Collection: data was collected over a 10 day period (the 2011-2012 Christmas holiday period). This period was chosen as the key researcher was available to conduct constant ethnographic research to ensure that the sensor units were operating correctly and to also record any events occurring in the kitchen-lounge that could possibly influence temperatures in the kitchen-lounge. The temperatures external to the flat were also noted. This was done so that the scope of the system could be established; that is, so that any factors, internal or external, could be ascertained which may:

- Contribute to unacceptable tempertures during cooking times and just after.
- Prevent temperatures becoming unacceptable during cooking and just after
- Contribute to unacceptable temperatures outside of cooking sessions.

a. ***Quantitative data collection:*** The sensor data was allowed to constantly record data over the 10 day period.

i. ***Ethnographic data collection:*** The events noted over a 10 day period were:

ii. Windows being opened and closed

iii. The extractor fan being turned on and off

iv. The kitchen-lounge door being opened and closed

v. The front door being opened and closed
vi. Candles being lit
vii. The heating being off and on at various times and being set at various levels.
viii. Many people being in the kitchen-lounge, sometimes bringing hot food
ix. The kettle or toaster being on
x. External temperature fluctuations
xi. Hot food (in a hot container) being taken out of the oven

The data from the sensors were then transferred to PC and then matched against the noted events.

No.	Date	Time	Waist level		Head level	
3407	23/12/2011	10:48:43	20.8	DEGREE C	21.7	DEGREE C
3408	23/12/2011	10:49:43	20.7	DEGREE C	21.7	DEGREE C
3409	23/12/2011	10:50:43	20.7	DEGREE C	21.7	DEGREE C
3410	23/12/2011	10:51:43	20.6	DEGREE C	21.6	DEGREE C
3411	23/12/2011	10:52:43	20.7	DEGREE C	21.5	DEGREE C
3412	23/12/2011	10:53:43	20.7	DEGREE C	30.7	DEGREE C
3413	23/12/2011	10:54:43	21.4	DEGREE C	36.2	DEGREE C
3414	23/12/2011	10:55:43	22	DEGREE C	37.6	DEGREE C
3415	23/12/2011	10:56:43	22.4	DEGREE C	40.1	DEGREE C
3416	23/12/2011	10:57:43	23.3	DEGREE C	40.5	DEGREE C
3417	23/12/2011	10:58:43	23.8	DEGREE C	40.8	DEGREE C
3418	23/12/2011	10:59:43	24	DEGREE C	41.3	DEGREE C
3421	23/12/2011	11:02:43	25.2	DEGREE C	42.4	DEGREE C

Table 7.15: Sample data from the sensors transferred to the PC

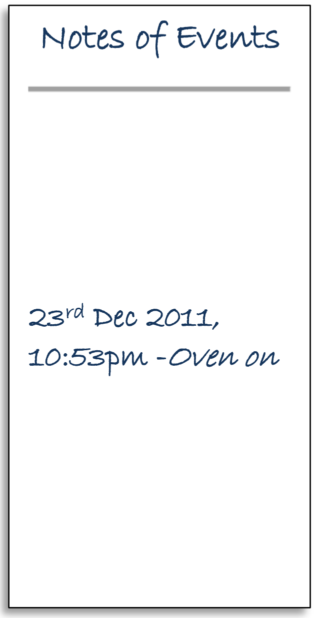


Figure 7.22: Event Notes

The data from the sensors and the notes were then analysed in Excel.

The whole procedure of collecting data from sensors was then repeated in August 2012 for 5 days: however, this time the events that were noted were solely when the cooker was turned on and off.

Findings:

- Temperatures over 25.4°C at waist-level do, indeed, only ever occur when the tenant is cooking or just afterwards. This suggests that outside and even internal temperature fluctuations do not have any significant impact on high kitchen-lounge temperatures; that is, there is no correlation between any of the events recorded (besides the cooker being turned on) and the unacceptable temperatures.

- Not every incidence of cooking produces unbearable temperatures: it does not occur when when one ring on the hob is turned on at a low heat for any length of time and it does not occur if two rings are on at a high heat for less than 11 minutes.
- During cooking, extremely high temperatures can, indeed, be reached. The maximum temperatures that have been reached (even with the extractor fan on, windows open and the living room door open in December 2011) are:
    - At waist level: 34.4°C
    - At head level: 49.9°C
- The length of time that temperatures over 25.4°C at waist level are reached can be for more than 1.5 hours – even with windows and doors open and the extractor fan on.
- The actual range of difference between the head-level temperature and waist-level temperature 15 minutes before the cooker is turned on (and at least 2 hours after any cooking has taken place) has been found to be never more than 1.2°C.
- There was no correlation between cooked food in a hot container adding to the temperature of the air. Although the temperature of a container when it was removed from the oven can be 119°C (as recorded with a temperature sensor) as soon as the cooker was turned off, the head-level and waist-level air started to drop in temperature. This is the same situation as when pans of food were cooking on the stove. For this reason, the effect of hot food and its container on the air temperature appears to be minimal. Therefore, the cooked food in its container is regarded as being an insignificant factor in causing excessive heat (at head–level and at waist-level). Also, there were many times over the Christmas period when people brought hot food to the tenant’s flat and this not correlate with waist-level or head-level temperatures reaching an unbearable level.

Conclusions:

1) **The actual temperature at which the tenant starts to find the atmosphere unbearable**

   This is established to be at 25.5°C at waist-level and at 27.6°C at head-level for this particular tenant.

2) **The extent to which cooking contributed to the tenants bills.**

   Cooking appeared to contribute less than 19.6% of the overall gas bill; the reminder of the gas bill is deduced to be due to the tenants other gas appliances which are the boiler (used for hot water and central heating). However, for other tenants who may have electric cookers, this situation may be quite different – their cooking may contribute significantly to their bills. Nevertheless, this particular tenant is expected to spend less than (£0.13x30 days) £3.90 per month on cooking - the tenant stated that he thought this was good value and that even if, for example, gas bills rose by 10% that he would only have to pay less than an extra £0.39 per month which would not be a concern to him. However, this did then bring into question how much he was spending on heating and hot water. To conclude, it appears that gas cookers are fairly efficient in heating food; this is to be expected as gas cookers provide a naked flame – little of the energy has to be transferred from one medium to another which is the case with electric cookers. For these reasons, the cost of cooking was not an issue worthy of further investigation in this field test.

3) **Whether this "unbearable" temperature and above is only ever reached and surpassed during and just after cooking – if "unbearable" temperatures were reached at other times then this would suggest that other factors contribute significantly to the high temperatures; that is, that they are not just to do with cooking and these other factors would require investigation.**

   The tenant's assertion that unaccepetable waist-level (over 25.4°C) and head-level (over 27.5°C) temperatures are produced which only occur during cooking times and just after has been confirmed. Also, the length of time these unnacceptable temperatures are produced can be up to 1.5 hours (despite any other external and internal events). Therefore, the system that produced these unacceptable temperatures appeared to be solely that of cooking.

Not every incidence of using the cooker raises the waist-level temperature above 25.4°C: sometimes the hob is on only briefly and/or at a low level and the waist-level and head-level temperatures do not reach this “unbearable” level.

The ceiling is low and can become excessively hot during cooking This is an issue because the tenant’s height can mean that, when standing and walking around the lounge-kitchen, there are times when he is breathing in air which is very hot – a maximum of 49.9°C has been recorded at the head-level.

4) T**he system to be investigated:** is that of the temperature of the kitchen-lounge whilst the cooker is on just after.

Limitations of the Problem Definition:

The field test has only focussed on one tenant: the “unbearable” temperatures only relate to this particular tenant and the field test has only focussed on his flat. If the issue is to be considered further to, for example, redesign new flats or refurbish existing flats other than that in the field test, it is recommended that other flats are investigated and other tenants’ heating preferences ascertained.

7.4.4 Application of the Quantitative SIU Method

STEP 1: Problem Definition

A primary Service Blueprint showing the side-effect of the current cooking capability to adversely increase room temperature was created (Figure 7.23) - the parameter values are added later.

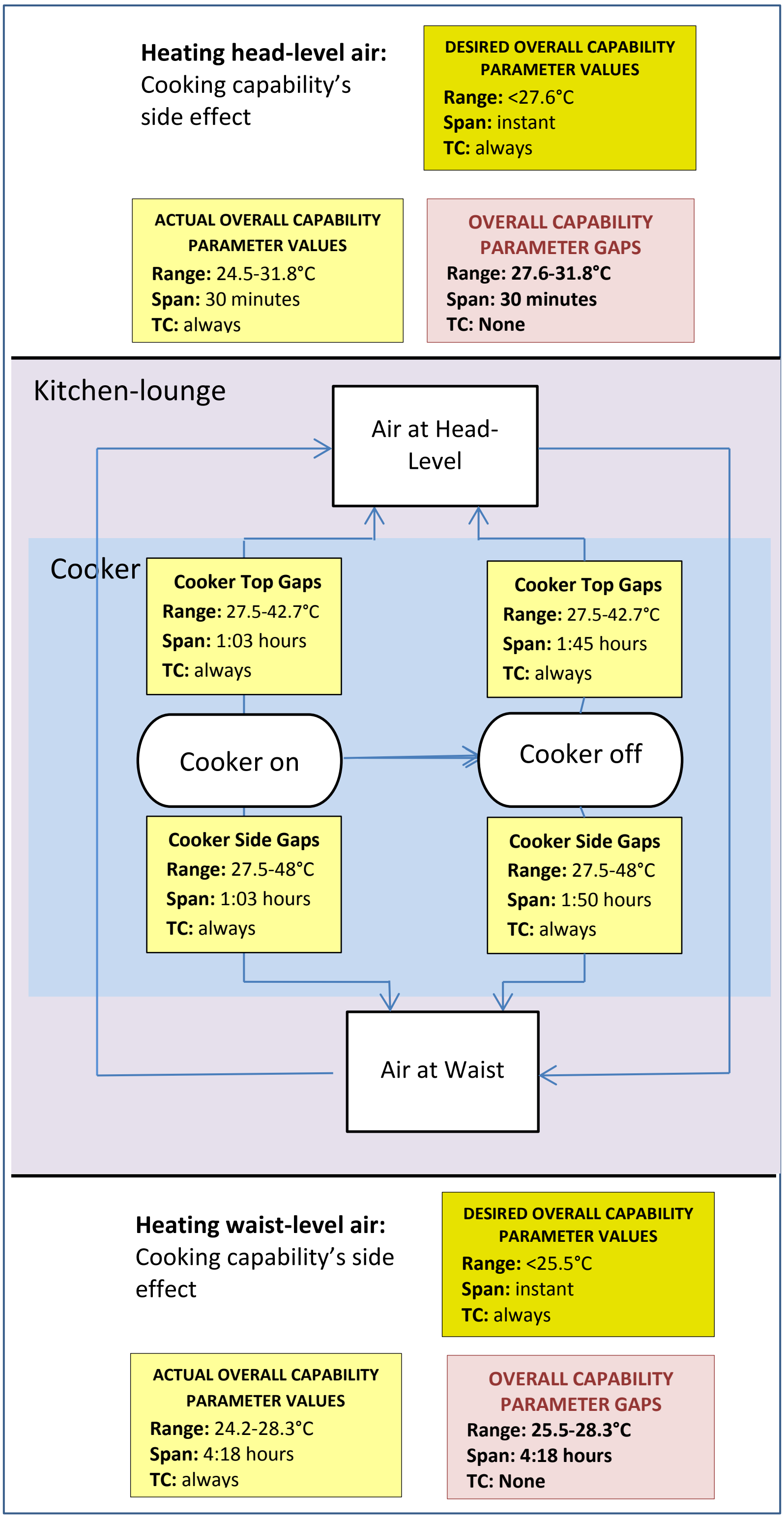


Figure 7.23: Service Blueprint of the cooking capability and its side-effect of heating the air (during cooking and after)

STEP 2: Find the Overall Capability Parameter Gaps

Here, the Desired and Overall Capability's parameter values were defined. From the difference of these values, gaps in the Overall Capability are reckoned.

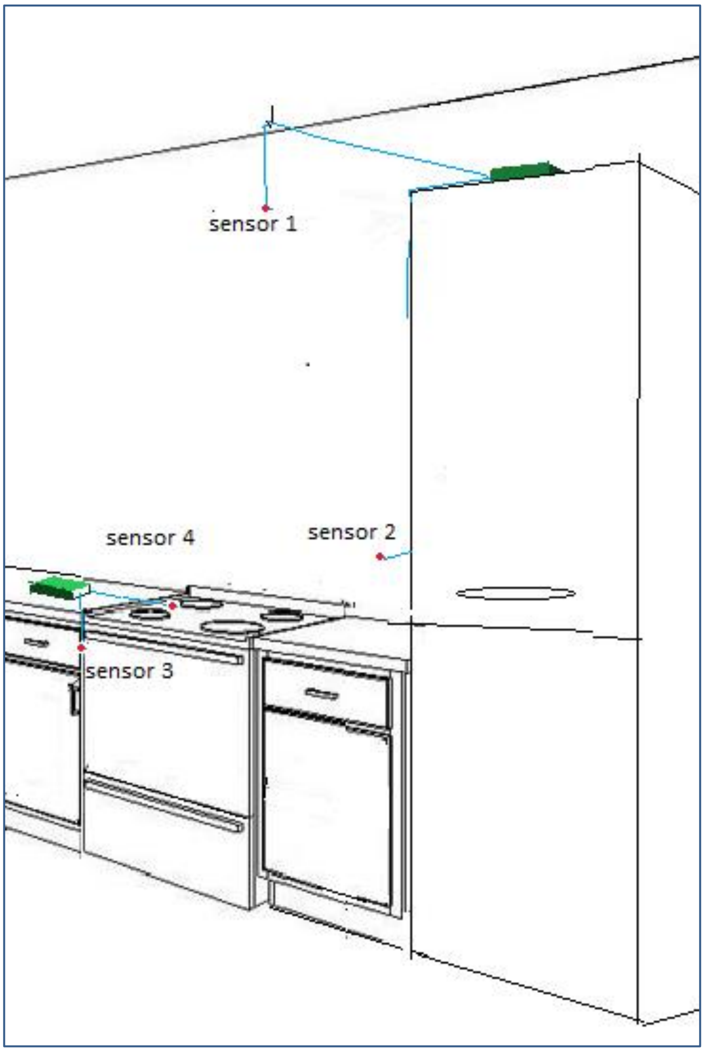


Figure 7.24: The position of the sensors

Exact data was required regarding the extent of the heat released during and after cooking. To accomplish this with minimum inconvenience to the tenant, four instances of cooking (roasting, grill on, rings on, roasting and rings on) were recorded and, for each instance, the window, front door and living room door were kept closed and, the extractor fan was on for the duration of cooking. One typical instance of cooking is depicted here. This is the roasting of meat and vegetables that took place on 20th September, 2012. To determine the exact temperatures that are reached during this cooking episode (and afterwards), the following method was used:

Placement of Sensors (Figure 7.24):

1. At the head-level (185cm from the floor and 135cm from the top of the cooker which has a height of 105cm) over the centre of cooker,

2. At waist- level (119cm from the floor and 30cm from the centre of the cooker which has a width of 49cm)

3. Touching the cooker at the hob between two rings

4. Touching the side of the cooker, 10 cm from the top of the cooker and 24.5cm from the side

For the course of the experiment, the windows were kept closed, the kitchen-lounge door was kept closed and the front door was not opened. This was to minimise the impact of any events upon temperatures during cooking. It was apparent that, even after cooking, the air remained quite hot for some time. To determine how hot the cooker remained even after cooking, sensors were placed on it to gauge this.

The readings were checked half an hour before cooking started for constant temperature readings (fluctuations of less than a degree) – these were recorded. This was the ambient temperature before cooing commenced.

Cooking a roast dinner: This experiment was conducted at three different times on three different dates – each experiment produced the same results within a one degree difference: the oven was turned on at Gas Mark 6 and the extractor fan was turned on after 5 minutes. The food in a roasting dish was placed in the oven. Altogether, the oven was left on for 55 minutes (from 8:40:43am to 09:35:43am). The food was then taken out of the oven and the temperature of the roasting tin was taken. The food was plated and the roasting tin placed in the sink and filled with water. The extractor fan was turned off. The data from the sensors and the times that the cooker was on and off as well as the time that the roasting tin was taken out of the oven along with the temperature of the roasting pan were then transferred to the PC for analysis:

Findings:

1. **Actual Waist-Level Temperature:** the actual range of the waist-level air during cooking was ***(range) 24.2-28.3°C***. The number of minutes that the waist-level temperature was over 25.4°C was calculated as the span of the actual overall waist-temperature which was (***span) 4hrs 18 minutes***. When the oven and rings are on at this gas mark and for this length of time, this range of temperature always occurs – this therefore gives this actual waist-level temperature time-cycle as being ***(TC) always***.

2. ***Desired Waist-Level Air:*** It has been established that the desired temperature that the tenant would like the waist- level air to be is less than 25.5°C (**range**) and for this to always be the case **(time-cycle)** . Furthermore, even though temperature fluctuations may occur, the tenant desires the waist-level temperature to instantly **(span)** revert back to being less than 25.5 °C. Note that the ideal temperature for the tenant has not been established – only the maximum temperature that the tenant can bear.
3. **Actual Head-level Temperature:** The actual range of the head-level air during cooking is ***(range) 24.5-31.8°C***. The number of minutes that the head-level temperature is over 27.6°C is calculated as the span of the actual overall head-temperature which was ***(span) 30 minutes***. When the oven is on at this Gas Mark and for this length of time, this range of temperature always occurs – this therefore gives this actual head-level *temperature time-cycle as* ***(TC) always.***
4. ***Desired Head-Level Air:*** It has been established that the desired temperature that the tenant would like the head- level air to be is less than 27.6°C (**range**) and for this to always be the case **(time-cycle)** . Furthermore, even though temperature fluctuations may occur, the tenant desires the waist-level temperature to instantly **(span)** revert back to being less than 27.6°C .

Conclusions:

As cost has not been deemed an issue, this is not depicted as a parameter.

- **Overall Waist-level temperature gaps:** the range that is actually above the maximum desired temperature of 25.4°C gives the overall waist–level temperature gaps as **25.5-28.3°C**. The length of time that this lasted for was **4:18 hours – this is the span gap**: that is, the effect lasted 4:18 hours more than desired.
- **Overall Head-level temperature gaps:** the range that is actually above the maximum desired temperature of 27.5°C gives the overall head–level temperature gaps as **27.6-31.8°C**. The length of time that this lasted for was **30 minutes – this is the span gap**: that is, the effect lasted 30 minutes more than desired.

STEP 3: Find the Gap-Located Capability(s) Within the System

Here, each of the Desired and Actual sub-capability's parameter values were defined. From difference of these values, gaps are located in the sub-capabilities.

As soon as the cooker was turned off, the head-level and waist-level air start to cool. This would indicate that the cooker being turned on (a naked flame) is the major contributing factor in over-heating waist and head level air. As there is a distinct correlation between the temperatures that the side and top of the cooker reach and the head-level and waist-level air temperatures (Figure 7.25) – this would indicate that during cooking and just after, the temperature of the cooker contributes to the temperature of the waist-level air and head-level air.

If, during the oven being on, the cooker (its top and side) could be kept to a temperature that is nearer to the temperature it is before cooking commences (given a leeway of, say, no more than 2°C more than the maximum desired waist level temperature), then this could substantially reduce the head-level and waist-level air becoming so hot.

Cooker on

Parameter	Desired Capability Value	Actual Capability Value	Capability Value Gap
Range	<27.5°C	24.2-42.7°C	27.5-42.7°C
Span	instant	1:05 hours	1:03 hours
TC	always	always	always

Table 7.16: Cooker's side temperatures (when the oven is on)

Parameter	Desired Capability Value	Actual Capability Value	Capability Value Gap
Range	<27.5°C	24.2-48°C	27.5-48°C
Span	instant	instant	1:03 hours
TC	always	always	always

Table 7.17: Cooker's top temperatures (when the oven is on)

Cooker off (just after cooking)

Parameter	Desired Capability Value	Actual Capability Value	Capability Value Gap
Range	<27.5°C	24.2-42.7°C	27.5-42.7°C
Span	instant	1:05 hours	1:45 hours
TC	always	always	always

Table 7.18: Cooker's top (when the oven is off)

Parameter	Desired Capability Value	Actual Capability Value	Capability Value Gap
Range	<27.5°C	24.2-48°C	27.5-48°C
Span	instant	instant	1:50 hours
TC	always	always	always

Table 7.19: Cooker's side (when the oven is off)

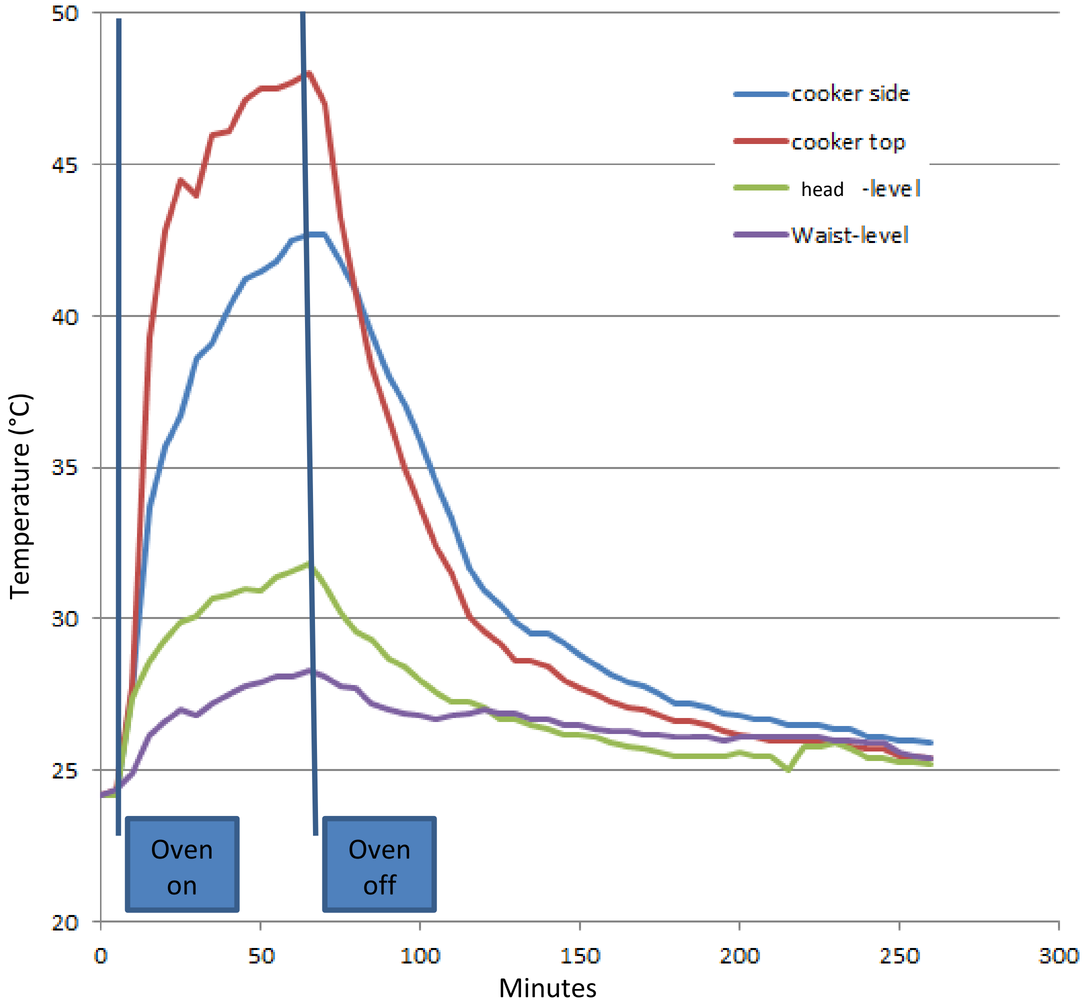


Figure 7.25: Cooker, Head Level and Waist Level Temperatures

Determine the Gap-Located Capability(s):

These are the offending capabilities. That is, they are the sub-capabilities that contribute to the gaps in the Overall Capability:

1. The cooker being on (and just after) - the waist-level and head-level air only ever reach unbearable temperatures when the cooker is on (and just after it has been on).

2. The local environment - even after the cooker has cooled, the waist-level air remains at unbearable temperature for about 2.5 hours afterwards. It is the local environment – the lounge-kitchen (rather than the wider environment) that is responsible for this as, if the there was no building structure in place to contain the air; the hot air would immediately disperse.

STEP 4: Corroborate the System Definition:

At the time of the study the housing association could not release the manpower to examine the findings. However, these findings were shown to two experts in heating and ventilation systems who have dealt with similar issues: they suggested that it could be the boiler that is the source of heat and, that hot air rising during cooking could leave cooler air to trigger the boiler. As the boiler had had no sensors placed on it, this had to be tested for. The cooking of a roast chicken meal was repeated in September 2012 and the boiler was turned off. The same temperatures at waist and head level were reached which meant that boiler activity was not a factor in this system.

The findings were also presented to an expert in civil engineering for his opinion. He examined the findings and concluded that these high head-level temperatures, by air currents mixing the air, could contribute heavily to the heat of the waist-level air and the length of time that the air remains hot. As the tenant's ceiling is low, this is expected to happen whenever, for example, the tenant moves round the room. He also suggested that it could be the dimensions, construction and/or ventilation system of the kitchen-lounge which could be containing the air and allowing the hot air to accumulate; such an assessment could mean that the local environment could have a significant impact upon the air temperature.

The findings were also compared to recommended indoor temperatures:

- ***Directgov*** is the UK government's digital service for people in England and Wales and it provides a single point of access to public sector information and services - It recommends that living rooms should be heated to around 18-21°C (64-70°F).

(http://www.direct.gov.uk/en/HomeAndCommunity/InYourHome/KeepingSafeAtHome/DG_10027755).

- ***TUC (Trades Union Congress)*** is a national trade union centre, that is, a federation of trade unions in the United Kingdom which represents the majority of trade unions. Their website (http://www.tuc.org.uk/workplace/tuc-12183-f0.cfm) states that "*The TUC has called for a maximum temperature of 30°C (27°C for those doing strenuous work), so that employers and workers know when action must be taken. It should be stressed that this is intended as an absolute maximum rather than an indication that regular indoor work at just below 30°C would be acceptable. Employers should still attempt to reduce temperatures if they get above 24°C and workers feel uncomfortable*."

From this, it does appear that the temperatures which are reached during and just after cooking can be far above those which are deemed to be comfortable temperatures.

STEP 5a: Operand-Operant Decomposition of a Gap-Located Capability:

Decompose the largest gap located capability into its operand and operant resources. The environment (the local and wider environment) is an enveloping capability that can, simultaneously, both accommodate and restrain many disparate capabilities that take place within it – it can have a negative or positive impact on many capabilities. As the hot air is contained by the local environment (the kitchen-lounge), the problem-space can be divided into two capabilities:

1) The cooker being on (and just after) which is the gap-located capability. The stakeholder who currently controls this is the tenant.
2) The environment of the flat – this has an impact on where heat collects (for example, more towards the ceiling) and how heat is dispelled (for example, through the extractor fan). This is under the control of the housing association (specifically, the maintenance staff and the architect and civil engineer).

Each of these capabilities can be decomposed into its constituent parts of: operant resource (the resource that is worked upon to produce an outcome), the operand resource (the resource which does the work) and the process by which the operand resource changes the operant resource (Figure 7.26).

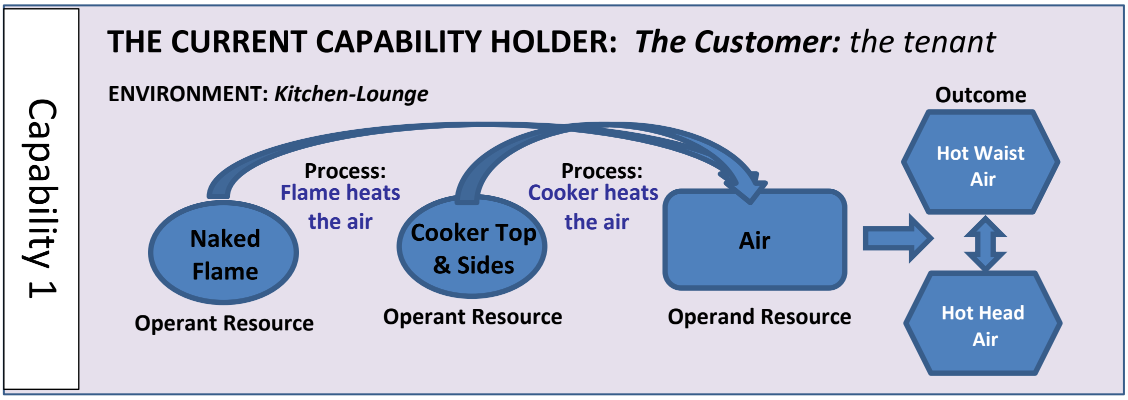


Figure 7.26: The Operand-Operant Diagram of the Cooker Capability

STEP 6a: Determine the Stakeholders and Their General Roles

Tenants: Some of the tenants (those who were interviewed for this field test) have serious medical conditions. Their needs are for comfortable housing which is convenient (that is, close to amenities they require). At the moment, it is the tenant who is responsible for the cooker that they place into the flat. As for the flat, it is the housing association which is responsible, ultimately, for the environment that is, the design, maintenance and refurbishment of the flats themselves.

STEP 7a: Compare the Capability to Other Similar Capabilities

To help generate solutions, comparisons across data sets can be made (if such data is available) for other similar capabilities where the gaps do not appear. Alternatively, qualitative comparisons can be made. In this case, only one kitchen-lounge in this block of flats was studied in detail; no data had been collected on any other similar kitchen-lounge were these gaps do not appear. However, it is known that microwaves emit less very little heat as compared to cookers and so this could be one possible solution.

STEP 8a: Propose Solutions

Apply a Proposals Matrix to the gap-located capability (Table 7.20) - each element in the decomposition diagram (operant resources, operand resources and the process that the operant resource uses to change the operand resource) is considered in turn for redesign. The application should be done with the help of other stakeholders and/or experts in that capability and process. For this case study, although the housing association was not available, two kitchen appliance sales store managers from two nationwide kitchen specialist retail companies were consulted. Each type of solution generated is then estimated as to the extent that it should close the gaps (High, Medium, Low). If a solution cannot be generated for a particular type of redesign then "N/A" (Not Applicable) can be stated. The solutions are then accepted or rejected by the stakeholder in question – the accepted solution(s) are then highlighted in red.

The Tenant

Types of Generic Change	Decrease in gaps		UNBEARBLE HEAT DURING COOKING - STEPS THE TENANT CAN TAKE
	RANGE	SPAN	
1) NEW CONCEPTUAL DESIGN	**High**	**High**	A new conceptual design (a new system) for tenants to have hot meals could be provided by meals on wheels or the tenant buying takeaways. This would totally remove the need to cook. Rejected - the tenant wants to cook his own food.
2) CHANGES REGARDING THE DESIRED PARAMETER(S) OF THE GAP(S) OF THE OFFENDING CAPABILITY			
a) MARKET SEGMENT/ RECEIVER SHIFT	**Low-High**	**Low-High**	The receiver here is the tenant – if the tenant suffers from the heat, the tenant could move to more suitable accommodation. Rejected – the tenant does not want to move.
3) CHANGES REGARDING THE OFFENDING CAPABILITY:			
a) SUBSTITUTE	**High**	**High**	**Operant (Naked Flame), Operant (Cooker)** – substitute the gas hob with an induction hob (these hobs are energy efficient and they do not heat the air – they heat the pan only). Special pans are needed for this. Positive side effects are that cooking time can be twice as fast as compared to conventional hobs and the possibility of burns are reduced which could benefit some types of disabled tenants as well as those with children. A negative side effect is they can also be noisy when more than one cooking zone (ring) is in use which could be an issue for an open plan kitchen-lounge. Another negative side effect is that because of the powerful electromagnetic field, induction cooking may not be suitable if the tenant (or any of their visitors) has a pacemaker fitted. For this reason, the tenant rejected this option.
	High	**High**	**Operant (Naked Flame), Operant (Cooker)** - halogen ovens could be used instead – these can cook food in about half the time and the casing can be cool to the touch which means that the oven would not continue to heat the air. A disadvantage is that the tenant would have to get used to a new way of cooking and halogen ovens do not have the capacity of traditional ovens – tenant rejected this idea.
	Low-Med	**Low-Med**	**Operant (Cooker) -** Substitute the Creda Capri for another gas cooker that emits less heat.
b) ELIMINATE	**High**	**High**	**Operant (Cooker) -**To eliminate the hob and oven, a microwave could be used instead – these do not heat the air and cooking time is drastically reduced. The tenant did not find this to be a generally acceptable way of cooking – rejected.
c) ADDITION	**Med**	**Med**	**Operant (Cooker) –** an air conditioning device could help to cool the air.
d) CUSTOMISE	**N/A**	**N/A**	There would appear to be no way to customize any of the elements of the capability to close these gaps.
4) ENVIRONMENTAL CHANGE			
a) CHANGE LOCAL ENVIRONMENT	**High**	**High**	This is defined here to be the area around the cooker: the gap in temperature range in this capability is produced by air being heated. Therefore, a way to treat this gap could be the addition of a cooker hood – this would remove most of the hot air. Other positive side effects could be a decrease in humidity as well as cooking odours as well as carbon monoxide. However, cooker hoods can be noisy. The tenant found this option acceptable.
b) CHANGE WIDER ENVIRONMENT	**N/A**	**N/A**	This is defined here as the kitchen-lounge: this is one part of the problem-space; that is, it is a separate capability that would affect the waist-level and head-level temperatures.

Table 7.20: The Proposals Matrix applied to the cooker capability

STEP 10: Next Tier?

Although the tenant can change the cooker, besides opening the windows and doors, there is little they can do to change the environment which dictates the way hot air collects within the kitchen-lounge. This capability belongs to the housing association who supplied the flat and those who work for it. This is to be explored to gauge how changes could be made to the kitchen-lounge room.

STEP 11: Increase the Tier by 1:

The Tier now becomes equal to 1: *The Housing Association*

STEP 6b: Operand-Operant Decomposition of a Gap-Located Capability

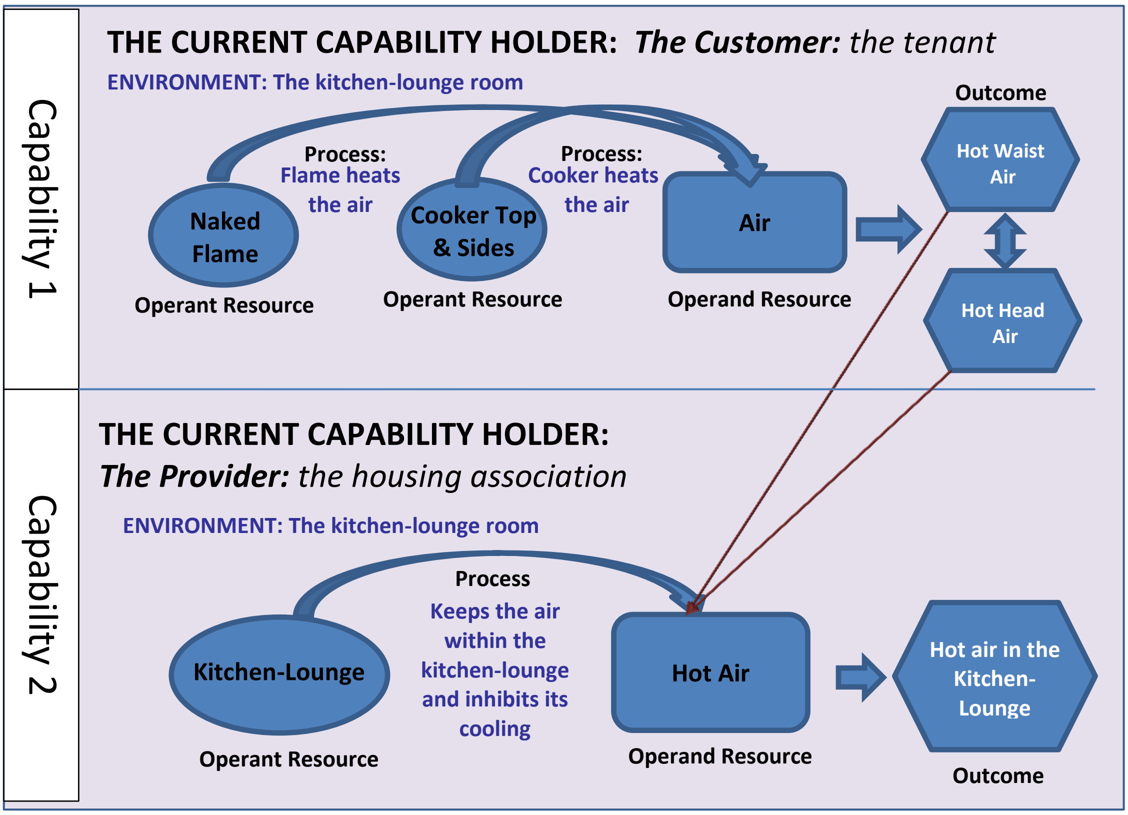


Figure 7.27: Operand-Operant Diagram of the kitchen-lounge Capability to retain hot air

STEP 7b: Determine the Stakeholders and Their General Roles

The Community Housing Association

One remit of the housing association is to provide people who are seriously ill with accommodation which is well placed (such as near to a doctor's surgery, pharmacy, hospital and shops) and for this accommodation to be affordable as well as comfortable for the tenant. The building of flats and houses are often performed by property developers who, instructed by the housing association, then make use of architect, civil engineers and builders. This information was gathered by the key researcher for this field test being invited to and attending a housing association's resident's meeting at which two housing association representatives were present.

In order to ensure that the existing apartments meet the needs of the current tenants and to inform the design of new apartments, the housing association gathers information from their tenants through surveys and by holding resident association meetings. Both forums allow the tenants to state any problems and make suggestions.

The housing association maintains and periodically refurbishes the accommodation it offers; for this it employs maintenance staff and experts such as civil engineers as well as builders who execute the designs.

STEP 8b: Compare the Capability to Other Similar Capabilities

It was known that if the kitchen is separate from the lounge, then kitchen temperatures should have little impact on lounge temperatures.

STEP 9b: Propose Solutions

The changes regarding the kitchen-lounge capability (see Table 7.21) were created with the help of a civil engineer and architect.

