CRANFIELD UNIVERSITY
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KONSTANTINOS GKEKAS

A UNIFIED MODELLING SYSTEM FOR SERVICE REPRESENTATION

SCHOOL OF APPLIED SCIENCES

PhD
Academic Year: 2008 - 2012

Supervisors
Dr. Jeffrey Alcock and Prof. Ashutosh Tiwari

September 2012

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This thesis is submitted in fulfilment of the requirements for the degree of PhD

Abstract

This PHD project aims to develop a service design system which has a customer-centric view and delivers a balance between profit and value for both customers and service providers. The system will enable designers to assess the design and provide decision support and rationale at an early service design development stage. Also during the lifecycle of the service it would provide a better cost estimation for the service provider to support its future decisions.

The two first chapters give an overview of the service field and the research area. Chapter 1, the introduction, states the aim and objectives of this research along with setting the field of the rationale behind the motivation and scope. Chapter 2, the literature review, gives a thorough overview of the service design area mentioning the theories, techniques, methodologies and methods that have been used directly or indirectly for service modeling/design. Chapter 3, the research methodology, states the rationale behind the decisions to conduct this research in terms of purpose, design, strategy and data collection techniques. Moreover an analysis of the current methodology structure which was based on the adaptation of the aforementioned decisions is provided.

In Chapter 4 there is a comparison among three different methods (Service Explorer (SE), Integrated Service CAD and Life cycle simulator (ISCL) and Service Blueprinting (SB)) as identified from the literature, which have been developed specifically for service design. The comparison looks at the dynamic features of each method. A dynamic feature is a property of a service method that has the ability to capture specific elements of the service design process which are subject to continuously change within a specific timeframe.

At first, there is a brief discussion on how each method is applied and what the output as a generic process is. It starts with identifying generic key concepts of the service design approach by applying all methods to a rental service scenario. Following that, we create a virtual service of a rental machine scenario and map the previously identified key concepts into specific elements of the rental service. We test all methods against these service concepts to identify how well and in what scope each one performs. A merging process of the service concepts is then carried out to form 4 categories which form the specific dynamic features. We test all methods against these features. In particular we find that, SB lacks dynamic capability. SE does well on prioritising individual customer requirements but provides neither a modular design process nor the ability to deal with changes during the service lifecycle. ISCL can provide a process for generating models by combining previously established building blocks and a life-cycle service simulation. However the resources are fixed and there is no prioritisation on the requirements. A pragmatic service deployment requires a service environment that is subject to change, which in turn is not provided by the current methods we compared.

The purpose of Chapter 5 is to demonstrate an open source agent-based simulation language that could be used for service design and to simulate the Emergent Synthesis (ES) methodology. This methodology was identified from the literature search as a potential solution to the research gap presented in Chapter 4. That would act as a validation of using the proposed method in the service design area. For this reason a service market is being used as a modelling example. First the area of agent-based modelling is introduced. Certain modifications take place according to the modelling language needs. Next step is the justification and discussion about these changes. The Systems Modelling Language (SySML) is being introduced as a diagrammatic notation method according to which the altered service market model is being represented.

The purpose of Chapter 6 is to provide a new approach for accurate design of a service by combining and developing a unified modelling system which covers all important key aspects of a service scenario. To demonstrate the applicability and the output of the system, a case study has been selected. The rest of this chapter is structured as follows. Then there is the introduction and investigation of the service case study. Also the purpose of that choice is stated. Next step is the full breakdown of the system, the current data flow and how the combination of the individual methods has been implemented. Results of each method are produced while visualising the connections between each input-output. A comparison takes place to show the difference of using each method individually and how the emergence of the system as a result of the combination process affects the output. Last step is the validation and the analysis of the results.

The penultimate chapter is the discussion, where the outcome based on the results of each chapter is discussed. In Chapter 4, we discuss the outcome of the comparative analysis process. In Chapter 5 we give the analysis and discussion of the service market modelling output and in Chapter 6 we place a discussion based on the system's output.

Last chapter is the conclusion where there is a brief restatement of the whole research work leading to major contribution points.

The major contribution of the developed system is the integration of three major methods and methodologies (SE, ISCL, ES) in order to provide answers to the inherent limitations of current techniques (representation of social behaviours in an environment that is subject to change) in the service design domain.

Keywords:

Service Design, Service Engineering, Customer Value,

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List of Acronyms

ABMS: Agent-based modelling and simulation

ABSS: Agent based social simulation

AHP: Analytical hierarchy process

A-S-E: Analysis, synthesis, and evaluation

ASM: Applied signposting model

ATS: Automated transport and sorting system

BPEL: Business Process Execution Language

BPMN: Business process modelling notation method

CAD: Computer-aided design

ChP: Channel parameter

CoP: Content parameter

CPE: Customer premise equipment

CPN: Coloured petri nets

CRM: Customer relationship management

DEMATEL: Decision making trial and evaluation laboratory

DES: Discrete event simulation

DFD: Data flow diagram

DM: Design matrix

EC: Engineering characteristic

EOL: End-of-life

ES: Emergent synthesis

FI: Function influence

FN: Function name

FP: Functional parameter

FXQFD: Fuzzy extended quality function deployment

HF: Harmful function

HoQ: House of quality

IDEF0: Integration definition for functional modelling

IFR: Ideal final result

IPPM: Integrated production process model

ISCL: Integrated service CAD and life cycle simulator

LKT: Institute of engineering design/CAD

MABS: Multi-agent based simulation

MAS: Multi-agent systems

MES: Manufacturing execution system

MSI: Marie stopes international

MVC: Model for balancing values and costs

PCN: Process Chain Network

PEC: product engineering characteristic

PDD: Property-driven design/development

PERT: Program evaluation and review technique

PF: Problem formulator

PUF: Primary useful function

PSS: Product service system

QFD: Quality function deployment

RSP: Receiver state parameter

S-AV: Satisfaction-attribute value

SB: Service blueprinting

SCM: Supply chain management

SEng: Service engineering

SE: Service explorer

SEC: Service engineering characteristic

SOA: Service-oriented architecture

SSME: Service science, management, and engineering

SySML: Systems modelling language

TNG: The next generation

TRIZ: Teoriya Resheniya Izobretatelskikh Zadatch

UF: Useful function

UML: Unified modelling language

VDI 2221: Guideline about the method of developing and engineering technical systems and products which is edited by the society of German engineers (VDI)

VEA: Virtual enterprise architecture

CHAPTER 1

Introduction

1.1 Research Background

In modern society the role of service has gone through radical changes. Productivity has become even more important than before.

A product service system (PSS) is a strategic shift in the business towards client-end solutions. Traditional models were used for designing and selling physical products. Nowadays, models are not being used to the products themselves, but are focusing on selling services or system of products.

Science and technology have joint forces in order to bridge the gap between science and services. Moreover the expectation of this combination is to create a systematic methodology of service studies. However, the lack of a consensus on studying and modelling services as science pose a difficulty on how to approach such systems. The difference between the nature of services and that of manufacturing adds up to it.

1.1.1 Service System

Kotler (1994) defines a service to be "any activity or benefit that one party can offer to another which is essentially intangible and does not result in the ownership of anything. Its production may or may not be tied to a physical product". The differences between manufactured products and services can be summarised into five categories: customer contact, quality, storability, tangibility and transportability (Armistead et al., 1995). A service is produced and consumed at the same time. Evaluating service quality is difficult to assess due to the need of qualitative measures. Services cannot be stored and most of them cannot be transported to somewhere else. Lastly most services do not have physical elements and thus are inherently intangible.

There are some important factors which played a significant role in establishing this new service-oriented model (1980s) over the traditional manufacturing one.

- The competitive factors of the new service-oriented model concentrate around continuous innovation, improved design, quality and customisation of goods rather than mass production of standardise products (Mont, 2001).
- Another important factor, which had serious impact on leading the direction of human development to services, was environmental awareness.
- Last but not least it is necessary to stress the social, environmental and economic implications of such models during the designing and marketing phase.

Service design (1990s) could be considered as an emerging field which has primary focus on creating customer experiences using both tangible and intangible elements. The end user of the service can mostly benefit in several application areas such as retail, banking, transportation, and healthcare.

The competitive factors of the new service-oriented model concentrate around continuous innovation, improved design, quality and customisation of goods rather than mass production of standardise products (Mont, 2001).

Another important factor, which had serious impact on leading the direction of human decisions to service development, was environmental awareness. In general, services are perceived as less polluting than products. Cleaner manufacturing processes, green design and services promote sustainability. The key factor in this scheme is the provision of a specific result or function without having the customer to acquire the products-in-use by the service. One should note though, that even services alone are not environmentally innocent and the more tangible a service is, the easier it is to measure its impact (Mont, 2001). Although many authors acknowledge that it is striking to see how often people are getting mislead (Tukker and Tischner, 2006). The real strength of servitisation is focusing on "the final need, demand, of function that needs to be fulfilled" (Tukker and Tischner, 2006). Understanding this fact will lead to a higher degree of freedom and increase our chance in finding better sustainable options.

Last but not least it is necessary to stress the social, environmental and economic implications of such models during the designing and marketing phase. Sometimes sharing of goods is not acceptable to users. At present leasing products seems more expensive than buying which can have an adverse effect on people selecting this option, despite the long-term benefits of maintenance and upgradability. Therefore in order to establish a holistic approach bridging sustainability, economic viability and acceptance to customers will require highest level of creativity, including the combination of traditional and advanced technologies, and collaboration of many diverse organisations.

1.2 Research Motivation

Thinking in services and service design during the product development phase has taken on enormous significance. At some point a shift occurred from the traditional manufacturing style of product development to servitisation and product-service systems. Servitisation refers to the paradigm shift while PSS is the combination of products and services. This demonstrates how crucial a service system became and how much important is this crossover between services and products rapidly affecting product development.

A number of authors have worked on service design, servitisation and product-service systems. However most of them focused more on the service provider view instead of placing the customer directly at the core of the service development. Currently very few have looked into this from a research viewpoint (Japanese research groups mostly) and companies face problems employing those principles or research outputs into their product development processes. Therefore an IMRC project was initiated which aims to provide a complete framework of service methodologies (methods, tools, techniques) to be applicable by companies in different areas.

There is a need for a good solution for designers that may help them to employ customer satisfaction and customer needs in the service sector into the product development cycle and cost estimation during the service lifecycle.

Another reason for conducting this research is the difference between manufacturers and customers. Different set of entities have different goals. The intention of this research is to bridge the gap between these two conflicting group of thoughts and bring them to the same platform focusing primarily on the balance, a niche between customers' value and service provider's profit.

1.3 Research Scope

This research is an integral part of the PSS micro project which goal is to design a product-service system for complex micro-integrated devices which is an IMRC funded project. The Unified Modelling System, which is going to be the outcome of this research, will have the capability of addressing the lack of current service design approaches while providing a service optimisation method with a customer-centric view.

The outcome of this research will be used by industries and corporations to improve their product development processes. The overall goal of PSS micro project is to develop a set of methodologies to facilitate the design of product-service systems in which 3-D micro-integrated devices form the physical core of the system. These methodologies would be designed for use by a micro-integrated device design team from the start of the design process.

Since the advent of service design methods, applying such on product devices form an integral part of many companies' strategies and cost estimation, where the latter is based on the lifecycle of the service itself. It is much important for them to be able to use such methods directly by making their own necessary adjustments according to their needs and preferences. In respect to that, the developed system also provides such capability. Apart from the conceptualisation approach, the system can also be used during the development phase of the service (implementation), and provide important insights by estimating future service costs which will rise from maintenance purposes or changes in the product development process. Based on these estimations, future service provisions could also be affected by the manufacturer's rationale of setting a balance between customer satisfaction and its own profitable business idea.

In addition, the system also helps to eliminate mistakes during the design stage, and to incorporate the 'customer voice' during a critical decision making stage of service provision. All those companies desiring to take advantage of the service design paradigm can use this system to improve their own service design approaches. In particular, the developed system has enormous scope for companies that face challenges in their design stage of the service sector.

1.4 Aim and Objectives

The aim of this research is to develop a service design system which has a customer-centric view and delivers a balance between profit and value for both customers and service providers. This leads to a better representation of real-world services. The system will enable designers to assess the design and provide decision support and rationale at an early service design development stage. Also during the lifecycle of the service it would provide a better cost estimation for the service provider to support its future decisions.

The main objectives of the research are to:

1. Identify and analyse the service design field and service design methods best practices through an extensive literature review.
2. Identify the research gap through comparative analysis of current service design approaches.
3. Determine the methodology that would fill the identified research gap which will be then incorporated into the proposed service design system.
4. Adapt, test and validate the methodology on a service scenario using an agent-based modelling language.
5. Develop a service design system which would include the methodology and make enhancements over the current service design approaches.
6. Validate the system through a case study.

1.5 Thesis Structure

This study presents a detailed discussion related to research introduction, literature review, research methodology, current service design practices, validation, discussion / conclusion and contribution to knowledge. Accordingly the thesis is divided into seven chapters. An illustration of the thesis structure is being given in figure 1-1. A briefly discussion on the contents of each chapter is given below.

Chapter 1 outlines the fundamental research issue. Research background, motivation, scope, aim and objectives, and outcomes of this study are clearly mentioned in this chapter.

Chapter 2 presents a critical review of the fields of service design and service science. The literature review helps to identify possible service design methods, techniques, theories, etc. which have been used to design a service. There are many different ways to tackle the service design problem and thus the literature review provides a breakdown of all the possible ways of achieving that by referring to multiple methods, such as methods that are unique and prototype, methods that derived from other fields as metaphors, and more generic ways, which can also be used to other fields. Each of these methods are comprehensively stated and analysed in order to provide the reader with the essential knowledge of the service design field and get a grip with the current state-of-the-art.

In Chapter 3, an overview of the research methodology is explained. In addition, the research purpose, research design, research strategy and data collection techniques are discussed in detail. Moreover, the adopted research methodology and justification of the reasoning is provided.

Chapter 4 presents a comparative analysis by contrasting the state-of-the-art methods which are unique in the service design sector. This uniqueness is based on how these methods were developed in the first place. They were developed from the ground-up having focused on the service design domain exclusively. Because of this reasoning they offer more capabilities and features than other methods adapted or used as metaphors or even methods with broader scope. Based on this analysis a research gap was identified. The chapter concludes by making a case on how this gap would be bridged by providing insights on a methodology that makes it the best candidate for solving this situation.

Chapter 5 establishes the candidate methodology as a proper solution to the problem statement. First the methodology is adapted in order to work for this specific domain and then a case study is chosen. Based on the results and the analysis it is shown that this methodology can work effectively in the service design domain and specifically in the social dynamics subdomain. To achieve this goal a generic agent-based modelling language and its produced-models are also tested and validated.

In Chapter 6 the developed service design system is explained. The architecture of the developed system, system components, system modules, system scenario and the case study for validation purposes is described in detail. The developed system is tested against a service scenario and comparison is conducted with previous established techniques from the literature.