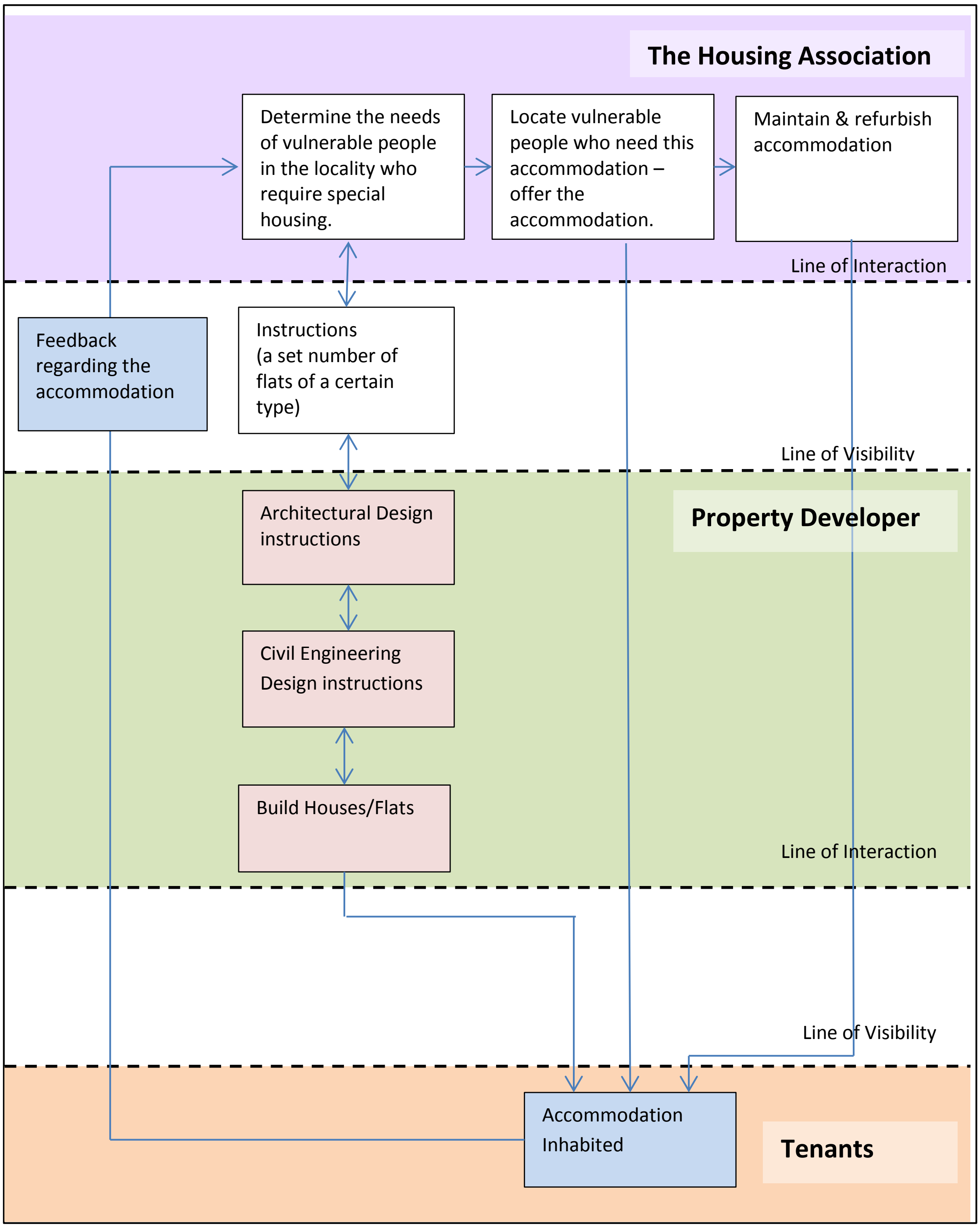


Figure 7.28: The stakeholders of this case study

Generic Change Types	Decrease in gaps		UNBEARBLE HEAT DURING COOKING - STEPS THE HOUSING ASSOCIATION CAN TAKE
	RANGE	SPAN	
1) NEW CONCEPTUAL DESIGN ARCHITECT & CIVIL ENGINEER	High	High	**Operant Resource (Kitchen-Lounge):** For new flats, the kitchen area could be architecturally designed as a separate room. This would probably increase the foot print of the flat and each new room would probably feel smaller – the cost of the build would probably also increase. Because of these repercussions this may not be an acceptable solution.
	Med -High	Med -High	**Operant Resource (Kitchen-Lounge):** For new flats, the architectural design could involve the kitchen and living area being partitioned at the head level only by using a decorative arch that can span from the walls of the room and could add aesthetic appeal to the room. The hot air rising towards the kitchen ceiling will be prevented from moving along into the living area and will be more confined to the kitchen area where it can be extracted out. This solution would need to be verified by measuring the temperature variation along the ceiling to see how it varies along the ceiling, with and without an arch.
	Low-Med	Low-Med	**Operant Resource (Kitchen-Lounge):** Higher ceilings or larger kitchen-lounges could help to disperse hot air. However, this could result in higher build costs.
	Low-Med	Low-Med	**Operant Resource (Kitchen-Lounge):** For new flats, the architectural design could involve sliding doors which separate the kitchen/cooking area.
2) CHANGES REGARDING THE DESIRED PARAMETER(S) OF THE GAP(S) OF THE OFFENDING CAPABILITY			
a) MARKET SEGMENT/ RECEIVER SHIFT	N/A	N/A	The property developer would most likely want to continue working for such an important customer as the housing association and It is unlikely that there would be a specialist property developer that could tackle the problem any better.
3) CHANGES REGARDING THE OFFENDING CAPABILITY:			
a) SUBSTITUTE MAINTENANCE STAFF	Med -High	Med -High	**Operant Resource (Kitchen-Lounge), Process:** Substitute the existing ventilation with heat recovery ventilation – also known as a heat exchanger, air exchanger or air-to-air exchanger, is a ventilation system that employs a counter-flow heat exchanger between the inbound and outbound air flow. Heat recovery ventilators (HRVs) recover the heat energy that would normally escape, and transfer the heat to fresh air as it enters the building. However, given the actual short time durations of cooker use, the amount of energy saved will probably not justify installing a system of such complexity.
	Med -High	Med -High	**Operant Resource (Kitchen-Lounge), Process:** Substitute the extractor fan for a more powerful fan.
b) ELIMINATE	N/A	N/A	**Operant Resource (Kitchen-Lounge), Process:** The only way to eliminate hot air being contained in a small space would be to open that space to the elements.
c) ADDITION MAINTENANCE STAFF	High	High	**Operant Resource (Kitchen-Lounge), Process:** A cooker hood could be installed into each of the flats – this solution also changes the local environment
d) CUSTOMISE CIVIL ENGINEER	Low	Low	**Operant Resource (Kitchen-Lounge), Process:** An arch could be added to existing flats. However, this may be very difficult to accomplish given the current configuration of existing flats.
	Low	Low	**Operant Resource (Kitchen-Lounge), Process:** Sliding doors could be fitted to seal off the kitchen area to reduce the heat from the cooker after cooking has taken place. The extractor fan may need to be moved to behind the sliding doors. However, it may difficult to customize existing flats and this would take away the feeling of openness and spaciousness of the living room.
4) ENVIRONMENTAL CHANGE			
a) CHANGE LOCAL ENVIRONMENT MAINTENANCE STAFF	Med	Med	This is defined as the flat in general: the door to the kitchen-lounge could be removed which would give hot air more room to disperse. However, this would then mean it would cost more to heat the room.
b) CHANGE WIDER ENVIRONMENT	N/A	N/A	There would appear to be no changes that could be made by the civil engineer to the wider environment which would to close these gaps

Table 7.21 The Proposals Matrix applied to the kitchen lounge

STEP 10b: Next Tier

No further Tiers are required to be examined.

STEP 12: Rate and Select Solutions

1. **The Cooker Capability:** The tenant in the field test flat commented that, although he had noticed that his kitchen-lounge becomes hot, he had not realised exactly how hot it can become until the findings from this study was presented to him and he was quite alarmed by the negative effect it may have on his health.

   This tenant in the field test was interested in the cooker hood solution. It should be noted that although the tenant can institute this change, the housing association could also consider adding such solutions to their flats as this could improve their offering as this would augment the PSS that they offer to vulnerable people. The tenant was particularly interested in the cooker hood solution if the housing association would purchase, install and maintain it.

   This field test findings and the Proposals Matrix was presented to the other two tenants who were originally interviewed; these tenants expressed their appreciation of this study. They had not realised exactly how hot their kitchen-lounges can become or the length of time that such heat can linger. Each of them expressed a belief that this contributes to their ill-health and a general feeling of malaise. They also expressed appreciation for the range of solutions that they can now consider. Nevertheless, all of the possible solutions from this Matrix were rejected by these two tenants – two of the tenants thought that a cooker hood would take up too much space and be too noisy for a small area.

2. **The Kitchen-Lounge Capability:** This Proposals Matrix was shown to the three tenants who were interviewed. They all favoured the solution of the housing association substituting their current extractor fan with one that is more powerful-this could be fairly easily and quickly accomplished by the housing association's maintenance staff.

The solutions would have to be selected or rejected by the housing association; it could well be the case that the housing association would have more pressing concerns to address. Nevertheless, this study could help to inform the future designs of new builds. The housing association (specifically, the maintenance staff, the architect and civil engineer) will need to ascertain if instituting any changes will impact upon any other capabilities or the aesthetic appeal of the flats.

7.4.5 Results

Notes were taken during the three validation sessions and these were written up by the author of this thesis and then presented back to the Validators. Revisions suggested by the Validators were then incorporated into this text; this happened several times until the Expert Validator deemed that no more revisions were necessary. The Validators' responses to questions regarding the validation are detailed in Appendix L.

The Tenant

The tenant believed that he would not have been able to explore various solutions to his problem so thoroughly without the SIU Method. He also stated that he had applied the SIU Method to a non-engineering problem (a teaching issue) with favourable results.

The Expert Civil Engineer

The SIU Method was found to be complete and to be reasonably easy to apply. The Civil Engineer did not know of any other method which could systematically produce such a wide range of solutions which consider each aspect of a system, especially those solutions which were particularly innovative.

The HVAC Consultants

The HVAC engineers tend to use their intuition as informed by their considerable experience of HVAC systems to solve client issues. They found the SIU Method useful in that it all steps in problem identification and solution generation are systematically covered – none can be accidently left out. They also found the method useful for knowledge transfer (between colleagues) about a client issue.

7.4.6 Application Conclusions

The solutions produced in this particular field test help to improve an existing product-service system (flats for rent) that are offered by a housing association: it does this by improving the use value that the tenant (the customer) would experience. This could be important for the housing association as one remit they have is to provide suitable rental accommodation for people who are or who have had serious illnesses: if this is not achieved then it could be the case that tenants may move and/or that the housing association's funding body could withhold funding.

7.5 Validation 4: A Truck Driving Instruction Case Study

A Qualitative Push Application of the SIU Method

7.5.1 Introduction

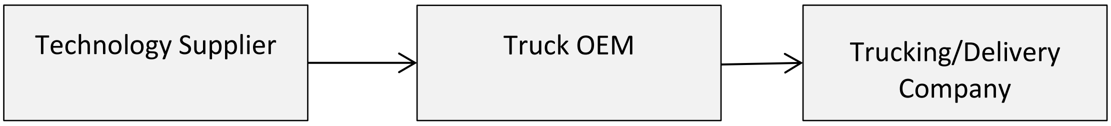


Figure 7.29: The value chain in this trucking instruction validation case study

A Technology Supplier to a Truck OEM had expressed interest in the SIU Method. Their usual procedure for generating new conceptual technologies and services is based upon their considerable expertise in computing, electronic and mechanical engineering, telecommunications and sensor technology and it starts with idea generation at their annual customer advisory group; the analysis and depiction of the issue that is performed by the SIU Method tends not to be performed by this company. Furthermore, the ideas that they generate and select tend not to be systematically compared with other possible solutions that could also satisfy that need of the customer. This is usually not a problem for them as the company is small and very client-facing. However, in the future, there could be times when they have to partner with other organisations for solution generation, assessment and development so a more structured method could be useful to them in those instances in order to share information across company boundaries.

Usually, the Technology Supplier starts the process of innovation by holding their annual customer advisory group from which suggestions are generally made by the customers with regards to how new products and services or the customisation of existing ones could fulfil their needs. However, there can be occasions when this happens in reverse where the Technology Supplier has an idea of how a technology or service could enhance their customers' processes. Receivers are often unaware of how new offerings (particularly new technology and business models) can improve their processes so it can be for providers and suppliers to demonstrate this. In such instances, it would be important for the Technology Supplier to have a method to fully detail (in a way that could be understood by the customers) how that technology could actually enhance customer processes above other solutions. Furthermore, that method should also allow any customer to perform those calculations and estimations based on their exact processes to further assess such a solution.

What follows next is an application of the Qualitative Version of the SIU Method to an example scenario where the actual starting point is where the Technology Provider has a solution in mind that they deem could greatly improve a certain process of their customers. Using the SIU Method in this way represents a *push* strategy rather than the *pull* strategies of enhancing systems in the previous case studies.

7.5.2 Method

This is depicted in Figure 7.30 and Figure 7.31. The paler grey areas represent data collection from the respondents.

1. A literature review on themes related to the study had been conducted before the investigation at the companies.
2. The truck OEM's UK head office was visited where a 'walkthrough' of main processes were conducted with a senior manager.
3. Five exploratory interviews were conducted with five senior engineering and business managers in the truck OEM over the course of seven hours. At each exploratory interview, the aim of the research (as presented in Chapter 1) was presented and then a semi-structured, exploratory interview was conducted to discover their AS-IS practice for using field data to influence PSS Conceptual Design.

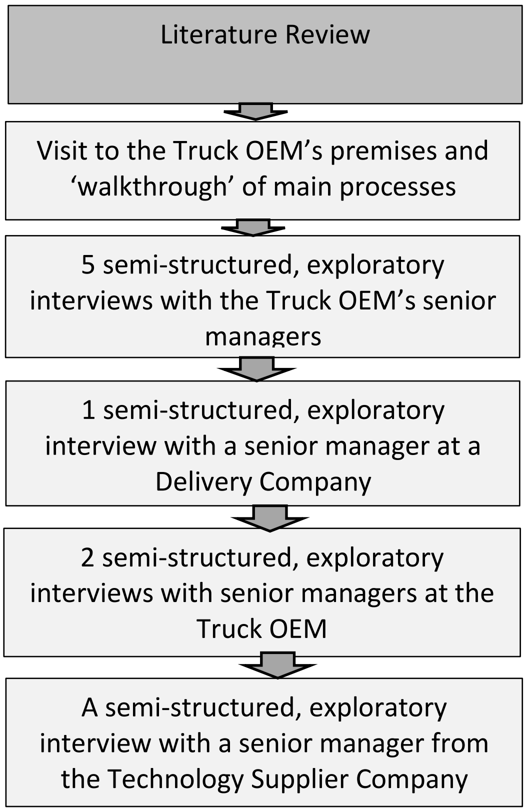


Figure 7.30: The background research - the Truck OEM, their customer and supplier.

Each interview was recorded then later transcribed and the findings were used for the investigation as described in Chapter 4.

4. After the SIU Method had been devised (see Chapter 6), a customer of the Truck OEM (which is a delivery company) was visited where the aim of the research (as presented in Chapter 1) was presented and then a semi-structured, exploratory interview (See Appendix M for the questions) was conducted with a senior manager to source possible case studies to apply the SIU Method to in order to assess the method's merits and demerits.
5. After the SIU Method had been devised (see Chapter 6), a Technology Supplier Company to the Truck OEM was visited. The meeting was attended by a senior manager of the Technology Supplier Company and two senior managers from the Truck OEM. The aim of the research (as presented in Chapter 1) was presented as was an overview of the SIU method (as previously outlined in Chapter 6). Then a semi-structured, exploratory interview was conducted with the senior managers from the Truck OEM (See Appendix N for the questions) to discover their AS-IS practice for using field data to influence PSS Conceptual Design. Each interview was recorded and then later transcribed and, again, the findings were used for the investigation as described in Chapter 4. They were also asked about possible case studies to apply the SIU Method to (these questions are also in Appendix N).
6. Then a semi-structured, exploratory interview was conducted with the senior manager from the Technology Supplier Company (See Appendix O for the questions) to uncover their AS-IS process for using field data to influence PSS Conceptual Design. The manager from the Technology Supplier Company was also asked about possible case studies to apply the SIU Method to (these questions are also in Appendix O). The interview was recorded and then later transcribed.

7. The senior manager at the Technology Supplier Company had expressed particular interest in the SIU Method. A teleconference was held with this manager to assess various cases that had been elicited in the previous interviews against which the SIU method could be validated. Any case study selected had to be a non-sensitive issue to the companies involved where the sharing of case information outside the companies would not compromise the proprietary knowledge of the companies involved. A case study was selected where this was the case and which would allow for the evaluation of the SIU Method against the way that the Technology Provider Company usually addresses such issues.

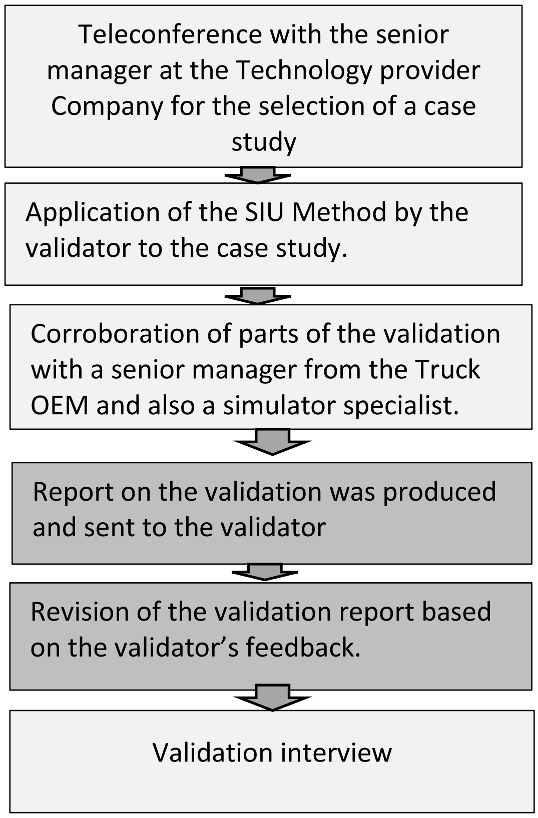


Figure 7.31: The Methodology for the validation of the instruction case study

8. The SIU Method was then applied by the validator to the selected case study. Notes were taken by the researcher during this time.
9. Parts of the validation were corroborated by a senior manager of the Truck OEM and by a Simulator specialist who is employed as a senior academic and also as a consultant in companies that produce simulators.
10. A report on the validation (the application of the SIU Method) was produced and sent to the validator.
11. The report was revised in the light of the feedback from the validator.
12. The validator was then interviewed (the interview questions are in Appendix P) with regards to the merits and demerits of the SIU Method. A report was created and then revised based on feedback from the validator.

Participants	Years of experience
Senior Manager 1 at the Truck OEM	8
Senior Manager 2 at the Truck OEM	5
Senior Manager 3 at the Truck OEM	11
Senior Manager 4 at the Truck OEM	7
Senior Manager 5 at the Truck OEM	10
Senior Manager 6 at the Truck OEM	7
Senior Manager 7 at the Truck OEM	9
Senior Manager at the Delivery Company	6
Senior Manager at the Technology Provider Company (The last 20 years of his employment has involved the gathering of customer requirements as well as solution development and provision).	5

Table 7.22: Job roles and years of experience of the interviewees (Background to Truck Case Studies)

Participants	Years of experience
Senior Manager 3 at the Truck OEM (same as in Table 7.22)	11
Senior Manager at the Technology Provider Company (same as in Table 7.22)	5
Senior Academic and Consultant in Simulators	12

Table 7.23: Job roles and years of experience of the interviewees (Instruction Case Study)

DATA COLLECTION	No. Of Respondents	Time (hrs)
1 'Walkthrough' of the main processes of the Truck OEM	1	1
5 interviews with the Truck OEM's senior managers	5	7
1 interview with a senior manager at a Delivery Company	1	2
2 interviews with senior managers at the Truck OEM	2	1
1 interview with a senior manager at the Technology Supplier Company	1	2.5
	Total	**13.5**

Table 7.24: How the data was collected against the number of interviewees and interview hours (Background to Truck Case Studies)

DATA COLLECTION	No. Of Respondents	Time (hrs)
Teleconference with the senior manager at the Technology provider Company for the selection of a case study	1	0.45
Application of the SIU Method by the validator to the case study	1	2
Corroboration of a part of the validation with a senior manager from the Truck OEM.	1	0.5
Corroboration of a part of the validation with a simulator specialist.	1	0.5
The validator was then interviewed with regards to merits and demerits of the SIU Method.	1	1
	Total	**4.45**

Table 7.25: How the data was collected against the number of interviewees and interview hours (Instruction Case Study)

7.5.3 Case Study Background

This validation is based on a case study of a Truck OEM and their Technology Supplier. The Truck OEM provides leased trucks which are equipped with sensors that can detect how the vehicle is being driven. A Technology Supplier Company is the supplier of this driving fault-detection system and they also supply other ancillary, high-tech capabilities. In order for the truck OEM to offer the trucks on a leased basis, they have to be aware of how the trucks are being driven so that they can take steps to reduce any driver misuse which could damage the asset. The drivers who have repeatedly made such driving faults (such as repeated harsh braking) are sent for re-training. Training (and the scheduling of the training) can be an expensive and protracted affair.

7.5.4 A Qualitative Application of the SIU Method

1. **Problem Definition**
    a. **Define the issue:**
        i. ***Gauge the Extent of the Issue***: To arrange driving instruction, the driver, the truck and the instructor all have to be scheduled which can take some time particularly as many driving instructors only give instruction from 9am-5am, Monday to Friday. Part of the reason for this is appears to be that some instructors favour daylight hours for instruction to be given. Another issue is that, for the faults that the driver has committed, it can be impossible for the conditions (such as car crashes and skidding in the snow) under which the fault occurred to be revisited at will. Because of the time it takes to schedule the driver, truck and instructor, instruction tends to be allocated for a whole day; this can mean that the driver may have to practice manoeuvres for which they have committed no faults whilst also not really being able to practice (because of the weather and road conditions that day) the faults that they had committed. In addition to this, the truck OEM's client (who are in the business of delivery) often have to release the driver from work for a whole day which can be added expense; without the driver, the whole delivery system for that driver and truck becomes unavailable.
        ii. ***The Severity of the Issue:*** The issue was reported by the senior manager from the Delivery Company and the validator confirmed that there had been end-users (delivery companies) who they interact with regularly who had expressed the same issue.

    b) Determine the scope of the system: The issues arise when the current instruction process is being scheduled and then delivered. The issue of the driver not being able to practice all of their driving faults appears to be to do with the impact of the environment at the time of driving instruction:

the conditions under which the original fault occurred cannot always be revisited or replicated.

c) Depict the Receiver's Current Process – The current driving capability is depicted in Figure 7.33. Extended Service Blueprinting is used here because (as will be shown later).

2. **Describe the Gaps in the Overall Capability:**

   i. **A Description of the Actual Overall Capability Parameter Values**:

   - ***Range:*** it is only possible for the driver to really practice some driving faults as the conditions of other faults cannot always be revisited or recreated during instruction
   - ***Span:*** one day
   - ***TC:*** it can take weeks to schedule the driver, instructor and the truck. Then, when driving instruction is given, it tends to be from 9am-5pm
   - ***Cost:*** the cost tends to be high as it encompasses the instructors salary and benefits, the cost of the truck along with its operation (such as MOT, insurance and fuel) and, often, the loss of the driver for a day

   ii. **A Description of the Desired Overall Capability Parameter Values:**

   - ***Range*****:** All of the faults that the driver committed (under the conditions they occurred) should be practiced**.**
   - ***Span*****:** The length of time that it takes to instruct the driver on just the driving faults that the driver had committed and for no other instruction to be given
   - ***Time-Cycle***: The instruction should also be available outside of office hours and on demand
   - ***Cost:*** For instruction to be less expensive and for it to be given outside the drivers hours of duty else there is the cost of replacing the driver for that time.

   iii. **The Overall Capability Parameter Gaps:**

   - ***Range*****:** Some of the faults that the driver committed (under the conditions they occurred) cannot always be practiced**.**

- ***Span***: Many hours
- ***Time-Cycle***: The instruction is not on demand and can take weeks to arrange
- ***Cost:*** high cost

3. **Describe the Gap-Located Capabilities within the Capability:**
   - **The Actual Sub-Capability Parameter Values**: these are depicted in Figure 7.33.
   - **Define the Desired Sub-Capability Parameter Values:** these are also depicted in Figure 7.33.
   - **The Desired Sub-Capability Parameter Gaps:** There are several Gap-Located Capabilities. These are at the driver, the truck and the instructor sub-capabilities. As all of these gaps appear to be large, they are grouped so that a common solution can be found for all of them later. The alternative would have been for each Gap-Located Capability to be explored separately during the course of several iterations of the body of the SIU Method.
4. **Corroborate the System Definition:** The system definition of the current driving instruction capability was corroborated with a senior manager from the Truck OEM.
5. **Create an Operand-Operant Diagram**

   Here, an Operand-Operant Diagram is created for the grouped Gap-Located Capabilities. The terms 'operant resource' and 'operand resource' are not fixed terms which can describe a resource but, rather, the terms describe the relation between two resources. For example, in this case study, the driver is an operant resource when driving the truck (which becomes an operand resource). However, the truck then becomes an operant resource in relation to the instructor who becomes an operand resource: this occurs because the movement of the truck changes the instructor's commands. Finally, the instructor becomes an operant resource when the instructor's commands change the behaviour of the driver who, at that moment, becomes an operand resource. Because of this, for this case study, each Gap-Located Capability can be described as both an operant and operand resource and is depicted as such.

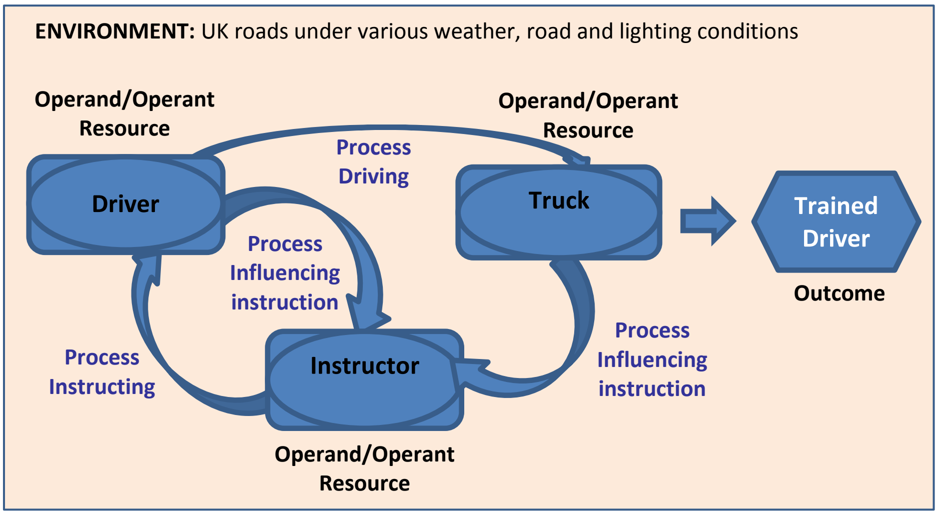


Figure 7.32: The Operand-Operant Instruction Capability

6. **Determine the Stakeholders:**

   The stakeholders are the driver, the instructor and the provider of the truck.

7. **Comparison of Similar Capabilities:**

   Driving simulators which give instruction allow for the practice and correction of all driving faults, including those in extremely dangerous conditions (such as car crashes), are possible. The instruction could last for minutes (for the practice and correction of one fault) or it could last for hours. It is possible for the simulator to be constantly available (24 hours a day, 7 days per week): this could mean that it could serve very many drivers who could just practice and correct individual faults as they arose whenever they had spare time outside of their driving duties. The cost of running a simulator is very low and software upgrades are often free.

8. **Propose solutions**

   These were performed by the validator who has considerable knowledge of the receivers (the drivers) and the instruction they receive as well as a wide knowledge of available technologies (Table 7.26). It was then corroborated by the simulator specialist.

9. **Next Tier?**

   For this validation, no further Tiers are to be examined.

10. **Next Gap-Located Capability?**

Other than the grouped Gap-Located Capabilities, there are no further Gap-Located Capabilities to be explored.

11. Rate and Select Solutions

The solutions were rated as to how much they are expected to close the gaps by the senior manager at the Technology Provider Company; those closing the gaps the most are highlighted in red. However, the solutions cannot be selected as this is for the customer to decide. The solution that appeared most often as a means to address various Design Options was that of a driving simulator which could be used to train errant drivers and also as means of hiring them. This driving simulator capability is depicted and compared against live driving instruction in Figure 7.34. This depiction was corroborated by the simulator specialist.

7.5.5 Results

The results of the validation are in Appendix P and can be summarised as follows:

To sum up the results of the validation, the SIU method was found to be comprehensive and no changes to it or any of the techniques it uses were suggested. An advantage of the Method was that it added more structure and helped to cover all aspects of a problem and solutions that could be generated. The Method was found to be quite straightforward to apply and it was believed that the Method could be used for any technological, service or process suggestion from a provider to the customer; if the provider wanted to make a suggestion to the customer, the Method can provide a good way to do it. The Method could also be useful if a provider was partnering with another company to produce a solution as the Method then could be a way of sharing information and making sure that all agree on the problem and the steps to address it.

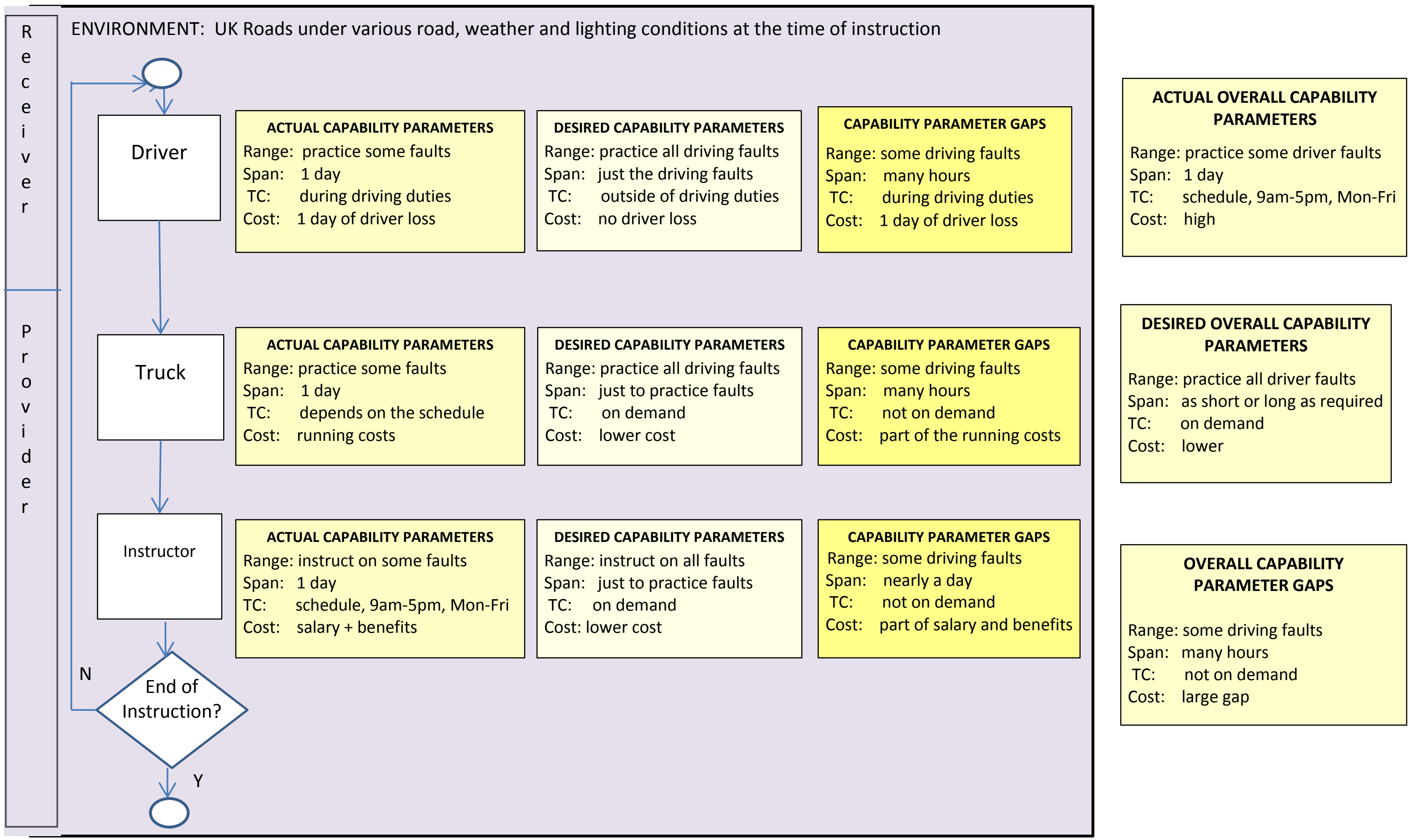


Figure 7.33: Live Driving Instruction

Types of Generic Change	Gap Decreases in the Driver, Truck & Instructor Capabilities				Driving Instruction Capability (Use Phase)
	range	span	TC	cost	
1) NEW CONCEPTUAL DESIGN	**High**	**High**	**High**	**High**	Perhaps on-the-fly instruction could be given – when a fault is detected, the signal could be sent to a driver help desk where an instructor could replay video from a camera installed in the driver's cab (so that driving conditions can be recorded) and then inform the driver remotely as to the fault and how to correct it. However, this could be a huge interruption and distraction for a working driver and it could be difficult to recreate the conditions under which the fault occurred.
2) MARKET SEGMENT /RECEIVER SHIFT	**High**	**High**	**High**	**High**	For some trucking companies it may be more cost effective to, rather than provide training, terminate the driver's contract. This could be the case for trucking companies where very few drivers commit faults and where some instruction could be given by other drivers.
	High	**High**	**High**	**High**	With regards to partnering, there are some driver-training companies which assert that they can reduce the costs as well as increase the availability and range of driving scenarios and also that drivers can be trained in a more piece-meal fashion. However, these companies tend to use driver simulation.
3) CHANGES REGARDING THE OFFENDING CAPABILITY:					
a) SUBSTITUTE	**High**	**High**	**High**	**High**	***Resources: driver, truck, instructor, Processes: driving, instructing:*** Replace the truck and instructor with a driving simulator.
b) ELIMINATE	**High**	**High**	**High**	**High**	***Resources: driver, truck, instructor, Processes: driving, instructing, influencing instructor:*** For top-up driver training not to matter, drivers would have to be hired who are already proficient in the driving styles that the provider favours as well as the full range of scenarios. Here, driving simulation could help to assess drivers before hiring them and then in giving them preliminary instruction before they start work.
	High	**High**	**High**	**High**	***Resources: driver, truck, instructor, Processes: driving, instructing, influencing instructor:*** Driverless trucks would mean that there is no need for training or, indeed, the driver. However, it may be many years before this technology is widely available.
c) ADDITION	**0**	**0**	**High**	↑	***Resources: truck, instructor, Processes: instructing, influencing instructor:*** Other trucks and instructors could be engaged. This may improve the availability (TC) but the problems of span and range will remain and cost will escalate.
d) CUSTOMISE	**High**	**High**	**High**	**High**	***Resources : driver***: Perhaps all of the drivers hired could be trained before they start their employment in all of the driving styles that the provider favours as well as the full range of scenarios. Driving simulation could help here.
4) ENVIRONMENTAL CHANGE					
a) CHANGE LOCAL ENVIRONMENT	**High**	**High**	**High**	**High**	If the full range of road and weather conditions could be created on demand then the necessary driving faults could be practiced. Driver simulation seems to be the only way for this to be accomplished.
b) CHANGE WIDER ENVIRONMENT	**Low**	**0**	**0**	↑	A driving area could be set up where various types of driving issues could be recreated. However, the full range of driving scenarios (such as car crashes or slippery conditions) would not be able to be recreated. Also, the costs could be very high especially if such an area was to be set up at different parts of the country.

Table 7.26: The Proposals Matrix applied to the gaps in the live instruction capability

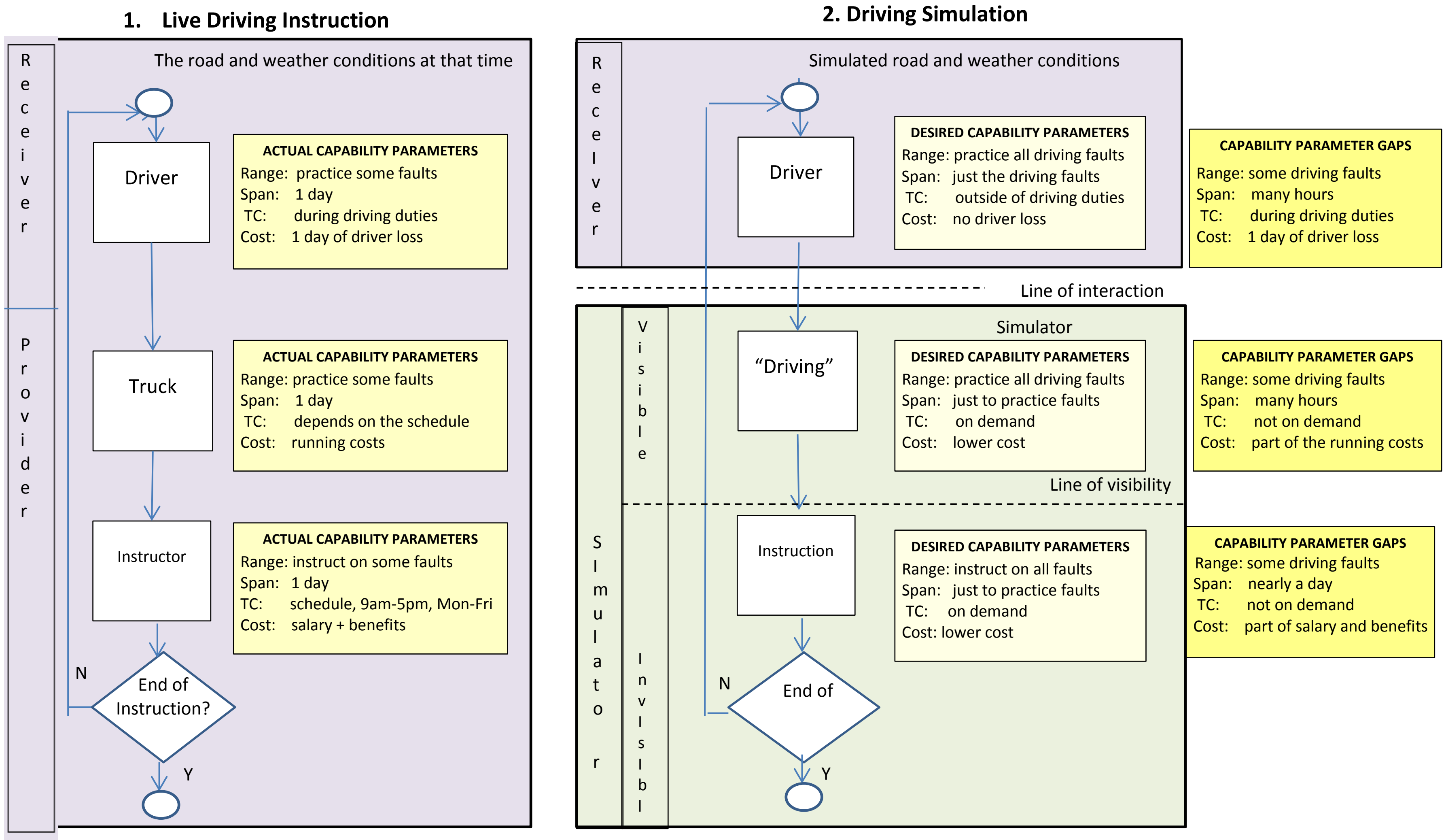


Figure 7.34: The live driving instruction capability compared to that of a driving simulator capability

7.5.6 Case Study Conclusions

This application of the method shows that it could be the provider who initiates change and, using their knowledge of the market and their customers, can apply this method. Using the SIU Method this way, the customer can learns about technological advances from the provider and better gauge their future requirements for improved competitive advantage (Alonso-Rasgado, 2004).