Chapter 7 presents the results and findings after validating the service system deployment. This chapter shows how the research findings answer the aims and objectives of the research. In addition, the novelty of the developed system, the impact of the system in the service design field and the contribution to knowledge are explained. Finally the limitations of the research and suggestions for future work are pointed out.

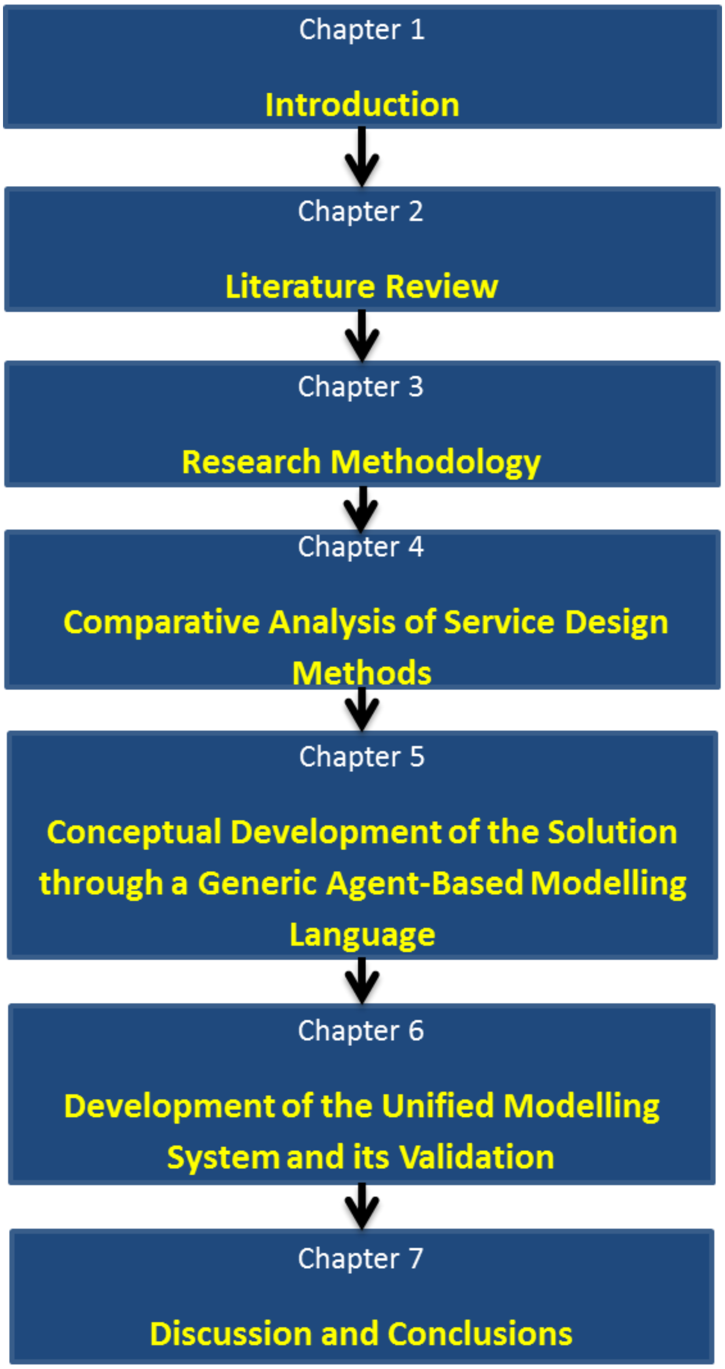


Figure 1-1: Structure of the thesis

1.6 Summary

This chapter aimed to outline the fundamental research issues. To accomplish this aim, the research background has been first introduced. A quick review of the service design area has been provided. Finally the research motivation and research scope are also discussed. Accordingly, the research aim, objectives, and an overview of the thesis structure have also been given.

CHAPTER 2

Literature Review

2.1 Introduction

Kotler (1999) defines a service to be "any activity or benefit that one party can offer to another which is essentially intangible and does not result in the ownership of anything**.** Its production may or may not be tied to a physical product".

The differences between manufactured products and services can be summarised into five categories: customer contact, quality, storability, tangibility and transportability (Armistead et al., 1995). A service is produced and consumed at the same time. Evaluating service quality is difficult to assess due to the need of qualitative measures. Services cannot be stored and most of them cannot be transported to somewhere else. Lastly most services do not have physical elements and thus are inherently intangible.

Service design could be considered as an emerging field which has primary focus on creating customer experiences using both tangible and intangible elements. The end user of the service can mostly benefit in several application areas such as retail, banking, transportation, and healthcare. There are some important factors which played a significant role in establishing this new service-oriented model over the traditional manufacturing one.

(For more information on the methods see appendix whenever there is an asterisk on the corresponding authors)

2.2 Methodology for Constructing the Literature Review

A survey of more than hundred papers (keywords, authors, paper titles, databases, search engines) was conducted in order to identify the relevant resources based on the research. After identifying the related papers searching for service design and service engineering (SEng) as keywords, next step was to find a way for a structural and solid representation according to literature study. Service engineering is a technical-methodological approach towards utilising existing engineering knowledge for efficient service development (Bullinger et al., 2003). Therefore the literature review was structured by gathering individual identified papers into two groups based on the service design scope: customer-focused and solution-oriented design. The difference lies within the original development of each approach. Approaches that have primary goal of analysing customer interactions formed the first group. The second group includes all of the approaches which try to provide solutions to initial and predefined problems. All the identified approaches have been developed or adapted specifically for service design and service design processes.

A number of papers belonged to a higher level of abstraction, a multidisciplinary field called Service Science, Management, and Engineering (SSME), a term introduced by IBM (Hefley and Murphy, 2008). It all started when Service Science term was first coined by Professor Henry Chesbrough of US Berkeley (Hefley and Murphy, 2008). It was later expanded through the inclusion of management and engineering disciplines. Over time though, the term "Services Sciences" prevailed (Hefley and Murphy, 2008). All papers that referred to this term were excluded because their main focus is a combination of service systems to form a system of systems approach.

In addition there is another term that involves services. It is called Service-Oriented Architectures (SOA). It is a collection of services which communicate with each other. It is a business-centric IT approach which involves web services and specific software development designed for enhancing their usability. The identified papers that belonged to this category were also excluded due to the fact that web services and IT infrastructure were the main focus areas.

Each of the individual techniques (both scopes included) will be listed below followed by a construction of common themes between these two groups in terms of interrelated processes, technique, methods, etc. Lastly a table (table 2-1) will be shown with all the relevant papers along with a figure (figure 2-1) depicting the structure of the common themes using a pyramid scheme.

The identified methods are the following:

- Teoriya Resheniya Izobretatelskikh Zadatch (TRIZ)
- Property-Driven Design/Development (PDD)
- User-Oriented / Modularisation-Based Design Process
- Quality Function Deployment (QFD) / Derivatives
- Service Blueprinting (SB) / Process Chain Network (PCN)
- Integration Definition Functional Modelling (IDEF0) / Data Flow Diagram (DFD)
- Use Cases / Unified Modelling Language (UML)
- Social Group Analysis / Interaction Maps
- Discrete Event Simulation (DES) / Simulation Methods
- Petri Nets

For identifying which of the previous approaches belong to different individual sections and finding the common themes between the two service design scope groups, two reviews based on design philosophies were used: Evbuomwan et al. (1996) and, Braha and Maimon (1997).

According to Braha and Maimon (1997) design is a fundamental human activity. It is central because it is related to purpose. Design is "what links creativity and innovation. It shapes ideas to become practical and attractive propositions for users or customers. Design may be described as creativity deployed to a specific end" (Sir Cox, G.). Based on Braha and Maimon paper on design philosophy (1997) the following categories were constructed:

H. A. Simon (1996) says that a designer is one who devises a course of action to obtain what it wants. But what is there in designing? Perhaps the most fundamental is what is said to be, a *design philosophy*. To illustrate this, an artist's design philosophy exemplifies the black-box view on design, which usually correspond to a view that designing should be chaotic. Since we are in the school of applied sciences, I can assume we agree that successful designing can be understood and organised, hence not being black-box.

Next in the hierarchy is the *design paradigm*. There are several design paradigms around; one of them, where the PDD approach relies to, is the paradigm that says that designing has three phases: analysis, synthesis, and evaluation (A-S-E) (Braha and Maimon, 1997). This is a very popular paradigm. Other paradigms include case-based, cognitive, algorithmic, and artificial intelligence.

Next level is the *design theory*. A theory emerges when there is a testable explanation for why the method behaves as it does. Based on the A-S-E paradigm, TRIZ presents a uniquely scientific theory of designing, which is based on the establishment of axioms. Taken in its own terms, axioms allows one to construct a so-called axiomatic logical structure, creating corollaries and theorems that allows one to understand and to predict what happens within the structure. There is a documented degree of resistance to such treatment to the subject of designing, but perhaps this is caused by a difference in design paradigm, or even design philosophy, and therefore this level (design theory) might not be the appropriate level to discuss this.

A design theory carries within it a model of the *design process*. Indeed, it can be a chicken/egg argument between which is the more fundamental, the process model or the theory. Here we subscribe to the view that the process model is derived from the theory, because the process model makes explicit how things should be done. Evbuomwan et al. (1996), states that the process model level is where all the abstract, fundamental things begin to take shape.

Once the process model is agreed on, the design theorist can then move to fix a particular design methodology that prescribes what to do. We take *design methodology* as a set of *methods*, *tools* that help designers in implementing the methods, and *guidelines* in implementing the tools (Braha and Maimon, 1997).

Since tools and guidelines can be said to be incorporated within a method, *design methods* are used to represent the lowest level of the pyramid. We can say that a particular method is anything that moves the design process forward. Methods can be identified as belonging more to A, S, or E phase, but classification can be difficult. Sketching, for example, can be said to contribute to all three phases. Zigzagging is both A and S. Constructing a design matrix (DM) (through zigzagging) is A and S, but DM is most importantly used in E. Zigzagging is a decomposition process while a DM represents the relationship between function requirements and design parameters. Figure 2-1 shows the holistic approach according to Braha and Maimon (1997).

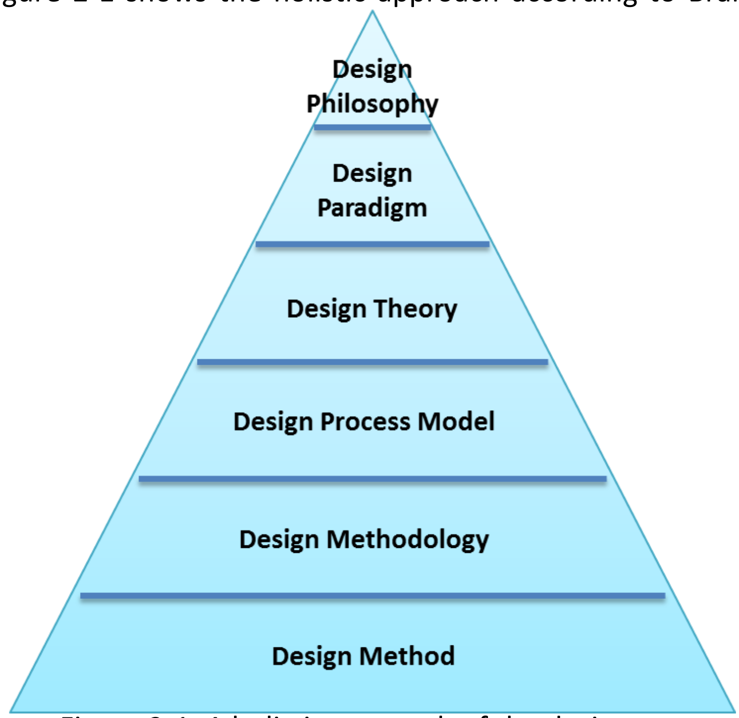


Figure 2-1: A holistic approach of the design area

Year	*Level 3*	*Level 4*		*Level 5*	*Level 6*					
	Service Design Theory	Service Design Process Model		Service Design Methodology	Service Design Method					
	TRIZ	PDD	User-oriented / Modularisation-based design process	QFD / Derivatives	Service Blueprinting / PCN	IDEF0 / DFD	Use Cases (UML)	Social Group Analysis	DES / Simulation Methods	Petri Nets
1981 - 1990					(Shostack, 1982) (Shostack, 1984)			(Bijker et al., 1987)		
1991 - 2000	(Low et al., 2000)							(Bijker et al., 1995)		
2001 - 2010	(Zhang et al., 2003) (Chai, 2005) (Zhang et al., 2005) (Lin and Su,	(Weber et al., 2004)	(Aurich and Fuchs, 2004) (Aurich et al., 2006) (Yu et al., 2008)	(Shimomura et al., 2005) (Shen and Wang, 2008) (Shimomura	(Morelli, 2002) (Morelli, 2003) (Boughnim and Yannou, 2005) (Bitner et al., 2008) (Hara et	(Morelli, 2006), (Durugbo et al., 2010)	(Morelli, 2002) (Morelli, 2003)	(Morelli, 2002) (Morelli, 2003) (Morelli, 2006)	(Tomiyama, 2001) (Arai and Shimomura, 2004) (Komoto et	(Tian et al., 2004) (Tian et al., 2007)

	2007) (Yang and Hsiao, 2009)			et al., 2008)	al., 2008) (Shimomura et al., 2009) (Hara et al. 2009)			(Makino et al., 2009)	al., 2005) (Arai and Shimomura, 2005) (Sakao and Shimomura, 2005) (Hara et al., 2006) (Sakao et al., 2006) (Yohei et al., 2006) (Arai et al., 2007) (Shimomura et al., 2007) (Sakao et al., 2008) (Komoto and Tomiyama, 2008) (Moller et al., 2008) (Makino et al., 2009)	
2011 - 2012				(Geum et al., 2012)	(Geum and Park, 2011), (Sampson, 2012)				(Hara and Arai, 2011)	

Table 2-1: Literature survey of the service design field mapped following the methodology in Chapter 2, Section 2.2

2.3 Service Design Theory

2.3.1 TRIZ

TRIZ is a Russian word and its English acronym following translation is "Theory of the solution of inventive problems". Credits for this methodology go to Genrich Altshuller. He started working on this theory in 1946 and tried to formalise techniques on creative thinking which led to new inventions (Altshuller, 1999). The outcome was the establishment of a creative framework after studying 200.000 patents followed by empirical data gathered from trends during the evolution of technical systems.

The basic idea on this framework is called "Principle of Abstraction". At first, a system which is classified within the problem area must be established, while trying to find out of a system in which its operators could map different categories of the problem to corresponding solutions. Altshuller saw that by applying this principle to problem invention had great potential. According to this principle the specified problem must be structured into a "contradiction matrix" and proposed solutions must address both technical and system level of it. Solutions at the technical level produced a sum of 40 inventive principles, 39 by 39 "contradiction matrix" along with some resolution principles dealing with the physical contradictions. Solutions at the system level may be derived by looking into eight further laws that are valid to every engineering system being developed. These laws were defined regarding Altshuller's observations on system evolution over time. TRIZ has found its way to a lot of applications in different areas such as finance and manufacturing (Low et al., 2000).