The customer could then (perhaps with the help of the provider and/or supplier) apply the Quantitative or Qualitative version of SIU Method to their exact processes to ascertain exactly the merits and demerits of the proposed solution as compared to other solutions or, indeed, the current situation.

It is important to note that despite any benefits that a driving simulator may offer, at the initiation phase, there could be a large cost in purchasing enough simulators to cater for the drivers who require training. Some possible solutions for this could be:

- Sharing; there are simulators that have been designed so that they can be shared by trucking companies and bus-driver training companies
- The simulator could be offered on a leased/rented or pay per use basis
- Payment in instalments.

Applying the SIU Method to the initiation phase of the solution could help to generate more possibilities. A solution such as a simulator could be a PSS which is offered by this Technology Provider to their clients. Either the Technology Supplier (if they have the requisite capabilities) could develop this or they could partner with suppliers of driving simulators to customise them to the exact requirements of their clients.

7.6 Validation 5: A Fault Reporting Capability

A Qualitative Application of the SIU Method to Generate and then Refine a Solution

7.6.1 Introduction

This validation is concerned with a truck PSS: a Truck OEM provides leased trucks which are equipped with sensors that can detect how the vehicle is being driven. For this validation, the SIU Method has been applied twice to this case study. The first application of the SIU Method finds the gaps a system has, then find where the gaps lie within the system and then generates solutions to fill those gaps. The SIU Method is then applied to the solution (in this case, a product) to refine that solution.

In 2011, this solution was developed and rolled by the truck PSS provider across several fleets.

7.6.2 Method

The background research to this validation had already been conducted as in (Section 7.5) which is depicted in Figure 7.30. The job roles and years of experience of the interviewees at that stage of the research is depicted in Table 7.22 and how the data was collected against the number of interviewees and interview hours is depicted Table 7.24. Then, for this validation, the following steps were taken (See Figure 7.35):

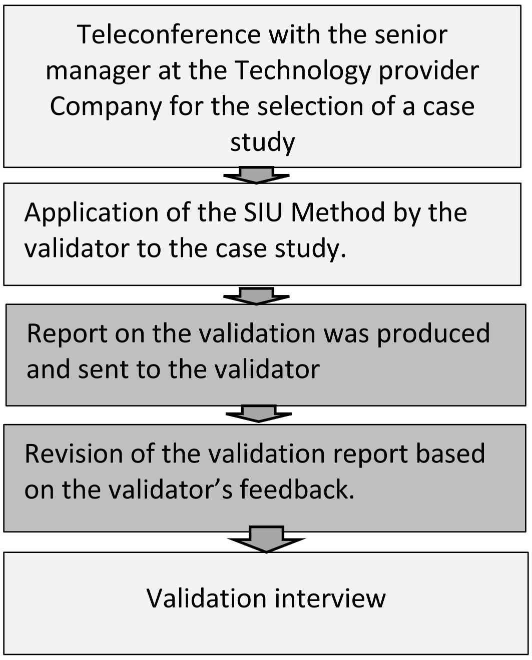


Figure 7.35: The Methodology for the validation of the Fault Reporting case study

10. During a teleconference with the senior manager at the Technology Supplier Company, a case study was selected which would allow for the evaluation of the SIU Method as applied to, not only solution generation, but also to solution refinement.

11. The SIU Method was then applied by the validator (the senior manager at the Technology Supplier Company) to the selected case study. Notes were taken by the researcher during this time.
12. A report on the validation (the application of the SIU Method) was produced and sent to the validator.
13. The report was revised in the light of the feedback from the validator.
14. The validator was then interviewed (the interview questions are in Appendix Q) with regards to the merits and demerits of the SIU Method. A report was created and then revised based on feedback from the validator.

The paler grey areas represent data collection from the respondents.

The validator in this case study is a Senior Manager at the Technology Provider Company who has been in his role for 5 years (the last 20 years of his employment has involved the gathering of customer requirements as well as solution development and provision). The hours spent with the validator for the data collection stages for this case study are listed in Table 7.27.

DATA COLLECTION	No. Of Respondents	Time (hrs)
Teleconference with the senior manager at the Technology provider Company for the selection of a case study	1	0.45
Application of the SIU Method by the validator to the case study	1	3
	Total	**3.45**

Table 7.27: How the data was collected against the number of interviewees and interview hours (Fault Reporting Case Study)

7.6.3 Case Study Background of the Fault Reporting Issue

This validation is based on a case study of a Truck OEM and their Technology Supplier. The truck company provides leased trucks which are equipped with sensors that can detect how the vehicle is being driven and the Technology Supplier Company is the supplier of this driving fault-detection system which is situated in each truck and which can link remotely to other devices. The Technology Supplier also supplies other ancillary, high-tech capabilities. In order for the Truck OEM to offer the trucks on a leased basis, they have to be aware of how the trucks are being driven so that they can take steps to reduce any driver misuse which could damage the asset. The Technology Supplier has provided the customers of the Truck OEM with a Fault Reporter which links to the fault-detection system and produces reports each month. The reports detail all of the driving faults that the drivers had committed that month and a warning is issued that drivers who continue to commit such driving faults will be sent for re-training.

7.6.4 A Qualitative Application of the SIU Method to Fault Reporting

1. Problem Definition:
   - **a) Define the issue:**

     i. ***Gauge the Extent of the Issue:*** An issue with the Fault Reporter is that the reports are only produced periodically and that the drivers have to be at the depot in order to see the reports. By the time the drivers see the report they have often forgotten what faults the report could be referring to. However, if the drivers could be informed immediately as to when they had committed a fault, they would then be able to attempt to adjust their behaviour straight away rather than unknowingly continuing with poor driving habits and then being sent for retraining.

     ii. ***The Severity of the Issue:*** The issue was raised by many customers at the Technology Supplier's annual customer advisory group from which suggestions are generally made by the customers with regards to how new products and services or the customisation of existing ones could fulfil their needs. The issue was deemed to be worthy of serious consideration by the Technology Supplier.
   - **b) Determine the scope of the system:** The issue arises when the Fault Reporter produces driving faults which have been detected from how the trucks are being driven. Although this data is sent in real-time, the Fault Reporter only reports the faults periodically and this happens at the depot.
   - **c) Depict the System**: Extended Service Blueprinting is used here as product operation is a concern (See Figure 7.37).

2. **Describe the Gaps in the Overall Capability:** The Fault Reporting Capability has a gap in its span parameter as there is no immediacy to faults being reported.
3. **Describe the Gap-Located Capabilities within the Capability:** There are gaps in two sub-capabilities and both gaps relate to span: In the *Display the Report to the Drivers* capability, the driver has to go to the depot to see the report and so the report has no immediacy. In the *Report Timing* sub-capability, the report is only produced monthly and so, again, the report has no immediacy (See Figure 7.37). As both Gap-Located Capabilities contribute heavily to the lack of immediacy in the Overall Capability gap, they are grouped so that a common solution to both can be found.
4. **Corroborate the System Definition:** The system definition of the current fault reporting capability was not corroborated for this validation by any other parties as the Senior Manager from the Technology Supplier Company had extensive knowledge of the Fault Reporting system.
5. **Operand-Operant Decomposition of the Gap-Located Capability:**

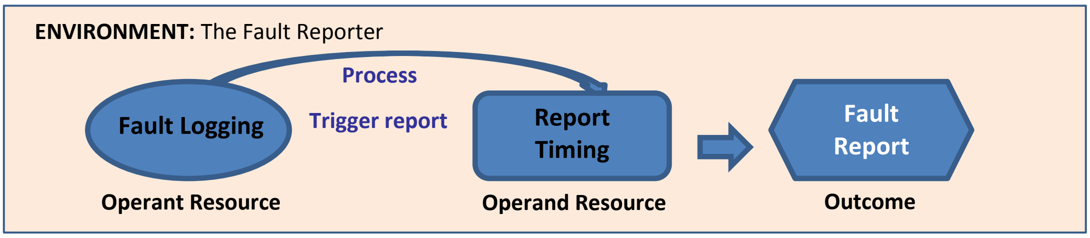


Figure 7.36: The Operant-Operand Diagram of the capability: Fault Reporter

6. **Determine the Stakeholders:** The stakeholders are the drivers who receive the resultant Fault Report and the Technology Supplier Company which created the Fault Logging and Report Timing mechanisms of the Fault Reporter.
7. **Comparison of Similar Capabilities:** It is known that there are trucking companies which make use of driver feedback modules which are devices that are located in the truck driver's cab and which connect to driving fault detection technology. These modules inform the driver immediately as to any faults they have committed.

8. **Propose Solutions:** These were performed by the validator who has considerable knowledge of the receivers (the drivers) as well as a wide knowledge of available technologies (See Table 7.28).
9. **Next Tier?:** For this validation, no further Tiers are to be examined.
11. **Next Gap-Located Capability?** Other than the grouped Gap-Located Capabilities, there are no further Gap-Located Capabilities to be explored.
12. **Rate and Select Solutions:** The solutions were rated as to how much they are expected to close the gaps by the senior manager at the Technology Provider Company; those closing the gaps the most are highlighted in red. Besides the introduction of a driver feedback device, other possible solutions which were expected to close the gaps are: live, on-the-fly instruction, driverless trucks, truck redesign so that poor driving cannot damage it and, again, the use of driving simulators so that drivers do not commit driving faults in the first place. However, such technologies (some in particular) can be extremely costly to initiate at present. The customers decided upon a driver feedback device and to also keep the Fault Reporter which produces summaries for individual drivers and across all drivers in a firm. The driver feedback device was also a solution that would be fairly low cost that could be sourced or developed reasonably quickly. Just as the Fault Reporter is linked to the Fault Detention System in the Tracking Unit, the driver feedback module would also be linked in this way. When discussing the form of the driver feedback module with customers, some wanted the module to be installed on the dashboard whilst others wanted it to be installed unobtrusively near to the driver's feet. Another benefit of the driver feedback device would be that some of the instruction that is normally performed by a driving instructor would be performed by the device; as soon as the driver has committed a driving fault, he would be informed of it by the device, just an instructor would. The solution of the driver feedback module is depicted in Figure 7.38.

The Current Situation

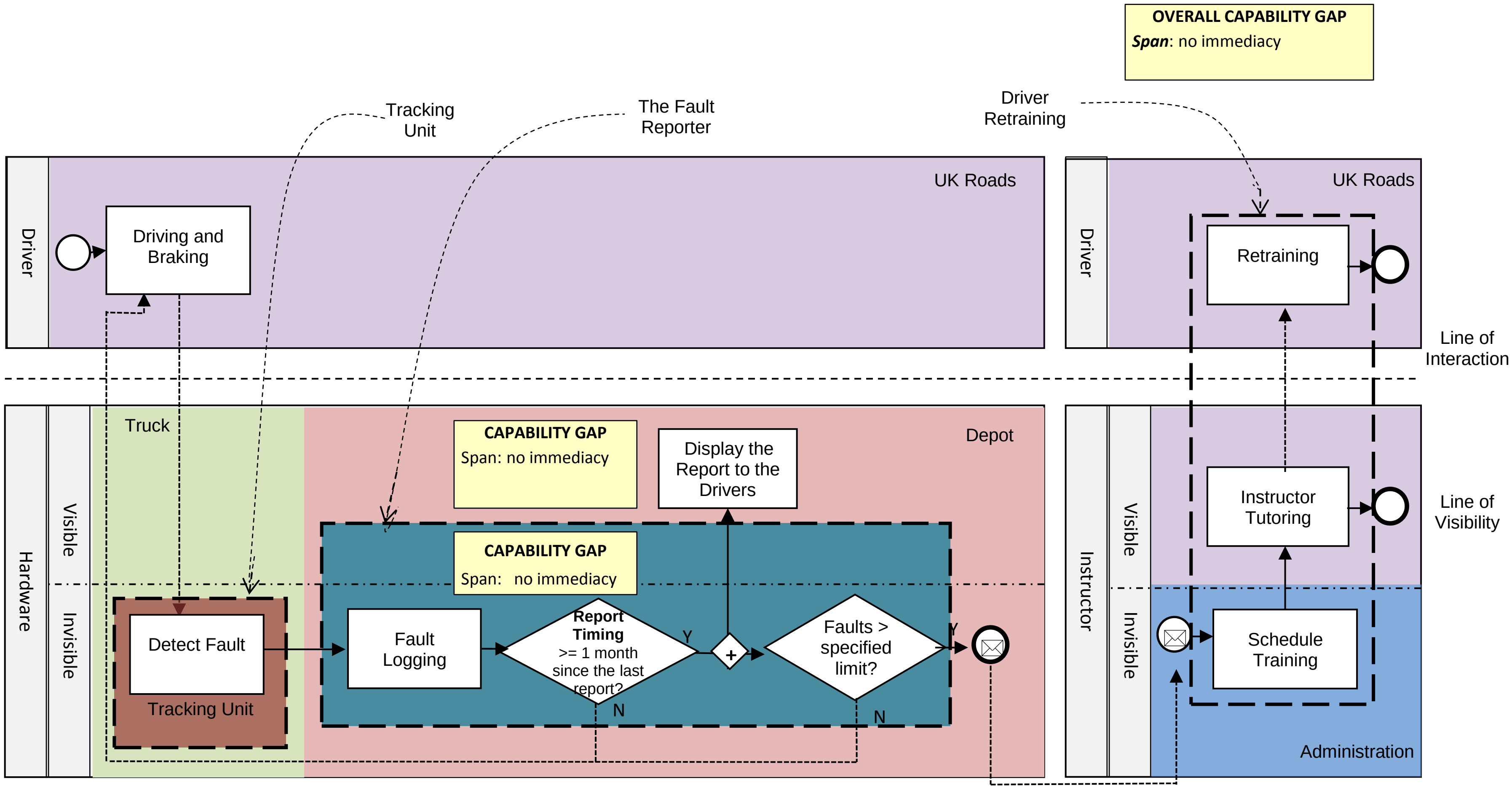


Figure 7.37: An Enhanced Service Blueprint Depicting the fault detection, reporting mechanism and the driver retaining capability

Types of Generic Change	RATING Span gap decrease for the Gap-Located Capabilities 1	2	Driving Fault Reporting Capability (Use Phase)
1) NEW CONCEPTUAL DESIGN	**High**	**High**	Perhaps on-the-fly instruction could be given – when a fault is detected, a signal could be sent to a driver help desk where an instructor could replay video from a camera installed in the cab (which has recorded the driving conditions) and then inform the driver as to the fault and how to correct it. However, this could be a huge interruption and distraction for a working driver and it could be difficult to recreate or revisit the conditions under which the fault occurred.
2) CHANGES REGARDING THE DESIRED PARAMETER(S) OF THE GAP(S) OF THE OFFENDING CAPABILITY			
a) MARKET SEGMENT /RECEIVER SHIFT	**0**	**0**	Across all drivers, the gap of fault reporting in a timely manner appears to be large. Therefore, this is not an option.
3) CHANGES REGARDING THE OFFENDING CAPABILITY:			
a) SUBSTITUTE	**High**	**High**	**Operant:** ***Report Timing and*** **Process** – Substitute the Fault Reporter capability with a driver feedback device that can tell the driver immediately when faults occur *and* that can signal the driving instructor to schedule driver re-training if a certain amount of faults have occurred within a set time frame.
b) ELIMINATE	**High**	**High**	**Operand:** ***Fault Logging,*** **Operant:** ***Report Timing and*** **Process** – To eliminate the whole system of fault logging and reporting, the driver would have to commit few faults which would mean that the driver would have to be already fully trained and practiced. Driver simulation could help to hire new drivers and/or further train existing drivers but there could be quite a heavy initial cost and lead time to set this up.
	High	**High**	**Operand:** ***Fault Logging,*** **Operant:** ***Report Timing and*** **Process** – Driverless trucks would make drivers redundant and so ensure that no damage occurred to the truck through poor driving. However, it may take many years for such trucks to become available. For this reason, this solution is, at this moment, rejected.
	High	**High**	**Operand:** ***Fault Logging,*** **Operant:** ***Report Timing and*** **Process** - This is another way to eliminate the whole system of fault logging and reporting. The truck could be redesigned so that poor driving either causes little damage or so that poor driving cannot occur. However, there would be huge development costs and a very long lead time to attempt to create such trucks.
c) ADDITION	**High**	**High**	**Operand:** ***Fault Logging,*** **Operant:** ***Report Timing and*** **Process -** Add a driver feedback device (whilst still keeping the Fault Reporter in operation) that informs the driver immediately if a fault occurs.
d) CUSTOMISE	**Medium**	**High**	**Operand:** ***Report Timing*** **-** Customise the Report Timing system to immediately report driving faults. However, the driver will still not see the report immediately but only when the driver reports back to the depot.
4) ENVIRONMENTAL CHANGE			
a) CHANGE LOCAL ENVIRONMENT	**High**	**High**	The only way to apply this appears to be to change the local environment of the Ecostyle reporting system from the depot to that of the cab and also for a driving fault to trigger an immediate report. However, this would mean a complete redesign of the Fault Reporting system so that it would fit neatly into the driver's cab and report faults in an unobtrusive way for the drive.
b) CHANGE WIDER ENVIRONMENT	**N/A**	**N/A**	This does not seem to apply here

Table 7.28: Proposals Matrix

The Solution

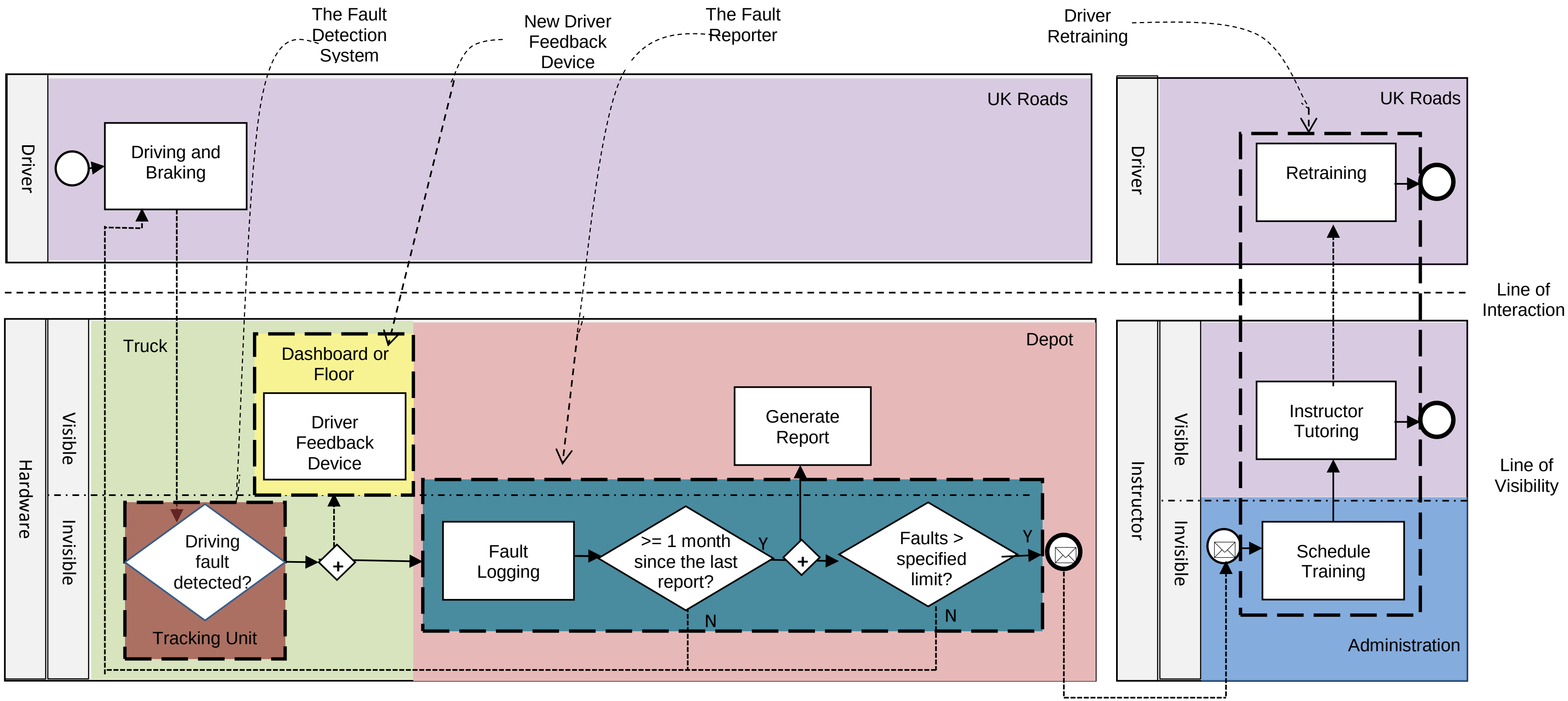


Figure 7.38: An Enhanced Service Blueprint depicting the solution: the addition of a Fault Reporting device

7.6.5 Case Study Background to Solution (Product) Refinement

Supplier Evaluation

The Technology Supplier sourced existing driver feedback modules that were on the market and found that two appeared to meet the basic requirements for the:

a) ***Use phase:*** Alert the driver to driving faults
b) ***Attuning phase:*** The driver feedback modules can be attuned to the types of vehicles that the Technology Supplier's customers use
c) ***Installation phase:*** The driver feedback modules can be installed either on the dashboard or at the driver's feet

However, there was an issue with the integration phase; these driver feedback modules were not able to integrate with the Technology Supplier's Fault Detection system that was installed in the trucks. For this reason, the Technology Supplier decided to create their own driver feedback module.

Product Development

The customers were consulted as to the features of the device and several versions were prototyped. Based on suggestions from customers, three prototypes were considered:

- A simple device which had three lights (red, amber and green), each of which would alert the driver to different types of driving faults
- A device which had a small LCD display screen
- A device which had a series of lights similar to that of a graphic equaliser on a stereo

A simple box with red, amber and green visual warnings and sound alerts (beeps which can be turned off if there are other people in the cab) was decided upon. If the driver commits a fault a visual and audible preliminary warning is issued and if the driver continues to commit the fault the driver is warned that the fault is now being recorded. Furthermore, the Technology Supplier could also develop this type of device at the right price point as compared to a device which had messages displayed on a screen. This prototype was developed and then field tested.

During the field tests, there was an issue with the audible warnings (the beeps) as there was a concern that it could be a distraction to drivers. The SIU Method is now applied qualitatively to this product to assess the gaps and then generate solutions.

7.6.6 A Qualitative Application of the SIU Method to Solution (Product) Refinement

1. **Problem Definition**
   - **a) Define the issue:**

     i. ***Gauge the Extent of the Issue***: The beep alerts are considered by the drivers in the field tests to be a distraction. This is an issue as, rather than just alert the driver to driving faults that have been committed, the device could actually *cause* driving faults.

     ii. ***The Severity of the Issue:*** Most of the test drivers found the beeps to be distracting.
   - b) **Determine the scope of the system:** The issue arises when the beep alerts are made.
   - **c) Depict the System:** This is depicted in Figure 7.40**.**
2. **Describe the Gaps in the Overall Capability:** The gap is in the range of the overall capability; it has been described as being too harsh and so is a distraction for the driver (See Figure 7.37)
3. **Describe the Gap-Located Capabilities within the Capability:** The gaps are located at the sound warnings which are issued (See Figure 7.40).

10. Corroborate the System Definition: The exact system definition of the product was known by the Senior Manager from the Technology Supplier Company as his company had developed the device.

11. **Operand-Operant Decomposition of the Gap-Located Capability:** This is depicted below (Figure 7.39).

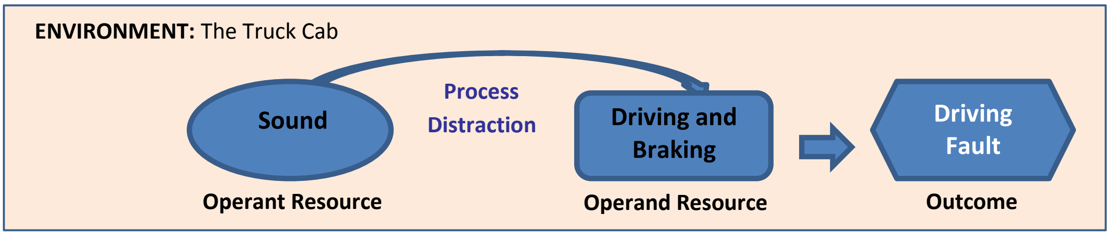


Figure 7.39: The Operant-Operand diagram of the distraction caused by the device

12. **Determine the Stakeholders:** The stakeholders are the driver and the Technology Supplier Company which developed the device and the sounds it makes.
13. **Comparison of Similar Capabilities:** It was known that satellite navigation systems use voice-recoded sound alerts and that this tends not to be a distraction.
14. **Propose Solutions:** These were performed by the validator who has considerable knowledge of the receivers (the drivers) and the instruction they receive as well as a wide knowledge of available technologies (See Table 7.28).
15. **Next Tier?:** For this validation, no further Tiers are to be examined.
16. **Next Gap-Located Capability?** For this validation, there are no further Gap-Located Capabilities to be explored.
17. **Rate and Select Solutions:** The solutions were rated as to how much they were expected to close the gaps by the senior manager at the Technology Provider Company; those closing the gaps the most are highlighted in red (Table 7.29). It was decided to replace the bleeps with speech messages which are similar to those used by Sat-Nav systems. Another solution that was generated by the Proposal's Matrix was the use of cameras to record the road in front and at the sides of the cab when driving faults occur; the Technology Supplier Company actually provides such cameras and they are encouraging more customers to use them. They have been found to be particularly useful when accidents have occurred to prove liability.

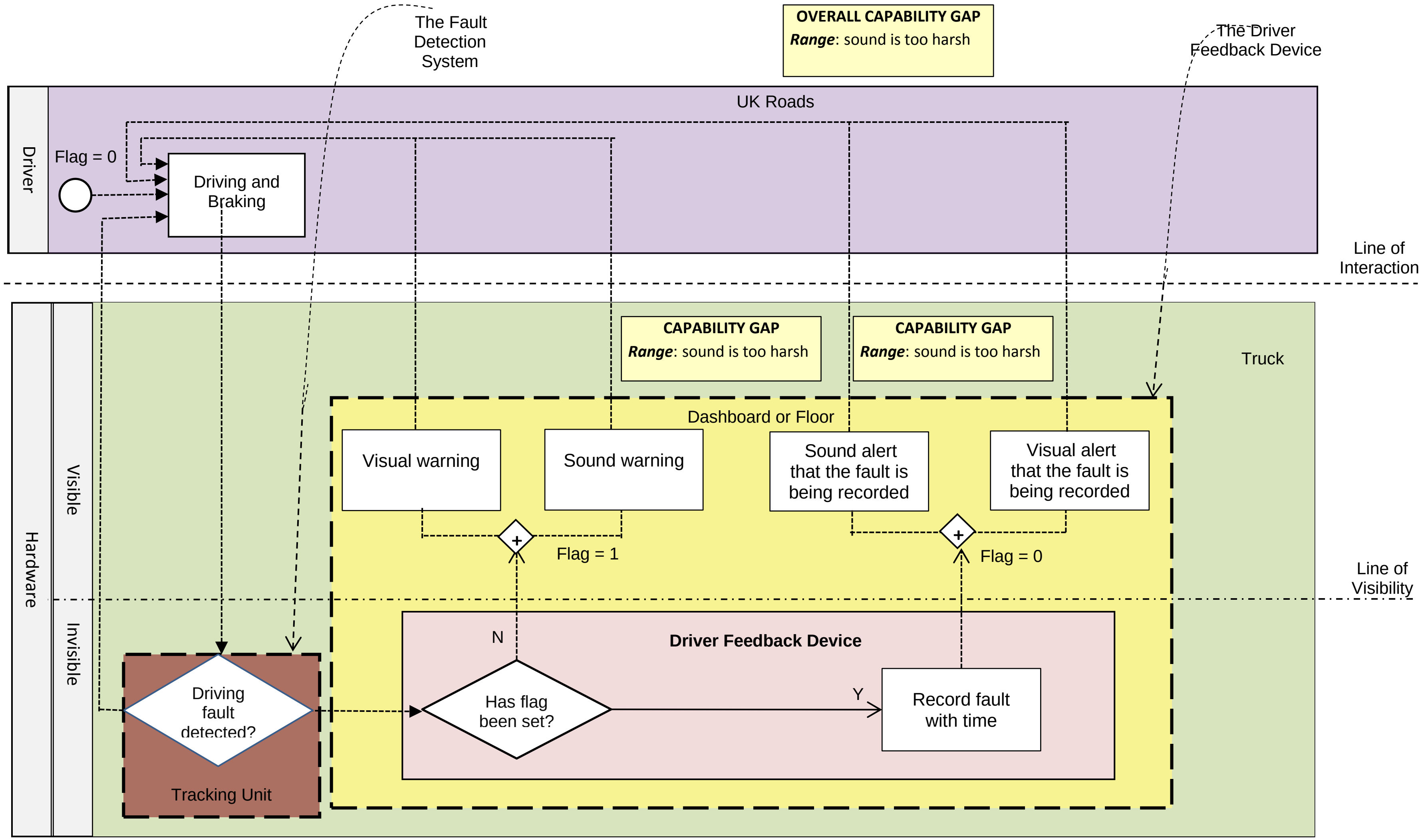


Figure 7.40: Basic operation of the driver feedback module

Types of Generic Change	RATING	Application to the Audible Sub-Capability
1) NEW CONCEPTUAL DESIGN	**Range gap decrease** **Low – High depending on the drivers**	If in-cab cameras were fitted, an SMS message along with a 10 second video of where they were when the fault happened could be sent to the driver's phone or email address so that the driver could see the fault message and video when on break. This solution could be developed further and may suit some drivers. However, the immediacy of informing the driver of the fault would be lost.
2) MARKET SEGMENT SHIFT	**N/A**	The beeps appear to be unsatisfactory across all drivers.
3) CHANGES REGARDING THE OFFENDING CAPABILITY		
a) SUBSTITUTE	**High**	***Process:*** Substitute the current bleeps for voice messages similar to those used for Sat-Nav systems. This type of audible messaging does not appear to cause a distraction to drivers.
b) ELIMINATE	**Low**	***Process***: Remove the beeps. However, the driver would then have to always notice the visual warnings. This may not be suitable for all drivers – rejected.
c) ADDITION	**N/A**	***Process***: Other than adding speech which would state the fault and whether an initial warning was being issued or that the fault was being recorded, this does not seem to apply
d) CUSTOMISE	**Low**	***Process***: Different types of beeps could be used which emit a softer sound.
4) ENVIRONMENTAL CHANGE		
a) CHANGE LOCAL ENVIRONMENT	**N/A**	The local environment does not impact upon this capability–the driver can hear the sound. The issue is with the sound being inappropriate –therefore, this is not applicable here.
b) CHANGE WIDER	**N/A**	There are no wider environmental variables that impact upon this capability. Not an issue here.

Table 7.29: The Proposal Matrix – addressing the issue of sound being a distraction

7.6.7 Results

To sum up the results of the validation, no changes were suggested to the SIU method. A limitation of the Method was that it could assume that a reported issue is worthy of conceptual redesign. However, it should be qualified who reported the issue (and assessed whether other customers from the same company see the issue in the same way) and assessed why this issue is more important to the customer than other issues. This insight from the validator was then used to enhance the SIU Method.

For small companies which are close to the customer, the Method could be unwieldy. However, for problems which are shared amongst different stakeholders, the Method could be a useful and methodological way to examine issues, generate solutions and share these amongst the stakeholders. The Method appears to be useful in refining products as well as business processes.

The validator suggested making the Workbook into an electronic guide which would allow scoring (validation checks) so that the person applying the method can be sure how well they've applied the method and parts of it they may have had to miss (because of lack of information, or example) will be noted – this should lead to an overall scoring which will indicate the trustworthiness of the outcome of that particular application of the method. After consideration, this suggestion was rejected due to lack of project time to further explore and possibly implement this suggestion.

7.6.8 Conclusions of the Truck Case Study Results

The SIU Method resulted in the same solution being generated and selected as the Technology Supplier's current procedure to address customer issues. However, the SIU Method allows the problem space to be unfolded systematically and generates a variety of solutions that could help to address the issue; this informs decision making in a much more deliberate way.

The SIU Method can be applied to not only generate solutions, but it can also be applied to refine those solutions (in this validation, this was a product). Therefore, it would appear that the SIU Method could be regarded as a PSS Design Method in its own right.

7.6.9 Solution Adoption in Industry

The idea for a device to inform drivers as to driving faults (a product) was made to the Truck OEM by the researcher in 2010 (Hussain et al, 2010). Although the Truck OEM initially rejected the idea, after their Technology Supplier then independently made the same suggestion, they did accept it and the Technology Supplier developed the product in 2011. The device has now been rolled out to several fleets.

7.7 Summary and Key Observations

In Section 7.1 the overall validation process followed was briefly described; then, each of the following Sections of Chapter 7 how each validator applied the SIU method to a case study and then validated the SIU Method and the Workbook.

The SIU Method has been applied to a wide range of industries and, from the case studies conducted, it appears that it can be used quantitatively or qualitatively to produce initial Conceptual PSS Designs. As the Method had produced the desired outcomes when applied to a laser cutting process, a domestic heat issue, throughout a value chain of an aero engine, driving instruction and driver fault reporting, it does appear (at this stage) to be a problem-solving method that it is applicable to and can improve any business process, user task, product and/or service. The Method can be used as a “pull” to pull solutions from the value chain to meet receiver issues and it can be used as a “push” where suppliers can use the Method to depict how a change to the receiver’s system (such as the addition of a product) can improve the receiver’s value creation system.

Furthermore, the SIU Method can improve Supply Chain Management. As the SIU Method can be applied to not only generate solutions, but also to refine those solutions (in this validation, this was a product), it would appear that the SIU Method could be regarded as a PSS Design Method in its own right.

For three of the validations, the solutions generated were adopted.

7.7.1 Positive Outcomes for the Validators

The positive outcomes for the validators are as follows:

- ***Case Study Validation 1: The Aero Engine***
    - The Expert in Product Development (also a Senior Academic in Aero Engines and PSS):
        - This expert maintains that, not only can the SIU Method improve processes, products and PSS but that it can also improve Supply Chain Management.
        - He was not aware of any other method that could produce the same or better results and stated that the method fills a gap in the current practice in industry.
        - He plans to use the method again in the near future.
- ***Case Study Validation 2: Excessive Heat Issue***
    - **The HVAC Consultants:**
        - ***Consulting with Suppliers:*** Looking at other supplier Tiers was not something that they knew how to do before using the SIU Method although they had seen faults with the design and layout of buildings which had caused HVAC problems. The SIU method now gave them a way to state these possible building issues and could provide an avenue for them to act as consultants to property developers.
        - ***Knowledge Transfer:*** It is used as a means for them to communicate with colleagues (especially new colleagues and those outside of the company) as to the nature of the problem and the steps that they had already taken.
        - ***A Checking Mechanism:*** The HVAC Consultants also refer to the SIU Method to use it as check-list to ensure that no steps or aspects of the system have been forgotten.
        - ***Decomposition:*** The Operand-Operant Diagrams were deemed to be particularly useful by the HVAC Consultants as they provide a way to ensure that each aspect of the problem is considered.

- **The Expert Civil Engineer (Consultant and Senior Academic):**
  - ***Usefulness for General Housing Design:*** The Expert Civil Engineer wishes to use the SIU Method to identify and resolve issues clients have had with previous buildings when he is designing new buildings. The SIU method was viewed as a problem-solving method that can be applied to any problem, particularly for complex situations. Furthermore it was viewed as being useful in producing short-term solutions as well as long-term solutions.
  - ***University Courses for Architects and Civil Engineers:*** The Expert Civil Engineer is planning to introduce the method into the course curriculum for Architects and Civil Engineers as part of the continuous courses run by the university.
  - ***Extension of an Existing Civil Engineering Tool:*** Taproot is used for accident investigations. The program guides the user to perform the investigation and finds the root causes of the incident and then suggests corrective actions. The output details a corrective action register, target dates and responsible persons and parties. As this tool is based on past performance and adherence to industry standards rather than innovation, the Expert Civil Engineer believes that the SIU method could work well with Taproot to add a management system development/ improvement aspect.
- **The Tenant:**
  - The tenant was presented with several options to address his heating issue.
  - ***Usefulness in Teaching Situations:*** The tenant is a teacher and he applied the SIU Method to a teaching issue he had which produced favourable results.

- ***Case Study Validation 3: Truck Driving Instruction***
  - **The Senior Manager at The Technology Provider Company :** the positive outcomes were:

- ***A Push Method:*** The qualitative version of the SIU Method can be used to detail to customers how a change in their systems (such as the introduction of a new product) could meet their functional needs more closely. After this has been demonstrated, each customer can then apply the quantitative version of the SIU Method to their exact systems to ascertain exactly the degree to which such a change will meet their needs more closely. The Senior Manager favours using the SIU Method if his company decides to make a suggestion to their customers.
- ***A Method for Partnering to Produce Solutions:*** The SIU Method can be used when partnering with other organisations to produce solutions. It allows detailed information regarding the issue and possible solutions to be shared in a way that can be understood by most stakeholders. This company tend not to do this but, if this ever did arise the Senior Manager favours using the SIU Method for this.

7.7.2 Merits and Demerits of the SIU Methodology

- **Merits of the SIU Method**
  - ***Advantages of the SIU Method:*** The method helps the problem space and solution space to be unfolded in a very systematic way and so ensures that no aspect of the problem or solution generation has been and this can foster innovation.
  - ***Skills required to use the Method:*** It appears that no special skills are required although some general training in the techniques and logic of the Method is required.
  - ***Production of the desired outcome:*** Furthermore, it can generate short-term or long term solutions to address issues which are unlikely to have been systematically generated without the Method. Some of the solutions are quite conventional changes whilst others can be innovative and high level PSS business models; this allows any PSS to be evaluated against other solutions.

  - ***The Techniques used by the Method:*** these all appear to be fitting for the Method and no changes have been suggested.

- **Demerits of the SIU Method**
  - A disadvantage reported by one respondent from a small, mobile, Technology Company whose technologists tend to be quite close to the customer was that the SIU Method is unwieldy and laborious. This can be particularly the case for the quantitative version of the Method. However, for core processes, the effort to apply the quantitative version of the Method to them could be worthwhile; it could allow that process to be constantly monitored and any changes in the process or customer needs can then be acted upon quickly. Nevertheless, improvement of the language of the SIU Method and the Workbook should take place. Furthermore, industry-specific versions of the SIU Method and computer systems could be created which could draw on a database of issues specific to a particular industry or process and relate them to the solutions which have been known to close the gaps. This would be an expert system which could be continually updated with new solutions and technologies as they arise.
  - All except one of the validators stated that they believed that the SIU method was complete. The demerit that this validator raised was a limitation could be that the method assumes that a reported issue is worthy of conceptual redesign. However, it should be qualified who reported the issue and assessed whether other customers from the same company see the issue in the same way it should also be assessed why this issue is more important to the customer than other issues. This point was raised in Chapter 6 (Section 6.6) so it is worthy of further consideration.

7.7.3 Feedback on the Workbook

- The language should be simplified more and there should be more instruction on the techniques, how the Method is derived and how it relates to servitization.

- The Workbook needs to look more like a user Manual; a side-bar showing which part of the Method is being followed at any given time would be useful as would a pull-out section showing the method steps and the techniques.
- A simpler case study should be used as an introduction and there should be a synopsis of other case studies to which the Method has been applied to show the user where the Method can be applied and its usefulness.
- An electronic guide could be created which would allow scoring (validation checks) so that the person applying the method could be sure how well they've applied the method and parts of it they may have had to miss (because of lack of information, for example) will be noted – this should lead to an overall scoring which will indicate the trustworthiness of the outcome of that particular application of the method.
- The addition of a video/multimedia tutorial showing the steps would be useful.
- A Workshop with the target users to assess the Workbook and generate ideas for its improvement should be held.

In the next Chapter, the key observations and findings of this research are further discussed.

8 Discussion and Conclusions

8.1 Discussion of the Research Findings

In this Section, several issues regarding the quality of the findings, along with their generalisability are discussed. Additionally, the applicability of the research findings in an industrial environment is explored.

8.1.1 Research Methodology

Every attempt has been made during this research to ensure that the methodology used would limit any possibility of the production of distorted results. This was mostly achieved through the adoption of a variety of methods during data collection (see Chapter 2): face-to-face interviews, case studies, teleconferencing, observation, analysis of company data collected from sensors and archival material from the collaborating companies were all used. As interviews can mainly capture the perceptions and opinions of the expert and not the actual situation, to compensate for this adverse effect, other additional methods were used such as observation and analysis of archival material. Semi-structured, exploratory interviews were used to generate theory as, from the literature review, it was apparent that theory in this domain area was nascent.

A case study approach was one of the main ways that data was collected and it was then used to refine and validate theory and the resultant SIU Method that had been generated. The researcher's active involvement in the choice of case studies strengthens the research methodology as the case studies were not just suggested by the experts, but they were chosen in accordance with the research objectives and questions of this study. As qualitative research can be prone to biased interpretation by the researcher which can lead to subjective results, member-checking was performed continuously at each stage of the research.

8.1.2 The Current Practice in Industry Producing Capital-Intensive PSS

Over the course of three years, a series of semi-structured interviews were conducted across a range of industries that produce technical, infomated and capital-intensive PSS. This was conducted to capture the AS-IS situation in industry with regards to using product-in-use data from industrial, technical, infomated products and PSS to inform PSS Conceptual Design (see Chapter 4).

The interviews revealed, conclusively, that in industry very little is truly known about how product-in-use data could be utilised to inform PSS Conceptual Design. Some suggestions from across the industries were gleaned as to how a method could start to be developed although exactly what data to collect and what this would indicate for PSS Conceptual Design was not forthcoming. The main requirements for the creation of a method to utilise product-in-use data for PSS Conceptual Design appeared to be:

- The definition of the problem space as the process in which the asset or PSS is embedded (rather than just a consideration of the asset or PSS), all of the elements within the process (such as other products and services) and any events or environmental impacts (which tends not to be monitored) upon the process; it is the accomplishment of the customer's goal that is of primary importance rather than the requirements of any individual product or PSS. Therefore, rather than product-in-use data, system in use data should be used.
- How a process or a similar process (or parts of the process) performs in one environment as compared to another environment: this makes it more possible to discover the circumstances that lead to asset, subsystem and even mission failure.
- The monitoring of, not just the asset or PSS, but also subsystems and components within it so that it can be ascertained which part of the asset may have contributed to any failure in the customer's mission.

Despite the emergence of a basic framework, the exact sources and types of data to be collected, how the data related to PSS Conceptual Design and then how that data should be processed to inform PSS Conceptual Design had to to be defined.

8.1.3 Framework Refinement and Ontology Development

Although it had been determined that, rather than use product-in use data to inform PSS Conceptual Design, that system-in-use data should be used, there was little insight as to how to depict a system, what data to collect from that system and how that data should be used. Therefore, to refine the framework, a decision was made to interview and observe a company which uses system-in-use data to inform PSS Conceptual Design. Even though this company did not offer a capital-intensive PSS, they do offer a technical, high level (a result-orientated business model) PSS (see Chapter 5). The findings from the interviews and the observations allowed the system elements to be defined, determined the types of data to collect, and determined how the data could be used to indicate the value loss of a customer's system and then the location of that gap within that system. Furthermore, Design Options were identified which can then be applied to the part of the system which contributed most to the value loss, the whole system, the receiver or impacting variables in the environment to increase the value-in-use of the system. Furthermore, rather than simply informing PSS Conceptual Design, the refined framework allowed initial conceptual designs to be generated which could then be evaluated by the stakeholders. The findings were triangulated with the literature and then the framework was applied and evaluated. A new concept (that was gleaned from the literature) was the notion of operand and operant resources which was used for an ontology that was validated by this company. The framework was now complete, albeit, industry specific.

8.1.4 Genericization of the SIU Method

The literature was reviewed to triangulate the identified SIU Method constructs as well as to genericize the Method and provide enough specify so that it could become a method which is applicable across industry. This involved the development of several new techniques which were developed specifically for this method. These are:

- ***Capability Parameterisation***: this is accomplished by using the generic parameters of range, span, Time-Cycle (TC) and cost.

- ***Enhanced Service Blueprinting:*** here, Service Blueprinting (simple or Extended) is made environment-specific and parameterised
- ***Operand-Operant Diagrams***: these allow a sub-capability to be decomposed into its operand and operant resource as well as the process that the operand uses.
- ***The Design Options:*** these allow various changes types of changes to be considered. These are: substitution of the offending part of the capability with another sub-capability, addition of another sub-capability, removal of the offending part of the capability and, lastly, customisation of the offending part of the capability.
- ***The Proposals Matrix:*** this allows the design options to be applied to the part of the capability which contributed most to the overall gaps to be considered as well as changes to the capability's environment (local or wider) along with changing the receiver of the capability and changing the whole capability. The expected reduction in gaps can then be rated and the acceptability of the proposal can be discussed by the stakeholders.

The conferring with experts resulted in a decision to offer user support for the SIU Method as a Workbook rather than a tool.

8.1.5 Validation

The SIU Method was applied to five case studies in disparate industries. All except for one of the validators stated that they believed that the SIU method was complete. The demerit that this validator raised was a limitation could be that the method assumes that a reported issue is worthy of conceptual redesign. However, it should be qualified who reported the issue and assessed whether other customers from the same company see the issue in the same way it should also be assessed why this issue is more important to the customer and firm than other issues. This point was also raised in Chapter 6 so it is worthy of further consideration. This is addressed in Section 8.3. All of the validators are either now using or intend to use the SIU Method again in the future.

8.1.6 Quality of the Findings

Throughout the course of this research, every attempt was made to ensure that the entire process (the gathering and analysis of data) was carried out in a methodical and systematic way. With regards to the case studies, a main limitation of case study selection was that it was virtually impossible to obtain a full set of detailed, data regarding any company process; the only case study when this was ever fully available was in the domestic heating case study in Chapter 7. Apart from this, the case studies selected were ones where the experts were accessible and willing to collaborate with the researcher before, during and after each case study. Here, the duration of the interviews or the workshops were mutually arranged, and the research protocol was sent to the interviewees in advance so that they could familiarise themselves with the research focus and issues. Such measures helped to ensure that the case studies could be carried out within the time scales available to the researcher.

An evaluation of the SIU Method took place (Chapter 6) with experts in the field. Then several validations took place, each of which exercised different paths in the Method and exercised both the qualitative and quantitative versions of the Method; the validations covered both the content, effectiveness and the use within an industrial environment. During the validations, the Workbook was also validated and then refined based on the results of the validations. The validation sessions proved that the SIU Method had utilised system-in-use data to systematically:

1. Identify the type and extent of gaps of customer processes
2. Locate the part of the system that contributed most to those gaps

From this, designs were generated which could increase the value-in-use of the customer's value creation system (meet the customer's functional needs more closely) by:

1. For the part of the system that contributed most to the value loss, considering its redesign by substitution, elimination, customisation or making an addition to it.
2. Considering changes to the local and wider environment to address any variables that may impact upon the value creation process.

3. Considering changing the receiver to one who whose needs the system will satisfy more closely or partnering with another company that can meet the receiver's needs.
4. Considering a completely new design of the value creating system.

The generated designs can then be evaluated by the degree to which they are expected to close the gaps. Also, any PSS Designs generated can be compared against other simpler and more conventional designs which have been generated to assess its merits. Those most acceptable to the customer can then be evaluated and further refined with other stakeholders.

As a consequence, product and/or service offerings can be enhanced, processes can be improved and advice to the customer can be given to support them and thus improve customer relations.

A major concern of the author during this investigation was the attainment of a high level of reliability with regards to the research findings which depended upon the research methods which were used. The formulation of a formal research strategy combined with a range of data collection methods and constant triangulation with the literature and industrial archival material such as sensor data sets enabled this.

8.1.7 Applicability

In this Section, the applicability of the research findings to industry and their potential business impact is discussed. Specifically, these research findings are:

- The SIU Method
- The Workbook

From the case studies that were conducted (Chapter 7), the SIU Method has been shown to be applicable in a wide range of contexts and industries in generating conceptual designs to improve (close identified gaps in) value-creating systems. These case studies are:

- **Case Study: *A Laser Job-Shop System*.** Here, several conceptual designs were generated to improve a laser job shop process. This was a quantitative, "pull" application of the SIU Method. The outcome of the method was that, to eliminate the gaps, the laser job-shop should consider moving some of its capability on or near to the premises of large and important clients; this recommendation was acted upon by the MD of this laser job-shop company.

- **Case Study: *Aero Engine Component Fabrication and its Value Chain*.** Many conceptual designs were generated so that the gap could be addressed by separate or combinations of Tiers in a values chain. These Tiers are: the airline, the engine manufacturer, the component manufacturer and the material supplier. This was a qualitative, “push” and “pull” application of the SIU Method.
- **Case Study: *A Cooking System and Building Design.*** Various conceptual designs were generated to reduce the side-effect of excessive heat that was produced by a domestic cooking process. Also, conceptual building designs and refurbishment were generated as another way to reduce or eliminate the issue. This was a quantitative, ”pull” application of the SIU Method.
- **Case Study: *A Driver Instruction System*.** Conceptual designs were generated to improve driving instruction that supports a truck PSS. This was a qualitative, ”push” application of the SIU Method. This showed how a supplier could make recommendations (such as product or process changes) to a customer by detailing how that recommendation is expected to improve that customer’s system.
- **Case Study: *A Fault Reporting System*.** Conceptual designs were generated to improve a driving fault reporting system that is used by a Truck OEM (that offers a truck PSS) that needs to monitor and improve poor driving that can damage the asset. The outcome of the SIU Method was that an in-cab device would be the solution which would eliminate the gaps (Hussain, 2010). Although the Truck OEM initially rejected this solution, when the Truck OEM’s technology supplier then independently made the same suggestion, a driver feedback device was subsequently developed and has now be rolled out to several fleets.

Although the SIU Method appears to be applicable to processes in general, further refinement of the Method and the format of the Workbook are required to ensure its ease of use.

8.1.8 Generalizability

As case studies have been performed across several industries, value-creating systems and sub-systems, the potential applicability of the SIU Method to other industries and contexts would appear to be high. Therefore, at this point, it would appear to be a safe claim that the SIU Method has a high generalizability and should apply to any system with which there is an issue.

The reason for the generalizability of SIU Method being high is attributed to the grounded approach which gathered the opinions of experts in many industries as to how SIU data could inform PSS Conceptual Design, the in-depth study of a company that actually uses SIU data to inform PSS Conceptual Design, the constant member-checking and the repeated triangulation with the literature.

Although the SIU Method was developed to generate initial capital intensive and industrial PSS Conceptual Designs, as shown in the Cooking Case Study (Chapter 7), the Method also appears to have applicability to low-cost, consumer and domestic PSS Design.

8.2 Recommendations for Improving the SIU Method

Change Management: For a method such as this to be firstly applied and then effected, careful attention should be paid to change management as although this method can suggest very innovative improvements to a capability, that does not necessarily mean that such changes should automatically be instituted; a through audit of existing stakeholders and ones that could be lost as well as new ones that the new solution will involve should help to determine who will be affected by the introduction of any solution and then any resistance to change can be ascertained, examined and catered for sensitively. Although this is outside of the scope of this research, for the SIU Method to become more apposite to industry, a recommendation is made for an extension to the Method so that this can be referenced.

Application cross multiple processes in a firm: Most firms (and individuals) will have several key processes that are important to them. From the case studies that were conducted, it can be seen that changes to one process can have knock-on effects to other processes. One example is in the driving instruction case study where the driving simulator could be used not just to train drivers in areas where they are deficient but also during the hiring process to test drivers as to their competency. Another example is in the aero engine value chain case study (Chapter 7) where the engine design could be changed so that the component could simply be replaced at regular intervals rather than maintained; this solution becomes more attractive if the aero engine OEM wishes to offer a “power-by-the-hour” business model. To do this, the SIU Method could be extended so that several parallel processes could be examined. Defining issues with several processes and generating solutions should help solutions to be found that could be beneficial across more than one process in any given firm. Therefore, even if a solution was costly to initiate for one process, the benefit it also brings to other processes may make that solution more cost-effective.

Business Strategy: The SIU Method can suggest changes and/or the development of new market segments, products, services and PSS; these all impact upon the business strategy of the firm. Furthermore, the Design Option of *Substitution* can force the consideration that competitors may be able to supply a more compelling value proposition for the customer. All of these issues seriously impact upon the business strategy for the firm (this was raised in Chapter 6) and there is also the matter of issue prioritisation and selection (this was raised in Chapter 7). For these reasons, a recommendation is made for the SIU Method to be tied more deliberately to business strategy.

8.3 Recommendations for Improving the SIU Workbook

The Workbook requires more refinement to ensure its ease of use. This could be conducted by holding workshops with industries who have expressed an interest in using the SIU Method, allowing them to follow the steps in the Workbook and then eliciting feedback as to how clear the steps are, whether the rationale behind each step (and the overall Method) was clearly explained and the general layout and sequence of the Workbook. A tutorial (perhaps a video tutorial) is also required to guide the user and inform them as to the background of the SIU Method. The language needs to be simplified and there should be more instruction on the techniques, how the Method is derived and how it relates to servitization. The Workbook also needs to look more like a user Manual; a side-bar showing which part of the Method is being followed at any given time would be useful as would a pull-out section showing the method steps and the techniques. A simpler case study should be used as an introduction and there should be a synopsis of other case studies to which the Method has been applied to show the user where the Method can be applied and its usefulness. An electronic guide could be created which would allow scoring (validation checks) so that the person applying the method could be sure as to how well they've applied the method and parts of it they may have had to miss (because of lack of information, for example); this should lead to an overall scoring which will indicate the trustworthiness of the outcome of that particular application of the method.

8.4 Research Limitations

In this Section, the overall research limitations are presented as well as the limitations in respect to the research methodology. As described in Chapter 3, a qualitative research approach was followed and, as such, concerns arise which are related to the limitations of a qualitative study. A major issue is associated with the replicability of obtained results, which cannot always be achieved easily as when a quantitative approach has been followed. However, in the investigation as to how industry uses product-in-use data (amd opinions as to how product-in-use data could be used) to inform PSS Conceptual Design (Chapter 4), very many respondents were interviewed across many industries for over a period of three years. Also, as constant member checking took place, this should also help to ensure the reliability of the results. The in-depth study with the HVAC Consultants (Chapter 5) and their subsequent feedback (Chapter 6 and Chapter 7) also spanned a period of three years. Although, this could have introduced researcher bias, it is believed that the constant member checking that took place would have uncovered this had it occurred.

To ensure that the case studies were conducted satisfactorily for this research, the following steps were taken:

1) Methodical planning prior to conducting the case studies in collaboration with the experts helped to ensure that everything was prepared and that both sides shared a common understanding of the requirements
2) The involvement of the author in the selection of the case studies ensured that they satisfied the needs of the research
3) De-briefing sessions so that the experts could comment and give feedback as to the resultant findings.

8.5 Future Work

If the SIU Method is to be used as a complete PSS Design Methodology, further case studies are required which will allow in-depth, longitudinal studies (covering life-cycle phases) of a capability as well as its contributing capabilities and those it contributes to; ideally, these should be core value-creating capabilities. Nevertheless, as such an undertaking can be difficult because of limited access to proprietary information regarding core capabilities, it is suggested that further research may have to just focus upon either capabilities which are transparent or those which are auxiliary capabilities to key value-creating capabilities to the case study company. Such a case study should be a novel situation where the SIU Method can be applied to, not only the use phase but also to the accepted solution's initiation, attuning and end-of life phases to close any gaps the solution may have. The SIU Method should then also be applied to supplier capabilities to assess and address any gaps in supply to the new solution. The implementation of the solution should be followed up and then assessed for its effectiveness as compared to other possible solutions which could have been implemented. This would be required for an in-depth assessment of the SIU Method.

If the SIU Method is to be used as a stand-alone PSS Design Method then, the technique for evaluating the conceptual designs will need to be changed. The reason for this is that several conceptual designs may be generated, each of which may satisfy different stakeholders in different ways. In such a situation, it would be important to assess which aspects of each solution is important to each stakeholder and also where the common ground is. A technique such as AHP could be useful here.

Industry-specific versions of the SIU Method and computer systems could be created which could draw on a database of issues specific to a particular industry or process and relate them to the solutions which have been known to close the gaps. This would be an expert system which could be continually updated with new solutions and technologies as they arise.

8.6 Conclusions

This section outlines the key research contributions:

8.6.1 Contribution to Theory Development and Reconceptualisations

It is the customer's value creating system which is the problem space and the solution space for PSS Conceptual Design. Furthermore, and quite remarkably, it also appears that the customer's value creating system is also the problem space and the solution space for Product Conceptual Design and also Service Conceptual Design. This is because any gaps in the system present an opportunity for the provider to fill those gaps such as with an enhanced product, service, PSS or advice to the customer regarding their use patterns or how they arrange their environment. This is a stark contrast to the conventional elicitation of requirements where the provider would deem the customer's issue and the solution to that issue to begin and end, quite often, solely with the provider's value proposition.

It is important to note that, throughout the ages, customers have traditionally designed their own value-creating systems and then sourced, evaluated, integrated and attuned various value propositions (including PSS) with their own resources to suit their own environments in order to achieve an aim they have. These customers then operate, maintain and make improvements to that system.

The idea of Conceptual Design is not new and this has been traditionally in the hands of the customer who is (it appears), essentially, a designer. However, in order to offer value propositions that more closely help to achieve customer goals, servitizing providers (and perhaps providers in general) need to either appropriate part of or assist those traditional design roles of the customer in order to help to design and implement systems which deliver more value in use. Thus, PSS Conceptual

Design (and perhaps Conceptual Design in general) should start with the design of the customer's value creating system and not just with the design of individual products and/or services.

This understanding has produced the following theoretical reassessments of existing PSS Design theory:

1. **The Data to Collect and Analyse**
    - **The established unit of observation: *Product-in-use.*** Although PSS literature stresses a need to close the design loop by feeding product-in-use data into PSS Conceptual Design, the term suggests that the provider's product offering is the primary unit of observation (and perhaps analysis) for PSS Conceptual design.
    - **The proposed unit of observation: *System-in-use.*** It is the customer's value-creating system that should be the primary unit of observation and this should also be the primary unit of analysis. This will inform the provider as to the degree to which that system meets the customer's functional needs. This can then be compared to other system designs (which may differ in small ways or be radically to the current system) to ascertain the degree to which any proposed solutions deliver more value in use than the current one and how the new solutions compare to each other.
2. **Integration of the Product and Service Elements**
    - **Integration in PSS Design:** Rather than the concern of the provider being that the product and service of their PSS be integrated together (as emphasised by the extant PSS literature), the concern should be that those product and service elements are integratable into the *customer's value creating system* and support it. Also, the product and service elements may not necessarily be directly related to each other although they will be integral parts of the customer's system.
3. **PSS Conceptual Design:**
    a) ***Types of Design to Generate:*** Extant PSS Design Methodologies tend not to have a coherent set of design options which can be applied to generate

possible designs (Annamalai Vasantha et al, 2012). However, if the customer's value creating system is regarded as the design space (that is, the problem-space and the solution-space), then each of the elements of that system can then be considered in turn for redesign in order to ascertain which change would improve value in use. Conventional, incremental solutions should be generated alongside any innovative solution (such as a PSS). This allows any innovative solutions (such as PSS) to be compared against more conventional solutions to gauge the merits and demerits of those innovative solutions.

b) **Which Sub-systems Should be Considered for Redesign:** A value-creating system is recursive. That is, it is composed of sub-systems which are value creating systems in their own right. This theoretical basis allows each stakeholder's contribution to be evaluated and, to address any system shortfall, each of the various value creating systems that have interacted can then be conceptually readjusted to ascertain which system(s) and which adjustment(s) at which tier could help to close any gap in the customer's system.

This theory that was generated lead to the following reconceptualizations:

- **A Reconceptualization of PSS**
  - **A current definition of PSS:** *'A PSS is an integrated product and service offering that delivers value in use.'* (Baines et al, 2007). This is a widely used definition. However, a PSS can *never* deliver value in use. At best this definition could be considered to be misleading and it could even be described as a misconception. It is the customer's system (in which value propositions are embedded), in accomplishing a task the customer deems necessary, that can actually deliver this – this is co-creation. Any given value proposition will only ever be a sub-set of that system and it can only help to support that system.
  - **A proposed definition of PSS:** *A customer's value-creating system delivers value in use. A PSS is a product and service value proposition which is integratable into*

a value-creating system and contributes to that system. It is important to note that a PSS may be one of many resources which contribute to that system.

- **A Reconceptualization of Servitization**
  - **A current definition of Servitization:** *"Adding a service to a core product".* From the interviews with industry, this phrase was stated very many times. It could be argued that this definition is essentially provider-centric; its consideration appears to be more with that of the provider's value-proposition rather than with the customer's value-creating system.
  - **A proposed definition of Servitization:** "*Serving a customer's overall goal"*. Besides adding services, there may well be other improvements to a customer's value-creating system that could be made which are more apposite and which also do not over-reach the provider's capabilities. The various solutions which can be generated (which can encompass PSS designs or be more conventional changes) should be compared against each other to evaluate which solution is the most appropriate. It is then for the stakeholders to reckon which part of the accepted solution each is best placed to offer and/or control. A PSS could be merely one possible type of value proposition (out of several) that could be viable and then only if it supports the customer's system needs (helps to achieve the customer's goal) more than any other generated solutions. PSS are not a panacea; it is important to ascertain when it is apposite to develop and offer a PSS and when another solution is more fitting for all of the stakeholders else 'the cure' (the PSS) could be worse than 'the disease' (the customer's issue). Such understanding should help providers from spiralling into the services paradox.

PSS Conceptual Design (along with, Product Conceptual Design and Service Conceptual Design) appears to be a function of process or, more precisely, system design. This is because it is the customer's value creating system which delivers value in use (achieves the customer's business aim) and the consideration of its redesign to increase value in use can generate Conceptual Product, Service and/or PSS Designs as well as suggestions to modify the environment and/or change the receiver.

8.6.2 The SIU Method

The research objectives were met by the development of the SIU Method which is a problem-solving method that can be used quantitatively or qualitatively. It generates initial Conceptual Designs which can be simple, conventional designs along with designs which can be very innovative and PSS Designs. This allows any PSS Conceptual Design to be evaluated against more conventional designs to assess which solution is the most apposite. The generated designs can address the part of the system which contributed most the value loss of the whole system, redesigns of the whole system, changes to the environment (local and wider) and changes to the receiver of the system. Using the same Method, these solutions could also be evaluated against supplier capability to ensure that suppliers do not over-reach their capabilities.

In addition to this, the SIU Method can open up the problem-space throughout the value chain which allows for different solutions to be generated at different tier levels; depending on which solutions have been selected, this then allows different capabilities at different tiers to become the focus for redesign.

8.6.2.1 The SIU Method as a PSS Design Method

The SIU Method, rather just utilising SIU data to inform PSS Conceptual Design, could be regarded as a PSS Design Methodology in its own right. This is because its theoretical underpinning allows for the assessment of value gaps and the consideration of redesign of all of the elements in a capability in any system to achieve an end. For this reason, it appears that the method applies to, not only the examination and closing of gaps in the use phase of a system but also:

- **Solution Refinement:** as shown in Chapter 7, it appears that the SIU Method could also be used here to refine the selected solution by closing any gaps the solution may have.
- **Lifecycle Engineering:** By also applying the SIU Method to the initiation, integration, attuning and end of life phases of the selected solution, gaps throughout the expected lifecycle of the solution can be pre-empted which

could lead to that solution being rejected (and new ones selected) or those gaps being closed by generating solutions. This would be achieved by applying the SIU Method in order to depict that phase of the solution, describe any gaps that it is expected to have and then generating designs to close the gaps.

- **Supplier Capability:** Using the SIU Method, the difference between what suppliers can presently offer (including what the customer will have to contribute to the new system) and the demands of the new solution can be assessed. This will inform supplier selection and could lead to solutions being rejected (and new ones selected) or new solutions could be generated to fill the gaps. This would be achieved by applying the SIU Method to find the gaps (the difference) between what the solution requires and what different suppliers currently offer; this can help to determine which supply meets the solution most closely and then designs can be generated to close the gaps.

As from the literature review, although currently the development of PSS solutions is ad hoc and the roles and involvement of stakeholders at the various stages of PSS development have not yet been fully defined, the above procedure for PSS Conceptual Design is structured and involves the customer and suppliers along with manufacturers to develop conceptual PSS solutions. Furthermore, this PSS Design procedure would help to develop PSS solutions which are aligned to all the stakeholders' capabilities; it does this by taking its starting point as the value-creating system rather than starting design from PSS types such as product-, result- and use-oriented. It would also improve the overall life cycle of a system by avoiding sub-optimizing any individual activity. This point is worthy of note. For example, in the laser job shop case study in Chapter 6, collecting data from just the laser system and its maintenance service would have revealed that the laser system has a high uptime but that it is being used to near capacity. Such limited understanding could have prompted the provider to develop a laser system with a higher capacity and offer it to the job shop. Alternatively, the job shop could have stated to the provider that they had clients who were complaining about the cost and time it takes for these clients to receive their laser-cut components; this could have prompted the provider to speed up the laser system and reduce its costs. However, as seen in Chapter 6, the support that the job shop actually required was for smaller capacity, dedicated process, lease or pay-per-use laser machines that they could put on the client's premises; this is a very different type of laser machine to those previously mentioned. Without appreciating that it is the job-shops processes that they should be designing for, the laser manufacturer could have invested a great deal and spent a lot of time developing machines that would have more capacity or be quicker and cheaper – none of which would have addressed this particular job shop's business issue.

8.6.2.2 The SIU Method Reframing Supply Chain Management

Although the many definitions of Supply Chain Management all tend to be focused toward a physical transfer of goods (Ellram et al. 2004), the SIU Method allows for the service that created those goods to also be considered during design. For the value chain to learn, what is required is an awareness of issues arising in the value chain and the ability to measure, not only any given firm's performance, but also the overall system performance (Lusch, 2011); the SIU Method, as illustrated by its application to the aero engine value chain case study (Chapter 7), facilitates this.

Petersen, Handfield and Ragatz (2005), in an empirical study performed on a sample of 134 predominantly manufacturing US companies, developed high-level scales to assess the technical ability of a supplier; their work suggests that the best method for coordinating the product, process and supply chain domains is to effectively integrate the supplier into the development stage of the product (Petersen et al., 2005) as, this way, coproduction would be fostered; the SIU Method can facilitate the introduction of the supplier during problem identification and also solution generation.

From the results of its application to the aero engine value chain case study (Chapter 7), the SIU Method appears to have moved Supply Chain Management (SCM) concerns from:

- Collaboration towards value co-creation,
- The consideration of the flow of goods towards the operant and operand resources that have produced those goods and services,

- ➢ Optimisation towards new business opportunities,
- ➢ Dyadic analysis towards network analysis

This has addressed several research questions (as taken from Lusch's research questions in his paper, "*Reframing Supply-Chain Management: A Service-Dominant Logic Perspective improving Supply Chain Management by taking a Service-Dominant Logic (S-D L) perspective*") regarding the improvement of SCM:

- *"How can the customer's value creating system be understood by SCM and how can the contribution of suppliers to this be understood?",* (Lusch, 2011).

  Understanding of the Customer's Value-Creating System: It is important to recognize that it is difficult, not to say impossible, to turn every expectation and need into explicit requirements and then stringently decompose these throughout the supply chain. In particular, service related requirements require a great deal of use situation and contextual understanding. However, showing how each stakeholder contributes to the end-customer's value creation system and depicting the customer's issue as parameterised gaps within that value creating system should help the issue to be understood throughout the value chain.

- *"How can SCM make competitively compelling value propositions not only for its customers but customers of customers and backward to the firm's suppliers and their suppliers?",* (Lusch, 2011).

  The SIU method facilitates innovative suggestions to be generated at lower tier levels which can "push" higher capabilities into new solutions and, similarly, innovative suggestions are also generated at higher tier levels which can "pull" lower capabilities into new solutions.

- *"How can the SCM learn more quickly and then act on this learning to continuously have a knowledge advantage and hence competitive advantage?",* (Lusch, 2011).

  The method is useful in capturing issues and generating solutions and so can be used for knowledge transfer to new projects so that the issues will not surface again, Furthermore, this method could be a means to "future–proofing" capabilities: 'What-if' analysis could be performed using the SIU Method as this could also be applied to see what gaps and solutions would be generated if, for example, a customer demanded a higher responsiveness from the provider or if a supplier put up their prices by, say, 10%; this would help to determine the flexibility in their capabilities and, by modifying the capabilities accordingly, could help to make them more future-proof.

- *"How can the SCM develop a global communication system that allows for diverse cultures operating around the world to work as an effective team?",* (Lusch, 2011).

  An overriding issue in this case study has been the information flow between the stakeholders, which is a common issue in value chains and in developing enduring, innovative solutions. The SIU Method can help to tackle this area by opening up the channels of communication between stakeholders. Furthermore, the system depiction is accomplished using a version of Service Blueprinting which is a common representation technique that is widely accepted and easily understood. Likewise, the operant-operand diagrams and Proposals Matrix would also appear to be fairly simple methods which should be comprehensible by most stakeholders. For these reasons, it is expected that the system depictions and gaps along with the generated solutions should be widely comprehended by a variety of stakeholders in any geographical location.

- *"How can the SCM open its innovation process to all members of the service ecosystem yet protect important property rights?",* (Lusch, 2011).

  For any given capability, the operant and operand resources as well as the process, environment, market segment and system can be considered for redesign so as to close the gaps within that capability. Furthermore, if that capability is drawn as part of other stakeholder's capabilities, those capabilities can also be explored for solutions to close the gaps. This unpacking of capability facilitates innovation as hitherto overlooked factors can now be considered for redesign. The case study shows that the SIU Method can be used even when capability information is incomplete and just based on qualitative information.

Following all of the steps prescriptively as in the quantitative version of the SIU Method could be unwieldy and industry tends to be more solutions-focussed rather than problem-orientated. However, using the qualitative version of the SIU Method allows for a speedy, general understanding and generation of solutions to be produced which also protects proprietary data. The results can be used as a 'rule-of-thumb' and as the start of a dialogue with other stakeholders to demonstrate how the method can produce pertinent results. This could then lead to further, more detailed exploration of the issue by each stakeholder applying the quantitative version of the SIU Method and then sharing those parts of the output of the method which are non-sensitive.

8.6.2.3 Customer Requirements

Within the PSS context, Toossi has identified several dimensions of value which are necessary for the provision of maintenance services (Toossi, 2012) but which could also apply to services and capabilities in general. Some of these dimensions of value are *Delivery*, *Locality*, *Cost Saving* and *Responsiveness*. The laser job shop case study (Chapter 6) showed how the speed and cost of *Delivery* and *Locality* of the provider can be prime concerns of their customers. The issue of *Cost Saving* and *Responsiveness* were also concerns and these were depicted and addressed. The SIU Method showed that the cost and speed (the capability parameters) of *Delivery* resulted in customers paying a much higher price and it took a long time for their laser cut parts to arrive. A possible solution was for the laser job shop to move some capability closer to the customer (increase *Locality*) which would result in *Cost Saving* and increased *Responsiveness*.

Other dimensions of value are *Communication*, *Detailed Analysis*, *Innovation*, *Proactiveness of the Service Provider*, *Service Driven Attitude*, *Quality of Service* and *Understanding the Customer's Business* (Toossi, 2012). From the Aero Engine value chain case study (Chapter 7), it can be seen that these dimensions of value that the customer requires have been improved by the application of the SIU Method.

This would suggest that this method provides a way to depict customer requirements as determined by the value-in-use they experience by locating and measuring gaps within a capability and then affording a technique to adjust the system in various ways so that these gaps can be reduced to improve value-in-use.

The author currently claims that the application of the SIU Method within an industrial environment can define the problem-space of any reported issue and then allow a wide solution-space to be identified so that initial, Conceptual PSS Designs and conventional designs can be generated to address that issue in a variety of ways.

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9 APPENDICES

9.1 Appendix A

Interview Questions (See Chapter 4.1)

Product Service Systems Conceptual Design:
Specific Topic: Maintenance Services

Objectives of this study:

- To identify the AS-IS process followed in industry to design (or plan) maintenance and related service activities.
- To identify the level of service network capability consideration at the maintenance design stage.
- To identify the level of feedback from customers, users and the PSS or asset to influence PSS Conceptual Design.

Semi-Structured Questions for:

- **companies producing industrial, capital-intensive, technical and infomated PSS with**
- **senior managers with at least five years' experience in their role and knowledge of PSS and maintenance**

Research aim:
The aim of this research is the development of a framework which uses product-in-use data to inform PSS conceptual design to address the issues customers have when using a PSS or product to meet their objectives.

Research stage & current insight: *(Focus for exploration)*
The AS-IS situation with regards to how industry which produce capital-intensive, infomated and technical PSS use product-in-use data to inform PSS Conceptual Design.

Case description: *(company type, respondent)*	
Company Name: ___________________	Job Title: __________________________
Respondent Name: _________________	Job Role Details: ____________________
Contact Details: ____________________	Years of Experience in that Job and in that Role: _____________

Case justification: *why this company? How does this company match the research aim? Why this validator?*
This company produces capital-intensive, technical and industrial PSS. The respondent at the company also has an extensive knowledge of servitization and PSS. The company is interested in methods to develop PSS as well as any possible, general improvements in its processes and those of its suppliers and customers.

Interview Questions

1. Organization

1. How big is the company?
2. How many products, maintenance contracts or PSS do you sell on average per year?
3. What types of PSS do you offer?
4. How is the company spread (the locations) and how does each division cater for maintenance?
5. What is the size of the maintenance service department?
6. Who are your customers and where are they located?

2. Design of Maintenance

1. What kinds of maintenance service are offered?
2. Why do you offer these maintenance services?
3. How do you decide which maintenance services should be offered?
4. Do customers demand particular maintenance services?
    - If so, why do customers expect these maintenance services?
5. Who in the organization plans these services?
    - What is the organizational structure of the maintenance service department?
    - How is the work divided within the maintenance department?
    - Who are the stakeholders for these maintenance services?
    - What are the roles and responsibilities of the stakeholders?
    - What resources (people, equipment, software) do you have to carry out these maintenance services?
6. How do you plan for these maintenance services?
    - Do you use any methods / tools to plan for these maintenance services?
    - Are you given maintenance service requirements from your customers? If so, what are they?
    - How do you decide on the resources (people, equipment, software) required for these maintenance services?
    - How do you decide whether to manufacture or buy any of these resources?

        i. What procedure, model or framework do you follow during the make or buy decision making process?
        ii. If you buy these resources; who is responsible for the supplier selection procedure?
7. What does a maintenance service plan contain?
8. Do you evaluate the maintenance services provided? If so:
    b. How do you evaluate these maintenance services?
    c. Are there any regulations and/or standards to which these maintenance services should adhere?
9. What are the challenges faced when offering these maintenance services to your customers?
10. What kinds of maintenance services would you like to offer to customers in the future?