However this approach is not flawless. There are some known limitations concerning its usability. One of the arguments talks about a mandatory expansion of both the contradiction matrix and inventive principles in order to catch up with the apparent vast diversity of technological areas. Another one mentions the difficulties combining this methodology with more conventional production methods (Cavalucci and Lutz, 1998).

A TRIZ methodology, which is related to product development, could be used as an optimisation process for services. One of the eight laws that consist of the TRIZ core methodology states that the evolution of technical systems will decrease human interaction. Empirical evidence supports this statement by seeing technical systems evolving through time. One example is the launderette facility which points to an automated washing machine relieving labours from performing tedious tasks. Consumers are paying for a launderette service which consists of washing machines and tumble dryers instead of the actual machinery. It is a fine example of a transition from products to services as well as an evolution step towards a higher degree of automation (Low et al., 2000).

There are three fundamental principles which provide the contradiction arguments that will resolve to a new invention. These are being revisited in the light of product/ service transition and are the following: Time separation, Space separation and Parts separation.

An interpretation of the time separation would be the occasional use of a product. The functionality of the product is under use only for a certain period of time and when needs arise. It is an important factor when designing a service. For example a taxi or car sharing service is being used only when customers need transportation. Dematerialisation is enhanced and takes the lead as a primary goal therefore this particular aspect of the service can be considered as a social innovation rather than a technical one. In the previous example the customer does not own the car but instead buys time for using the car’s functionality.

The second principle, space separation, brings forth the contradictory design parameters of the product for a parallel use when is present and absent. A scenario of teleworking can be thought as an example of this. The person may need to be present for a meeting without being physically there. Two options can be visualised considering this separation. The former would be separation of the person while the latter would be separating meeting locations. For the former, one can easily see the practical problems emerging from the implementation. The latter though could represent a driving force for teleworking concepts and other video conferencing solutions. Telecommunications technology gives rise to greener solutions via reducing the fuel consumption of transport vehicles.

The third principle can be seen as separation between ownership and for service promotion. Take for example telecommunication services that require access to two essential components. The first one is infrastructure and second is the Customer Premise Equipment (CPE). Both of them have different ownerships and are driven by different design criteria. Despite this fact the exclusion of one renders the service inoperable. The goal is the delivery of a single entity while having separated ownerships. This separation process can affect service design to a product-oriented or service-oriented model thus reducing material consumption. An example of such a service is Kodak cameras. Kodak sells single-use cameras with the necessity to be returned over to it for processing the pre-loaded film. There is no consumer ownership in this particular model.

The last principle depicts the concept behind modular designs. This is one of the fundamental elements concerning lifecycle design (Ishii, 1998). Modular designs will improve a field of activities, e.g. outsourcing strategies, during manufacture as well as repairing, disassembling and component use of a product after reaching end-of-life (EOL) (Low et al., 2000).

For building a framework first we must identify the basic needs of a service which in turn will help in providing the appropriate functions for supporting them. A launderette service implements a customer need of delivering clean clothes. The functions that derive from this need are the washing and drying of clothes. The design of a service also requires being sustainable. Due to the fact that the establishment of complex relationships between actors is part of the design process, the formulation process must be tested not only against social but also legal acceptance.

Next is the selection of technologies which will support the previously identified functions for need fulfilment within the service design. In the launderette example there could be a list with all of the alternative technologies that perform the washing function. In addition different options can be proposed for implementing different programs like cold wash, weight sensitive wash, etc. The limitation of these options is the current available technology. Then products that utilise these technologies are purchased or customary built according to specifications. Eventually this will provide the infrastructure of the service which can be either independent or dependent with each other (Low et al., 2000).

For achieving a greener infrastructure two important elements are required: individual products must be of a low environmental impact and the inter-relationships between product systems have to be optimised.

For the first element, wherever TRIZ can be applied, it will provide energy, resource and pollution reduction by making individual products greener. One solution would be looking at the engineering parameters in the contradiction matrix. That could motivate and generate solutions that could tackle such factors mentioned above. A different approach to product design could look into multi-user environments where the service provider is responsible for its products rather than the consumer. TRIZ principles could be deployed and lead to innovative processes to achieve grouping of functions and technologies.

The second element could provide the basis for a step further down to reduction impact by structuring and controlling dynamic relationships among product systems. In the launderette example, for achieving energy reduction one solution would be to reuse the hot water generated by the system during washing and transfer it as an input to the tumble dryers. Thinking of these optimised inter-relationships between different product systems could be encouraged by applying TRIZ engineering parameters and its principles (time, space, part separation). In general though, current efforts are focusing on the redesign of products which in turn offers an incremental but no radical reduction impact (Low et al., 2000). This trend started in the 1990s (Sferro et al., 1993). Depiction of this theory can be seen in figure 2-2.

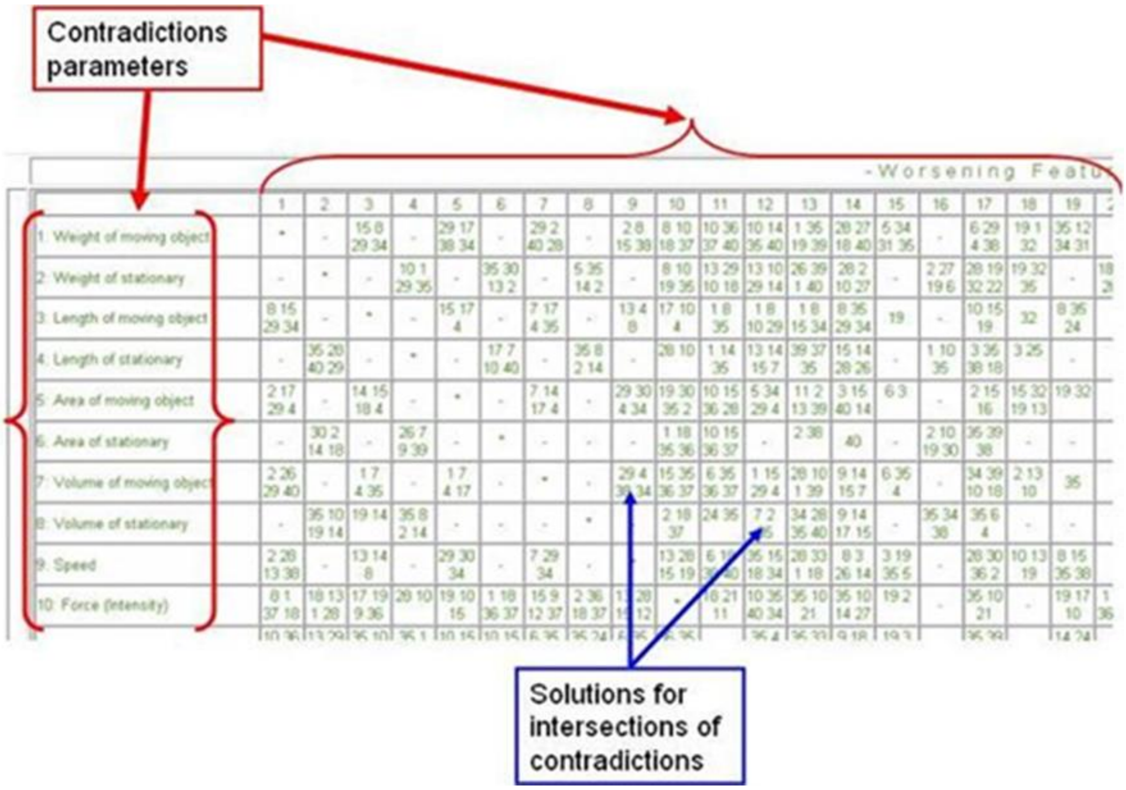


Figure 2-2: TRIZ theory contradiction matrix

Zhang et al. (2003) and Chai et al. (2005)* developed a framework for a systematic service design approach based on the TRIZ theory. Their model consists of five stages:

1. Preliminary problem analysis
2. Problem modelling and formulation
3. Contradiction analysis
4. Contradiction elimination
5. Solution evaluation

A list of identified service problems starts the procedure and acts as input to first stage. The first two stages define and form the input list with the TRIZ language in order to provide more information to help problem solving for the next stages. Then using contradiction analysis the problems are formed into typical TRIZ contradictions. In stage 4 some TRIZ problem resolution methods are employed for eliminating the previously formulated contradictions. During the final stage, the ideas that have been generated by this process are being evaluated through the TRIZ unique criteria of ideal final result (IFR). A pool is being generated formed by these evaluated solutions which are the final output of the whole process. In the unpleasant case that solutions haven't been found or in the light of new problems on the resolved solutions, the process must return to the first stage to restate the original problem.

A case study was conducted by Zhang et al. (2003)* in order to show the effectiveness of their framework. Their method improved a car entry system in a family resort island in Singapore known as Sentosa Island. The method analysed and eliminated the negative effects as a result of the increment on entry cars.

Another case study conducted by Zhang et al. (2005) and Chai et al. (2005)* also shows the application of TRIZ methods for problem resolution. By performing an appropriate modification on these methods, it is verified that TRIZ can solve service problems. This case study involves on restructuring the service operations of a university canteen by generating concept solutions to tackle the problematic situation. The operation hours of the canteen do not meet the demands of some students and staff for food serving.

Another case study conducted by Chai et al. (2005)* also shows the effectiveness of this framework based on TRIZ. The problem at hand was to redesign the sightseeing scheme at the Sentosa Island in order to attract more visitors. A new leisure program was developed for the visitors. They could bring their own bicycles or rent one from predefined designated points to better enjoy travelling to new areas of the island. Another reason to develop such program was the inability to see the entire island on foot.

Lin and Su (2007)* proposed a new procedure that follows the same principles as other methodologies based on TRIZ and is built upon the already defined three basic stages: problem definition, solution generator, solution evaluation. Following that, they extended the process to seven stages.

A case example for demonstrating the effectiveness of the previous process involved a company that is a specialist in developing online database applications (Lin and Su, 2007)*. The problem that the company had was with its service operations and with creating valuable services which could increase customers' satisfaction. The outcome was finding a new way to systematise idea generation. From a preliminary analysis and investigation it was found that several service contradictions existed. Therefore it was correct to assume that TRIZ could help resolving the apparent service problems by eliminating the embedded contradictions.

TRIZ has also been employed to resolve issues with service design in the medical, healthcare and care-giving services. The study involved the development of innovative information technology-enabled services by proposing mechanisms to tackle technical problems when developing tangible products (Yang and Hsiao, 2009)*. The project was called K hospital and it had the following targets:

- Find out the service specifications for community care concerning patients that had a stroke.
- Outline system functions to support healthcare services.
- Framework development for a care service alliance.

These services were designed to offer continuously care and consisted of monitoring the physiology of patients, diagnostic tests, home visits, delivery of medicines at home place, social benefits applications and consultation services for health issues. The proposals they did to solve those issues and meet the targets varied from the inclusion of new technologies, business models and social organisations.

2.4 Service Design Process Model

2.4.1 Product-driven Design/Development

For competitive reasons in the sustainable development area the need of a new perspective in product development process is required in order to achieve a minimisation in the development time while finding the golden mean between customers' fulfilment, economical efficiency and ecological awareness. The purpose of a continuous methodology is to guide the designer along the whole development process, starting from the initial requirements to the final description of the product. There is a close link between this methodology and suitable product modelling methods, and thus this methodology may be extended in order to meet new concepts (Weber et. al., 2004).

A current problem that exists concerning PSS is the division between requirement fulfilment of both products and services. PSS are very important in current marketplace although there is lack on how to develop them in a formalised way. Traditional design methodologies like VDI 2221 (The Association of German Engineers, 1993) cannot be used for PSS development due to their strong orientation on the physical and functional properties of the product. It should be mentioned that within business engineering there are some models which can be used for expressing services but approaches on developing them are still highly conceptual (Weber et. al., 2004).

PDD stands for Property-driven design/development. It is a new approach on product development created by the Institute of Engineering Design/CAD (LKT). It was originally designed for material products. The main point of this concept is making a clear distinction between characteristics describing the structure and components of a product and properties which describe the product's behaviour. The previous distinction is based on Andreasen's approach (Andreasen, 1995). If a material product is concerned, its characteristics are very similar to what Hubka and Eder (1996) mentions as "internal properties" (Hubka and Eder, 1996) and Suh as "design parameters" (Suh, 1990). Consequently properties can be correlated to Hubka's and Eder's "external properties" and Suh's functional requirements. Although the designer can determine the characteristics, the properties are the outcome of the chosen characteristics and thus can be changed only by utilising an indirect way. A structure is needed in order to handle all of these different characteristics and properties in various products.

By using such structure two main activities can be identified in the development/design process.

- Analysis: it can be performed by conducting experiments or by using simulation methods. The properties of a product are determined or predicted based on the known characteristics of it.
- Synthesis: it is the main activity during product development. Characteristics of a given product are determined based on its known properties. Because properties for the user/costumer of the product are relevant, a list of the required properties is established before starting of the design/development phase. The goal of the designer is to find appropriate solutions and determine the characteristics that will meet the user's/customer's satisfaction based on the required properties.

Before looking into applying this process to PSS, a first step is to detect whether such distinction between characteristics and properties is possible and to what extent will be useful for the service elements of PSSs.

The first problem lies within the context of characteristics and properties. These terms have various meanings. There is no consensus among the definitions of each term. A solution to this problem is to define characteristics, properties of services and the correlation between these two in such a way that is meaningful for the application of the PDD concept. Weber et al. (2004) believes that characteristics and the classification of those differ whether a material or a service is taken into account. He also states that properties cannot be classified into a general category because tangible and intangible components of a PSS have equal evaluation. A first step towards a solution for classification was based on the work of Corsten (2001), Knoll (1993) and Konieczny (2001). The concept that was prevailed had properties as an evaluation measure of the PSS by the user and characteristics as a mean for describing the structure and components of a PSS. A distinction between tangible and intangible components according to their characteristics and structure is easy to be made thus a connection among them is fairly easy to be established. As far as properties are concerned three main classes derived from the service engineering field (Bullinger et al., 2003) have been created.

- Search properties: properties that are already known before utilising the PSS. Customers may use them for product/PSS search. Most properties on tangible components are of this kind.
- Experience properties: this kind of properties is based on the use of the PSS thus they cannot be judged beforehand.
- Credence properties: properties that no evaluation can take place by the customer due to its lack of knowledge or means for appropriate judgement. Moreover they may need a long period of time for the actual evaluation to occur. In either case, customers must rely on the fact that the PSS incorporates them.

A service-oriented or a product-oriented approach is preferable in order to work out the properties of a PSS. All properties and qualities of a PSS must be identified. During the PSS lifecycle properties that are classified and belong to different phases may be of a lower or higher importance according to customer's needs. These considerations can be included in the product model. It helps to understand possible scenarios and evaluate them accordingly thus capturing the knowledge of a PSS as a holistic approach in its lifecycle.