3. Supply network

11. Do you directly offer these services to your customers? If so :
    a. Where are your maintenance offices located?
12. Do external suppliers assist you in providing these maintenance services?
    b. What is the total number of suppliers involved in maintenance?
    c. Where are these suppliers located?
    d. Who from which department is responsible for dealing with suppliers for maintenance services?
    e. What kind of products and what kind of services do you acquire from external suppliers for maintenance services?
    f. How do you manage (i.e. control, plan and coordinate) your suppliers?
        i. Do you evaluate the services and/or products provided from suppliers?
        ii. If so:
            1. How do you evaluate these products and services acquired from suppliers and what kind of measures do you use?
            2. What is the difference between the measures for products and the measures for services acquired from the supplier?
    g. Are suppliers involved in the design of maintenance services? If so:
        i. What is the suppliers' role and involvement in the design of maintenance services?

4. How Product-In-Use Data is used to Influence PSS Conceptual Design

Field Data and PSS Conceptual Design:

1. How do you think a PSS should meet a customer's needs?

   [If there is a pause or no answer, then ask:]

   i. How do you think a PSS should differ to a product in terms of satisfying customer's needs?

2. Do you utilise product-in-use or PSS-in-use data to inform PSS Conceptual Design?

   If so:

   a) Where do you collect data from to influence PSS Conceptual Design?

   b) What type of data is collected?

   c) How is the data collected?

   d) Could you describe typical data sets?

   e) What does the data indicate?

      I. Why is it important for the data to indicate this?

      II. How is the data processed to indicate this?

   f) Is this augmented with feedback directly from customers and/or users?

   g) What tools, techniques or methods are used?

   h) How does the data inform PSS Conceptual Design?

   i) Specifically, have maintenance, maintainability or **[if you have availability contracts]** availability contracts been influenced by such data?

   j) Who (or which department) is responsible for analysing the data?

   k) Could I see a sample data set or documents that that relate to this?

   If not (they don't utilise data from the field to inform PSS Conceptual Design):

   a) Where do you think data should be collected from to influence PSS Conceptual Design?

   b) What type of data should be collected?

c) How should the data be collected?

b) What should the data indicate?

   I. Why should the data indicate this?

   II. How could the data be processed to indicate this?

d) What tools, techniques or methods could be used?

e) How could the data inform PSS Conceptual Design?

   [If there is a pause, no answer or “don’t know” then ask:]

   I. For example, could the data be mapped to different PSS Designs?

   [If the answer is yes, then ask:]

   II. How could this be accomplished?

Summarize and list of actions

Other methods: *(e.g. survey, observation, recording, notes)* Notes will be taken during the interview. The interview will also be recorded.

Analysis techniques & Plan: *e.g. type up notes / create cause and effect diagrams / create matrix / transcribe & code, etc.* A report will be created, describing the findings from all of the interviews within this sample. The feedback that the respondents give will be used to refine the conclusions and questions and will then be and presented to the respondents to check their validity.

9.2 Appendix B

An Anonymised Sample Data Set of an HVAC System (See Chapter 5)

Date and Time	Fan Coil Unit 6	Fan Coil Unit 5	Fan Coil Unit 4	Fan Coil Unit 3	Fan Coil Unit 2	Fan Coil Unit 1	Ceiling	Desk Level	Floor	Supply Air	Corner Office	Low Pressure Hot Water	Chilled Water	Outside Air Normal	Outside Air Radiant
27/01/2009 00:00	99.8	30.8	31.1	32.1	29.8	21.1	22.7	22.1	21.8	20.8	20.9	49.8	21.8	13.9	20
27/01/2009 00:01	99.7	31	31.8	33	31.1	21.1	22.7	22.7	21.8	20.8	21	49.7	21.8	14.1	20
27/01/2009 00:02	99.9	31.7	31.9	33.8	32.7	21.1	22.7	22.7	21.8	20.9	21.6	49.1	21.8	14.8	20
27/01/2009 00:03	33	31	31.8	34	33.7	21.1	22.7	22.8	21.8	20.9	21.8	49	21.8	15	20
27/01/2009 00:04	32	29.8	30	33.8	34	21.1	22.7	22.9	21.8	20.9	21.8	49	21.8	14.8	20
27/01/2009 00:05	30.1	28	28.1	32.8	34.1	21.1	22.7	22.9	21.8	21	21.9	48.9	21.8	14.7	20
27/01/2009 00:06	28	26.8	26.8	31.1	33.8	21.1	22.7	22.9	21.8	21	22	48.9	21.8	14.7	19.9
27/01/2009 00:07	26.8	25.9	25.8	30.1	32.9	21.6	22.7	22.9	21.8	21	22	48.9	21.8	14.9	19.9
27/01/2009 00:08	25.7	25.1	25	28.9	32	21.6	22.7	22.9	21.8	21	22	49	21.8	14.7	19.9
27/01/2009 00:09	24.8	24.8	24.8	27.9	31	21.6	22.7	22.9	21.8	21.1	22	49.1	21.8	14.8	19.9
27/01/2009 00:10	24.1	24.7	24.6	27	30.7	21.6	22.7	22.9	21.8	21.1	21.9	49.1	21.8	14.9	19.9

A Sample of HVAC data which is collected by sensors from each of the devices in an HVAC Process

9.3 Appendix C

Interview Questions (See Chapter 5)

Product Service Systems Conceptual Design:

Specific Topic: Maintenance Services

Objectives of this study:

- To identify the level of feedback from customers, users and data from the PSS or asset used to influence PSS Conceptual Design.

Semi-Structured Questions for:

- **A company producing low-cost, technical and infomated PSS with**
- **senior managers with at least five years' experience in their role**

Research aim:

The aim of this research is the development of a framework which uses system-in-use data to inform PSS conceptual design to address the issues customers have when using a PSS or product to meet their objectives.

Research stage & current insight: *(Focus for exploration)*

The AS-IS situation with regards to how industry use system-in-use data to inform PSS Conceptual Design.

Case description: *(company type, respondent)*

- Company Name: ___________________________________

Respondent 1

Respondent Name: ____
Contact Details: ____
Job Title: ____
Job Role Details: ____
Years of Experience in that Job and in that Role: ____________________________________

Respondent 2

Respondent Name: ____
Contact Details: ____
Job Title: ____
Job Role Details: ____
Years of Experience in that Job and in that Role: ____________________________________

Respondent 3

Respondent Name: ____

Contact Details: _______________________________________

Job Title: ____

Job Role Details: ____

Years of Experience in that Job and in that Role: ___________________________________

Case justification: *why this company? How does this company match the research aim? Why this validator?*

This company produces low-cost, technical PSS which supports their clients in offering capital-intensive PSS. The aim of this investigation is to ascertain the AS-IS situation for how this company uses system-in-use data to influence PSS Conceptual Design.

Interview Questions

1. Organization

a) How big is the company?
b) How many products, maintenance contracts or PSS do you sell on average per year?
c) What types of PSS do you offer?
d) How is the company spread (the locations).

2. How Product-In-Use Data is used to Influence PSS Conceptual Design

Field Data and PSS Conceptual Design:

3. How do you think a PSS should meet a customer's needs?

   [If there is a pause or no answer, then ask:]

   ii. How do you think a PSS should differ to a product in terms of satisfying customer's needs?

4. Do you utilise product-in-use or PSS-in-use data to inform PSS Conceptual Design?

   If so:

   a) Where do you collect data from to influence PSS Conceptual Design?

   b) What type of data is collected?

c) How is the data collected?

d) Could you describe typical data sets?

e) What does the data indicate?

   III. Why is it important for the data to indicate this?

   IV. How is the data processed to indicate this?

f) Is this augmented with feedback directly from customers and/or users?

g) What tools, techniques or methods are used?

h) How does the data inform PSS Conceptual Design?

i) Specifically, have maintenance, maintainability or **[if you have availability contracts]** availability contracts been influenced by such data?

j) Who (or which department) is responsible for analysing the data?

k) Could I see a sample data set or documents that that relate to this?

If not:

f) Where do you think data should be collected from to influence PSS Conceptual Design?

g) What type of data should be collected?

h) How should the data be collected?

c) What should the data indicate?

   I. Why should the data indicate this?

   II. How could the data be processed to indicate this?

i) What tools, techniques or methods could be used?

j) How could the data inform PSS Conceptual Design?

[If there is a pause, no answer or "don't know" then ask:]

   I. For example, could the data be mapped to different PSS Designs?

[If the answer is yes, then ask:]

   II. How could this be accomplished?

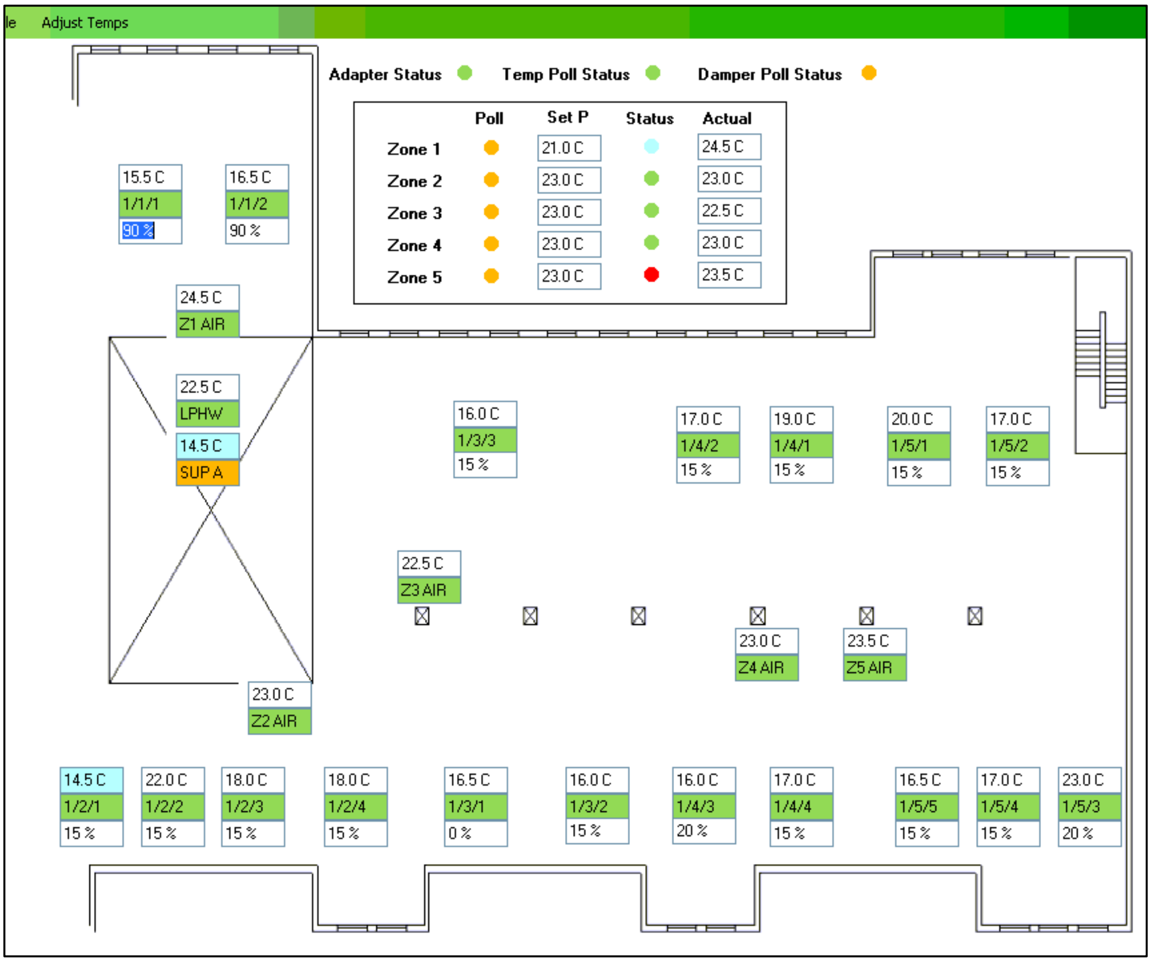
Summarize and list of actions

Other methods: *(e.g. survey, observation, recording, notes)* Notes will be taken during the interview. The interview will also be recorded.

Analysis techniques & Plan: *e.g. type up notes / create cause and effect diagrams / create matrix / transcribe & code, etc.* A report will be created, describing the findings from all of the interviews within this sample. The feedback on this report that the respondents give will be used to refine it and it will then be and presented to the respondents to check its validity.

9.4 Appendix D

A Floor Plan of a Space under Investigation (See Chapter 5)



9.5 Appendix E

A Scenario of Usage to Validate the Ontology (See Chapter 5)

Background to the HVAC Scenario

A potential client has raised an issue with the HVAC Consultants that the users of a room in their building have found that room to be too cold. This means that the heating capability of the room is at a level below that which is required. This overall heating capability consists of:

- A way (operand resources – several radiators) to heat (a process) the air (the operand resource).
- This will take place in an environment:
    - *Local environment:* the room – this room is 30' x 30'. There will be a door, two windows and a ventilation in this room along with the 10 users of that room.
    - *Wider environment*: One of the room's walls being exposed to the outside environment and the remaining walls are shared with other rooms.

The first task would be to find out where the problem is; the users could, for example have found that when sitting at their desks they become too cold. The exact temperature of this area would need be polled and it should then be established what temperature the users desire.

To find which part of this system (the heating capability) which has contributed most to the excessive coldness, each part of this system can be examined using temperature sensors.

Scenario:

A correlation is found between the outside temperature and the room temperature; only on cold days does the room become excessively cold.

To conceptually redesign this system, a change to each part of the capability can be considered in turn:

- ***The environment:***
    - *Wider environment:* perhaps a board (an advertising board, for example) could be placed on the outer wall – this could partially insulate that room.
    - *Local environment:* The room could be insulated.

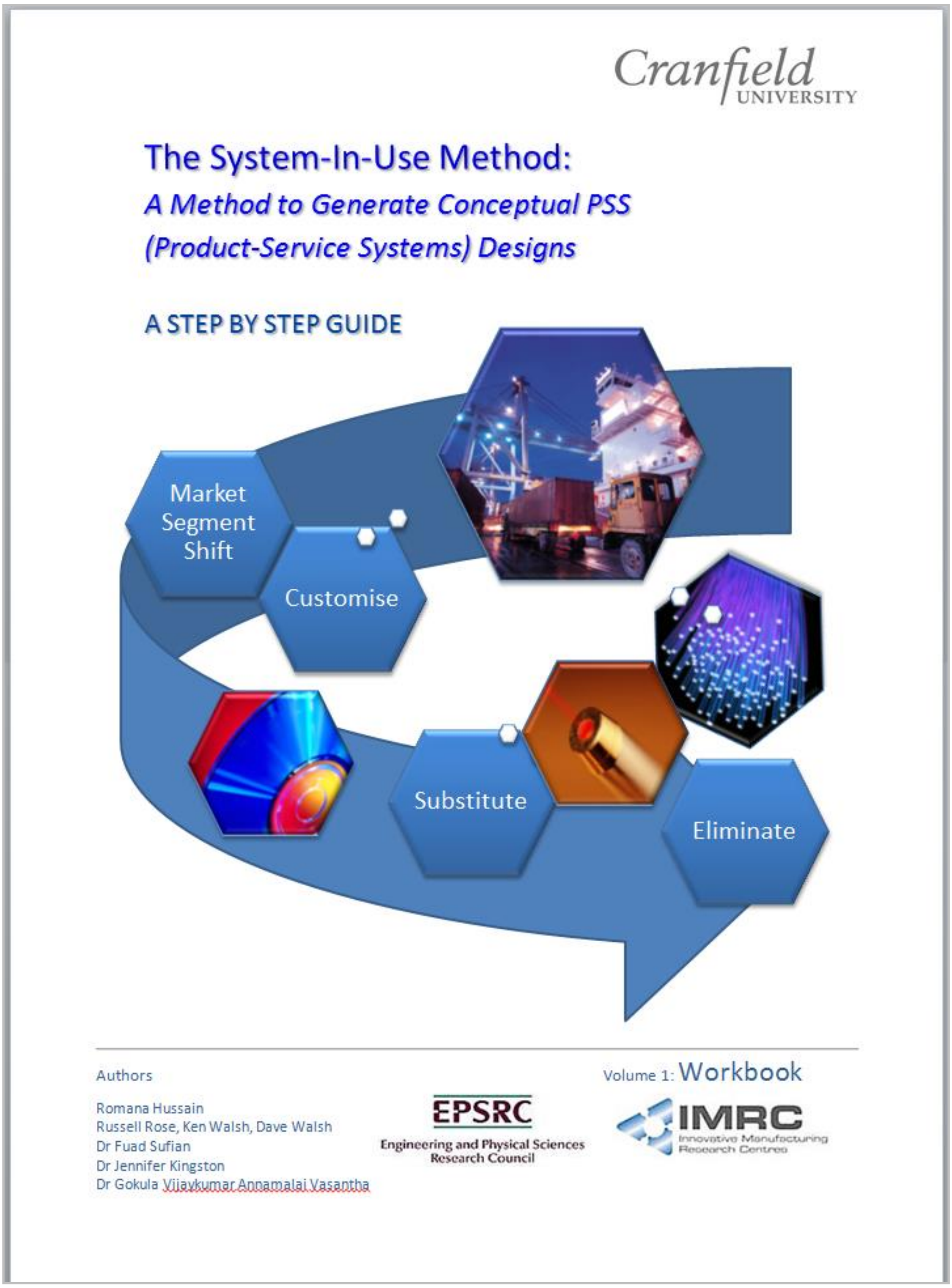
- ***The heating resource (the operant):*** perhaps this could be changed in several ways:
    - More heating units added.
    - The setting of the radiators could be increased to a higher level.
    - Substitute the radiators for more powerful ones.
    - Elimination of the radiators does not seem to be a reasonable option in this particular scenario.
- ***The air (the operand)***: the only way to change this appears to be with the ventilation system:
    - Substitute the current ventilation system with one that does not let in too much cold air or with one that heats the air as it enters the room.
    - Elimination of the ventilation system does not seem to be a reasonable option here.
    - If too much cold air from outside is being let into the room, then the ventilation system could be adjusted to reduce this.
    - An addition of a ventilator hood could minimise the amount of cool air being let in.
- **The process**: the way the air is heated:
    - The radiators could be kept on (perhaps to a lower heat) even when the room is unoccupied – this may allow the room to be kept at a warmer temperature.
    - The addition of a reflective material behind the radiators could deflect more heat back into the room.
    - The only way to substitute the process of heating the air would appear to be with a new heating system such as underfloor heating.
    - Elimination of the process would not be reasonable here.

Other possible solutions are:

- ***Redesign the whole system****:* Replace the whole heating system with one that can produce the desired temperatures.
- ***Change the receiver:*** If the room is an issue, then perhaps the users could be moved to another room and this room could, for example, be used or storage or for workers using computers – the computers could increase the temperature of the room.

9.6 Appendix F

The Workbook (See Chapter 6)



Cranfield UNIVERSITY

The System-In-Use Method:

A Method to Generate Conceptual PSS (Product-Service Systems) Designs

A STEP BY STEP GUIDE

Authors

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EPSRC Engineering and Physical Sciences Research Council

Volume 1: Workbook

IMRC Innovative Manufacturing Research Centres

Contents

1 Overview of the Workbook

This Workbook has been created to help organisations to generate initial ideas as to what sorts of PSS they could consider developing (or, if they already produce PSS, how they could improve their PSS) and how these match up against other more conventional designs. The objective of this Workbook is to provide a step-by-step guide for initial PSS Conceptual Design.

The method presented in this workbook generates Conceptual PSS (Product-Service Systems) Designs from how customers actually use products and services: it depicts reported problems as an issue with a system, determines where value is lost within that system and then, to increase value, generates possible solutions based on supplier capabilities. The solutions are then evaluated to determine which close the gaps the most and which the stakeholders find acceptable.

Although later stages of solution refinement are outside of the scope of this research, suggestions are made in this Workbook as to how this method can be applied to also help to further refine solutions.

1.1 Authors

- **Romana Hussain** – Researcher at Cranfield University in Product-Service Systems
- **Russell Rose, Ken Walsh, Dave Walsh *** – are HVAC (Heating, Ventilation and Air Conditioning Systems) systems consultants at Mowjo-E (http://www.mowjo-e.com/). They are based in Kingston, Milton Keynes. This company can be regarded as a servitization enabler - they can help to support building product-service systems (such as hospitals, apartment complexes and office blocks which are leased or rented out). They can support these high value, technical product-service systems by establishing a pleasant climate in the building for tenants or lease-holders and by reducing the energy bills for HVAC systems: this would make the occupation of the building more comfortable and affordable for its tenants. A core service that Mowjo-E offer is the rationalisation of HVAC systems so that large energy savings can be made on existing heating and ventilation systems: by using sensors, trouble spots can be identified as can HVAC systems which may be working in opposition to each other– addressing these issues can result in huge energy savings. For this service, they offer a functional result; that is, the creation of a pleasant building (or floor) climate at a much lower energy cost. A business model that they offer is one where they will accept a rolling percentage of the energy savings that they've instituted. This business model represents a "win-win-win" where the building users benefit from a pleasant climate, managers are able to cater for users but at lower costs, Mowjo-E receives a percentage of the savings and (because less energy is being used) there is also a reduction in carbon emission.
- **Dr Fuad Sufian*** - Associate Professor at Sana'a University, Yemen, and Civil Engineering Consultant
- **Dr Jennifer Kingston** - Lecturer and Course Director of the MSc in Astronautics & Space Engineering at Cranfield University's Space Research Centre
- **Dr Gokula Vijaykumar Annamalai Vasantha** – researcher at Cranfield and Strathclyde University in the Conceptual Design of Product-Service Systems

1.2 Acknowledgements

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The research supporting this workbook ran from 2009 until 2013. Academic Journal papers from this research can be found at https://dspace.lib.cranfield.ac.uk/

* Special thanks have to be extended to those who inspired and made this workbook possible with their ingenuity, care and collegiality:

- **Russell Rose**, **Ken Walsh** and **Dave Walsh** of Mowjo-E (HVAC Consultancy) for such remarkable and refreshing foresight, innovation and systemic thinking. Their "win-win-win" business models offered are inspirational and ones that many companies can only aspire to. The method in this work book has been greatly influenced and shaped by their instruction - many thanks also for their cordiality.
- **Dr Veronica Martinez** at Cranfield University for her interest in this work.
- **Dr Helen Lockett** at Cranfield University for suggesting a study such as this.
- **Dr Fuad Sufian** for his assistance and care and, most of all, for his enduring wisdom.

2 Foreword & Introduction

What is a Product-Service System (PSS)?

Quite simply, a product-service system offering is an integrated product and service package that can be used to help a customer's task to be fulfilled[1].

Why are Product-Service Systems Important for the UK Manufacturing Sector?

The UK manufacturing sector cannot compete on cost with manufactured goods from low cost economies. Therefore, in order to gain competitive advantage, the UK manufacturing sector needs to find new ways in which they can deliver extra value to their customers.

To do this, the deeper needs of the customer (the goal that the customer is trying to achieve when they are using a product or even a service) have to be understood more clearly so that the provider can cater more finely to these needs. As customers integrate products and services into a system to achieve a goal they have[2], providers need to know about the customer's system and goal so that they can then, not only determine how well their products and services serve it, but what gaps are in that system. Any gaps in the customer's system (or any negative side-effects produced) present an opportunity for the provider to fill those gaps with solutions (or minimise any unwanted side-effects) and hence gain competitive advantage. Product-Service systems represent one way that those gaps can be closed.

What Types of Product-Service Systems are there?

- ***A Product Oriented PSS*** - is a PSS where the customer owns the product but additional services such as maintenance are provided.
- ***Use Oriented PSS*** - This is a PSS where ownership of the product is retained by the provider, who then (for a fee) allows customers to use the product per unit of use or time: this can take the form of the product being shared, pooled or leased.
- ***Result Oriented PSS*** - This is a PSS where products are replaced by services, such as, for example, voicemail replacing answering machines[3].

What is Product-Service Systems Conceptual Redesign?

This is the redesign of an existing system (a business or use process) with which there is dissatisfaction. The new redesigns may stipulate new requirements for elements (that is, products and services) within that system or be a totally new redesign of the whole system. It is then for the stakeholders (such as the provider, customer and suppliers) to allocate the provision, roles and responsibilities of the various parts of that system ; that is, decide upon which parts of the system each stakeholder is able to offer, run and be responsible for. It is important to note that not all of the designs generated will result in the suggestion of a PSS offering from a provider as any PSS solution should be compared against other possible conventional redesigns to assess that PSS's merits and demerits.

When Should PSS Designs be adopted?

PSS offerings are not a panacea; they are merely another solution by which a provider can augment their offering. There could be other more conventional changes which could address any issue more exactly, easily, timely and cheaply. It can be the case, even though a PSS offering could appear to address an issue, that the disruption and costs in the initiation phase may make that solution (at that moment in time) prohibitive for the customer and provider. In such a case, at that moment in time, the "cure" would be worse than the condition. Therefore, it is important to note that PSS offerings are only one change that can be made to improve a customer's system (although they can offer huge improvements in value) and that they should be evaluated against other possible improvements.

What is the System-In-Use Method?

This method documents, confirms and quantifies issues and then depicts them as a loss in the outcome of a system; it then determines where value is lost within that system and then, to increase value, generates possible solutions based on supplier capabilities. Solutions are then rated as to the extent to which they are expected to close the gaps and also which are acceptable to the customer. The suggested solutions could take many forms including that of the creation of PSS offerings. The process could be initiated by the:

- **Provider:**
    - To suggest an improvement to a customer process based on new supply capability (this is a "push")
    - To examine the system of one or more customers (in which their offering is embedded) to see how they could better serve the customer.
- **Customer:**
    - As a way to report a problem to a provider with regards to a system in which they use that provider's offering (this is a "pull")
    - As a way to for the customer to make improvements to their own system.

The next stages of prototype development can occur where the solutions can be further evaluated and refined – this stage is outside of the scope of this Workbook.

How are More Refined PSS Prototypes then Developed?

Although this is outside the scope of this Workbook, this can be touched upon briefly here.

The gaps in any new solutions could be found and filled using this method – this would represent a further level of refinement and evaluation of the new solutions.

The ability of the suppliers to meet new solutions could be determined by charting the gaps between the new solution and what the supplier can offer. The gaps could be then filled using this method.

The method could also be used to find and address gaps in, not only in the use-phase, but also in the initiation, integration, attuning and end-of-life phases of the new solution. All of the stakeholders (such as customers and providers) could then collectively assess the solutions.

2.1 How to Use this Workbook

This Workbook aims to provide a step-by-step guide to generating conceptual PSS designs. There are two versions of the SIU Method: one which utilises quantitative data and another which utilises qualitative data. The version shown in this workbook is the quantitative version.

- **For Customers Using Products, Services or PSS**

  This Workbook can be used by anyone wishing to analyse any dissatisfactions and improve any system they have. The solutions produced can generate steps that the customer can take and/or steps that the provider can take.

- **For Providers of Products, Services or PSS**

  This Workbook will allow providers to gain a deeper understanding of how well their offering fulfils their customer's needs and how any issues could be looked at systematically. The solutions produced can result in the improvement of their offering and their general service to the customer.

3 The System-In-Use Method

3.1 Introduction to the SIU Method

Meeting a Need: Customers embed products and services into a system with their own resources in order to achieve a goal they have. The degree to which that system (this can also be termed as a capability) meets their aims is the degree of usefulness of that system (this is often referred to as value-in-use). Systems are composed of sub-systems (also termed as sub-capabilities) which are systems in their own right.

Assessing the Usefulness of a System: to assess this, the difference between what the customer wanted to accomplish and what they actually accomplished with the system can be reckoned.

Assessing the Value Loss in a System: to find out where in that system value was lost, the degree to which each sub-system contributed to the overall value loss can be gauged.

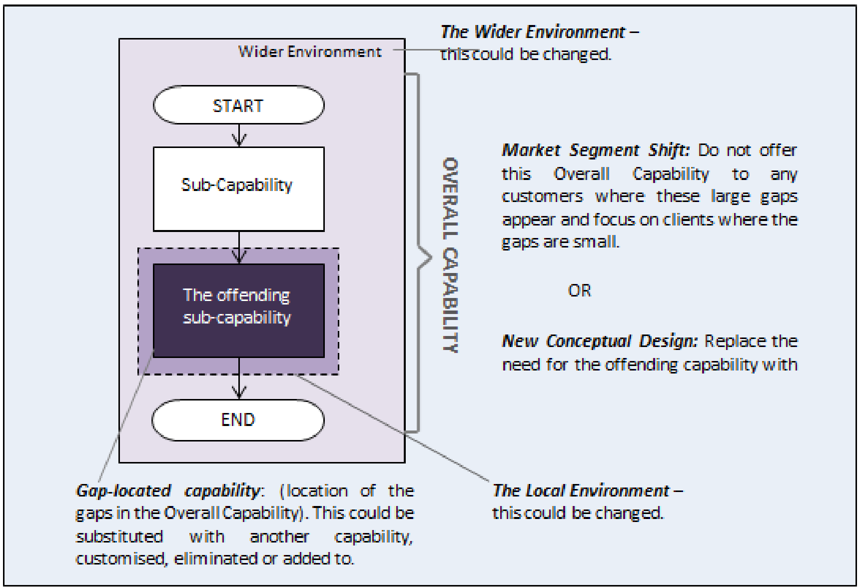


Figure 3.1.1: The elements in a capability that can be changed

Generating New Designs: this can be accomplished by considering changes to various parts of the system (See Figure 3.1.1):

a) Changes that can be considered to the overall system are: changes to the environment (local and wider), a completely new conceptual system or changing the receiver to one whose needs are met by the system.
b) Changes that can be considered to that part of the system which contributed most to value loss are: customisation, elimination or addition to that sub-system. Alternatively, the offending part of the system could be substituted with another sub-system.

Examination of the Value Chain: because the customer's system is composed of sub-systems, each supply that contributed to the offending part of the system (which could be a product or service) can also be assessed in terms of how a change to each supply could improve that offering and so improve the customer's overall system.

Note:

Careful attention should be paid to change management as although this method can suggest very innovative improvements to a capability, that does not necessarily mean that such changes should automatically be instituted; a through audit of existing stakeholders and ones that could be lost as well as new ones that the new solution will involve should help to determine who will be affected and then any resistance to change can be ascertained, examined and catered for sensitively.

3.2 Overview of the System-In-Use (SIU Method)

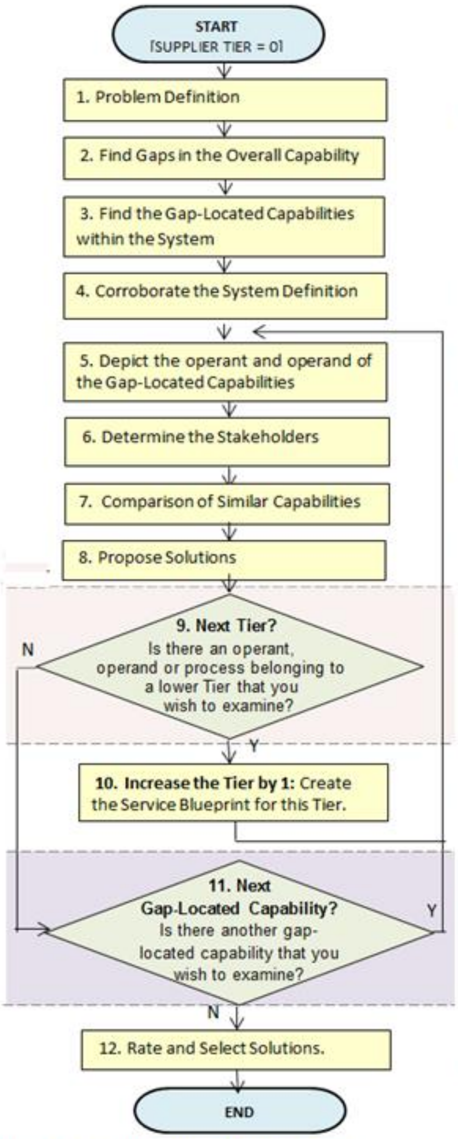


Figure 3.2.1: The System-In-Use Method

Description

Start with the end user (Tier 0)

1. Determines the issue and the system in which the issue arose. The system is then depicted.

2. Determines what the issue is with the system

3. Finds where the issue is within the system

4. Ensures the legitimacy of the system depiction.

5. Decomposes the issue within the system for further exploration

6. This defines which stakeholder is responsible for each part of the Gap-Located Capability.

7. Aids possible solution generation

8. Considers changes to the system.

9. Examines other parts of the decompose issue within the system for further solution generation.

10. Ensures that the value chain is considered systematically and depicts the next supplier Tier.

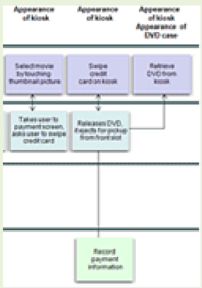
11. If the issue has found to lie in more than one part of the system, then this gap can similarly be explored and solutions generated and evaluated.

12. The solutions can then be rated and the most acceptable ones can then be selected.

3.3 A Quantitative Version of the SIU Method

System Parameters
Range: this describes the level of an effect. Examples are temperature and weight.
Span: this describes the length of time it takes for an effect to be reached. Examples are hours and days.
Time Cycle (TC): this describes the times an effect can be operational for use. Examples are days and weeks.
Cost: the monetary cost of an effect. Examples are pounds and pennies.

See Section 3.4 for more details



Service Blueprinting is flowcharting technique for service depiction. Extended Service Blueprinting allows detailed product operation to also be shown.

START: At the start, the Supplier Tier is set to 0 – this is the end-user (or the capability nearest to the end-user) that the applier of the method can collect data from. The parameters to collect data for are in Section 3.4.

1. **Problem Definition:**

For any capability in which there is dissatisfaction, start with the end-users capability (or, if little is known about this, start with the capability nearest to the end-user from which data can be collected).

a) ***Quantify the issue:***

i. Determine which parameter the issue could refer to (such as cost, range, span or TC) and determine the issue's units. Collect data to quantify the issue. This will then help to either confirm or debunk the reported issue.

ii. The Severity of the Issue: Check with other stakeholders to determine if they are aware or have experienced this issue and how important they believe it to be. This will help to determine how many stakeholders are affected by the issue and its importance to the stakeholders.

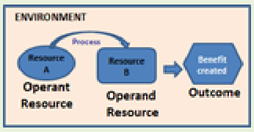
b) ***Determine the scope of the system:*** collect data on when the issue arises and how long it lasts. Note any events or changes and the time they occur in that environment when the issue is present. Then compare these changes and events to when the issue arises – this will help to determine the scope of the system to be investigated and gauge the frequency of the issue.

c) ***Depict the System:*** using Service Blueprinting, depict how all of the sub-capabilities are integrated into a process in the overall capability. Label the environments that each of the capabilities is located in. For simplicity, Service Blueprinting could be used or, if detailed product operation is a concern, then Extended Service Blueprinting could be used instead.

2. **Find Gaps in the Overall Capability:** This quantifies the issue.
   a) ***Define the Desired Overall Capability Parameter Values:*** Determine what ideally should have happened for there not to have been dissatisfaction. This indicates the level and type of performance that is required for the receiver's goal to be accomplished satisfactorily.
   b) ***Define the Actual Overall Capability Parameter Values:*** Collect data on what really happened in the capability in question.
   c) ***Find the Overall Capability Parameter Gaps:*** This is the difference between what actually happened and what should have happened: the gap between the actual and desired capability. Examples of possible data sources are interviews with the receivers and owners of the process, data from sensors and the systems analysis of the process. Add the gaps to the Service Blueprint.

3. **Find the Gap-Located Capabilities within the Capability:**
   a) **Define the Actual Sub-Capability Parameter Values:** Find the actual parameter values for each of the sub-capabilities in the capability. This indicates how each sub-capability actually behaved.
   b) **Determine the Gaps within the Capability:** This can be accomplished in one of two ways:
      I. By Expert Assessment:
      - Define the Desired Sub-Capability Parameter Values: To do this, an expert in that process and the sub-capability in question can state the parameters of how the sub-capability should have behaved in order for the gaps not to be present in the overall capability.
      - Determine the Sub-Capability Parameter Gaps: Determine which sub-capabilities of the system contributed most to the issue by finding the difference between the actual sub-capability parameter values and the desired sub-capability parameter values.

      II. Gap Contribution to the Overall System:
      Gauge the proportion to which a sub-capability's parameter has contributed to the same parameter in the gap of the overall capability.
   c) **Find the Gap-Located Capability:** For large gaps, decompose the sub-capability by creating a more detailed blueprint of it and, again, find the gaps. Again, find which sub-capabilities have the largest gaps. This can be repeated until the lowest level of decomposition is reached. The sub-capability(s) with the largest gap(s) become the Gap-Located Capability(s). Add this to the Service Blueprint.



Operand-Operant Diagrams are decompositions that allow for how an effect was created to be examined. See Section 3.4 for more details.

1) NEW CONCEPTUAL DESIGN
2) MARKET SEGMENT/ RECEIVER SHIFT
3) CHANGES REGARDING THE OFFENDING PART OF THE SYSTEM
a) SUBSTITUTE
b) ELIMINATE
c) ADDITION
d) CUSTOMISE
4) ENVIRONMENTAL CHANGE
a) CHANGE LOCAL ENVIRONMENT
b) CHANGE WIDER ENVIRONMENT

Design Options that can be applied to the system to generate new designs. See section 3.4 for more details.

4. **Corroborate the System Definition:** Where possible, consult with other relevant stakeholders, experts and archival material as to the legitimacy of the system depiction.

5. **Operand-Operant Decomposition of the Gap-Located Capability:** Each Gap-Located Capability can then be decomposed into its constituent parts of: operant resource, the operand resource and the process by which the operand resource changes the operant resource. If there are several large Gap-Located Capabilities then, rather than decompose each one, they can be grouped and an Operand-Operant Diagram can be created to show the relationships between them; this will allow a common solution to be found later.

6. **Determine the Stakeholders:** Define the stakeholders responsible for each part of the Gap-Located Capability.

7. **Comparison of Similar Capabilities:** to help generate possible solutions, comparisons across data sets can be made (if such data is available) to other similar capabilities where the gaps do not appear or where the gaps are reduced. Alternatively, qualitative comparisons could be made.

8. **Propose Solutions:** If possible, with the help of relevant stakeholders and experts, apply the third Design Option (Changes Regarding the Offending Capability) in the Proposals Matrix to the operand, operant and operand's process in the largest Gap-Located Capability. Then apply the first, second and fourth Design Options to the Overall Capability.

9. **Next Tier?:** If desired, another supplier Tier could be explored. There could be an operand or operant resource or process that the operand uses which has contributed to the Gap-Located Capability that could be decomposed further and then have the Proposals Matrix applied to it. The resultant Proposals Matrix can eventually (outside the scope of this research) be presented to that particular supplier as they have the expertise to fully correct and evaluate any possible solutions.

Overall Parameter gap 1 decrease
HIGH
MEDIUM
LOW
N/A

These are the ratings that proposed solutions can be given. See 3.4 for more details.

10. **Increase the Tier by 1:** A methodological check to ensure that the value chain is considered systematically and creation of the Service Blueprint for this Tier.

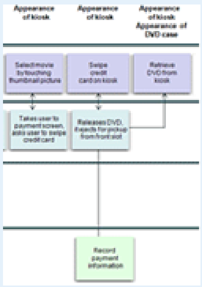
11. **Next Gap-Located Capability?:** If there is more than one Gap-Located Capability, then this can be examined similarly; this then becomes the largest Gap –Located Capability to examine.

12. **Rate and Select Solutions:** Each solution can then be estimated as to the extent that it should close the gaps (as High, Medium or Low). If a solution cannot be generated for that type of redesign then "N/A" (Not Applicable) is stated. For options which make the gap bigger, a "↑" symbol can be stipulated and for options which do not change the gaps, a "0" can be given. The solutions which close the gaps the most and which are acceptable can then be selected.

3.4 A Qualitative Version of the SIU Method

System Parameters
Range: this describes the level of an effect. Examples are temperature and weight
Span: this describes the length of time it takes for an effect to be reached. Examples are hours and days.
Time Cycle (TC): this describes the times an effect can be operational for use. Examples are days and weeks.
Cost: the monetary cost of an effect. Examples are pounds and pennies.

See Section 3.4 for more details



Service Blueprinting is flowcharting technique for service depiction. Extended Service Blueprinting allows detailed product operation to also be shown.

START: At the start, the Supplier Tier is set to 0 – this is the end-user (or the capability nearest to the end-user) that the applier of the method can collect data from. The parameters to collect data for are in Section 3.4.

1. **Problem Definition**:

For any capability in which there is dissatisfaction, start with the end-users capability (or, if little is known about this, start with the capability nearest to the end-user from which data can be collected).

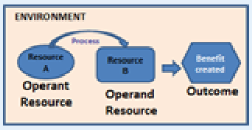
a) **Define the issue:**

   i. ***Gauge the Extent of the Issue:*** Describe how important the issue is.

   ii. ***The Severity of the Issue:*** Check with other stakeholders to determine if they are aware or have experienced this issue and how important they believe it to be. This will help to determine how many stakeholders are affected by the issue and its importance to the stakeholders.

b) ***Determine the scope of the system:*** Describe when the issue arises and how long it lasts. Describe any events or changes and the time they occurred in that environment when the issue was present. Then compare these changes and events to when the issue arises – this will help to determine the scope of the system to be investigated and gauge the frequency of the issue.

c) ***Depict the System:*** create a basic Service Blueprint of the end-customer's capability (or, if little is known about this, depict the capability nearest to the end-user about which there is knowledge using the known, partial information of the applier (who could be from any given company in the value chain). If possible, label the environments that each of the sub-capabilities is located in. Service Blueprinting could be used or, if detailed product operation is a concern, then Extended Service Blueprinting could be used. Examples of possible data sources are interviews with the receivers and owners of the process and systems analysis.



Operand-Operant Diagrams are decompositions that allow for how an effect was created to be examined. See Section 3.4 for more details.

2. **Describe Gaps in the Overall Capability:** Describe what is believed to be different about the Actual Overall Capability and that of the Desired Overall Capability. Add these to the Service Blueprint.
3. **Describe the Gap-Located Capabilities within the Capability:** Describe where the gaps within the capability(s) are estimated to be situated (which sub-capability(s)). What are believed to be the sub-capability(s) with the largest gap(s) become the Gap-Located Capability(s). Add this to the Service Blueprint.
4. **Corroborate the System Definition:** Where possible, consult with other relevant stakeholders, experts and archival material as to the legitimacy of the system depiction.

5. **Operand-Operant Decomposition of the Gap-Located Capability:** Each Gap-Located Capability can then be decomposed into what is estimated to be its constituent parts of: operant, the operand resource and the process by which the operand resource changes the operant resource. If there are several large Gap-Located Capabilities then, rather than decompose each one, they can be grouped and an Operand-Operant Diagram can be created to show the relationships between them; this will allow a common solution to be found later.

6. **Determine the Stakeholders:** Define the stakeholders responsible for each part of the Gap-Located Capability.

7. **Comparison of Similar Capabilities:** to help generate possible solutions, comparisons across data sets can be made (if such data is available) to other similar capabilities where the gaps do not appear or where the gaps are reduced. Alternatively, qualitative comparisons could be made.

1) NEW CONCEPTUAL DESIGN
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b) ELIMINATE
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d) CUSTOMISE
4) ENVIRONMENTAL CHANGE
a) CHANGE LOCAL ENVIRONMENT
b) CHANGE WIDER ENVIRONMENT

Design Options that can be applied to the system to generate new designs. See section 3.4 for more details.

Overall Parameter gap 1 decrease
HIGH
MEDIUM
LOW
N/A

These are the ratings that proposed solutions can be given. See 3.4 for more details.

8. **Propose Solutions:** If possible, with the help of relevant stakeholders and experts, apply the third Design Option (Changes Regarding the Offending Capability) in the Proposals Matrix to the operand, operant and operand's process in the largest Gap-Located Capability. Then apply the first, second and fourth Design Options to the Overall Capability.

9. **Next Tier?:** If desired, another supplier Tier could be explored. There could be an operand or operant resource or process that the operand uses which has contributed to the Gap-Located Capability that could be decomposed further and then have the Proposals Matrix applied to it. The resultant Proposals Matrix can eventually (outside the scope of this research) be presented to that particular supplier as it is that stakeholder that has the expertise to fully correct and evaluate any possible solutions.

10. **Increase the Tier by 1:** A methodological check to ensure that the value chain is considered systematically and creation of the Service Blueprint for this Tier.

11. **Next Gap-Located Capability?:** If there is more than one Gap-Located Capability, then this can be examined similarly; this then becomes the largest Gap –Located Capability to examine.

12. **Rate and Select Solutions:** Each solution can then be estimated as to the extent that it should close the gaps (as High, Medium or Low). If a solution cannot be generated for that type of redesign then "N/A" (Not Applicable) is stated. For options which make the gap bigger, a "↑" symbol can be stipulated and for options which do not change the gaps, a "0" can be given. The solutions which close the gaps the most and which are acceptable can then be selected.

3.5 Techniques used by the SIU Method

1. **System Depiction:** Service Blueprinting (simple or Extended) are used. However, the environments in which the system is located will also be shown as will the parameters of the system once Steps 2 and 3 have been completed. This type of environment-specific, parameterised service blueprinting is referred to as Enhanced Service Blueprinting.

2. **Capability Parameterisation and Gap Analysis:**
The parameters and examples of units that could be used are in Table 3.4.1.

	Parameter Types	Examples of units that could be used
1	Range: this describes the level of an effect	This depends on what the capability is. Examples are temperature and weight.
2	Span: this describes the length of time it takes for an effect to be reached.	This could be expressed in minutes, hours, days, weeks, months or years.
3	Time Cycle (TC): this describes the times an effect can be operational for use.	This could be expressed as a percentage of time or the days of the week or hours that the effect can be available.
4	Cost: the monetary cost of an effect	Pounds, pennies or fractions of a penny could be used.

Table 3.4.1: Parameters in the SIU Method and examples of units that could be used

The Overall Capability: For the Desired Overall Capability Parameters, this data can be collected from the owners, users and customers of the capability. Some examples of how the data could be collected for the Actual Overall Capability parameters are: from sensors, in-service records and systems analysis. The difference between the actual overall capability parameters and the desired overall capability parameters gives the overall capability parameter gaps. See Figure 3.4.1 for an example.

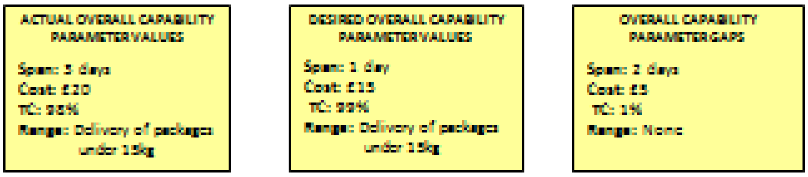


Figure 3.4.1: An example of the parameters for an Overall Capability for Delivering Packages

Sub-capabilities: Each sub-capability is parameterised similarly. Determining the gaps within the system can be accomplished in one of two ways:

a) By Expert Assessment:

- ***Define the Desired Sub-Capability Parameter Values:*** For each sub-capability, define the desired parameter values for each of the sub-capabilities in the system. To do this, an expert in that process and sub-capability can state the parameters of how the sub-capability should have behaved in order for the gaps not to be present in the overall capability.

- ***Determine the Sub-Capability Parameter Gaps:*** Determine which sub-capabilities of the system contributed most to the issue by finding the difference between the actual sub-capability parameter values and the desired sub-capability parameter values.

b) **Gap Contribution to the Overall System:**
Gauge the proportion to which a sub-capability's parameter has contributed that parameter gap in the overall capability.
Each type of parameter must have the same units or descriptor for its actual and desired parameter in the overall capability or in any given sub-capability.

3. Operand-Operant Diagrams

Service Blueprinting (simple and extended) facilitates decomposition as each sub-capability (product or service) in any blueprint can be blueprinted in its own right to reveal its internal operation. In addition to this, any sub-capability can be decomposed into its operand resource, operant resource, the process that operand uses and the environment: this allows for how an effect was created to be examined. For a Gap-Located Capability, an Operand-Operant Diagram can be created. The elements of the diagram are shown in Figure 3.4.2:

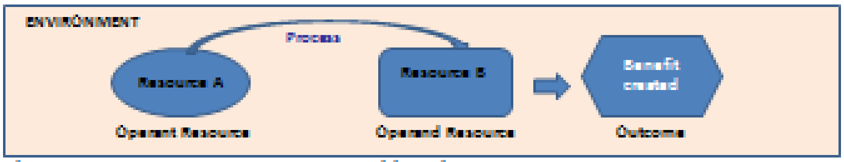


Figure 3.4.2: An Operant-Operand Decomposition Diagram

4. The Application of Design Options and Solution Assessment

The Proposals Matrix (Table 3.4.2) allows design options to be applied to the system so that new designs can be generated which close the gaps. For each parameter gap in the Gap-Located Capability, a column can be added to the Matrix stating the parameter. In the example Proposals Matrix (Table 3.4.2) there are two parameters in the Overall Capability. Option 3 (*Changes Regarding the Offending Capability*) is applied to the Gap-Located Capability which contributed most to value loss and Options 1, 2 and 4 are applied to the overall system. The design options in the left-hand Column of the Proposals Matrix are detailed in Table 3.4.2. A full description of the Design Options in the Proposals Matrix are listed in Table 3.4.3.

To appraise the solutions, "High", "Medium" or "Low" or, if the design option appears not to apply, "N/A" can be stipulated. For options which make the gap bigger, a "↑" symbol can be stipulated and for options which do not change the gaps, a "0" can be given. The solutions that close the gaps the most and which are acceptable can then be ringed or highlighted.

Types of Generic Change for the Use Phase	RATING		Application to this Case
	Overall Parameter gap 1 decrease	Overall Parameter gap 1 decrease	
1) NEW CONCEPTUAL DESIGN			
2) MARKET SEGMENT/ RECEIVER SHIFT			
3) CHANGES REGARDING THE OFFENDING CAPABILITY			
a) SUBSTITUTE			
b) ELIMINATE			
c) ADDITION			
d) CUSTOMISE			
4) ENVIRONMENTAL CHANGE			
a) CHANGE LOCAL ENVIRONMENT			
b) CHANGE WIDER ENVIRONMENT			

Table 3.4.2: The Proposals Matrix

Design Options: These can be used to generate new designs by considering changes to various parts of the system (Figure 3.1.1).

a. Changes that can be considered to the overall system:
   i. The environment (local and wider)
   ii. A completely new conceptual system
   iii. Changing the receiver to one whose needs are met by the system.
b. Changes that can be considered to the part of the system which contributed most to value loss:
   i. Substitution
   ii. Customisation
   iii. Elimination
   iv. Addition

Types of Generic Change
1) NEW CONCEPTUAL DESIGN Basically replace the need for the offending capability with something entirely different to meet the same goal (the overall capability) - a new Conceptual design.
2) MARKET SEGMENT/RECEIVER SHIFT Do not offer this Overall Capability to any market segment or receiver where these large gaps appear and focus on markets or receivers where the gaps are small; this should lead to increased specialisation for the capability provider. Alternatively, partner with a provider that can fill the gaps more closely.
3) CHANGES REGARDING THE OFFENDING CAPABILITY :
a) SUBSTITUTE - Find an alternative way to meet the needs that are supposed to be met by the offending capability. Find substitutes that could reduce or remove the gaps for the offending capability.
b) ELIMINATE - Simply remove the offending capability and do not replace it with anything. However, there could be ramifications for other phases in the lifecycle or for higher or lower capabilities in which this capability is embedded.
c) ADDITION - Add a capability alongside the offending capability to reduce the gaps.
d) CUSTOMISE - Modify the offending capability so that the capability gaps will be reduced or removed.
4) ENVIRONMENTAL CHANGE
a) CHANGE LOCAL ENVIRONMENT - Change the environment around the offending capability. If an affecting environmental variable is reducing the performance of the capability then that capability could be enveloped to protect it from this variable.
b) CHANGE WIDER ENVIRONMENT - Make changes to the wider environment which could close the gaps. This could involve petitioning local government to reduce or remove the affecting variable. If constraints such as standards, policies or regulations are contributing to the gaps and if there are no processes which the capability would adversely affect if the constraints were removed, then this could suggest that these constraints should be questioned.

Table 3.4.3: The Design Options

4 Field Test of the Method

4.1 A Cooking Problem: The Generation of Excessive Heat

4.1.1 Introduction to the Case Study:

This field test shows how the SIU method can be used to support an existing product-service system: that is, improve its effectiveness.

A UK community housing association offers a product-service system (these are flats for rent which are maintained and periodically refurbished). Semi-structured interviews were held with three tenants who each have a one bedroom flat in a block of flats which is provided by this housing association. The flats are very similar in size and layout – each has an open-plan kitchen-lounge.

Exploratory interviews with the users (the tenants, each of whom had a serious medical condition) revealed one issue that, whilst cooking and just after, their kitchen-lounge would often become unbearably hot and that, even in the middle of winter, at least one window would have to be opened. This was a particularly serious issue for one tenant who stated that his illness meant that he had breathing problems and that when the kitchen-lounge became that hot that there were times that he felt dizzy. All of the tenants complained that they often got headaches and that they deemed the sometimes excessive heat in the kitchen-lounges to be a major contributing factor. Another issue that surfaced was that they believed their utility bills to be fairly high and that the energy used to cook contributed greatly to this.

The tenants have said that these unbearable temperatures only happen during and just after cooking – never at any other time. They also stated that this happens in all seasons. In summer, the tenants stated that the kitchen-lounges tend to be quite warm anyway, and so unbearable temperatures during cooking and just after are reached even more quickly.

Figure 4.1.1: A floor plan of the field test flat

A particular flat was used for a field test of the SIU method – (see Figure 4.1.1). The dimensions of the kitchen-lounge are:

- **Height:** 2.4m (approximately 7ft 10½ in)
- **Width:** 3.5m (approximately 11ft 6½ in)
- **Length:** 5.8m (approximately 19ft 1½ in)

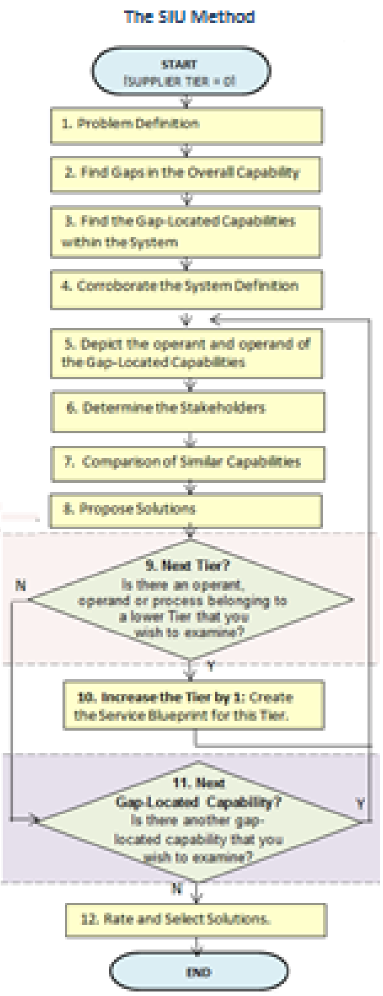
The tenant of this flat is 6" 1' (185.42cm) and so, when standing, the ceiling is only 1" 9 ½' (54.58cm) above him.

The flat is situated on the corner, ground floor of a block of flats. The bottom wall (against which the cooker rests) in the floor plan (Figure 4.1.3) is shared with an adjacent flat. The remaining three sides are exposed.

The issue to be investigated is that of cooking and its negative side effect (making the kitchen-lounge air unbearably hot) that has been reported. The next section details how the SIU Method was applied.

4.1.2 The stakeholders who applied the SIU Method

The SIU Method was firstly applied by the tenant (who is an English teacher, a "non-technologist" and who had little prior knowledge of PSS). This iteration was performed so that he could determine possible changes that he could make to his cooking capability. The next iteration of the SIU Method was performed by an expert civil engineer to determine possible changes that the Housing association could make to the environment (the kitchen-lounge):



The Tenants Application (First Iteration)	The Expert's Application (Second Iteration)
Tier 0	Tier 1
STEP 5: (Section 4.1.7) The cooker capability	**STEP 5:** (Section 4.1.13) The kitchen-lounge
STEP 6: (Section 4.1.8) The tenant owns this.	**STEP 6:** (Section 4.1.14) Owner: the housing assoc.
STEP 7: (Section 4.1.9) For example, a microwave.	**STEP 7:** (Section 4.1.15) For example, a separate kitchen.
STEP 8: (Section 4.1.10) Changes to the cooer capability.	**STEP 8:** (Section 4.1.16) Changes to the cooer capability.

4.1.3 Problem Definition

Note: The steps were conducted by the tenant with the help of the author. It was important to:

1) ***Quantify the issues:***
   - The actual temperature at which the tenants start to find the atmosphere unbearable. This will be used later as the Desired Overall Capability Parameter.
   - The extent to which cooking contributed to the tenants' bills – to determine if this was significant.
2) ***The System which gave rise to the issues:*** It was necessary to determine whether this "unbearable" temperature and above is only reached during and just after cooking – if "unbearable" temperatures were reached at other times then this would suggest that other factors contribute significantly to the high temperatures; that is, that they are not just to do with cooking and these other factors would require investigation. It was also important to determine where in the kitchen-lounge "unbearable temperatures" were reached.

1. **Establishing the threshold of "unbearable temperatures":** In the field test flat, all of the windows and doors were closed and, using a standard thermometer, the ambient temperature was taken at the tenant's waist- level (this is also the tenants head height when he sits at the dining room table, which he stated is often where he sits) and around the kitchen-lounge – each corner and the centre of the room registered 23°C within 1°C. The tenant stated that he did not find this temperature uncomfortable. When the tenant started cooking, he was asked to state at what point he started to find the temperature wholly unbearable. At this point, thermometer readings taken were 25.5°C at the tenant's waist-level. At that point, thermometer readings were taken at the same level at various other points in the kitchen-lounge and the readings were the same within 0.5°C. The temperature of the air at the tenant's head height when standing (which is 185cm) was then also taken in the same way – this was 27.6°C. Thus, the temperature at which the air starts to become "unbearable" is established to be 25.5°C at waist-level and at 27.6°C at head-level for that particular tenant.
2. **Establishing the cost of cooking:** To gauge this, a typical, high energy-use cooking session was studied along with a gas bill provided by the tenant – the tenant viewed this bill as being a fairly typical gas bill. This cooking session was the making of a roast chicken meal using the tenant's Creda Capri gas oven. All appliances that use gas (the boiler and heating) were turned off and a gas meter reading was taken. A chicken with potatoes and stuffing were placed in the oven at Gas Mark 6 for 55 minutes – half way through this cooking time, two gas rings were turned on at a middle heat for 20 minutes to boil vegetables. Then, the gas meter reading was taken again. From this, the amount of energy units used up and the resultant cost of the energy used was calculated in the following way:

a) *Reading the units:* the units are expressed in metric units - the last 3 digits (with a red border) which are displayed by the gas meter represent fractions of a unit. The readings were:
   - START 2025.847
   - FINISH 2026.066

   This difference gave (0.218) as the amount of units used during this cooking session

b) The metric units are then converted to kWh (the gas suppliers make this conversion so that so that their bills can be compared to electricity bills) in the following way (as presented on a bill dated 15th August 2009, by British Gas, the tenant's supplier):

metric units used		calorific value		volume correction		to convert to kWh		gas used in KWh
0.218	×	39.5965	×	1.02264	÷	3.6	=	2.448

Table 4.1.1: Conversion of the metric units to KWh

c) The cost of the units used for this cooking session are calculated as:
   a. On the tenant's gas bill, there are two tariffs: the first 646 kWh are priced at £0.06846 and the next 450.74 units are priced at £0.03275.
   b. The tenant's bill showed that he had used 1096.74 kWh. This would mean that 59% of his bill (646/1096.74*100) would be at the higher tariff and the remaining 41% would be at the lower tariff.
   c. These percentages with the tariffs above were used to cost the cooking session:
      i. 41% x 2.448 kWh x £0.03275 = £ 0.03287
      ii. 59% x 2.448 kWh x £0.06846 = £ 0.09888

   The sum of these gave the total cost of cooking a whole roast dinner as £0.13

The tenant's bill showed that he had used 1096.74 kWh of gas over an 88 day period over from 19th May 2009 to 15th August 2009. Therefore 1096.7÷ 88 = 12.4625 kWh/day – this is the average kWh used each day. This would mean that the cooking of a roast meal (which the tenant did infrequently – he usually did not cook that much food or for that length of time) every day would only represent 19.6% (2.448÷12.4625 /100) of his total gas use that day.

The process was repeated over consecutive days using other types of cooking. These were:

a) Cooking food under the grill for 15 minutes: cost = £0.04p
b) Just using two rings on the hob for 20 minutes at a medium heat: cost = £0.06p
c) Baking a meal (just using the oven and not the rings) for 30 minutes at gas mark 6: cost = £0.07p

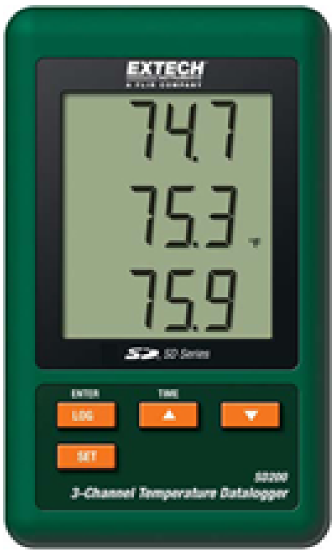


Figure 4.1.2: Extech SD200 unit

3. Establishing if "unbearable temperatures" are only reached during and just after cooking:

To do this, Extech SD200 three channel temperature data loggers (temperature sensors, Figure 4.1.2) were put in place in this tenant's kitchen-lounge on the 20th December 2011. The sensors were to be there for over a week and so had to be placed at positions that were unobtrusive for the tenant (see Figure 4.1.3).

Sensor 1: was secured between the kitchen window and the sink, at the tenant's waist level when standing (this is 119cm from the floor) and this is also the tenant's head height when sitting at the dining table. This sensor was 190cm away from the centre of the cooker.

Sensor 2: at head-level by the cooker (183cm from the floor and 103cm from the centre of the cooker).

The sensors were set to record the temperature at these points every minute in degrees Centigrade. Alongside the temperature, the date, time, and the number of the reading were also automatically recorded.

Testing the Sensor units: before the tenant started cooking, it was ensured that the windows were kept closed along with the kitchen-lounge door and the front door. To test if the sensors were working, the readings were compared with that of a conventional thermometer: the readings were in agreement.

There was also a check to ensure that the temperature readings taken by the unit could be transferred to an Excel spread sheet on a PC.

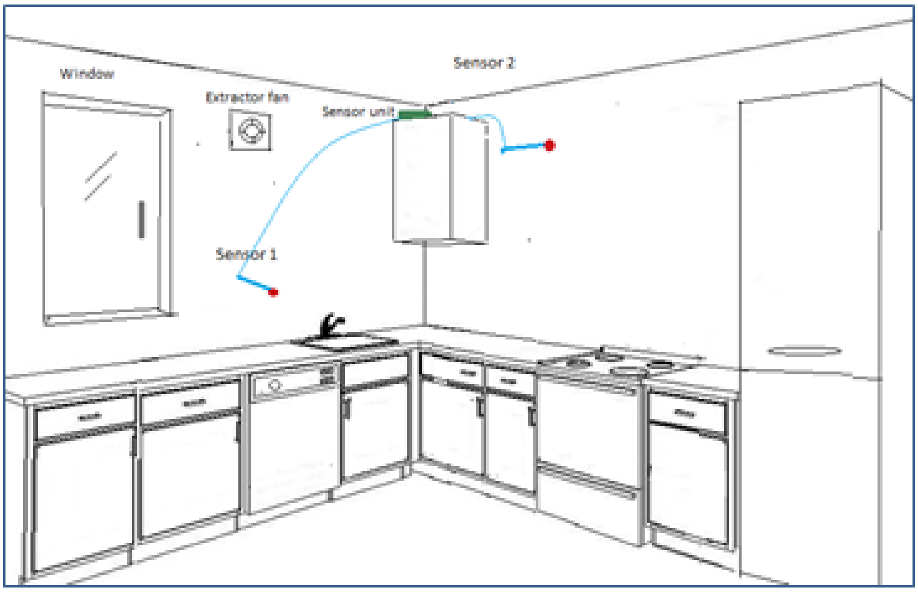


Figure 4.1.3: Layout of the kitchen area and the position of the sensors

Data Collection: data was collected over a 10 day period (the 2011-2012 Christmas holiday period). This period was chosen as the key researcher was available to conduct constant ethnographic research to ensure that the sensor units were operating correctly and to also record any events occurring in the kitchen-lounge that could possibly influence temperatures in the kitchen-lounge. The temperatures external to the flat were also noted. This was done so that the scope of the system could be established; that is, so that any factors, internal or external, could be ascertained which may:

- Contribute to unacceptable tempertures during cooking times and just after.
- Prevent temperatures becoming unacceptable during cooking and just after
- Contribute to unacceptable temperatures outside of cooking sessions.

a. ***Quantitative data collection:*** The sensor data was allowed to constantly record data over the 10 day period.
   i. ***Ethnographic data collection:*** The events noted over a 10 day period were:
   ii. Windows being opened and closed
   iii. The extractor fan being turned on and off
   iv. The kitchen-lounge door being opened and closed
   v. The front door being opened and closed
   vi. Candles being lit
   vii. The heating being off and on at various times and being set at various levels.
   viii. Many people being in the kitchen-lounge, sometimes bringing hot food
   ix. The kettle or toaster being on
   x. External temperature fluctuations
   xi. Hot food (in a hot container) being taken out of the oven

The data from the sensors were then transferred to PC and then matched against the noted events.

No.	Date	Time	Waist level		Head level	
5407	25/12/2011	10:48:45	20.8	DEGREE C	21.7	DEGREE C
5408	25/12/2011	10:49:45	20.7	DEGREE C	21.7	DEGREE C
5409	25/12/2011	10:50:45	20.7	DEGREE C	21.7	DEGREE C
5410	25/12/2011	10:51:45	20.6	DEGREE C	21.6	DEGREE C
5411	25/12/2011	10:52:45	20.7	DEGREE C	21.5	DEGREE C
5412	25/12/2011	10:53:45	20.7	DEGREE C	30.7	DEGREE C
5413	25/12/2011	10:54:45	21.4	DEGREE C	36.2	DEGREE C
5414	25/12/2011	10:55:45	22	DEGREE C	37.6	DEGREE C
5415	25/12/2011	10:56:45	22.4	DEGREE C	40.1	DEGREE C
5416	25/12/2011	10:57:45	23.3	DEGREE C	40.5	DEGREE C
5417	25/12/2011	10:58:45	23.8	DEGREE C	40.8	DEGREE C
5418	25/12/2011	10:59:45	24	DEGREE C	41.3	DEGREE C
5421	25/12/2011	11:02:45	25.2	DEGREE C	42.4	DEGREE C

Table 4.1.2: Sample of data from the sensors transferred to the PC

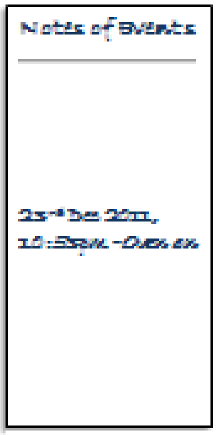


Figure 4.1.4: Event Notes

The data from the sensors and the notes were then analysed in Excel.

The whole procedure of collecting data from sensors was then repeated in August 2012 for 3 days: however, this time the events that were noted were solely when the cooker was turned on and off.

Findings:

- Temperatures over 25.4°C at waist-level do, indeed, only ever occur when the tenant is cooking or just afterwards. This suggests that outside and even internal temperature fluctuations do not have any significant impact on high kitchen-lounge temperatures; that is, there is no correlation between any of the events recorded (besides the cooker being turned on) and the unacceptable temperatures.
- Not every incidence of cooking produces unbearable temperatures: it does not occur when when one ring on the hob is turned on at a low heat for any length of time and it does not occur if two rings are on at a high heat for less than 11 minutes.
- During cooking, extremely high temperatures can, indeed, be reached. The maximum temperatures that have been reached (even with the extractor fan on, windows open and the living room door open in December 2011) are:
    - At waist level: 34.4°C
    - At head level: 49.9°C
- The length of time that temperatures over 25.4°C at waist level are reached can be for more than 1.5 hours – even with windows and doors open and the extractor fan on.
- The actual range of difference between the head-level temperature and waist-level temperature 15 minutes before the cooker is turned on (and at least 2 hours after any cooking has taken place) has been found to be never more than 1.2°C.
- There was no correlation between cooked food in a hot container adding to the temperature of the air. Although the temperature of a container when it was removed from the oven can be 119°C (as recorded with a temperature sensor) as soon as the cooker was turned off, the head-level and waist-level air started to drop in temperature. This is the same situation as when pans of food were cooking on the stove. For this reason, the effect of hot food and its container on the air temperature appears to be minimal. Therefore, the cooked food in its container is regarded as being an insignificant factor in causing excessive heat (at head–level and at waist-level). Also, there were many times over the

Christmas period when people brought hot food to the tenant's flat and this not correlate with waist-level or head-level temperatures reaching an unbearable level.

Conclusions:

1) **The actual temperature at which the tenant starts to find the atmosphere unbearable**
   This is established to be at 25.5°c at waist-level and at 27.6°C at head-level for this particular tenant.
2) **The extent to which cooking contributed to the tenants bills.**
   Cooking appeared to contribute less than 19.6% of the overall gas bill; the reminder of the gas bill is deduced to be due to the tenants other gas appliances which are the boiler (used for hot water and central heating). However, for other tenants who may have electric cookers, this situation may be quite different – their cooking may contribute significantly to their bills. Nevertheless, this particular tenant is expected to spend less then (£0.13x30 days) £3.90 per month on cooking - the tenant stated that he thought this was good value and that even if, for example, gas bills rose by 10% that he would only have to pay less than an extra £0.39 per month which would not be a concern to him. However, this did then bring into question how much he was spending on heating and hot water. To conclude, it appears that gas cookers are fairly efficient in heating food; this is to be expected as gas cookers provide a naked flame – little of the energy has to be transferred from one medium to another which is the case with electric cookers. For these reasons, the cost of cooking was not an issue worthy of further investigation in this field test.
3) **Whether this "unbearable" temperature and above is only ever reached and surpassed during and just after cooking – if "unbearable" temperatures were reached at other times then this would suggest that other factors contribute significantly to the high temperatures; that is, that they are not just to do with cooking and these other factors would require investigation.**
   The tenant's assertion that unaccepetable waist-level (over 25.4°C) and head-level (over 27.5°C) temperatures are produced which only occur during cooking times and just after has been confirmed. Also, the length of time these unnacceptable temperatures are produced can be up to 1.5 hours (despite any other external and internal events). Therefore, the system that produced these unacceptable temperatures appeared to be solely that of cooking.
   Not every incidence of using the cooker raises the waist-level temperature above 25.4°C: sometimes the hob is on only briefly and/or at a low level and the waist-level and head-level temperatures do not reach this "unbearable" level.
   The ceiling is low and can become excessively hot during cooking This is an issue because the tenant's height can mean that, when standing and walking around the lounge-kitchen, there are times when he is breathing in air which is very hot – a maximum of 49.9°C has been recorded at the head-level.
4) **The system to be investigated:** is that of the temperature of the kitchen-lounge whilst the cooker is on just after.

Limitations of the Problem Definition:

The field test has only focussed on one tenant: the "unbearable" temperatures only relate to this particular tenant and the field test has only focussed on his flat. If the issue is to be considered further to, for example, redesign new flats or refurbish existing flats other than that in the field test, it is recommended that other flats are investigated and other tenants' heating preferences ascertained.

A primary Service Blueprint showing the side-effect of the current cooking capability to adversely increase room temperature was created (Figure 4.1.5) - the parameter values are added later.

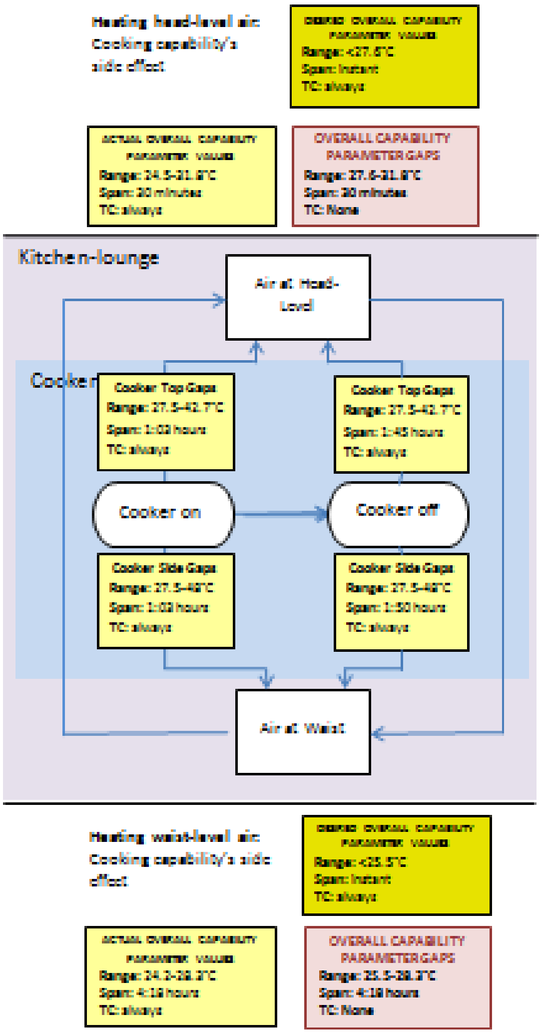


Figure 4.1.5: Service Blueprint of the cooking capability and its side-effect of heating the air (during cooking and after)

4.1.4 Find the Overall Capability Parameter Gaps

Here, the Desired and Overall Capability's parameter values were defined. From the difference of these values, gaps in the Overall Capability are reckoned.

Exact data was required regarding the extent of the heat released during and after cooking. To accomplish this with minimum inconvenience to the tenant, four instances of cooking (roasting, grill on, rings on, roasting and rings on) were recorded and, for each instance, the window, front door and living room door were kept closed and, the extractor fan was on for the duration of cooking. One typical instance of cooking is depicted here. This is the roasting of meat and vegetables that took place on 20th September, 2012. To determine the exact temperatures that are reached during this cooking episode (and afterwards), the following method was used:

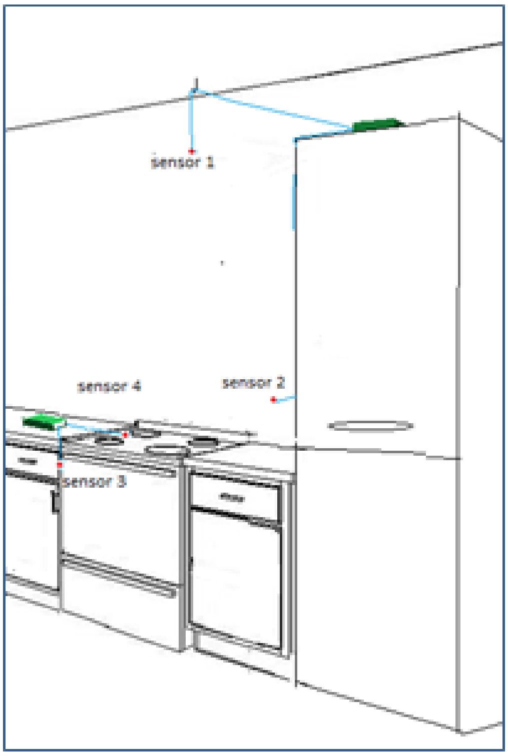


Figure 4.1.6: The position of the sensors

Placement of Sensors (Figure 4.1.6):

1. At the head-level (185cm from the floor and 135cm from the top of the cooker which has a height of 105cm) over the centre of cooker,
2. At waist- level (119cm from the floor and 30cm from the centre of the cooker which has a width of 49cm)
3. Touching the cooker at the hob between two rings
4. Touching the side of the cooker, 10 cm from the top of the cooker and 24.5cm from the side

For the course of the experiment, the windows were kept closed, the kitchen-lounge door was kept closed and the front door was not opened. This was to minimise the impact of any events upon temperatures during cooking. It was apparent that, even after cooking, the air remained quite hot for some time. To determine how hot the cooker remained even after cooking, sensors were placed on it to gauge this.

The readings were checked half an hour before cooking started for constant temperature readings (fluctuations of less than a degree) – these were recorded. This was the ambient temperature before cooing commenced.