The shell model (Weber et. al., 2004) is a framework which provides an integrated way for products and services including customer input. The model begins from the customer's needs of certain values or qualities. From this initial step technical requirements will be identified. They will mainly consist of properties because characteristics are not important for the customer. Another point that needs to be mentioned is the interactions within society, customer and company (Andreasen and McAloone, 2002). A holistic view of the intended PSS requires these factors to be included because of their potential influence on the required properties. The PSS has the advantage of responding to the potential change of the requirements. Requirements can change due to the difficulty in identifying them properly. It can be readjusted by modifying the intangible components, even after shipping the PSS to the customer.

The classes of properties that were mentioned before give the customer a suitable way to figure out the needed ones. The first stage is to derive the characteristics based on the required properties. This process is called initial synthesis. The second step would be the analysis where the actual list of properties will be tested and examined through the development phase. Mathematical models, simulation methods, etc. would be used for evaluating the relations between characteristics and properties. By finishing this step a draft of the PSS is created. The difference between actual properties and required ones form the starting point of the next step in synthesis phase. A modification or additional characteristics will take place in order to bridge the gap between actual and required properties. This is an iterated process. The cycle of synthesis, analysis and evaluation will continue until this difference acquires a really small value. For the service components of a PSS customer needs to be integrated because it plays an important role in service accomplishment. The customer acts as a feedback device, as a control measure during this iteration by constantly looking into current state of properties and characteristics. Lastly, because a PSS also includes service elements, these can be adjusted even during its usage phase to reflect the current needs and expectations (Weber et al., 2004).

2.4.2 User-Oriented / Modularisation-Based Design Process

In order to maximise product performance it is imperative to consider a holistic approach, meaning the entire product life cycle (Aurich and Fuchs, 2004). Technical PSS are PSS, technical services from a life cycle engineering perspective. The term product may not be restricted to physical products but otherwise can be thought in a wider sense, for example as a combination of tangible and intangible components (Jeswiet, 2003). This wider sense is what technical services mainly represent. The contribution of such systems involves improvement in function fulfilment, reduction of environmental impact and usage increase.

A distinction between products and services exists and is based on different points of view concerning lifecycle. From a manufacturer's view physical parts of the technical services consists of product design, manufacturing, remanufacturing, etc. whereas intangible components are mainly about service design and production. From a customer's view the lifecycle is a bit different. It consists only of the purchase of products, usage and disposal (Aurich and Fuchs, 2004). Customer has specific expectations from the manufacturer for service provision during lifecycle phase such as product performance, maintenance and disposal. Product design can also be influenced by servicing. Product faults are frequently identified through maintenance process or other services and continuous redesign is needed to overcome these weaknesses. Feedback from the generated information derived from product usage is therefore crucial (Warnecke and Schulke, 2000). Moreover the quality of the product lifecycle assessments is also affected by this information gathering. These assessments are depended on a common base knowledge which offers reliable information about major parts of this lifecycle (Hauschild et al., 1999). They also play an important role as decision support methods for strategic product planning (Saling et al., 2002). All of the above depict the correlation between service offering and product design giving rise to innovation.

Three service functions can be distinguished which address users or manufacture's demands. The first one is called support function. It ensures the availability of the corresponding product and guarantees its use. Next is the requirements fulfilment which enhances product use by offering complementary means. Lastly information gathering operates as an internal function and provides the manufacturer with all the information acquired from product use (costumer experiences, expectations or suggestions). The user in this case is only indirectly addressed through product refinements.

Several definitions about services exist though are focusing on processes, results and markets without looking from an engineering point of view. This point of view requires more tangible design objects. These kind of technical services like maintenance or supply of spare parts have strong relationships with products. Their influence towards product design is significant (maintainability or disassembly). If these physical objects are excluded, services are mainly intangible. Their production is different than that of products due to the fact that servicing and consumption occurs in parallel. Thus servicing processes is the second design objects concerning a PSS. The information flow is the last part of the service design framework. For the existence of mutual product support the costumer must provide detail description of the problem in order for the manufacturer to correctly process the information and provide proper solutions (Aurich and Fuchs, 2004).

No general service design framework exists in contrast to product design. Because of this interrelation between physical and non-physical components rethinking product design in the concept of services is required. Three are the current main strategies towards PSS according to Spath and Demuss (2003). The first one shows the traditional view of manufacturing to make reliable products at their core process. They have structured product design orientation. In this case services take the role of liability and are offered to ensure smooth product's functionality. Thus service design is non-existent or highly intuitive.

The second strategy aims at offering products enhanced by services. Results from product design come in several different variants which in turn are supplemented by a set of services. Products and services are combined together to meet customer's specifications and interoperability is achieved. Although the focus still lies within products, their correct functionality is supported by services. For example, reduction on maintenance using prevention measures can increase product's operation time which in turn enhances product's main functionality.

Third strategy is mostly user driven. Its aim is to provide a unique solution to meet customer's needs. Services and products are fused together which involves the integration of service elements into the product design process. PSS represent these user-oriented solutions which require concepts derived from customer's demands. At the moment this strategy is restricted by a limitation on possible product configurations.

Each of the strategies requires different approaches. Because the first strategy is based on strong product design processes, the approach should involve product analysis, product-related design activities and information exchange. Influences from manufacturer-user on product design should also be addressed. Approach based on function processes offered from the second strategy should also involve the addressing of manufacturer-user relations, information exchange as well as analysis of the service offering. A service design process can emerge by integrating all service characteristics into product design. As far as the third strategy is concerned, the integration of both processes is essential after analysing the overlaps and aligning information exchange with organisational standards (Aurich and Fuchs, 2004).

The approach for the third strategy has been tested with an enterprise of an investment goods company. The goal was to develop a phase oriented service design process. This enterprise had already produced a systematic product design process as well as a function-oriented approach based on the second strategy. For these reasons the applicability of the user-oriented process (third strategy) could be proven. It consisted of three main phases: analysis, concept, execution and each of them spawned in two sub-phases. A generalisation of this approach was essential to satisfy multiple needs.

The analysis phase started with the identification of customer demands. It was a necessity for the specification of service targets and requirements to occur. Next step was performance studies to be conducted about technical feasibility and demand-use performance. Concept phase started by determining at which level the service function was fulfilled. An underlying recurring development of ideas trying to fulfil customer demands took place with respect to the objects from service design. Servicing processes and information flow were predetermined by specifying the previous ideas. Moreover the relations between the service and product that are under investigation had to be examined. A general definition of systems of services, information flow and exchange, servicing, and materials that services are going to use, was necessary and corresponded with the modelling sub-phase. As a final step, in the execution phase, planning about realisation structures, resources, specification of responsibilities and staff qualification had to be conducted. Especially an increase on staff qualifications was crucial due to the parallel nature of service application, both servicing and service consumption. A service prototype was tested together with a pilot user during the last sub-phase. More sub-phases may be considered if improvements need being incorporated.

Another process proposed by Aurich et al. (2006)* for PSS systematic design relates products with technical services upon a modularisation approach. First a technical service model is defined and then a systematic service design process is derived for supporting this model. Finally the integration of product and technical service design is achieved by a modularisation approach resulting in a modular design of technical PSS.

Another interesting feature of the modified Integrated Production Process Model (IPPM) is the ability to design generic processes from selection and compilation of appropriate process modules. These in turn can be adapted to meet specific requirements imposed by companies. An allocation process is proposed by Aurich et al. (2006)* for accomplishing the previously discussed feature.

A case study to demonstrate the previous process involved an enterprise which developed heavy road construction machines as its main capability. It was also a technology leader in this area and thus it relied on service network consisting of many different branches and independent partners. Implementing such a process helped the enterprise to intensify the already existing relationships as well as gain new customers. The design process took the form of a checklist in order to provide comparability with the existing product design process. This checklist systematised previously service design activities while emphasising on applying project management techniques. It also specified each design phase according to objectives, activities, methods, tools, information sources, etc.

Another modularisation-based design, which builds upon Aurich et al. (2006) previous work, tries to redeem deficiencies appeared on the previous approach. Yu et al. (2008)* developed an industrial service design and modelling method according to the modularisation concept mentioned previously to enhance the competiveness of enterprises.

Integration and participation of the customers through the entire design process is a necessity. First of all they can provide suggestions and useful information for optimisation purposes. Moreover their requirements pose constraints to the service attributes, contents and processes. Therefore it should be noted that by not integrating customers' demands into the service design may lead to unexpected and negative results. On the other hand too much customers' interference can bring about confusions, process gaps or loss of information. That is why an effective solution would be to establish a management data system for collection, storage and analysis of customers' inputs.

An effective solution for service modelling is by splitting the service model with a modularisation approach making independent modules which can then be modified, added, deleted or swapped quickly according to internal or external influences. The modelling should aim at ensuring quality and delivery of services. The modelling approach splits into three subcategories: process of service module design, classification of service modules and the industrial service module.

An overview of the application of the previous process is given by a case study on a medium size machining manufacturer. One of its main activities is the development of complex machine tools. The manufacturer wanted to realise customer satisfaction and reduce time/ cost for service design.

2.5 Service Design Methodology

2.5.1 Quality Function Deployment / Derivatives

QFD is a methodology that has been widely used in manufacturing systems (Hauser and Clausing, 1988). It is a systematic way for collecting, organising and analysing qualitative information to achieve quality products. Customers give their requirements which are mapped into defined and measurable parameters. QFD has been selected as the basis of their methodology based on four aspects: customer is carefully considered during the developing process, it can be used for both products and, services and processes, it brings together multi-functional teams and finally is a structured method having a great deal of flexibility. In addition to QFD, fuzzy set theory and analytical hierarchy process (AHP) (Saaty, 1980) is being used for establishing the methodology deployed by Shen and Wang (2008). Fuzzy set theory, which tries to quantify the intangible properties and AHP, which is a multi-criteria decision making technique, is applied for determining the importance of customer needs and the relationship between customer and ECs.

A critical role in PSS design is the design discipline. Customer needs should be correctly translated into product and service parameters. Moreover intangible elements can be “visible” through design with the added benefit of better management and a cleaner specification of service offerings. The methodology proposed by Shen and Wang (2008) is based on fuzzy extended quality function deployment (FXQFD) which can help in determining PSS optimal engineering characteristics which should satisfy customer needs.

First PSS parameters must be defined. These are the attributes on both tangible and intangible services which provide offerings to customers. These parameters have the name of engineering characteristics (EC) for this particular methodology. Therefore ECs of a PSS consist of product engineering (PECs) and service engineering characteristics (SECs). The design goal of a PSS is to increase customer satisfaction. There are also design constraints such as the total cost and criteria on a certain EC. The SECs can be considered equivalent to traditional engineering characteristics like in the case of a product-oriented service. On the other hand there is difficulty in obtaining the SECs because there is no current service design methodology from an engineering point of view. Although there are methods that provide graphical representations none of these can help extracting ECs. Another problem exists on the relationship between product and service elements. Due to the fact that both of them are mutually depended they must be determined simultaneously at the core level having the same goal and constraints. Last important aspect of the problem definition is consistency. Different actors have different preferences of solving common problems and reach proposed goals. Therefore a harmonisation among all stakeholders is imperative within design process.

First step of the methodology is to analyse the SECs. In order to accomplish that Shen and Wang (2008) defined SECs using three dimensions: service outcome, process and resource. Thus SECs description takes the form of these three attributes. Service outcome describes what has been done for meeting customer needs. It represents the change from the initial state to a new state according to customer's preferences. Service process represents the chain of activities which the service needs to function. It defines the interactions between customers and resources. Lastly the service resource gives the static supplies based on service requirements. In general the most important SECs are that of service outcome. They represent PSS performance at the system level. They are directly related to PECs thus need to be simultaneously determined. Service process and resource may have a lower impact to PECs giving them the ability of being designed separately.

The next phase tries to organise the information using a House of Quality (HoQ) model. Building this model requires seven steps. At first customer needs are identified through survey reports, group discussions or interviews. Second PECs and SECs must be specified. PECs are the performance of the product element while SECs are the attribute of service outcome. Third includes market evaluation. It prioritises customer needs and provides selling points. The AHP method helps evaluating priorities. Step four concerns the development of a relationship matrix of customer needs/ ECs. One to one correlation between customer needs and ECs takes place. The measurement considers the extent of meeting customer needs towards a specific attribute. Benchmarking technical competitors and setting constraints form the last two steps.

In third step relationships between PECs and SECs have to be evaluated by professionals. After completion of this procedure the correlation matrix is then created.

The harmonisation process is demonstrated by a weighted average algorithm. Any discrepancy can be resolved through reconciliation.

Before reaching sixth and final step ECs targeted values must be determined. This process is formulated as an optimisation problem. Thus using mathematical modelling an optimal solution is achieved.

After having determined service outcome, service process and resource can be designed by a further deployment of HoQ. Service blueprinting can also be applied as an alternative method. Concerning product elements, further design is required which is now possible by knowing the PECs at the system level. Depiction of the HoQ in QFD is shown in figure 2-3.

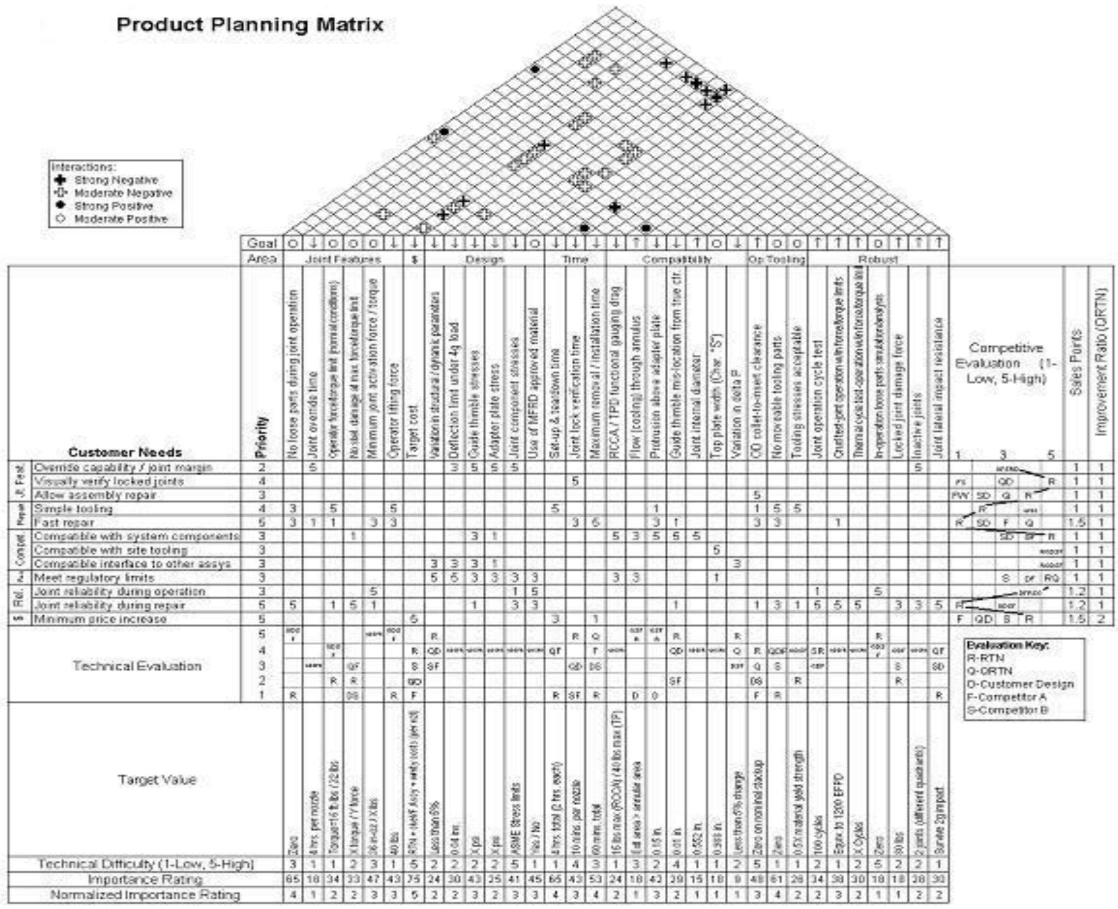


Figure 2-3: HoQ matrix

QFD has also been applied to service evaluation under the service engineering scheme (Tomiyama, 2001) by Arai and Shimomura (2005). The method based on that has the ability to evaluate effects of a service towards a service customer or receiver. Moreover mathematical methods have also been applied to help differentiation between functions and structures of a service (Shimomura et al., 2008)*.

For a demonstration of the methodology a clothes-washing service has been used. It is applied using a service CAD method named service explorer (Arai and Shimomura, 2004).

A designer can use this framework in order to gain a better understanding of the service elements and confirm which of these have higher needs for implementation.

A solid framework which creates a service modularisation technique was proposed by Geum et al. (2012). They employed and modified the House of Quality (HoQ) structure in QFD in two distinct ways, a driver-based and an interrelationship-based approach. For the first approach module drivers, which were identified from a literature survey, were used to represent the service characteristics. Twofold module drivers were identified, one for common themes and another one for service-specific elements. The second approach considered the interdependent nature of the service offering and thus was decomposed according to three predefined dimensions, service process, service outcome, and service prerequisites. Then the modularisation of the service was conducted through a HoQ structure. Two matrices were used, one to represent the relationships between module drivers and to analyse the decomposed service components, and a second one for the identification of the interrelationships between those components. The former was called Strategic Modularability Matrix and the latter Interrelated Components Modularability Matrix. Lastly an analysis of clusters was conducted to identify the module candidates. Geum et al. (2012)

illustrated the previously proposed approach to a restaurant service. It showed that a flexible modularisation was possible by selectively applying the module drivers where each one had different weight based on the service firm's characteristics, circumstances and strategies. Moreover the use of the three different dimensions to analyse the service provided a concrete framework for service managers to understand their firm's current service offering (Geum et al., 2012).

2.6 Service Design Method

2.6.1 Service Blueprinting / PCN

Innovative methods, techniques and practices were in need due to crave for service innovation in the world's economies and the change in trend for businesses towards value creation through costumers' experiences. One of these techniques was service blueprinting. It is a customer-focused approach for service innovation and improvement (Bitner et al., 2008). It was proposed by Shostack (1982, 1984), and since then has evolved significantly and is currently been used as a useful approach for addressing many challenges concerning service design. Service blueprints are mainly customer-oriented and companies can visualise service processes, customers' interactions and physical evidence of their services from a customer's point of view.

Services incorporate some characteristics that depict the need of this method. First and most distinctive of all is their process nature (Gronroos, 2007). Their dynamic nature, which changes through time by an event sequence composed of discrete steps, can be viewed as a chain of activities that allow for correct functionality of the service. Service blueprinting help managers to deal with the challenges of service process design and analysis. It can represent a service at multiple detail levels. It can also provide details of each step for further refinement as well as visual overview of the process from a holistic view. Another characteristic is "customer experience".

According to Carbone (1994) all services create this kind of experience because customers create experiences by using them. Critical points of customer interaction, physical evidence and other functional, emotional experiences can be visualised by service blueprinting. Identifying hidden support processes may provide a clear vision for companies to build services on top of these experiences achieving improved customer and organisational outcome.

In general service blueprints are relatively easy for stakeholders to understand, learn, use or even modify to meet particular requirements. They also play an important role through the service design process by allowing designers to reach the deepest levels of the company while keeping connections to customer actions and processes. Lastly by visually rendering the underlying organisational structure of a process it is highly useful in the concept development phase of a service. A key point to service success is that every party related can easily access this information forming a common point of reference to all. A service blueprint is shown in figure 2-4.

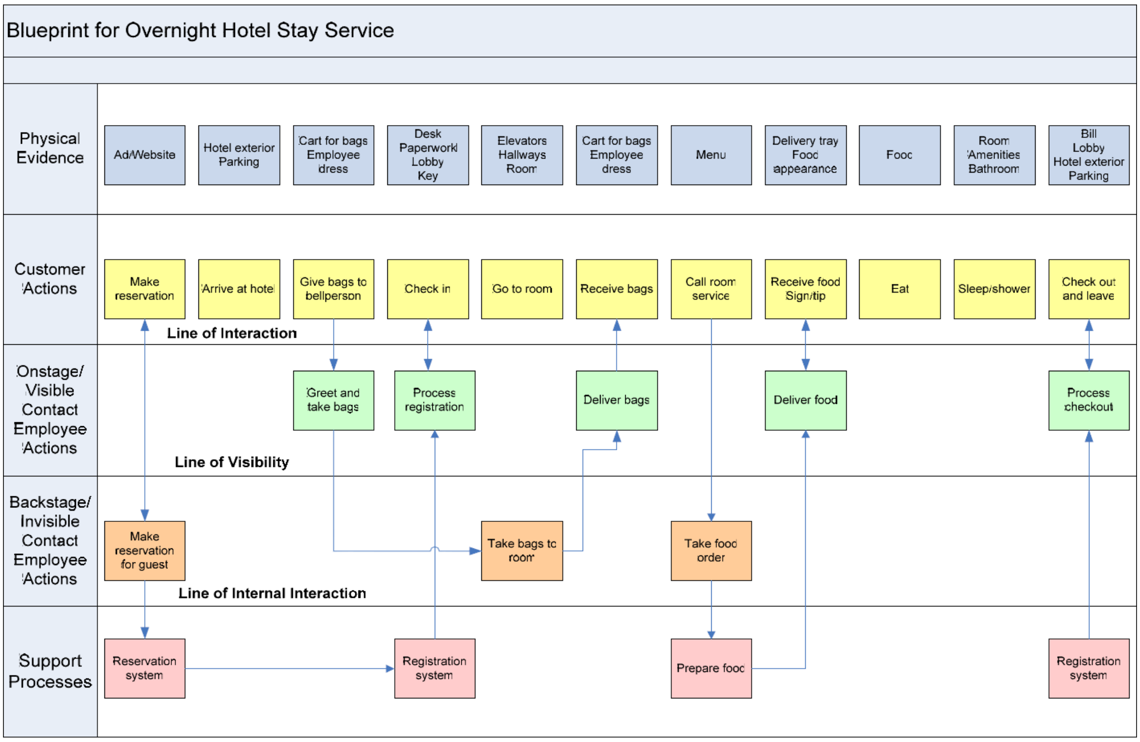


Figure 2-4: A service blueprint

The marketer or the supplier of a service must know the structure of each of the elements, products and services. First of all “knowing the product” is relatively easy. It is all about engineering specifications, physical properties, etc. The same does not stand for services. It is almost incomprehensible. There are neither equivalents to products specifications nor a common knowledge overcoming possible obstacles. To deal with the situation Shostack proposed the following combination of methods derived from three unique systems.

Some marketing studies involved customer interaction both with elements of the system and considering time sequence of events. For this reason Shostack (1982) proposed several elements from different techniques to be suitable correlated and connected through adaptation in order for the graphical representation to include the missing time variable. Three disciplines were involved: time/ motion engineering (for planning and manufacturing and product assembly), PERT charting (used in management for time/ cost analysis) and system/ software design (currently used in computer science for task scheduling in software engineering).

Time/ motion engineering can offer a precise system for process planning. Apart from their initial use in assembly lines they have been adapted and applied to service operations such as check processing and preparation of fast-food. If we look at the low level of this discipline we would find that these kind of engineering methods are very precise and highly developed. They play a major role in utilities such as cost control, output, and efficiency of the assembly line. Equal applicability can also be seen in services (Shostack, 1982). It consists of eight basic charts but only three of these are most relevant for service analysis. These are the Operation process chart; it gives a chronological sequence of operations, materials, etc. that are used in manufacturing processes; the Flow process chart; it contains more detail than the previous chart and its main focus is to show any sub-proces

ses that may exist; the third one is called Flow diagram; its main purpose is to order the symbols and descriptions, which has been used in the previous two charts, along with providing a schematic of the physical layout and location of all operations (Shostack, 1982).

PERT charting is being used basically for scheduling of products and is not valid for process description. Time dimensions and costs for each part of the project can be shown but there is not much visual detail to explain its symbology. On the other hand its project visualisation methods incorporate concepts like critical pathing, which shows minimum time of project completion. These kinds of charts are typically used for establishing cost/ time trade-off analysis (Shostack, 1982).

System/ software design has its roots in software engineering. If we look at a computer system we can see all kinds of various programs that exist and are conceptually and operationally relevant to services. Some of them have the role of data processing, while others are supervisors and their mission is to coordinate and schedule the work of application programs, using load balancing techniques. In addition there are some other programs which provide support to others by trying to maintain their functionality within acceptable levels. One such group is called multiprogramming and its purpose is task handling. A specific program, the task scheduler, makes the decisions in order to achieve load balancing among various programs and multiple tasks. Keeping lists, interruption handling, sequence control and data management is all part of task management which is an integral part of the operating system. All of the above were mentioned in order to show that an analogy between software design and successful service deployment exists and therefore must be thoroughly examined (Shostack, 1982).

Although each of the above three methodologies are equally important for analysing a service, yet they are incomplete considering service marketer’s needs. Time/ motion engineering for example does not deal with other service functions apart from human performance. Software design does not involve time or cost as perceived by humans nor does it provide alternative process execution routes. Lastly there is no analogue offering to consumers in PERT charting (Shostack, 1982).

Boughnim and Yannou (2005) have used the service blueprinting method for development of a PSS. Their case study consists of a service provision for designing and setting the workplace of an organisation.

In general blueprint is a two dimensional matrix of a process. The horizontal axis sets chronologically the actions of the service provider and customer. The vertical separates different areas of action using unique lines (Field, 2004). Three are the lines that have been identified throughout the years:

- Line of interaction: it defines and splits the actions of the customer and the provider of the service.
- Line of visibility: this separates visible and invisible actions by the customers
- Line of internal interaction: it distinguish between front and back office activities.
- Support processes: required processes for service delivery and are been carried out in the area below the line of internal interaction.

Zeithaml and Bitner (2000) proposed and added two more lines to the previous strategy the line of implementation and order penetration. The former differentiates management from support zone while the latter, which lies below the line of internal interaction, splits the customer's activities between induced and independent.

Boughnim and Yannou (2005) case study shows blueprinting method as a means for modelling all processes, actions and interactions of the company. For this reason they chose an industrial company that differs from the original manufacture/sell company by providing workplace services instead. Promoting effective working and space efficiency were the main goals of this study. They tried to model a workplace service to assist them on service performance. The example they chose was about renovating and organising an old building to becoming the head office of a company. At first they identified the particular areas of the service based on the previous four lines that were mentioned before. Then they precisely analysed every process, every element of the service in order to achieve an overview of the service inner workings. That provided useful information to perform an evaluation analysis based on current environmental and economic factors.

By assessing the performance of the company's service, made it feasible to compute the cost on environmental impact during the service lifecycle. The company now has the ability to make a simulation system which will model different service provisions on top of this information structure. Last but not least, finding advantages and disadvantages, creating arguments and preparing scenarios for potential clients are some of the tasks that the company may now well achieve.

Case study examples (Yellow, Aramark, IBM, Marie stopes international, San Francisco giants) from Bitner et al. (2008)*, based on their study, research and work with companies, show how this method has been effectively used and adapted for service innovation, improvement on quality and changing companies' strategy, now focused around customers.

Hara et al. (2008)* tried to solve two different problems and created a framework that would deal with these. The problems at hand originated from two separate fields: marketing and engineering.

From a marketing point of view the problem lay between analysing and designing the service activity for the customer. Despite of the extensive research on service development methods, service activities are seen directly related to customer needs with little acknowledgment of their effects to customers.

In the engineering field the problem lay on the function and service activity design separation. Tangible or intangible elements of a service acquire a functional form. Although service activity involves human elements that actualise functions, the relationship between this process and its correlated functions has yet to be studied.

The proposed method combined a function model from engineering field and a service activity model from marketing one. The service activity model was produced using Business process modelling notation method (BPMN) (Havey, 2005) for making a service blueprinting. This method also made possible the service activity elements become design objects while making the blueprint. Looking at the BPMN structure one can locate the service delivery process and the customer-provider interactions. Function is the purpose in human minds and the system can implement this by providing certain services to satisfy specific human behaviours.

This framework has been demonstrated using the BPMN modeller and service explorer (Sakao and Shimomura, 2007), (Arai and Shimomura, 2004) on an elevator operating service (Hara et al., 2008)*. The stakeholders of the service are the elevator user, the elevator company and the security company. The user is the service receiver and final customer. First of all the basic functions (RSPs) of the user going to a shop must be identified. These are: security and safety of the service, time and effort for movement, service availability and nice environment. Four view models according to the previous RSPs were created. Then service activities were modelled in the service blueprint using the BPMN method.

Another representation scheme similar to the previous one is provided by an extended service blueprint ((Shimomura et al., 2009), (Hara et al., 2009))*. The regular blueprint has been innovated to include also physical processes apart from human only. The service design process is represented by three phases: customer value identification, design of service contents and service activity. As it is showed previously it illustrates the relationship between RSP, the view model and the extended blueprint. The extended blueprint defines human processes as activities performed by humans and physical processes as activities performed by hardware. For implementation purposes BPMN methods were used. The benefit from this extension is the representation of actions among providers and customers for good cooperation and understanding of the service flow. Designers can then see how processes interact and influence each other. Regularly service designers do not take customer needs into account. Connecting the extended blueprint to the view model enables product designs to meet customer demands and identify their specific role among the entire service.

Service blueprinting has also been used for integrating products and services to form PSS models. A sustainable approach to this direction was attained by Geum and Park (2011)*. They proposed a new and effective design method for PSS. They named it a product-service blueprint.