Cooking a roast dinner: This experiment was conducted at three different times on three different dates – each experiment produced the same results within a one degree difference: the oven was turned on at Gas Mark 6 and the extractor fan was turned on after 5 minutes. The food in a roasting dish was placed in the oven. Altogether, the oven was left on for 55 minutes (from 8:40:43am to 09:35:43am). The food was then taken out of the oven and the temperature of the roasting tin was taken. The food was plated and the roasting tin placed in the sink and filled with water. The extractor fan was turned off. The data from the sensors and the times that the cooker was on and off as well as the time that the roasting tin was taken out of the oven along with the temperature of the roasting pan were then transferred to the PC for analysis:

Findings:

1. **Actual Waist-Level Temperature:** the actual range of the waist-level air during cooking was ***(range) 24.2-28.3°C***. The number of minutes that the waist-level temperature was over 25.4°C was calculated as the span of the actual overall waist-temperature which was ***(span) 4hrs 18 minutes***. When the oven and rings are on at this gas mark and for this length of time, this range of temperature always occurs – this therefore gives this actual waist-level temperature time-cycle as being ***(TC) always***.
2. ***Desired Waist-Level Air:*** It has been established that the desired temperature that the tenant would like the waist- level air to be is less than 25.5°C **(range)** and for this to always be the case **(time-cycle)** . Furthermore, even though temperature fluctuations may occur, the tenant desires the waist-level temperature to instantly **(span)** revert back to being less than 25.5 °C. Note that the ideal temperature for the tenant has not been established – only the maximum temperature that the tenant can bear.
3. **Actual Head-level Temperature:** The actual range of the head-level air during cooking is ***(range) 24.5-31.8°C***. The number of minutes that the head-level temperature is over 27.6°C is calculated as the span of the actual overall head-temperature which was ***(span) 30 minutes***. When the oven is on at this Gas Mark and for this length of time, this range of temperature always occurs – this therefore gives this actual head-level ***temperature time-cycle as (TC) always***.
4. ***Desired Head-Level Air:*** It has been established that the desired temperature that the tenant would like the head- level air to be is less than 27.6°C **(range)** and for this to always be the case **(time-cycle)** . Furthermore, even though temperature fluctuations may occur, the tenant desires the waist-level temperature to instantly **(span)** revert back to being less than 27.6°C .

Conclusions:

As cost has not been deemed an issue, this is not depicted as a parameter.

- **Overall Waist-level temperature gaps:** the range that is actually above the maximum desired temperature of 25.4°C gives the overall waist–level temperature gaps as **25.5-28.3°C**. The length of time that this lasted for was **4:18 hours – this is the span gap**: that is, the effect lasted 4:18 hours more than desired.
- **Overall Head-level temperature gaps:** the range that is actually above the maximum desired temperature of 27.5°C gives the overall head–level temperature gaps as **27.6-31.8°C**. The length of time that this lasted for was **30 minutes – this is the span gap**: that is, the effect lasted 30 minutes more than desired.

4.1.5 Find the Gap-Located Capability(s) Within the System

➢ First Iteration

Here, each of the Desired and Actual sub-capability's parameter values were defined. From difference of these values, gaps are located in the sub-capabilities.

As soon as the cooker was turned off, the head-level and waist-level air start to cool. This would indicate that the cooker being turned on (a naked flame) is the major contributing factor in over-heating waist and head level air. As there is a distinct correlation between the temperatures that the side and top of the cooker reach and the head-level and waist-level air temperatures (Figure 4.1.7) – this would indicate that during cooking and just after, the temperature of the cooker contributes to the temperature of the waist-level air and head-level air.

If, during the oven being on, the cooker (its top and side) could be kept to a temperature that is nearer to the temperature it is before cooking commences (given a leeway of, say, no more than 2°C more than the maximum desired waist level temperature), then this could substantially reduce the head-level and waist-level air becoming so hot.

Cooker on

Parameter	Desired Capability Value	Actual Capability Value	Capability Value Gap
Range	<27.5°C	24.2-42.7°C	27.5-42.7°C
Span	instant	1:05 hours	1:03 hours
TC	always	always	always

Table 4.1.3: Cooker's side temperatures (when the oven is on)

Parameter	Desired Capability Value	Actual Capability Value	Capability Value Gap
Range	<27.5°C	24.2-48°C	27.5-48°C
Span	instant	instant	1:03 hours
TC	always	always	always

Table 4.1.4: Cooker's top temperatures (when the oven is on)

Cooker off (just after cooking)

Parameter	Desired Capability Value	Actual Capability Value	Capability Value Gap
Range	<27.5°C	24.2-42.7°C	27.5-42.7°C
Span	instant	1:05 hours	1:45 hours
TC	always	always	always

Table 4.1.5: Cooker's top (when the oven is off)

Parameter	Desired Capability Value	Actual Capability Value	Capability Value Gap
Range	<27.5°C	24.2-48°C	27.5-48°C
Span	instant	instant	1:30 hours
TC	always	always	always

Table 4.1.6: Cooker's side (when the oven is off)

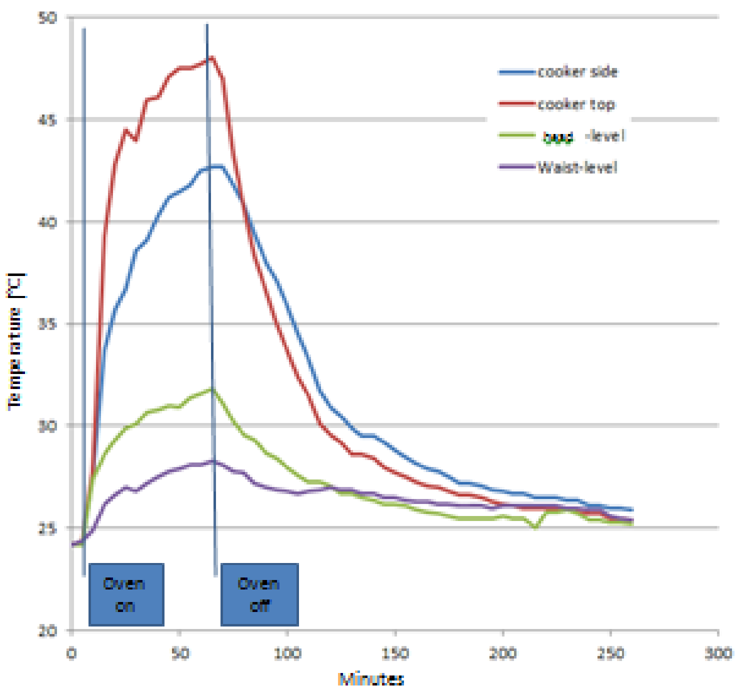


Figure 4.1.7: Cooker, Head Level and Waist Level Temperatures

Determine the Gap-Located Capability(s):

These are the offending capabilities. That is, they are the sub-capabilities that contribute to the gaps in the Overall Capability:

1. The cooker being on (and just after) - the waist-level and head-level air only ever reach unbearable temperatures when the cooker is on (and just after it has been on).
2. The local environment - even after the cooker has cooled, the waist-level air remains at unbearable temperature for about 2.5 hours afterwards. It is the local environment – the lounge-kitchen (rather than the wider environment) that is responsible for this as, if the there was no building structure in place to contain the air; the hot air would immediately disperse.

4.1.6 Corroborate the System Definition

At the time of the study the housing association could not release the manpower to examine the findings. However, these findings were shown to two experts in heating and ventilation systems who have dealt with similar issues: they suggested that it could be the boiler that is the source of heat and, that hot air rising during cooking could leave cooler air to trigger the boiler. As the boiler had had no sensors placed on it, this had to be tested for. The cooking of a roast chicken meal was repeated in September 2012 and the boiler was turned off. The same temperatures at waist and head level were reached which meant that boiler activity was not a factor in this system.

The findings were also presented to an expert in civil engineering for his opinion. He examined the findings and concluded that these high head-level temperatures, by air currents mixing the air, could contribute heavily to the heat of the waist-level air and the length of time that the air remains hot. As the tenant's ceiling is low, this is expected to happen whenever, for example, the tenant moves round the room. He also suggested that it could be the dimensions, construction and/or ventilation system of the kitchen-lounge which could be containing the air and allowing the hot air to accumulate; such an assessment could mean that the local environment could have a significant impact upon the air temperature.

The findings were also compared to recommended indoor temperatures:

- ***Directgov*** is the UK government's digital service for people in England and Wales and it provides a single point of access to public sector information and services - It recommends that living rooms should be heated to around 18-21°C (64-70°F). (http://www.direct.gov.uk/en/HomeAndCommunity/InYourHome/KeepingSafeAtHome/DG_10027755).
- ***TUC (Trades Union Congress)*** is a national trade union centre, that is, a federation of trade unions in the United Kingdom which represents the majority of trade unions. Their website (http://www.tuc.org.uk/workplace/tuc-12183-f0.cfm) states that *"The TUC has called for a maximum temperature of 30°C (27°C for those doing strenuous work), so that employers and workers know when action must be taken. It should be stressed that this is intended as an absolute maximum rather than an indication that regular indoor work at just below 30°C would be acceptable. Employers should still attempt to reduce temperatures if they get above 24°C and workers feel uncomfortable."*

From this, it does appear that the temperatures which are reached during and just after cooking can be far above those which are deemed to be comfortable temperatures.

4.1.7 Operand-Operant Depiction of the Gap-Located Capability

➢ **First Iteration**

Decompose the largest gap located capability into its operand and operant resources. The environment (the local and wider environment) is an enveloping capability that can, simultaneously, both accommodate and restrain many disparate capabilities that take place within it – it can have a negative or positive impact on many capabilities. As the hot air is contained by the local environment (the kitchen-lounge), the problem-space can be divided into two capabilities:

1) The cooker being on (and just after) which is the gap-located capability. The stakeholder who currently controls this is the tenant.
2) The environment of the flat – this has an impact on where heat collects (for example, more towards the ceiling) and how heat is dispelled (for example, through the extractor fan). This is under the control of the housing association (specifically, the maintenance staff and the architect and civil engineer).

Each of these capabilities can be decomposed into its constituent parts of: operant resource (the resource that is worked upon to produce an outcome), the operand resource (the resource which does the work) and the process by which the operand resource changes the operant resource (Figure 4.1.8).

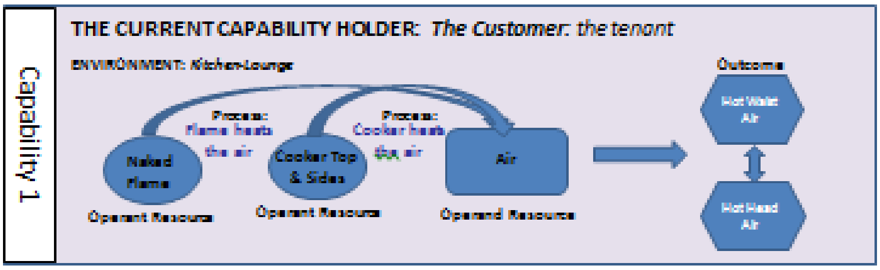


Figure 4.1.8: The Operand-Operant Diagram of the Cooker Capability

4.1.8 Determine the Stakeholders and Their General Roles

- First Iteration

Tenants: Some of the tenants (those who were interviewed for this field test) have serious medical conditions. Their needs are for comfortable housing which is convenient (that is, close to amenities they require). At the moment, it is the tenant who is responsible for the cooker that they place into the flat. As for the flat, it is the housing association which is responsible, ultimately, for the environment that is, the design, maintenance and refurbishment of the flats themselves.

4.1.9 Compare the Capability to Other Similar Capabilities

- First Iteration

To help generate solutions, comparisons across data sets can be made (if such data is available) for other similar capabilities where the gaps do not appear. Alternatively, qualitative comparisons can be made. In this case, only one kitchen-lounge in this block of flats was studied in detail; no data had been collected on any other similar kitchen-lounge were these gaps do not appear. However, it is known that microwaves emit less very little heat as compared to cookers and so this could be one possible solution.

4.1.10 Propose Solutions

- First Iteration

Apply a Proposals Matrix to the gap-located capability (Table 4.1.7) - each element in the decomposition diagram (operant resources, operand resources and the process that the operant resource uses to change the operand resource) is considered in turn for redesign. The application should be done with the help of other stakeholders and/or experts in that capability and process. For this case study, although the housing association was not available, two kitchen appliance sales store managers from two kitchen specialist retail companies were consulted. They were shown the Proposals Matrix and were asked for advice as to what kitchen appliances could address each design option. Each type of solution generated is then estimated as to the extent that it should close the gaps (High, Medium, Low). If a solution cannot be generated for a particular type of redesign then "N/A" (Not Applicable) can be stated. For options which make the gap bigger, a "↑" symbol can be stipulated and for options which do not change the gaps, a "0" can be given. The solutions are then accepted or rejected by the stakeholder in question – the accepted solution(s) are then highlighted in red.

The Tenant

Types of Generic Change	Decrease in gaps		UNBEARABLE HEAT DURING COOKING - STEPS THE TENANT CAN TAKE
	RANGE	SPAN	
1) NEW CONCEPTUAL DESIGN	High	High	A new conceptual design (a new system) for tenants to have hot meals could be provided by meals on wheels or the tenant buying takeaways. This would totally remove the need to cook. Rejected - the tenant wants to cook his own food.
2) CHANGES REGARDING THE DESIRED PARAMETER(S) OF THE GAP(S) OF THE OFFENDING CAPABILITY			
a) MARKET SEGMENT/ RECEIVER SHIFT	Low-High	Low-High	The receiver here is the tenant – if the tenant suffers from the heat, the tenant could move to more suitable accommodation. Rejected – the tenant does not want to move.
3) CHANGES REGARDING THE OFFENDING CAPABILITY:			
a) SUBSTITUTE	High	High	Operant (Naked Flame), Operant (Cooker) – substitute the gas hob with an induction hob (these hobs are energy efficient and they do not heat the air – they heat the pan only). Special pans are needed for this. Positive side effects are that cooking time can be twice as fast as compared to conventional hobs and the possibility of burns are reduced which could benefit some types of disabled tenants as well as those with children. A negative side effect is they can also be noisy when more than one cooking zone (ring) is in use which could be an issue for an open plan kitchen-lounge. Another negative side effect is that because of the powerful electromagnetic field, induction cooking may not be suitable if the tenant (or any of their visitors) has a pacemaker fitted. For this reason, the tenant rejected this option.
	High	High	Operant (Naked Flame), Operant (Cooker) - halogen ovens could be used instead – these can cook food in about half the time and the casing can be cool to the touch which means that the oven would not continue to heat the air. A disadvantage is that the tenant would have to get used to a new way of cooking and halogen ovens do not have the capacity of traditional ovens – tenant rejected this idea.
	Low-Med	Low-Med	Operant (Cooker) - Substitute the Creda Capri for another gas cooker that emits less heat.
b) ELIMINATE	High	High	Operant (Cooker) -To eliminate the hob and oven, a microwave could be used instead – these do not heat the air and cooking time is drastically reduced. The tenant did not find this to be a generally acceptable way of cooking – rejected.
c) ADDITION	Med	Med	Operant (Cooker) – an air conditioning device could help to cool the air.
d) CUSTOMISE	N/A	N/A	There would appear to be no way to customise any of the elements of the capability to close these gaps.
4) ENVIRONMENTAL CHANGE			
a) CHANGE LOCAL ENVIRONMENT	High	High	This is defined here to be the area around the cooker: the gap in temperature range in this capability is produced by air being heated. Therefore, a way to treat this gap could be the addition of a cooker hood – this would remove most of the hot air. Other positive side effects could be a decrease in humidity as well as cooking odours as well as carbon monoxide. However, cooker hoods can be noisy. The tenant found this option acceptable.
b) CHANGE WIDER ENVIRONMENT	N/A	N/A	This is defined here as the kitchen-lounge: this is one part of the problem-space; that is, it is a separate capability that would affect the waist-level and head-level temperatures.

Table 4.1.7: The Proposals Matrix applied to the cooker capability

4.1.11 Next Tier?

Although the tenant can change the cooker, besides opening the windows and doors, there is little they can do to change the environment which dictates the way hot air collects within the kitchen-lounge. This capability belongs to the housing association who supplied the flat and those who work for it. This is to be explored to gauge how changes could be made to the kitchen-lounge room.

4.1.12 Increase the Tier by 1

The Tier now becomes equal to 1: *The Housing Association*

4.1.13 Operand-Operant Depiction of a Gap-Located Capability

- Second Iteration

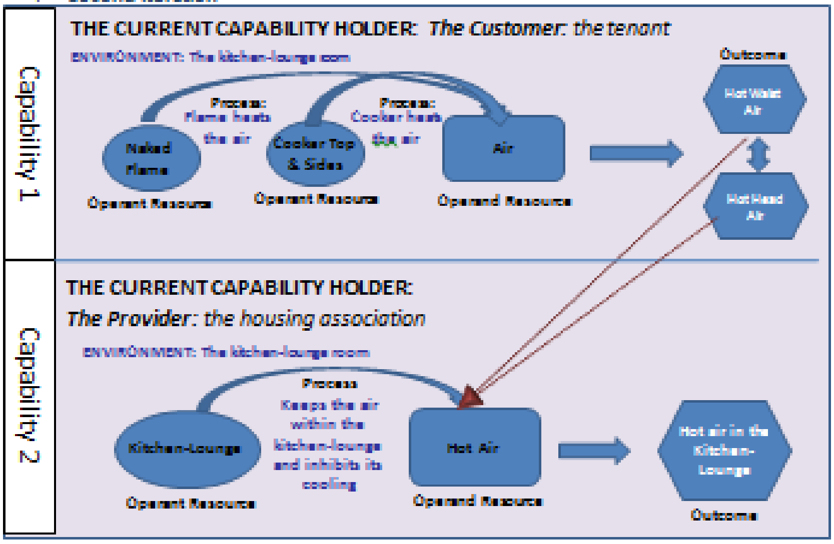


Figure 4.1.9: The Operand-Operant Diagram of the kitchen-lounge Capability to retain hot air

4.1.14 Determine the Stakeholders and Their General Roles

- Second Iteration

The Community Housing Association

One remit of the housing association is to provide people who are seriously ill with accommodation which is well placed (such as near to a doctor's surgery, pharmacy, hospital and shops) and for this accommodation to be affordable as well as comfortable for the tenant. The building of flats and houses are often performed by property developers who, instructed by the housing association, then make use of architect, civil engineers and builders. This information was gathered by the key researcher for this field test being invited to and attending a housing association's resident's meeting at which two housing association representatives were present.

In order to ensure that the existing apartments meet the needs of the current tenants and to inform the design of new apartments, the housing association gathers information from their tenants through surveys and by holding resident association meetings. Both forums allow the tenants to state any problems and make suggestions.

The housing association maintains and periodically refurbishes the accommodation it offers; for this it employs maintenance staff and experts such as civil engineers as well as builders who execute the designs.

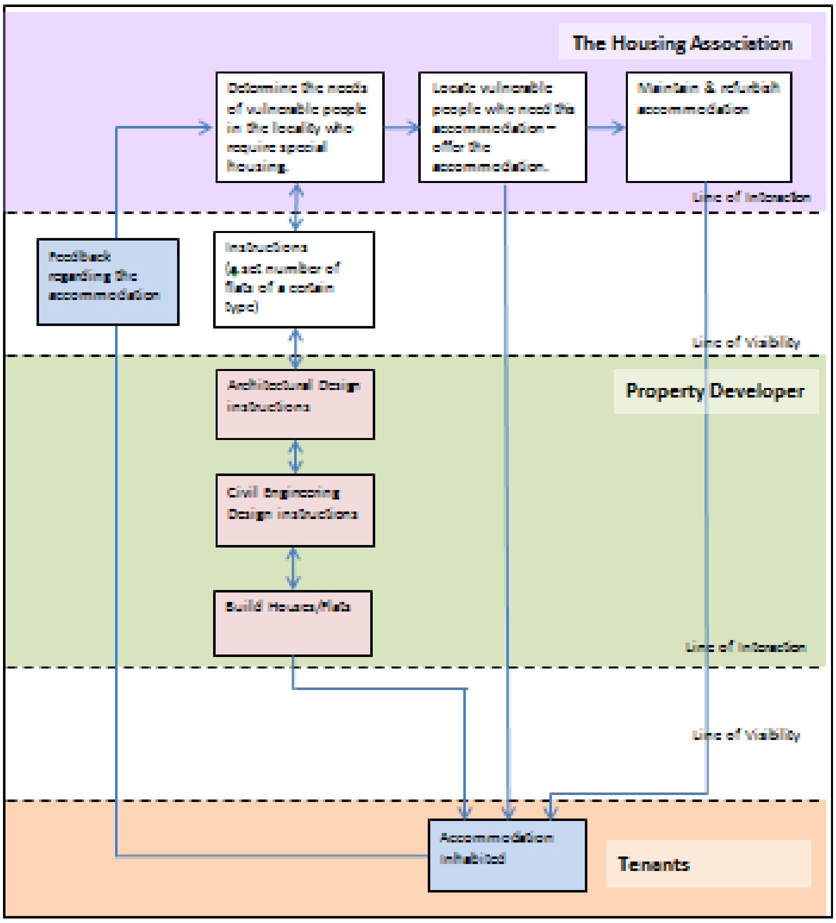


Figure 4.1.10: The stakeholders of this case study

4.1.15 Compare the Capability to Other Similar Capabilities

- Second Iteration

It was known that if the kitchen is separate from the lounge, then kitchen temperatures should have little impact on lounge temperatures.

4.1.16 Propose Solutions

The changes regarding the kitchen-lounge capability (see) were created with the help of a civil engineer and architect.

- Second Iteration

Generic Change Types	Decrease in gaps		UNBEARABLE HEAT DURING COOKING - STEPS THE HOUSING ASSOCIATION CAN TAKE
	RANGE	SPAN	
1) NEW CONCEPTUAL DESIGN ARCHITECT & CIVIL ENGINEER	High	High	**Operant Resource (Kitchen-Lounge):** For new flats, the kitchen area could be architecturally designed as a separate room. This would probably increase the foot print of the flat and each new room would probably feel smaller – the cost of the build would probably also increase. Because of these repercussions this may not be an acceptable solution.
	Med -High	Med -High	**Operant Resource (Kitchen-Lounge):** For new flats, the architectural design could involve the kitchen and living area being partitioned at the head level only by using a decorative arch that can span from the walls of the room and could add aesthetic appeal to the room. The hot air rising towards the kitchen ceiling will be prevented from moving along into the living area and will be more confined to the kitchen area where it can be extracted out. This solution would need to be verified by measuring the temperature variation along the ceiling to see how it varies along the ceiling, with and without an arch.
	Low-Med	Low-Med	**Operant Resource (Kitchen-Lounge):** Higher ceilings or larger kitchen-lounges could help to disperse hot air. However, this could result in higher build costs.
	Low-Med	Low-Med	**Operant Resource (Kitchen-Lounge):** For new flats, the architectural design could involve sliding doors which separate the kitchen/cooking area.
2) CHANGES REGARDING THE DESIRED PARAMETER(S) OF THE GAP(S) OF THE OFFENDING CAPABILITY			
a) MARKET SEGMENT/ RECEIVERSHIFT	N/A	N/A	The property developer would most likely want to continue working for such an important customer as the housing association and it is unlikely that there would be a specialist property developer that could tackle the problem any better.
3) CHANGES REGARDING THE OFFENDING CAPABILITY:			
a) SUBSTITUTE MAINTENANCE STAFF	Med -High	Med -High	**Operant Resource (Kitchen-Lounge), Process:** Substitute the existing ventilation with heat recovery ventilation – also known as a heat exchanger, air exchanger or air-to-air exchanger, is a ventilation system that employs a counter-flow heat exchanger between the inbound and outbound air flow. Heat recovery ventilators (HRV's) recover the heat energy that would normally escape, and transfer the heat to fresh air as it enters the building. However, given the actual short time durations of cooker use, the amount of energy saved will probably not justify installing a system of such complexity.
	Med -High	Med -High	**Operant Resource (Kitchen-Lounge), Process:** Substitute the extractor fan for a more powerful fan.
b) ELIMINATE	N/A	N/A	**Operant Resource (Kitchen-Lounge), Process:** The only way to eliminate hot air being contained in a small space would be to open that space to the elements – not acceptable.
c) ADDITION MAINTENANCE STAFF	High	High	**Operant Resource (Kitchen-Lounge), Process:** A cooker hood could be installed into each of the flats – this solution also changes the local environment
d) CUSTOMISE CIVIL ENGINEER	Low	Low	**Operant Resource (Kitchen-Lounge), Process:** An arch could be added to existing flats (as in the 1. New Conceptual Design) – however, this may be very difficult to accomplish given the current configuration of existing flats.
	Low	Low	**Operant Resource (Kitchen-Lounge), Process:** Sliding doors could be fitted to seal off the kitchen area. This could help to reduce the heat from the cooker after cooking has taken place. The extractor fan may need to be moved to behind the sliding doors. However, it may difficult to customise existing flats and this would take away the feeling of openness and spaciousness of the living room.
4) ENVIRONMENTAL CHANGE			
a) CHANGE LOCAL ENVIRONMENT MAINTENANCE STAFF	Med	Med	This is defined as the flat in general: the door to the kitchen-lounge could be removed which would give hot air more room to disperse. However, this would then mean it would cost more to heat the room.
b) CHANGE WIDER ENVIRONMENT	N/A	N/A	There would appear to be no changes that could be made by the civil engineer to the wider environment which would to close these gaps

Table 4.1.8: The Proposals Matrix applied to the kitchen lounge

4.1.17 Next Tier?

No further Tiers are required to be examined.

4.1.18 Rate and Select Solutions

1. **The Cooker Capability:** The tenant in the field test flat commented that, although he had noticed that his kitchen-lounge becomes hot, he had not realised exactly how hot it can become until the investgation was performed and he was quite alarmed by the negative effect it may have on his health.

   This tenant in the field test was interested in the cooker hood solution. It should be noted that although the tenant can institute this change, the housing association could also consider adding such solutions to their flats as this could improve their offering as this would augment the PSS that they offer to vulnerable people. The tenant was particularly interested in the cooker hood solution if the housing association would purchase, install and maintain it.

   This field test findings and the Proposals Matrix was presented to the other two tenants who were originally interviewed; these tenants expressed their appreciation of this study. They had not realised exactly how hot their kitchen-lounges can become or the length of time that such heat can linger. Each of them expressed a belief that this contributes to their ill-health and a general feeling of malaise. They also expressed appreciation for the range of solutions that they can now consider. Nevertheless, all of the possible solutions from this Matrix were rejected by these two tenants – two of the tenants thought that a cooker hood would take up too much space and be too noisy for a small area.

2. **The Kitchen-Lounge Capability:** From this Proposals Matrix, all three tenants favoured the solution of the housing association substituting their current extractor fan with one that is more powerful- this could be fairly easily and quickly accomplished by the housing association's maintenance staff.

   The solutions would have to be selected or rejected by the housing association; it could well be the case that the housing association would have more pressing concerns to address. Nevertheless, this study could help to inform the future designs of new builds. The housing association (specifically, the maintenance staff, the architect and civil engineer) will need to ascertain if instituting any changes will impact upon any other capabilities or the aesthetic appeal of the flats.

5 Conclusions of the Field Test

The solutions produced in this particular field test help to improve an existing product-service system (flats for rent) that are offered by a housing association: it does this by improving the use value that the tenant (the customer) would experience. This could be important for the housing association as one remit they have is to provide suitable rental accommodation for people who are or who have had serious illnesses: if this is not achieved then it could be the case that tenants may move and/or that the housing association's funding body could withhold funding. In this field test no differing business models were derived.

The opinion of the expert civil engineer, architect and the experts in heating and ventilation systems is that this method produces results which, if the housing association deemed this issue to be a priority, are detailed enough to inform them as to the issue and possible initial solutions. From this, more refined design and investigation could then take place and the capability of suppliers to provide solutions could be assessed.

6 Further Information & References

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9.7 Appendix G

Job Shop Interview Questions (See Chapter 7)

Case Study Assessment for the Application of the SIU Method to Laser Systems Assess its Merits and Demerits

Semi-Structured Questions for:

- **Laser job shops using industrial, capital-intensive, technical and infomated PSS with**
- **Managing directors with at least five years' experience in their role**

Research aim:

The aim of this research is the development of a method which uses system-in-use data from an existing PSS or product to generate initial PSS conceptual designs to address issues customers have when using that PSS or product to meet their objectives.

Research stage & current insight: *(Focus for exploration)*

A system-in-use method has been developed; this stage requires the application of this method to a case study to assess its merits and demerits.

Case description: *(company type, respondent)*

- Company Name: ________________________________

  Respondent Name: ____
  Contact Details: _____________________________________
  Job Title: ____
  Job Role Details: ____
  Years of Experience in that Job and in that Role: _________________________________

Case justification: *why this company? How does this company match the research aim? Why this validator?*

This company uses laser cutting machines (capital-intensive, technical and industrial PSS). The respondent at the company also has knowledge of servitization and PSS. The company is interested in methods to develop PSS as well as any possible, general improvements in its processes and those of its customers.

Interview Questions

1. Organization

1. How big is the company?
2. How many products or PSS do you sell on average per year?
3. Do you offer any types of PSS or are you the recipient of any types of PSS?
4. How is the company spread (the locations).

2. How Product-In-Use Data is used to Influence PSS Conceptual Design

Field Data and PSS Conceptual Design:

1. How do you think a PSS should meet a customer's needs?

   [If there is a pause or no answer, then ask:]
   How do you think a PSS should differ to a product in terms of satisfying customer's needs?

2. Do you utilise product-in-use or PSS-in-use data to inform PSS Conceptual Design?

   If so:
   a) Where do you collect data from to influence PSS Conceptual Design?
   b) What type of data is collected?
   c) How is the data collected?
   d) Could you describe typical data sets?
   e) What does the data indicate?
      I. Why is it important for the data to indicate this?
      II. How is the data processed to indicate this?
   f) Is this augmented with feedback directly from customers and/or users?
   g) What tools, techniques or methods are used?
   h) How does the data inform PSS Conceptual Design?

i) Specifically, have maintenance, maintainability or **[if you have availability contracts]** availability contracts been influenced by such data?

j) Who (or which department) is responsible for analysing the data?

k) Could I see a sample data set or documents that that relate to this?

If not:

l) Where do you think data should be collected from to influence PSS Conceptual Design?

m) What type of data should be collected?

n) How should the data be collected?

o) What should the data indicate?

  I. Why should the data indicate this?

  II. How could the data be processed to indicate this?

p) What tools, techniques or methods could be used?

q) How could the data inform PSS Conceptual Design?

[If there is a pause, no answer or "don't know" then ask:]

  I. For example, could the data be mapped to different PSS Designs?

[If the answer is yes, then ask:]

  II. How could this be accomplished?

3. Potential Case Study Assessment:

1. What issues have been reported to you regarding the laser cutting service that you provide? For example has there been a customer(s) who has stated that when using your offering in a process to meet a business objective, a problem has surfaced. Or, has an issue been reported to you by a member of your staff?
   [If the answer is yes, then ask:]
   Could the data from that case be made available (the data can be anonymised)? Could I use this for a case study to apply the aforementioned method to?

2. Have you had any issues with the laser machine and/or the maintenance that was provided? How do you think this could be improved?
   [If the answer is yes, then ask:]
   Could the data from that case be made available (the data can be anonymised)? Could I use this for a case study to apply the aforementioned method to?

Summarize and list of actions

Other methods: *(e.g. survey, observation, recording, notes)* Observation of the job shop processes. Notes will be taken during the interview. The interview will also be recorded.

Analysis techniques & Plan: *e.g. type up notes / create cause and effect diagrams / create matrix / transcribe & code, etc.* One or more case studies will be selected from the findings from the interviews within this sample. The System-In-Use Method (which has been outlined to you) will then be applied to the selected case study to assess its relative merits and demerits. If a case study is undertaken with this company, the case study(s) which (if it is a case study you have suggested) will be presented as a report to you and any feedback that you give will be used to refine that report and could be used to change the System-In-Use Method; the case study will then be presented at the AILU (Associated Industrial Laser Users) Annual General Meeting to check its validity.

9.8 Appendix H

Laser Technology Company Questions (See Chapter 7)

Case Study Assessment for the Application of the SIU Method to Laser Systems to Assess its Merits and Demerits

Semi-Structured Questions for:

- **companies producing industrial, capital-intensive, technical and infomated laser PSS with**
- **senior managers with at least five years' experience in their role**

Research aim:

The aim of this research is the development of a method which uses system-in-use data from an existing PSS or product to generate initial PSS conceptual designs to address issues customers have when using that PSS or product to meet their objectives.

Research stage & current insight: *(Focus for exploration)*

A system-in-use method has been developed; this stage requires the application of this method to a case study assess its merits and demerits.

Case description: *(company type, respondent)*

- Company Name: ___________________________________
  Respondent Name: ____
  Contact Details: ____
  Job Title: ____
  Job Role Details: ____
  Years of Experience in that Job and in that Role: ___________________________________

Case justification: *why this company? How does this company match the research aim? Why this validator?*

This company produces capital-intensive, technical and industrial PSS. The respondent at the company also has extensive knowledge of servitization and PSS. The company is interested in methods to develop PSS as well as any possible, general improvements in its processes and those of its customers.

Interview Questions

1. Organization

1. How big is the company?
2. How many products, maintenance contracts or PSS do you sell on average per year?
3. Do you offer any types of PSS or are you the recipient of any types of PSS?
4. How is the company spread (the locations).

2. How Product-In-Use Data is used to Influence PSS Conceptual Design

Field Data and PSS Conceptual Design:

1. How do you think a PSS should meet a customer's needs?

   [If there is a pause or no answer, then ask:]
   How do you think a PSS should differ to a product in terms of satisfying customer's needs?
2. Do you utilise product-in-use or PSS-in-use data to inform PSS Conceptual Design?

   If so:
   a) Where do you collect data from to influence PSS Conceptual Design?
   b) What type of data is collected?
   c) How is the data collected?
   d) Could you describe typical data sets?
   e) What does the data indicate?
      I. Why is it important for the data to indicate this?
      II. How is the data processed to indicate this?
   f) Is this augmented with feedback directly from customers and/or users?
   g) What tools, techniques or methods are used?
   h) How does the data inform PSS Conceptual Design?
   i) Specifically, have maintenance, maintainability or **[if you have availability contracts]** availability contracts been influenced by such data?
   j) Who (or which department) is responsible for analysing the data?
   k) Could I see a sample data set or documents that that relate to this?

   If not:
   l) Where do you think data should be collected from to influence PSS Conceptual Design?
   m) What type of data should be collected?
   n) How should the data be collected?

o) What should the data indicate?
    I. Why should the data indicate this?
    II. How could the data be processed to indicate this?
p) What tools, techniques or methods could be used?
q) How could the data inform PSS Conceptual Design?

[If there is a pause, no answer or "don't know" then ask:]

For example, could the data be mapped to different PSS Designs?

[If the answer is yes, then ask:]

How could this be accomplished?

3. Potential Case Study Assessment:

1. What issues have been reported to you regarding the technology and services that you provide? For example has there been a customer(s) who has stated that when using your offering in a process to meet a business objective, a problem has surfaced. Or, has an issue been reported to you by a member of your staff?

   [If the answer is yes, then ask:]

   Could the data from that case be made available (the data can be anonymised)? Could I use this for a case study to apply the aforementioned method to?
2. Have you had any issues with any technology or services that are provided to you? How do you think this could be improved?

   [If the answer is yes, then ask:]

   Could the data from that case be made available (the data can be anonymised)? Could I use this for a case study to apply the aforementioned method to?

Summarize and list of actions

Other methods: *(e.g. survey, observation, recording, notes)* Observation of their products. Notes will be taken during the interview. The interview will also be recorded.

Analysis techniques & Plan: *e.g. type up notes / create cause and effect diagrams / create matrix / transcribe & code, etc.* One or more case studies will be selected from the findings from the interviews within this sample. The System-In-Use Method (which has been outlined to you) will then be applied to the selected case study to assess its relative merits and demerits. If a case study is undertaken with this company, the case study(s) which (if it is a case study you have suggested) will be presented as a report to you and any feedback that you give will be used to refine that report and could be used to change the System-In-Use Method; the case study will then be presented at the AILU (Associated Industrial Laser Users) Annual General Meeting to check its validity.

9.9 Appendix I

Method Evaluation Questions (See Chapter 7)

SIU Method Evaluation

Research aim:

The aim of this research is the development of a method to inform PSS Conceptual Design based on gaps within a customer's value creating system.

Research stage & current insight: *(Focus for exploration)*

The method has been developed (based on findings from the literature, interviews with senior managers in industry and case studies). The current focus for exploration is the evaluation of the first version of this method (which was developed by the researcher) to assess its merits and demerits.

Case description: *(company type, validator)*

- Company: PSS provider. Specifically ________________________________
- Validator: ____

Case justification: *why this company? How does this company match the research aim? Why this validator?*

The company provides industrial, technical and infomated PSS.

Questions to be covered in the interview:		Responses
1.1.	Is the structure of the method comprehensive?	
1.2.	Would you suggest any changes to any part of the method?	
1.3.	What are the advantages and disadvantages of the method?	
1.4.	Does the method produce the expected outcome?	
1.5.	Any suggestions for further improvement?	

Other methods: *(e.g. survey, observation, recording, notes)*

Notes will be taken during the interview.

Analysis techniques & Plan: *e.g. type up notes / create cause and effect diagrams / create matrix / transcribe & code, etc.*

Any suggestions will be considered to refine the method. The revised method will then be presented to you.

9.10 Appendix J

Method Evaluation Questions (See Chapter 7)

Case Study Assessment for the Application of the SIU Method to Validate the Method

Semi-Structured Questions for:

- **companies producing industrial, capital-intensive, technical and infomated PSS with**
- **senior managers with at least five years' experience in their role**

Research aim:

The aim of this research is the development of a method which uses system-in-use data from an existing PSS or product to generate initial PSS conceptual designs to address issues customers have when using that PSS or product to meet their objectives.

Research stage & current insight: *(Focus for exploration)*

A system-in-use method has been developed; this stage requires the application of this method to a case study assess its merits and demerits.

Case description: *(company type, respondent)*

Company Name: ________________________________
Respondent Name: ____
Contact Details: _____________________________________
Job Title: _______________________________________
Job Role Details: ____
Years of Experience in that Job and in that Role: _________________________________

Case justification: *why this company? How does this company match the research aim? Why this validator?*

This company produces capital-intensive, technical and industrial PSS. The respondents at the company also have an extensive knowledge of servitization and PSS. The company is interested in methods to develop PSS as well as any possible, general improvements in its processes and those of its customers.

1. Organization

1. How big is the company?
2. How many products, maintenance contracts or PSS do you sell on average per year?
3. Do you offer any types of PSS or are you the recipient of any types of PSS?

4. How is the company spread (the locations).

2. How Product-In-Use Data is used to Influence PSS Conceptual Design

Field Data and PSS Conceptual Design:

1. How do you think a PSS should meet a customer's needs?

   [If there is a pause or no answer, then ask:]
   How do you think a PSS should differ to a product in terms of satisfying customer's needs?