Sampson (2012) introduced a visual framework called Process Chain Network (PCN). A PCN diagram can depict processes and interactions of a service network. It can also identify a network's value, assesses the performance and value of processes and identify potential improvements on processes leading to innovation. PCN improves on the service blueprinting method in three ways. First it takes on "the nature of interaction" which acts as a differentiating process step. Actions are categorised according to entities involvement and their interactions. Second PCN can depict all entities as being individual to each other in term of interactions and processing. Third PCN improves over service blueprinting by representing service processes as forming a network where multiple entitles seem to act independently. A process in that sense is a sequence of steps. A process chain is a sequence of steps having a defined purpose. A process entity defines any entity that participates in a process. Entities that benefit from a process chain are called specific beneficiaries and in general represent users of a service (i.e. customers). Generic beneficiaries are entities having generic resources and typically represent service providers. For every process entity there is a process domain which defines the steps of the process from start to end. In that process domain there are three regions of interaction. First is the direct interaction where a process entity interacts with another process entity (i.e. people to people). Second is the surrogate interaction where a process entity interacts with another's process information but not with the process entity itself (i.e. people). Third are the independent processing steps where a process entity acts on its own resources.

PCN framework helps service designers to use a method for visualising service operations including situations where otherwise might have been difficult to conceptualise. Moreover these diagrams enable designers to depict complex processes and propose alternatives. Researchers can use them for visualising, analysing and solving service operational problems. They have been successfully deployed to a numerous of cases and service scenarios. These include a pizza – restaurant service, a healthcare service for medical diagnosis and a furniture retail service. a PCN diagram can be seen in figure 2-5.

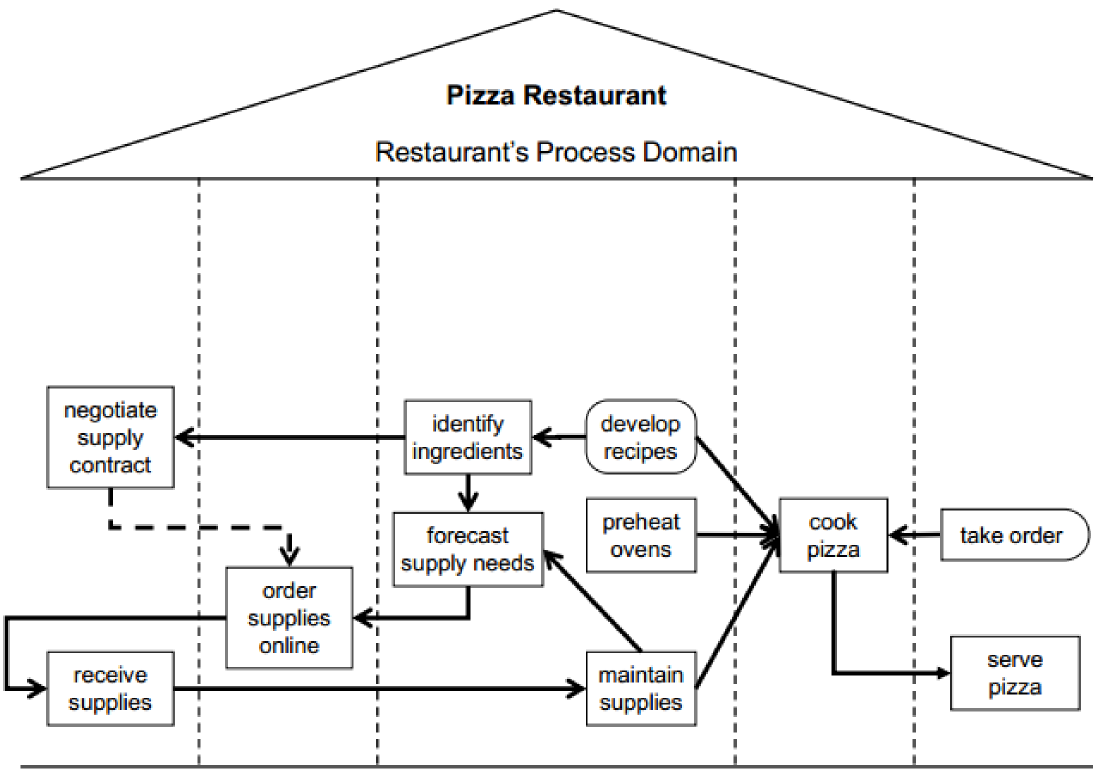


Figure 2-5: A PCN diagram

2.6.2 IDEF0 / DFD

The development of the physical part of the PSS relies on the technological and mechanical characteristics of the product but the service elements introduce new variables. These include time dimension, the dimension about the interactions among people and probably other, not so profound dimensions having relations to cultural and social frames.

A helpful method that could support an approach for designing such a system is Integration definition for function modelling (IDEF0) (Morelli, 2006). The primary purpose of this method is to help system engineers in order to analyse business processes or other kind of system processes using several techniques for avoidance of complex diagrams produced by other methods. It can also provide a complete description of a complex systemic structure. It is a modelling language that can represent details of functions and actions through time progression without breaking linkage between system's elements. The representation of the system involves a series of boxes which represent a function of the system. From the left side of the box inputs are entered and outputs are produced as a result of the function's transformation. Input arrows from the top give the needed conditions for the function to operate correctly thus giving valid outputs. The outputs are given by the right arrows of the box. Lastly the arrows at the bottom side represent mechanisms that provide additional support to the function or linkage between portions of the same model.

Apart from the main boxes there are also sub-boxes that are produced by a hierarchy decomposition process while each of them can be further analysed according to the same logic as mentioned previously.

Logical, time-related and physical connections between components and phases of the system can be represented accurately while one can recompose the system any time by looking at the boxes in a hierarchical order. IDEF0 is covering part of the methodological problems related to PSS design. It can also cope with systems having higher predictability. This method has been used and tested by several projects undertaken by industrial design students at Aalborg University and proved to be very helpful when there was limited range of users' choices. Dealing with a wide range of choices increased the complexity and was too difficult for this technique to manage (Morelli, 2006). It should be mentioned that by combining IDEF0 with scenarios and use cases may provide a better picture of a PSS configuration and help defining the system using other systemic approaches. An IDEF0 diagrammatic representation can be seen in figure 2-6.

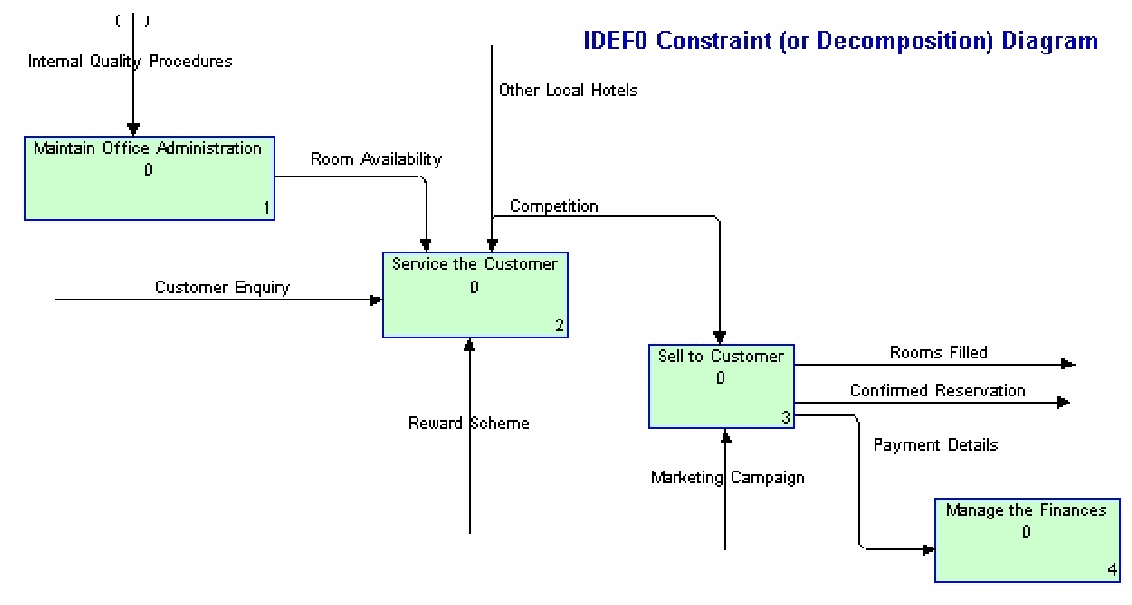


Figure 2-6: An IDEF0 decomposition diagram

A similar approach that has been used in the service design process is the Data Flow Diagram (DFD). In contrast to IDEF0 arrows, which represent constraining relationships, arrows in DFDs show how objects (including data) actually flow, or move, from one activity to another. This flow representation, combined with data stores and external entities, gives DFD models more resemblance to some of the physical characteristics of a system—that is, issues of object movement (data flows), object storage (data stores), and object procurement and distribution (external entities). In contrast to IDEF0, which views systems as interconnecting activities, the data flow diagramming views systems as nouns. The context data flow diagram often consists of an activity box and external entities. The activity box is usually labelled with the name of the system. The addition of external entities does not alter the fundamental requirement that a model needs to be built from a single viewpoint and must have a well-defined purpose and scope (Mershon, 1997). A DFD is shown in figure 2-7.

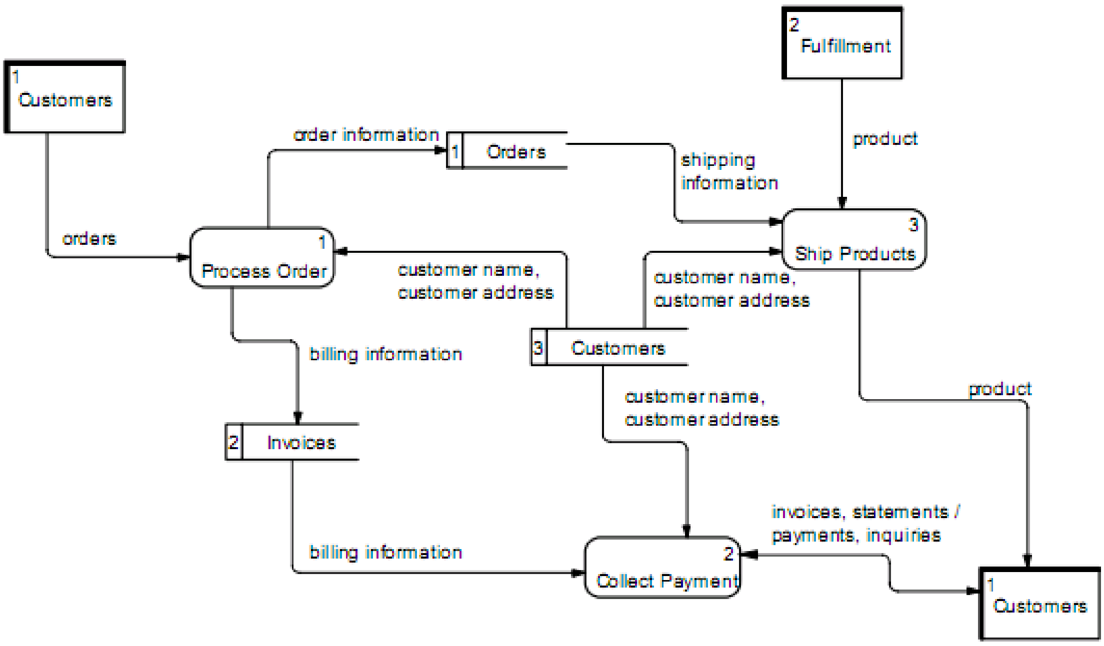


Figure 2-7: A DFD representation

DFD have been used in a PSS scenario involving a library service. They were used in the process of determining the information flow and uncertainty of the PSS interlibrary loan service. The reduction of the identified uncertainties and the increase of the usable information improved specific functions of the PSS scenario. The possible improvements of the PSS delivery showed that it is possible to assess customer interactions with different computational units based on the interpretation and delivery of information (Durugbo et al., 2010b).

2.6.3 Use Cases / Unified Modelling Language (UML)

A use case is a diagrammatic way to represent flow of events using a plain language descriptor. It involves actors, post-conditions for each case, alternate paths and other relevant components. This description is usually organised within templates that list all relevant information required for each case.

The design process involves using ideas in future configurations. Because of that the design activity heavily relies on visualisation procedures. Moreover it is critical for the success of a project to establish a communication with the clients. It will be they who should verify the validity of it and produce a plan where other actors can understand and execute according to the design process (Morelli, 2002).

The diagrammatic representation which was mentioned previously has a specific focus on the interactions between individual actors and the system itself. The most common method used for such representations is the Unified Modelling Language (UML). At first UML was used in computer science and information systems but it was extended in order to cover several other disciplines. It is basically a diagram that describes actors, use cases and the intermediate relationships/ connections. It can also contain triggers and actions for specific events although the lack of time sequence and linearity is a major downside.

Scenarios can also be developed through use cases based on actors' profiles. Actors can also be part of different PSS configurations. Events (use cases) describe the sequence of an action that is included in a scenario. Mapping a PSS through use cases and scenarios can help the designer to identify the gap and intervene to rectify it. For its design, task decomposition and analysis of the requirements are taken place in order to figure out its nature and help the designer to identify which component, either a service or a product, is needed to meet it (Morelli, 2006). A case study which involved both use cases and scenarios was the telecentre project (Morelli, 2003). The telecentre project was focused on creating and developing a PSS, an urban telecenter, which would support new working approaches using highly sophisticated information and communication techniques. They used this technique in terms of formulating existing problems in such a way that it would help generate a list of requirements. Use cases were based on hypothetical users' behaviours. A UML use case diagram is shown in figure 2-8.

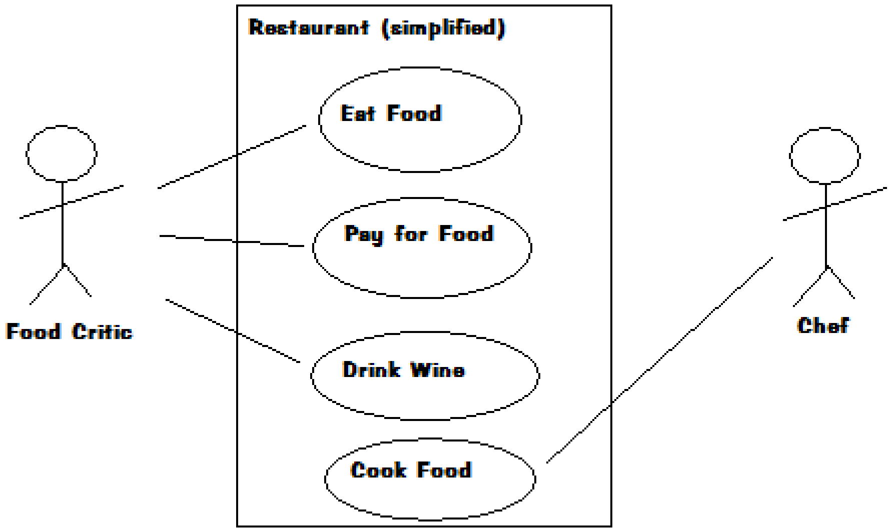


Figure 2-8: A use case diagram

2.6.4 Social Group Analysis / Interaction Maps

The interaction between different actors and physical elements during the use phase is what actually consists of a PSS. An emphasis should be given to the social and technological interaction and finding the golden mean between them. Social and cultural patterns of the actor ought to uniformly blend with the embedded technological knowledge of the service elements in use (Morelli, 2002). This mixture of different components gives the impression that the engineer – sociologist, mentioned by Callon (1989), has the same function as the current designer. According to this view, the role of the designer is to linkage the physical/ technological parts with the attitude of a certain social group which in turn will accept or reject the provided service.