2. Do you utilise product-in-use or PSS-in-use data to inform PSS Conceptual Design?

   If so:

   a) Where do you collect data from to influence PSS Conceptual Design?

   b) What type of data is collected?

   c) How is the data collected?

   d) Could you describe typical data sets?

   e) What does the data indicate?

      I. Why is it important for the data to indicate this?

      II. How is the data processed to indicate this?

   f) Is this augmented with feedback directly from customers and/or users?

   g) What tools, techniques or methods are used?

   h) How does the data inform PSS Conceptual Design?

   i) Specifically, have maintenance, maintainability or **[if you have availability contracts]** availability contracts been influenced by such data?

   j) Who (or which department) is responsible for analysing the data?

   k) Could I see a sample data set or documents that that relate to this?

   If not:

l) Where do you think data should be collected from to influence PSS Conceptual Design?

m) What type of data should be collected?

n) How should the data be collected?

o) What should the data indicate?

   I. Why should the data indicate this?

   II. How could the data be processed to indicate this?

p) What tools, techniques or methods could be used?

q) How could the data inform PSS Conceptual Design?

[If there is a pause, no answer or "don't know" then ask:]

For example, could the data be mapped to different PSS Designs?

[If the answer is yes, then ask:]

How could this be accomplished?

3. Potential Case Study Assessment:

1. What issues have been reported to you regarding the technology and services that you provide? For example has there been a customer(s) who has stated that when using your offering in a process to meet a business objective, a problem has surfaced. Or, has an issue been reported to you by a member of your staff?
   [If the answer is yes, then ask:]
   Could the data from that case be made available (the data can be anonymised)? Could I use this for a case study to apply the aforementioned method to?

2. Have you had any issues with any technology or services that are provided to you? How do you think this could be improved?
   [If the answer is yes, then ask:]
   Could the data from that case be made available (the data can be anonymised)? Could I use this for a case study to apply the aforementioned method to?

Summarize and list of actions

Other methods: *(e.g. survey, observation, recording, notes)* Observation of products at the company. Notes will be taken during the interview. The interview will also be recorded.

Analysis techniques & Plan: *e.g. type up notes / create cause and effect diagrams / create matrix / transcribe & code, etc.* One or more case studies for validation of the SIU Method will be selected from the findings from the interviews within this sample. You may then be asked to apply the System-In-Use Method (which has been outlined to you) to this case study to assess its relative merits and demerits. The results of the application will be written up by the researcher and will be presented as a report to you and you will be asked for feedback. This feedback will then be used to amend the report which will then again be forwarded to you. You will then be interviewed with regards to how you view the merits and demerits of the SIU Method.

9.11 Appendix K

Aero Engine Case Study – SIU Method Validation (See Chapter 7)

Aero Engine Case Study Validation
SIU Method (qualitative, recursive application throughout a value chain) validation questionnaire (11 Jan 2013)

Research aim:

The aim of this research is the development of a method to generate possible solutions (prototype Conceptual PSS designs) based on gaps within a customer's value creating system. This method should be able to be used qualitatively, quantitatively and form a basis for product as well as service specification.

Research stage & current insight: *(Focus for exploration)*

The method has been developed (based on findings from the literature, interviews with senior managers in industry, observation and case studies). The current focus for exploration is the validation of a version of this method, which was developed by the researcher. This version is qualitative and shows how the method can be applied throughout a value chain.

Case description: *(company type, validator)*

- Company: PSS provider – a manufacturer of aero engine components, aero engines and product-related services
- Validator: Senior Company Specialist in Product Development, employed at this company for 8 years. The previous 10 years of his employment were as an engineering specialist at an aero engine and aero engine component manufacturer.

Case justification: *why this company? How does this company match the research aim? Why this validator?*

This company is an industrial, capital intensive, technical and infomated PSS provider. The validator at the company is also a leading senior academic in servitization and industrial PSS. The company is interested in methods which develop PSS.

The aim of this application of the method is to demonstrate how it can be used by Supply Chain Management to:

- Comprehend the customer's value creating system along with the contribution of suppliers.
- Determine how suppliers can generate competitively compelling value propositions and capability improvements, not only for their customers but also for customers of customers, as well as backward to the firm's suppliers and their suppliers.
- Learn more quickly and then act on this learning to continuously have a knowledge advantage and hence competitive advantage.
- Develop a global communication system that allows for diverse cultures operating around the world to work as an effective team

- Open its innovation process to all members of the service ecosystem yet protect important property rights.

Questions to be covered in the interview:		**Responses**
1.6.	Is the structure of the method comprehensive?	"The method appears to be comprehensive."
1.7.	Would you suggest any changes to any part of the method?	"I had insisted that the method should *not* be applied by just by one company to the value chain – the stakeholders in the value chain should also be involved. Thankfully, I now see that this has been made explicit in the instructions for the method. I understand that a focal company can firstly apply the method to the value chain in order to show the other stakeholders how the method works and the sorts of possible solutions/ideas that could be generated and then, once the support and commitment of the other stakeholders have been won, a more exacting application of the method by all of the stakeholders can follow. I am satisfied with this."
1.8.	What are the advantages and disadvantages of the method?	"The method fills a gap in the current practice in industry. The method helps the problem space and solution space to be unfolded in a very systematic way. It also obliges the applier of the method to consider aspects of the issue which may usually be overlooked – this can foster innovation. It also helps suppliers understand how they contribute to the end customer's processes. A disadvantage could be that to realize to the method's full potential, a simultaneous/coordinated application would be required in several organisations; this is a major challenge and a possible disadvantage of the approach. Nevertheless, I consider the method to be applicable "stand alone" (even if it is only applied by one stakeholder, it would still allow them to see possibilities for change throughout the supply chain which could inform decision-making) as well as in a collaborative context through the supply chain."
1.9.	What skills (which personnel) and resources are required to use the method?	"It is expected that each of the stakeholders in the value chain would be able to apply the method fairly easily after it had been demonstrated to them – no

		special skills are required. Nevertheless, a walk through and training in the method would be required by personnel before they apply it, to guide them in the logic of the method and to introduce the dependencies/concepts.”
1.10.	What is the scope of the method?	“It appears that it can be used to generate various types of solutions from issues with how a product is being used – these solutions can be PSS solutions or more conventional solutions. Some solutions relate to changes in service or business processes and some relate to product or material changes.”
1.11.	Does the method produce the expected outcome?	“Yes, the outcome of applying the method to this particular case study is that it improves SCM and generates prototype Conceptual PSS Designs to increase value in use. Without this method, it is highly unlikely that all of the possible solutions to tackle such an issue could have been generated so comprehensively. Furthermore, I would expect that the method should also apply to novel situations. However, this is a deployment/adoption issue rather than a research issue at present.”
1.12.	Can the method improve processes?	“Yes”
1.13.	What did the method add?	“A systematised way of exploring a wide range of possible options to address an issue.”
1.14.	Any suggestions for further improvement?	“In this case study, the method was applied retrospectively to an issue that has already been resolved. However, the method should also be applied to a novel issue to ascertain how the method can influence how that issue is addressed to test the limits of the method more thoroughly.”
1.15.	Could any other method have been used to generate the same or better results?	“I am not aware of any method that could generate the same results.”
1.16.	Would you use the SIU Method again?	“I am intending to use it again sometime in the near future.”
Techniques Used by the SIU Method		

1.17.	System Depiction – is Service Blueprinting adequate or would you use another technique?	"Service Blueprinting is widely accepted for PSS Design. It appears to be adequate.
1.18.	Is the representation of a capability (a system – see Figure 2) complete? Would you add, remove or change anything?	"It appears to be complete."
1.19.	Are the Design Options (see Figure 2) complete? Would you add, remove or change anything?	"They appear to be complete."
1.20.	Operand-Operant Diagrams (Figure 2) –are these adequate to show how an effect is created or would you use another technique?	"It appears to be a useful and simple technique and fitting for this method.
1.21.	Are the Parameters (see Table 2) complete? Would you add, remove or change anything?	"The parameters appear to be complete."
1.22.	Would you change anything as to how the Gap Analysis is performed?	"The Gap Analysis in the Method appears to produce reasonable results. I would not change anything.
1.23.	Would you change anything as to how the Proposals Matrix is constructed or applied?	The Proposals Matrix is easy to use and apply the design options. I would not change anything."
	The Workbook	
1.24.	Have the SIU Method and its techniques been presented fully?	"More detail on the techniques is required.
1.25.	Does the workbook follow the general format of a user manual?	"On each page, a side bar showing the method steps which are being followed would make the Workbook clearer."
1.26.	Does the case study illustrate the SIU Method well?	The case study is very detailed – a simpler case study is required and perhaps a synopsis of other case studies

		should be included."
1.27.	Does the Workbook have an adequate overview of PSS?	"This seems to be fine."
1.28.	Does the Workbook have an adequate overview PSS Conceptual Design	This seems to be fine."
1.29.	Is the SIU Method background and steps clearly explained in a user-friendly way?	"More background to the logic of the SIU Method is required."
1.30.	How could the Workbook be further improved?	"A video tutorial showing the steps would be helpful. A Workshop with the target users to assess the Workbook and generate ideas for its improvement should be held."
Revisions to the Validation Case Study Notes		
1.31.	Are there any revisions you would now like to make with regards to how the case study was written up by the researcher?	"No, I am satisfied with the final version"

Other methods: *(e.g. survey, observation, recording, notes)*

Notes will be taken during the interview. The interview will also be recorded.

Analysis techniques & Plan: *e.g. type up notes / create cause and effect diagrams / create matrix / transcribe & code, etc.*

A report will be created, describing the findings from the interview and necessary amendments will be made to the method.

9.12 Appendix L

HVAC Case Study – SIU Method Validation (See Chapter 7)

Heating Case Study Validation
SIU Method (quantitative, recursive application) validations

Research aim:

The aim of this research is the development of a method to generate possible solutions (prototype Conceptual PSS designs) based on gaps within a customer's value creating system. This method should be able to be used qualitatively, quantitatively and form a basis for product as well as service specification.

Research stage & current insight: *(Focus for exploration)*

The method has been developed (based on findings from the literature, interviews with senior managers in industry, observation and case studies). The current focus for exploration is the validation of a version of this method, which was developed by the researcher. This version is quantitative and shows how the method can be applied to two tiers in a value chain.

Case description: *(company type, validator)*

- Company: None
- Validator: A freelance English teacher – a non-technologist with little knowledge of PSS

Case justification: *why this company? How does this company match the research aim? Why this validator?*

See Below:

The aim of this validation of the method is to assess how it can be applied by different stakeholders at different Tiers (Tier 0 is the tenant and Tier 1 is the civil engineer) and then to assess the merits and demerits of the SIU Method as compared to how professional, experienced consultants in that domain (HVAC Consultants) would have addressed the issue:

1) The first iteration of the SIU Method (in this case study) is applied by a non-technologist (Tier 0 - the tenant) who has little knowledge of PSS and engineering – this is to test the general usability of the Workbook and the SIU Method.
2) The second iteration of the SIU Method (in this case study) is applied by an expert civil engineer (Tier 1) who has little knowledge of PSS– this is to test the usability of the Workbook and the SIU Method for someone who is an engineer but not very familiar with PSS. This is also conducted to assess how the SIU Method can inform building design.
3) The results of the application are then presented to HVAC consultants to assess the merits and demerits of the SIU Method as compared to how they would have addressed the issue.

A report will be created, describing the findings from the validations. The report will be circulated to the validators and, from the feedback, any necessary amendments will be made to the report.

a) Results of the Validation with the Tenant

Questions		Responses
1.32.	Is the structure of the method comprehensive?	"It produced useful results to address my cooking problem."
1.33.	Would you suggest any changes to any part of the method?	"No."
1.34.	What are the advantages and disadvantages of the method?	"It allows just about anyone to apply it to a problem they have when they are trying to accomplish something."
1.35.	What skills (which personnel) and resources are required to use the method?	"I don't really have that many skills in technical things so I don't think any in particular are needed."
1.36.	What is the scope of the method?	"I think it can be used for any problem."
1.37.	Does the method produce the expected outcome?	"It produced more solutions than I expected."
1.38.	Can the method improve processes?	"Yes – it gave me a range of options to choose from to sort out my cooking issue. It also made me feel confident that all possible avenues had been explored."
1.39.	What did the method add?	"I wouldn't have been able to explore this cooking issue so thoroughly without this method and I simply wouldn't have thought of some of the solutions without it."
1.40.	Any suggestions for further improvement?	"I think the Method could be explained in a simpler way."
1.41.	Could any other method have been used to generate the same or better results?	"I don't know. I don't know of any."
1.42.	Would you use the SIU Method again?	"Yes – I've applied it to an issue I had with students in a class I was teaching. Some were not doing well, so I considered changing the environment (could they hear me properly or were they being distracted by something happening at the back of the class), changing the receiver (perhaps those students should be in another class), the whole system of teaching (rather than following a teacher giving a lesson, perhaps they should be following a tutorial book or multimedia that they can mostly work through at their own pace). Also, perhaps the student could be customised or added to (extra lessons could be given). It allowed me to a full set of possibilities to address the issue."
1.43.	System Depiction – is Service Blueprinting adequate or would you use another technique?	"I think I understood it although there was a learning curve for me. I suppose the technique is fine."
1.44.	Is the representation of a capability (a system – see Figure 2) complete? Would you add, remove or change	"It makes sense to me."

	anything?	
1.45.	Are the Design Options (see Figure 2) complete? Would you add, remove or change anything?	"I can't think of anything that should be added or changed."
1.46.	Operand-Operant Diagrams (Figure 2) –are these adequate to show how an effect is created or would you use another technique?	"I like these diagrams – for my teaching issue I applied the method to the diagram was:" **Process** (Teaching) **Teacher** **Student** (Operant) (Operand)
1.47.	Are the Parameters (see Table 2) complete? Would you add, remove or change anything?	"The parameters seem to work."
1.48.	Would you change anything as to how the Gap Analysis is performed?	"The Gap Analysis makes sense."
1.49.	Would you change anything as to how the Proposals Matrix is constructed or applied?	"I can't think of anything."
1.50.	Have the SIU Method and its techniques been presented fully?	"The second version of the Workbook is easier to follow but I think it could be made a bit clearer."
1.51.	Does the workbook follow the general format of a user manual?	"It needs to look a bit more like a user manual and have more guidance on the steps."
1.52.	Does the case study illustrate the SIU Method well?	"I think the case study is fine but there should be a simpler case study as an introduction to the method. My teaching issue could be used."
1.53.	Does the Workbook have an adequate overview of PSS?	"I understood it."
1.54.	Does the Workbook have an adequate overview PSS Conceptual Design	"I'm not so sure about this part."
1.55.	Is the SIU Method background and steps clearly explained in a user-friendly way?	"More guidance on the steps is required."
1.56.	How could the Workbook be further improved?	"As an introduction, a very simple case study showing how to apply the method would be useful."

b) Results of the Validation the Expert Civil Engineer

Questions		Responses
1.57.	Is the structure of the method comprehensive?	"There appear to be no aspects that have been omitted."
1.58.	Would you suggest any changes to any part of the method?	"I have no changes to recommend at this point."
1.59.	What are the advantages and disadvantages of the method?	"It's a problem-solving method and I would imagine it would be very useful to solve complex situations. It is useful in that it can produce short-term solutions as well as long-term solutions."
1.60.	What skills (which personnel) and resources are required to use the method?	"I think anyone with any basic engineering skills could use the method."
1.61.	What is the scope of the method?	"The scope could be wide. I would expect it to apply to any task."
1.62.	Does the method produce the expected outcome?	"It produces a whole set of solutions that can be used to deal with a problem."
1.63.	Can the method improve processes?	"Yes"
1.64.	What did the method add?	"A deep understanding of all of the factors that make up a system and how to adjust parts of the system to make it function better."
1.65.	Any suggestions for further improvement?	"Not yet – I would need to apply it to a more complex problem."
1.66.	Could any other method have been used to generate the same or better results?	"We use a computer package called Taproot for accident investigations. The program guides the user to do the investigation, finds root causes of the incident and then comes up with suggested corrective actions. The output is a report laid out in a formal format and with a corrective action register with target dates and responsible persons and parties. However, this is based on past performance and adherence to industry standards rather than innovation. I think the SIU method would work well with Taproot and could be part of a management system development/ improvement aspect."
1.67.	Would you use the SIU Method again?	"Yes, I will use it again for general housing design to identify and resolve issues clients have had with previous buildings. I will also eventually introduce the method into the course curriculum for Architects and Civil Engineers as part of the continuous courses run by the university"
1.68.	System Depiction – is Service Blueprinting adequate or would you use another technique?	This seems to be fine.
1.69.	Is the representation of a capability (a system – see Figure 2) complete? Would you add, remove or change anything?	"I think this is a comprehensive representation."

1.70.	Are the Design Options (see Figure 2) complete? Would you add, remove or change anything?	"I have not yet thought of anything else."
1.71.	Operand-Operant Diagrams (Figure 2) –are these adequate to show how an effect is created or would you use another technique?	"This is fine."
1.72.	Are the Parameters (see Table 2) complete? Would you add, remove or change anything?	"I have nothing to add to this yet."
1.73.	Would you change anything as to how the Gap Analysis is performed?	"The Gap Analysis is fine."
1.74.	Would you change anything as to how the Proposals Matrix is constructed or applied?	"No."
1.75.	Have the SIU Method and its techniques been presented fully?	"Seems to be".
1.76.	Does the workbook follow the general format of a user manual?	"This could be improved."
1.77.	Does the case study illustrate the SIU Method well?	"Yes".
1.78.	Does the Workbook have an adequate overview of PSS?	"I think so."
1.79.	Does the Workbook have an adequate overview PSS Conceptual Design	"I think so."
1.80.	Is the SIU Method background and steps clearly explained in a user-friendly way?	"More explanation is required."
1.81.	How could the Workbook be further improved?	"A pull-out section showing the method steps and the techniques would be useful. I think the SIU Method could be made into an industry-specific computer system to be used with a system such as Taproot."

c) Results of the Validation the HVAC Consultants

Questions		Responses
1.82.	Is the structure of the method comprehensive?	"Very. We tend to work intuitively so we don't often think about the actual steps that we use."
1.83.	Would you suggest any changes to any part of the method?	"No – it seems to follow all of the steps that we follow."
1.84.	What are the advantages and disadvantages of the method?	"We don't see any disadvantages. The advantage is that the method is all laid out in black and white so it could help us not to forget any of the steps - which we sometimes do. It highlights the usefulness of understanding the needs of the client's customer. Also, the idea of looking at different Tiers is not something that we really knew how to do. We'd been in buildings and seen faults with the design and layout that had caused HVAC problems. The method now gives us a way of laying this out; we're now thinking about using this to act as consultants to property developers and housing associations."
1.85.	What skills (which personnel) and resources are required to use the method?	"I think that you would need to have some sort of technical background."
1.86.	What is the scope of the method?	"It seems to be that it can be used for any technical problem. It certainly applies to HVAC issues but, from this case study application, it also applies to building design."
1.87.	Does the method produce the expected outcome?	"Yes, absolutely – we cannot think of any other solutions"
1.88.	Can the method improve processes?	"Of course."
1.89.	What did the method add?	"A fully detailed way of identifying the causes of a problem and a very detailed way to spawn solutions."
1.90.	Any suggestions for further improvement?	"None."
1.91.	Could any other method have been used to generate the same or better results?	"We use the same method - but ours isn't written down."
1.92.	Would you use the SIU Method again?	"Yes – I had to pass work onto other HVAC consultants so I used it then to explain to them what the problem was and what I'd done. We also use it as a sort of check-list to make sure that we've covered all of the 'bases' because, sometimes, we'd get into the van and then realise that we'd forgotten to look at something."
1.93.	System Depiction – is Service Blueprinting adequate or would you use another technique?	"This is a better way to depict what's going on in a system as opposed to the floor maps we use."
1.94.	Is the representation of a capability (a system – see Figure 2) complete? Would you add, remove or change anything?	"Yes – this is how we think of a system. We'd just never drawn it."

1.95.	Are the Design Options (see Figure 2) complete? Would you add, remove or change anything?	"These are exactly all of the possibilities that we run through; in fact, we hadn't realised that this is what we do until you had pointed it out to us – we just did it naturally."
1.96.	Operand-Operant Diagrams (Figure 2) –are these adequate to show how an effect is created or would you use another technique?	"We hadn't thought about this before – it is useful to see all of the elements that produce an effect. We'd never done this before – we never really knew how to. We always relied on our experience but it can be so easy to overlook something. "
1.97.	Are the Parameters (see Table 2) complete? Would you add, remove or change anything?	"These are the parameters that we use –we just call them different names."
1.98.	Would you change anything as to how the Gap Analysis is performed?	" This is exactly what we do. What really happened is not always what has been reported. Also, we need to know exactly what happened in order to design a solution. This helps us to assess the extent to which different solutions could reduce the problem. Nothing needs to be changed. "
1.99.	Would you change anything as to how the Proposals Matrix is constructed or applied?	"I like the Proposals Matrix – it makes sure that you've considered every single possible type of change to the system. It leaves nothing to chance. What we normally do is brain storm. That could be an issue because with brain-storming you can forget to consider all possibilities. Before now, I'd never seen a Proposal's Matrix. It represents a very clear way to generate a comprehensive set of solutions which you can then show clients for them to choose from."
1.100	Have the SIU Method and its techniques been presented fully?	"We think so but other people may think differently. It probably needs to use more simplified language and more background on the derivation of the method is required. More clarification on Service Blueprinting and how to use it is required. "
1.101	Does the workbook follow the general format of a user manual?	"Maybe a bit more detail is needed for people new to this method."
1.102	Does the case study illustrate the SIU Method well?	"Yes – this is exactly how we would have approached the excessive heat issue."
1.103	Does the Workbook have an adequate overview of PSS?	"Perhaps a bit more detail is needed."
1.104	Does the Workbook have an adequate overview PSS Conceptual Design	"A bit more detail on how the Method is derived would be good. More explanation is required of how the method relates to servitization. "
1.105	Is the SIU Method background and steps clearly explained in a user-friendly way?	"Seems to be."
1.106	How could the Workbook be further improved?	"Multimedia showing a video of someone applying the method against the steps in the method."

9.13 Appendix M

Interview Questions for the customer of the Truck PSS Provider (See Chapter 7)

Case Study Assessment for the Application of the SIU Method to Validate the Method

Semi-Structured Questions for:

- **A company using industrial, capital-intensive, technical and infomated PSS with**
- **A senior manager with at least five years' experience in their role**

Research aim:

The aim of this research is the development of a method which uses system-in-use data from an existing PSS or product to generate initial PSS conceptual designs to address issues customers have when using that PSS or product to meet their objectives.

Research stage & current insight: *(Focus for exploration)*

A system-in-use method has been developed; this stage requires the application of this method to a case study assess its merits and demerits.

Case description: *(company type, respondent)*

Company Name: ______________________________
Respondent Name: ____
Contact Details: ___________________________________
Job Title: _____________________________________
Job Role Details: ____
Years of Experience in that Job and in that Role: _______________________________

Case justification: *why this company? How does this company match the research aim? Why this validator?*

This company uses capital-intensive, technical and industrial PSS. The company is interested in any possible, general improvements in its processes and those of its customers.

1. Organization

1. How big is the company?
2. Please describe the contract that you have with the truck OEM.
3. Could you outline the company's main business processes?

2. How Product-In-Use Data is used to Influence PSS Conceptual Design

Field Data and PSS Conceptual Design:

How do you think a PSS should meet a customer's needs?

[If there is a pause or no answer, then ask:]

How do you think a PSS should differ to a product in terms of satisfying customer's needs?

2. Potential Case Study Assessment:

1. What issues have been reported to you regarding the services that you provide? For example has there been a customer(s) who has stated that when using your offering in a process to meet a business objective, a problem has surfaced. Or, has an issue been reported to you by a member of your staff?

   [If the answer is yes, then ask:]

   Could the data from that case be made available (the data can be anonymised)? Could I use this for a case study to apply the aforementioned method to?
2. Have you had any issues with any technology or services that are provided to you? How do you think this could be improved?

   [If the answer is yes, then ask:]

   Could the data from that case be made available (the data can be anonymised)? Could I use this for a case study to apply the aforementioned method to?

Summarize and list of actions

Other methods: *(e.g. survey, observation, recording, notes)*

Notes will be taken during the interview. The interview will also be recorded.

Analysis techniques & Plan: *e.g. type up notes / create cause and effect diagrams / create matrix / transcribe & code, etc.*

One or more case studies for validation of the SIU Method will be selected from the findings from the interviews within this sample. You may then be asked to apply the System-In-Use Method (which has been outlined to you) to this case study to assess its relative merits and demerits. The results of the application will be written up by the researcher and will be presented as a report to you and you will be asked for feedback. This feedback will then be used to amend the report which will then again be forwarded to you. You will then be interviewed with regards to how you view the merits and demerits of the SIU Method.

9.14 Appendix N

Interview Questions for the Truck PSS Provider (See Chapter 7)

Case Study Assessment for the Application of the SIU Method to Validate the Method

Semi-Structured Questions for:

- **companies producing industrial, capital-intensive, technical and infomated PSS with**
- **senior managers with at least five years' experience in their role**

Research aim:

The aim of this research is the development of a method which uses system-in-use data from an existing PSS or product to generate initial PSS conceptual designs to address issues customers have when using that PSS or product to meet their objectives.

Research stage & current insight: *(Focus for exploration)*

A system-in-use method has been developed; this stage requires the application of this method to a case study assess its merits and demerits.

Case description: *(company type, respondent)*

Company Name: ________________________________
Respondent Name: ____
Contact Details: _____________________________________
Job Title: _______________________________________
Job Role Details: ____
Years of Experience in that Job and in that Role: _________________________________

Case justification: *why this company? How does this company match the research aim? Why this validator?*

This company produces capital-intensive, technical and industrial PSS. The respondents at the company also have an extensive knowledge of servitization and PSS. The company is interested in methods to develop PSS as well as any possible, general improvements in its processes and those of its customers.

2. How Product-In-Use Data is used to Influence PSS Conceptual Design

Field Data and PSS Conceptual Design:

1. How do you think a PSS should meet a customer's needs?

   [If there is a pause or no answer, then ask:]
   How do you think a PSS should differ to a product in terms of satisfying customer's needs?

2. Do you utilise product-in-use or PSS-in-use data to inform PSS Conceptual Design?

   If so:

   a) Where do you collect data from to influence PSS Conceptual Design?

   b) What type of data is collected?

   c) How is the data collected?

   d) Could you describe typical data sets?

   e) What does the data indicate?

      I. Why is it important for the data to indicate this?

      II. How is the data processed to indicate this?

   f) Is this augmented with feedback directly from customers and/or users?

   g) What tools, techniques or methods are used?

   h) How does the data inform PSS Conceptual Design?

   i) Specifically, have maintenance, maintainability or **[if you have availability contracts]** availability contracts been influenced by such data?

   j) Who (or which department) is responsible for analysing the data?

   k) Could I see a sample data set or documents that that relate to this?

   If not:

   l) Where do you think data should be collected from to influence PSS Conceptual Design?

m) What type of data should be collected?

n) How should the data be collected?

o) What should the data indicate?

   I. Why should the data indicate this?

   II. How could the data be processed to indicate this?

p) What tools, techniques or methods could be used?

q) How could the data inform PSS Conceptual Design?

[If there is a pause, no answer or “don’t know” then ask:]
For example, could the data be mapped to different PSS Designs?
[If the answer is yes, then ask:]
How could this be accomplished?

3. Potential Case Study Assessment:

1. What issues have been reported to you regarding the technology and services that you provide? For example has there been a customer(s) who has stated that when using your offering in a process to meet a business objective, a problem has surfaced. Or, has an issue been reported to you by a member of your staff?
   [If the answer is yes, then ask:]
   Could the data from that case be made available (the data can be anonymised)? Could I use this for a case study to apply the aforementioned method to?

2. Have you had any issues with any technology or services that are provided to you? How do you think this could be improved?
   [If the answer is yes, then ask:]
   Could the data from that case be made available (the data can be anonymised)? Could I use this for a case study to apply the aforementioned method to?

Summarize and list of actions

Other methods: *(e.g. survey, observation, recording, notes)*

Notes will be taken during the interview. The interview will also be recorded.

Analysis techniques & Plan: *e.g. type up notes / create cause and effect diagrams / create matrix / transcribe & code, etc.*

One or more case studies for validation of the SIU Method will be selected from the findings from the interviews within this sample. You may then be asked to apply the System-In-Use Method (which has been outlined to you) to this case study to assess its relative merits and demerits. The results of the application will be written up by the researcher and will be presented as a report to you and you will be asked for feedback. This feedback will then be used to amend the report which will then again be forwarded to you. You will then be interviewed with regards to how you view the merits and demerits of the SIU Method.

9.15 Appendix O

Interview Questions for the Technology Supplier (See Chapter 7)

Case Study Assessment for the Application of the SIU Method to Validate the Method

Semi-Structured Questions for:

- **A Company supplying technology to a provider of industrial, capital-intensive, technical and infomated PSS with**
- **A senior manager with at least five years' experience in their role**

Research aim:

The aim of this research is the development of a method which uses system-in-use data from an existing PSS or product to generate initial PSS conceptual designs to address issues customers have when using that PSS or product to meet their objectives.

Research stage & current insight: *(Focus for exploration)*

A system-in-use method has been developed; this stage requires the application of this method to a case study assess its merits and demerits.

Case description: *(company type, respondent)*

Company Name: ________________________________
Respondent Name: ____
Contact Details: _____________________________________
Job Title: _______________________________________
Job Role Details: ____
Years of Experience in that Job and in that Role: _________________________________

Case justification: *why this company? How does this company match the research aim? Why this validator?*
This company supplies technology to a provider of industrial, capital-intensive, technical and infomated PSS. The respondent at the company also has an extensive knowledge of servitization and PSS. The company is interested in methods to develop and support PSS as well as any possible, general improvements in its processes and those of its customers.

1. Organization

1. How big is the company?

2. What types of PSS do you offer or support?
3. Are you the recipient of any types of PSS?

2. How Product-In-Use Data is used to Influence PSS Conceptual Design

Field Data and PSS Conceptual Design:

3. How do you think a PSS should meet a customer's needs?

   [If there is a pause or no answer, then ask:]
   How do you think a PSS should differ to a product in terms of satisfying customer's needs?

4. Do you utilise product-in-use or PSS-in-use data to inform PSS Conceptual Design?

   If so:
   a) Where do you collect data from to influence PSS Conceptual Design?
   b) What type of data is collected?
   c) How is the data collected?
   d) Could you describe typical data sets?
   e) What does the data indicate?
      I. Why is it important for the data to indicate this?
      II. How is the data processed to indicate this?
   f) Is this augmented with feedback directly from customers and/or users?
   g) What tools, techniques or methods are used?
   h) How does the data inform PSS Conceptual Design?
   i) Specifically, have maintenance, maintainability or **[if you have availability contracts]** availability contracts been influenced by such data?
   j) Who (or which department) is responsible for analysing the data?
   k) Could I see a sample data set or documents that that relate to this?

   If not:

l) Where do you think data should be collected from to influence PSS Conceptual Design?

m) What type of data should be collected?

n) How should the data be collected?

o) What should the data indicate?

   I. Why should the data indicate this?

   II. How could the data be processed to indicate this?

p) What tools, techniques or methods could be used?

q) How could the data inform PSS Conceptual Design?

[If there is a pause, no answer or "don't know" then ask:]
For example, could the data be mapped to different PSS Designs?
[If the answer is yes, then ask:]
How could this be accomplished?

3. Potential Case Study Assessment:

1. What issues have been reported to you regarding the technology and services that you provide? For example has there been a customer(s) who has stated that when using your offering in a process to meet a business objective, a problem has surfaced. Or, has an issue been reported to you by a member of your staff?
   [If the answer is yes, then ask:]
   Could the data from that case be made available (the data can be anonymised)? Could I use this for a case study to apply the aforementioned method to?

2. Have you had any issues with any technology or services that are provided to you? How do you think this could be improved?
   [If the answer is yes, then ask:]
   Could the data from that case be made available (the data can be anonymised)? Could I use this for a case study to apply the aforementioned method to?

Summarize and list of actions

Other methods: *(e.g. survey, observation, recording, notes)*

Notes will be taken during the interview. The interview will also be recorded.

Analysis techniques & Plan: *e.g. type up notes / create cause and effect diagrams / create matrix / transcribe & code, etc.*

One or more case studies for validation of the SIU Method will be selected from the findings from the interviews within this sample. You may then be asked to apply the System-In-Use Method (which has been outlined to you) to this case study to assess its relative merits and demerits. The results of the application will be written up by the researcher and will be presented as a report to you and you will be asked for feedback. This feedback will then be used to amend the report which will then again be forwarded to you. You will then be interviewed with regards to how you view the merits and demerits of the SIU Method.

9.16 Appendix P

Truck Driving Instruction Case Study– SIU Method Validation (See Chapter 7)

Method (qualitative, push, product-oriented version) validation questionnaire

Research aim:

The aim of this research is the development of a method to generate possible solutions (initial PSS prototypes) based on gaps within a customer's value creating system. This method should be able to be used qualitatively, quantitatively and form a basis for product as well as service specification.

Research stage & current insight: *(Focus for exploration)*

The method has been developed (based on findings from the literature, interviews with senior managers in industry and case studies). The current focus for exploration is the validation of a version of this method, which was developed by the researcher. This version is a "push" from the provider.

Case description: *(company type, validator)*

- Company: a technology provider to a company which delivers PSS
- Validator: Channel Account Manager for the Technology Supplier Company (employed at this company for 5 years). The previous 15 years of his employment also involved the gathering of customer requirements as well as solution development and provision.

Case justification: *why this company? How does this company match the research aim? Why this validator?*

This company enables capital-intensive, technical and high value asset PSS to be delivered by their client. The validator at the company also has a very extensive knowledge of servitization and PSS. The company is interested in methods which develop PSS.

Questions to be covered in the interview:		**Responses**
1.1.	Is the structure of the method comprehensive?	Yes – 9/10 for comprehensiveness
1.2.	Would you suggest any changes to any part of the method?	No – seems to be complete.
1.3.	What are the advantages and disadvantages of the method?	The advantages are that it adds more structure – it can help ensure all aspects have been covered.
1.4.	What skills (which personnel) and resources are required to use the method?	No extra skills would seem to be required. Certainly, the departments dealing with product design, service design and customer requirements capture use other methods similar to this.
1.5.	What is the scope of the method?	Seems that it could be used for any technological suggestion to the customer.
1.6.	Does the method produce the expected outcome?	Yes – it generates a set of solutions which can then be evaluated. Solutions which seem reasonable can then be presented to the customer and we can show why we think the solutions should help them. The customers can then evaluate the solutions and we could refine them.
1.7.	Can the method improve processes?	Yes – it could improve customer processes.
1.8.	What did the method add?	If the company was thinking about making a suggestion to the customer, this could be a good way to do it.
1.9.	Any suggestions for further improvement?	No- seems to be complete.

Other methods: *(e.g. survey, observation, recording, notes)*

Notes will be taken during the interview. The interview will also be recorded.

Analysis techniques & Plan: *e.g. type up notes / create cause and effect diagrams / create matrix / transcribe & code, etc.*

A report will be created, describing the findings from the interview and necessary amendments will be made to the method.

9.17 Appendix Q

A Fault Reporting Case Study– SIU Method Validation (See Chapter 7)

Method (qualitative, product-oriented version) validation questionnaire (11 Jan 2013)

Research aim:

The aim of this research is the development of a method to generate possible solutions (Conceptual PSS prototype Designs) based on gaps within a customer's value creating system. This method should be able to be used qualitatively, quantitatively and form a basis for product as well as service specification.

Research stage & current insight: *(Focus for exploration)*

The method has been developed (based on findings from the literature, interviews with senior managers in industry and case studies). The current focus for exploration is the validation of a version of this method, which was developed by the researcher. This version is qualitative and shows how the method can be applied to a business process and then to a product to refine solutions. It also demonstrates the merits of this method as compared to others currently used in industry.

Case description: *(company type, validator)*

- Company: a technology provider to a company which delivers PSS
- Validator: Channel Account Manager for the Technology Supplier Company (employed at this company for 5 years). The previous 15 years of his employment also involved the gathering of customer requirements as well as solution development and provision.

Case justification: *why this company? How does this company match the research aim? Why this validator?*

This company enables capital-intensive, technical and high value asset PSS to be delivered by their client. The validator at the company also has a very extensive knowledge of servitization and PSS. The company is interested in methods which develop PSS.

The aim of this application of the method is to demonstrate how it can:

1. Refine solutions (in this case, a product) as well as improve business processes
2. Define the problem space and solution space, compared to other methods currently used in industry,

Questions to be covered in the interview:		**Responses**
1.10.	Is the structure of the method comprehensive?	Yes – 9/10 for comprehensiveness

1.11.	Would you suggest any changes to any part of the method?	Yes – a limitation could be that the method assumes that a reported issue is worthy of conceptual redesign. However, it should be qualified who reported the issue (and assessed whether other customers from the same company see the issue in the same way) and assessed why this issue is more important to the customer than other issues.
1.12.	What are the advantages and disadvantages of the method?	A disadvantage could be that the method is unwieldy and laborious – this is particularly an issue for small, mobile, technology companies whose technologists tend to be quite close to the customer (that is, there tends to be a fairly direct link to the customer). With regards to advantages, the method is very structured and methodological and so can help ensure that nothing has been missed when examining a problem or generating solutions. It could also be useful when there is a need to share knowledge between stakeholders if some projects require a partnership.
1.13.	What skills (which personnel) and resources are required to use the method?	No extra skills would seem to be required. Certainly, the departments dealing with product design, service design and customer requirements capture use other methods similar to this.
1.14.	What is the scope of the method?	It appears that it can be used to refine products as well as business processes.
1.15.	Does the method produce the expected outcome?	Yes – it defines issues and generates a set of solutions which can then be evaluated. Solutions which seem reasonable can then be presented to the customer and we can show why we think the solutions should help them. The customers can then evaluate the solutions and we could refine them.
1.16.	Can the method improve processes?	Yes
1.17.	What did the method add?	Structure and thoroughness
1.18.	Any suggestions for further improvement?	An electronic guide which would allow scoring (validation checks) so that the person applying the method can be sure how well they've applied the method and parts of it they may have had to miss (because of lack of information, or example) will be

		noted – this should lead to an overall scoring which will indicate the trustworthiness of the outcome of that particular application of the method.

Other methods: *(e.g. survey, observation, recording, notes)*

Notes will be taken during the interview. The interview will also be recorded.

Analysis techniques & Plan: *e.g. type up notes / create cause and effect diagrams / create matrix / transcribe & code, etc.*

A report will be created, describing the findings from the interview and necessary amendments will be made to the method.