If we look at the technological artefacts and the structure of a PSS we will identify an influence by the socio-technical attitude of its designers/developers. Cultural frames have passed through the physical characteristics of the artefacts (Morelli, 2006). It plays an important role during the PSS development phase. For example, limitations of the artefact's characteristics may emerge when these are beyond the socio-technical scope of designers. High levels of automation help these limits to become more profound.

In a project (telecentre) that was conducted by Morelli (2003), one can clearly identify the above statement. During the design phase, the team had to overcome severe limitations concerning the use of remote file exchange and sharing. The internet settings in physical locations and firewall systems were to blame. They had built the communication system having security issues in mind. The problem lay with the nomadic workers. They wanted to communicate using the internet without really care about the imposed security measures. That brought forth a crucial limitation in the PSS design for this category.

Accoding to Bijker (1987) social groups relevant to a PSS are not only those that have a direct effect to it but also indirect participators can increase the development complexity. Thus this complex picture gives a different perspective to scenarios that must be satisfied by the PSS and affect the development phase.

For example, in the telecentre project (Morelli, 2003) a neighbourhood centre in a school was developed by having strong influences from school personnel that were not part of this project or aware of their presence.

A methodology which can be applied in order to analyse and understand this heterogeneous mix of elements has been proposed by Bijker (1995). He suggested a set of criteria which describes the technological, cultural and social frames within actors and system artefacts.

These criteria can be used as a profile generator for potential users of a service. In order for the designer to create such profiles, a thorough analysis of users' characteristics based on interviews, surveys or hypothetical use cases should be conducted as part of a workshop process organised by the service design team.

By looking into these profiles it is possible to generate interaction maps between the actors in the system (there may also be layers of interaction) or on interaction scenarios. An interaction map can emphasise direct and indirect relationships between the actors in the system. It can also point out how much the system is dependent on the infrastructural conditions. Some of them are highly concerned for decisional levels and cannot be altered. These conditions should be treated as external to the system and design solutions must be focused on them accordingly.

Another map can focus instead on social groups' interaction emphasising each group's participation in the system. This kind of interaction can also be valid for design purposes by helping different social groups to identify their sole interactions taking into account various organisational and social scenarios. An interaction map can be seen in figure 2-9.

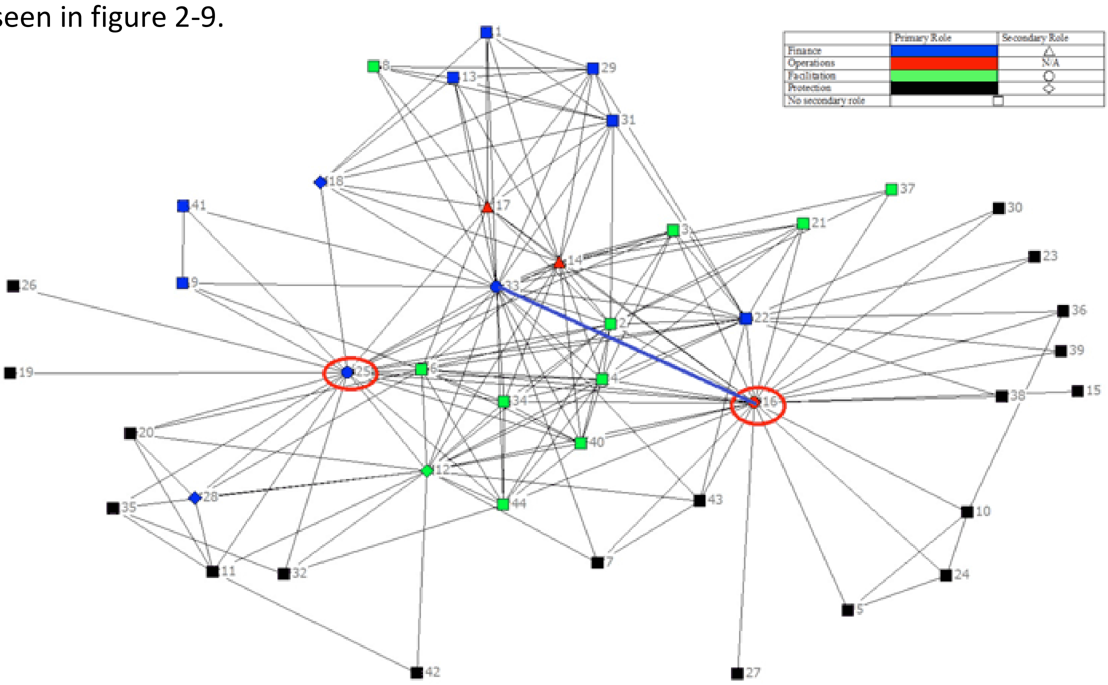


Figure 2-9: An interaction map

The embedded technological frames should not be neglected due to the facts that are relevant to the development of the service. They often enhance or limit the prospect of it (for example the operating system poses a strong influence to the dissemination of information within a PSS) (Morelli, 2002).

Makino et al. (2009) used the ethnomethodology in order to study and analyse social group behaviours to be used as a part of their interactive service design process. They constructed a model of the service processes by using ethnographic field observation. The ethnomethodology is a study method of sociology to identify specific norms, orders, or rules behind human behaviour by observing the actual work environment. An ethnographic approach seems mandatory when one needs to answer what kind of knowledge and expertise people use in a cooperative environment. This approach can also be part of the social group analysis for service modelling. It formed the key process for deploying a human-centric service design where human factors had to be properly considered and reflected during the iterative process of service development (Makino et al., 2009). It also provided the ability of extracting the field experts' knowledge that was required to create, modify and improve that service model.

2.6.5 DES / Simulation Methods

Discrete event simulation (DES) is about a method that can be used for system modelling and how this system evolves through time by representing each change as a separate event. There are numerous applications that make use of this, particularly in manufacturing systems. Some attempts have been made of using this method in service design, which are going to be discussed below. A DES simulation can be seen in figure 2-10.

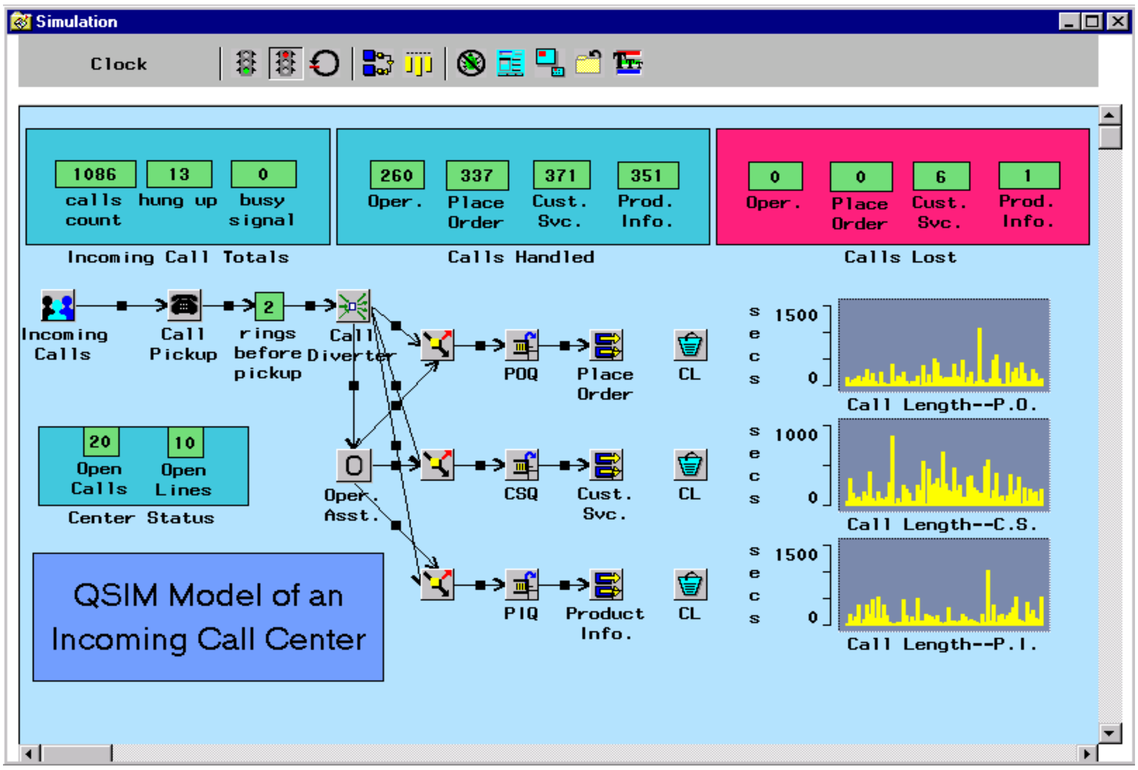


Figure 2-10: A DES simulation model

DES has already been applied for complex service design. A virtual enterprise architecture (VEA) has been modelled and simulated using the previous method and principles from the Design Science Research (Simon, 1996) for the development of a automated baggage handling system which can be used in airports (Moller et al., 2008). It involves an automated transport and sorting system (ATS). A virtual enterprise is a network of several different organisations in order to achieve a common goal. This goal in particular is service provision to customers. A logistic service has been evaluated using DES modelling as a service separated from products themselves and a framework has been generalised and validated for VEA based on DES (Moller et al., 2008). A relationship between service design and DES has been identified. If we consider the logistic service as a type of PSS, engineers involved in industry should be able to design the service system much like a product designer develops a new product.

From the VEA development process useful experience about the application of simulation methods was provided. First of all by this it was verified that present simulation packages can be used along with industrial control systems. Moreover they have identified what is the required knowledge for developing software solutions concerning networking problems. Lastly an initial step has been established for further and future research on applied simulation models for a virtual enterprise (Moller et al., 2008).

A demonstration of the previous research was conducted using a real world case study, the Singapore Changi airport. A new automated baggage handling system was about to open. Added value to the ATS by simulating different stages of the development process and the underestimation of the cost for model production were the main findings (Moller et al., 2008).

The conclusion is that DES can be used for innovative PSS design as an advanced simulation technique (Moller et al., 2008). It improves the understanding of the final product and service. Moreover it illustrates that by mastering this modelling process, leading companies can use the attained knowledge for innovative products and solutions on the market. The idea behind this is trivial. One needs having the ability to model its ideas, play with the derived models and learn by doing such (Schrage, 2004). Consequently the advanced simulation model, where its core function is based on DES, plays the role of prototyping in service design (Moller et al., 2008).

Computer aided methods have existed for a long time within design and manufacturing systems and in general they are considered as methods that help reduce lead times during production and being capable of eliminating stages (Hill, 2004). Thus these kinds of technologies play an important role during product engineering and service systems.

DES has been proposed as CAD method for production engineering by Klingstam and Gullander (1999). A lot of commercial methods exist that are based on DES. The goal of using this kind of model is to imitate the behaviour of entities when an event occurs at a specific point in time. The entities are components of the system which are being described as variables. Therefore when a change occurs to a specific variable, an action is triggered and the actual timing of this is called an event. These multiple events are the driving force of the simulation and the simulation clock. Each of the events is distinct and between them nothing happens. Thus time in DES is not continuum but is proceeding in irregular intervals.

The availability of strong commercial products for modelling and simulating event based models is the real strength of DES. It can also include several packages that will extend its capabilities such as set theory, probability calculus, general programming languages, 3D technologies, etc. One of the disadvantages using such standardised methods is that the simulation model is integrated within the package. It involves servers, queues, routing rules, programming logic, etc. That hinders the modularisation and reuse of the produced architecture.

There is also another approach for service modelling started by a Japanese group at University of Tokyo back in 2001. Tomiyama (2001) defined service in a different scope and defined service engineering in a narrower form than the initial definition of the group mentioned in Section 2.2. It can be considered as a subset and therefore will not pose any further confusion to the reader. A new paradigm has been conceived that reduces the production and consumption of artefacts in order to bring balance against environmental and social constraints. This paradigm has been called Post mass production paradigm (PMPP) (Tomiyama et al., 1995), (Tomiyama, 1997), (Tomiyama, 1999). For establishing this, current approaches needed being redeveloped. Dematerialisation for example, needed knowledge about product lifecycle and service contents in order to affect and enrich their value. This required engineering methods to look into services and not only their functions. It was called service engineering. Its purpose was the designing of innovative products that would generate more value in a holistic view.

Service engineering under these conditions intensified service contents within a product lifecycle or value chain for dematerialisation purposes. It was called a method, which is actually a specific view of the discipline described in Section 2.2. Under this concept service is defined as an activity. It cannot be stored or cease to exist and it consists of certain elements such as service channel and contents. Artefacts are included into these elements. A framework includes a service receiver, service provider, artefacts and environment. The service receiver takes the service contents from the service provider through a service channel. Service contents are defined as changes in the receiver's state, which is one of the most important features of the service activity.

Tomiyama (2001) under this definition of the service engineering concept proposed the service modelling. This formed the test bed for designing, producing and developing services. The service elements of the modelling method include service goal, service environment, and service channel.

- Service goal: satisfaction of service receiver's needs by changing its state.
- Service environment: the service is established within an environment, which contains the service provider, receiver and channel, in which service contents are sent.
- Service channel: it determines the quality of service (frequency, convenience, etc.).

On top of these definitions it was possible to develop a service modelling method that would take in account these propositions.

Aria and Shimomura (2004) proposed a service modelling method and created a method based on the service engineering context mentioned previously. Service design is a search for both physical and non-physical structures but the main difference from traditional design lies on the evaluation measures. The design was based on the receiver's satisfaction level that is depicted by a change in its state. Thus state changes should be expressed by the received contents. Their proposed model consists of receiver's state, flow model, view model and scope model.

Receiver state parameters (RSP) represent a change of the receiver. A representation through a set of RSPs can be sufficient. RSPs consist of qualitative values including Boolean logic. This gives the ability to make comparisons between two RSPs. RSPs, as mentioned before, can change through service contents. These contents include various functions and each function has a function name (FN), function parameters (FP) (operating objects) and function influences (FI) (effects of the operating objects). RSPs are also functions because they can be described by FPs and FIs. In addition RSPs can be written as functions of contents because their state can change in correspondence to supply of contents. Content parameters (CoPs) express contents and channel parameters (ChPs) express the parameters of a channel in the same way like CoPs. ChPs can change the CoPs flow and indirectly influence RSPs.

One of the typical services is the travel agent. It arranges and purchases tickets on behalf of its customers. In this scenario, contents are not the tickets themselves even though they are been delivered to customers. Complex multiple structures can deliver services by various go-betweens. Intermediate agents are both providers and receivers. When an agent acts as a receiver its other side is hidden by the system and vice versa. The flow model of the service is the sequential chain of contents and channels through the intermediate agents that exist between provider and receiver.

A change in the RSPs can occur according to the subjective evaluation of the received contents. An RSP can include many CoPs because the evaluation occurs in this way. ChPs may support many CoPs. ChPs exist within agents in the flow model. The definition of the view model consists of a CoPs/ ChPs tree having a single RSP at its root. It is expressed as a graph with nodes and arcs. The functionality of the view model is to visually illustrate the relationships among parameters (RSP, CoP, ChP) using directed arcs (see figure 2-11). By utilising this model RSPs can be improved by changing the FPs.

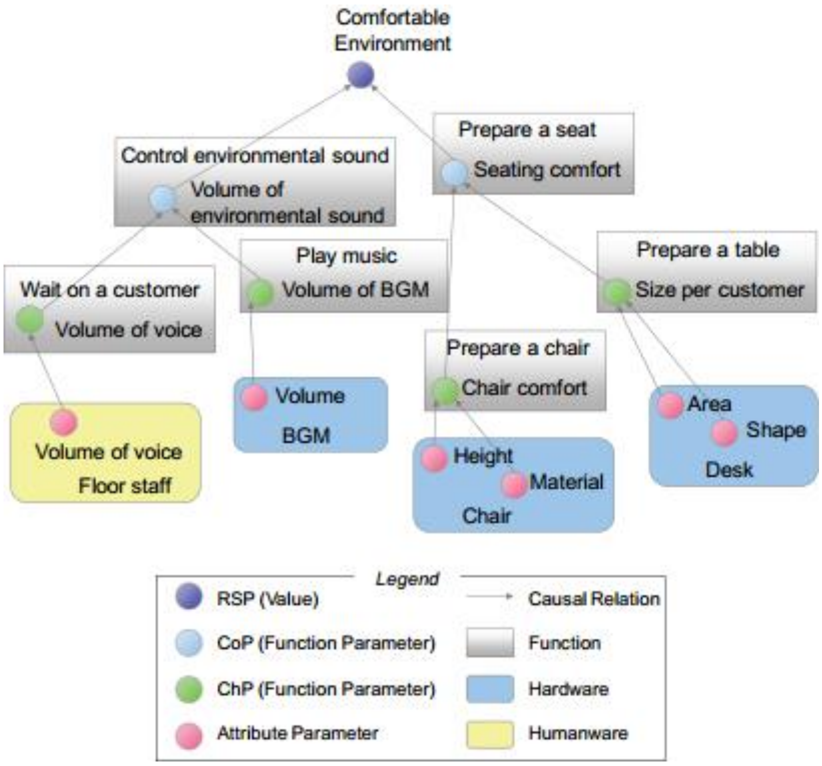


Figure 2-11: Interrelationships between parameters

Due to the fact that practical services tend to have rather complicated structures of connected intermediate agents, it is necessary to specify the effective range of the service; from the initial provider to the final receiver. The scope model can deal with all RSPs within those limits (providers/ receivers) instead of just one (view model). A scope model can handle multiple view models, multiple RSPs, and thus it can help designers to have a better understanding of the real activities between the two.

A prototype CAD system has been developed for this purpose named service explorer which can help service design (Arai and Shimomura, 2004), (Hara et al., 2006), (Arai et al., 2007). A designer can thus operate the service in different ways:

- Can express a service model according to the aforementioned definition.
- Can edit models by modifying arcs, change attributes of functions, etc.
- Can evaluate the service as a whole by assigning values to each component.

- Can search similar service models from a database.

A case study of a rental service appliance demonstrated the effectiveness of Service explorer (Hara et al., 2006). The rental company rents several materials which are part of a set of home appliances to a customer for a specified period. The authors studied from the whole set the washing machine part. First using service explorer they described the target receiver and the value. The demographic and psychological data of the customer were described. Some of its properties (self-respect, sense of fulfilment, etc.) were set using basic values. A scenario was created for the costumer using all of its actions. A hierarchical tree of RSPs was created according to its actions based on its previous values. Secondly, the whole service provision was described. The three agents were arranged within the flow model: the customer, rental company and manufacturer. The rental company provides service such as machine rental, installation, repair, etc. and the manufacturer provides the rental company with services for covering machine manufacturing and repair. It also provides the customer with functions concerning washing clothes. Third and last step is the description of realisation structures. In the view model there are function structures that correspond to RSPs and entities that are connected to these functions. Using these steps it is possible to construct a service for each RSP based on the customer's initial values. Thus the customer can be evaluated by the designers of the service.

Arai and Shimomura (2005)* introduced to the prototype CAD system an evaluation and quantification method for evaluating customer's satisfaction. The method used QFD and AHP to accomplish that. The most important issue while designing and modelling a service is service evaluation. The proposed method (Sakao et al., 2003) starts by determining each of RSP, CoP and ChP. A designer determines the weight each parameter would have using the QFD (Akao, 1990) approach. By decomposing the importance of each RSP, options in service improvement options can be identified. RSPs are supported by other components like CoPs and ChPs. Then the

AHP (Saaty, 1980), (Manassero et al., 2004) and the DEMATEL (Warfield, 1976) method are being used to determine the importance of each component. These two methods are powerful quantification tools dealing with subjective factors. It is generally difficult to evaluate the parameters expressed in a service because they tend to look subjective.

The case study in which this evaluation method has been demonstrated involves a hotel service. This service was investigated through interviews from both workers and the owner of the hotel.

Another novel method of evaluating a service and showing customers' satisfaction using quantitative methods was proposed by Yoshimitsu et al. (2006)*. It transforms the customer satisfaction into a quantitative value in order to be measured. Therefore the designer can know the improvement of an upgraded service based on customers' point of view. This new evaluation method uses and combines two methods, Kano model from manufacturing field and prospect theory from behavioural economics. Kano model is a satisfaction model proposed by Kano et al. (1984). It was proposed for quality management. According to customer satisfaction, quality attributes get categorised into five categories of elements and they form a two dimensional graph, where the horizontal axis shows the degree of fulfilment and the vertical axis the quality elements as part of customers' satisfaction. On the other hand prospect theory, which was proposed by Kahneman and Tversky (1979), describes how people evaluate losses and gains based on empirical evidence. It includes two theories, the theory of value and weight function. The first one describes the relationship of value between losses and gains while the second represent each person's behaviour according to a psychological probability. The presented graph shows on the horizontal axis losses and gains, and on the vertical value.

Another addition to the Service CAD named Service Explorer (Aria and Shimomura, 2004) was the model for balancing values and costs (MVC). This addition became a reality by Sakao and Simomura (2005). It provided a way to balance the value and cost of multiple stakeholders which are related to the service.

It was an extension to the flow model for SE mentioned before. Its role was to identify related agents with their values and costs for the service under investigation. Environment also plays the role of an agent in the MVC model. RSPs are the state parameters of a service receiver that has its value changed according to the service provision. The added cost is not only economic one but also time for service provision is considered. Using this proposition the environment impact is modelled as cost. Using evaluation functions the authors represented the balance between cost and value of the provider and the end receiver. AHP and other similar methods acted as a basis for this decision making procedures. Some operations that can improve a service under this model are agents exchange and addition of service contents (Sakao and Shimomura, 2005).

Another application of the service explorer CAD method by Shimomura et al. (2007)* helped in redesigning the services offered by a global warehouse manufacturer. The core objective was the development of a service in terms of supporting customers' material handling operations.

There is another method which offers service evaluation in the form of combining the benefits of the "Service Explorer" method, in terms of the service design modelling, integrating the same concepts and principles, along with a lifecycle simulator for testing the service with the current market conditions.

"Integrated Service CAD and lifecycle simulator" (ISCL) is a design method for systematic design of Product Service Systems. It consists of two modules. The first one, the Service CAD supports the generation of alternative PSS designs based on the concepts of service modelling. The second, the lifecycle simulator, analyses the economic effects and environmental performance of services from a holistic perspective because it takes them into account from initiation to termination. This method can be sought as similar to other CAD/CAE methods for product design where designers define models of products by modelling their geometry and analyse the performance of each design through computational means. It has been successfully applied to PSS such as functional upgrading services where computer-embedded products need to be maintained by software upgrades or module replacements instead of replacing the whole system. The main goal of using such a method is for the manufacturer to cut down the maintenance cost and optimise the service's lifecycle cost by considering also the overall users' benefits. Another reason would be the identification of a service design layout which would also reflect the current market and technological conditions (Komoto et al., 2005)*.

Hara and Arai (2011)* have tried to model and simulate service processes as a design customisation method by combining the service explorer method and the applied signposting model along with service blueprinting. A case study to test this process involved personalised bags in terms of product lead time as a mean of customer expectation which gave the provider different strategies to try. Lastly they tested how customer satisfaction varies during the lifecycle of the service.

The case study was about a design customisation service of personalised bags. The goal was to evaluate the trends of customer satisfaction based on delivery times. Based on the results they gathered, which was the outcome of the simulation process, there was an indication that the over promise strategy worked well for all customer types that were tested. For an increase of customer satisfaction it was shown that an over promise on the actual delivery time could well do the trick.

Another method for modelling and simulating services was proposed by Makino et al. (2009)*. The method was called “interactive method for service design”. This method deals mostly with services that are heavily depended on human expertise and performance. The construction of the simulated model was based on ethnographic field observation. Then the model was validated by experts after looking at the results. During the design phase experts’ opinions played a vital role to reach the final design though this interactive process. Therefore the final design also reflected experts’ views. For a demonstration of the proposed design method Makino et al. (2009) applied it to simulate the ground aircraft operations at a large airport. The airport of choice was the Tokyo International Airport. The output of this method showed that the simulation could do well on the replication of the observed data of these operations. Moreover it demonstrated the usefulness of creating new design options. The increase of the available design pool did not hinder the process of assessing them for service performance improvement.

2.6.6 Coloured Petri Nets

Petri Nets are graphical methods that are being used for describing and analysing concurrent processes. These processes arise within systems that have many components. These graphics along with the rules for their coarsening and refinement were invented by a man called Carl Adam Petri (Petri, 1962). They also offer a graphical notation much like UML activity diagrams, service blueprinting, etc. The notations include choice, iteration and concurrent execution. What makes them different from other notations is that there is a mathematical background and definition for their semantics. There is also a mathematical theory for process analysis.

Tokens represent objects in the model. A petri net consists of two types of nodes: places and transitions. Arcs exist only from a place to a transition or vice versa. A place may have zero or more tokens. Their graphical notation is represented by circles for places, bars for transitions, arrows for arcs and dots for tokens. Properties of petri nets include sequential execution (tokens are executed in sequence), synchronisation (for multiple inputs, a transition will occur only when there are tokens at each of the input places), merging (occurs when tokens arrive for service at the same time), concurrency (gives the ability to model systems having distributed control while multiple processes (tokens) are executed concurrently in time) and conflict (if more than one token is ready to fire, it will lead to the disabling of other transitions) (Murata, 1989).

An extension to the original petri nets which were discussed above is called coloured petri nets (CPN). It combines the strength of the standard petri nets with the advantages of a high-level programming language. Petri nets provide the basics for process interaction while programming language gives the basics for data type definition and data value manipulation. Another difference is that tokens are differentiated by “colours”. Moreover is more concise than black and white dots of the standard petri nets model. That helps avoiding a lot of duplication appeared in the original petri nets form. A CPN is shown in figure 2-11.

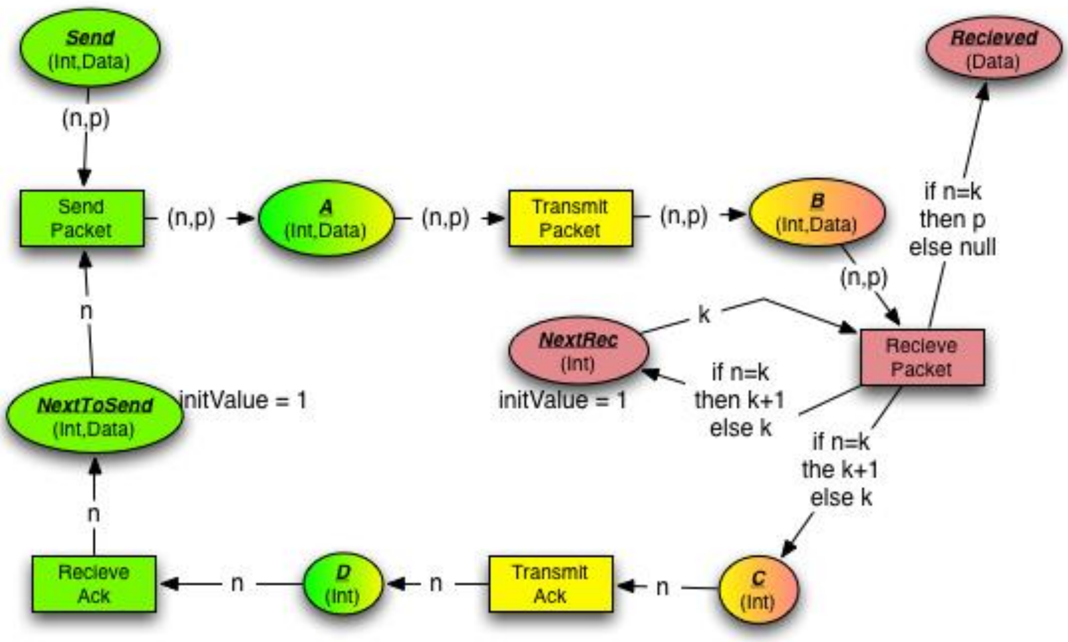


Figure 2-12: A CPN model

This type of petri nets has been used by Tian et al. (2004)* for modelling service engineering and a case was presented by modelling a popular service system. The service system is actually a restaurant. They used a modelling method called CPN-tools for this reason.

First of all there must be a clear understanding about the definition of service engineering in this context. This term has been used by some people (Tomiyama, 2001) in a narrower sense where the meaning is somewhat different from the one mentioned in Section 2.2. In this context a service is defined as an activity that can change the state of the service receiver and a service model consists of three sub-models: the scope model, the view model and the flow model (Shimomura et al., 2003). Moreover a computer-aided method called service explorer (Hara et al., 2004) has been developed as a representation method of the above model. It provides a network of parameters and can determine the relationships between them using weight evaluation techniques.

The considered restaurant service was comprised by four main processes: 1) a wholesale provider gave the raw materials (meat, spice, etc.); 2) customers came into the restaurant and evaluated it in terms of “sitting for having a dinner”. If they did so then they would order food and waited for serving, 3) the restaurant was going to cook food for them. Moreover it would provide a comfortable environment and maybe attractive music, etc. 4) lastly customers after eating their cooked food, would pay and leave. A hierarchical coloured petri net was structured by representing the flow relationships of wholesalers-restaurant-customers interactions. The processes 1) - 4) were depicted using substitution transitions: “provide goods”, “whether to eat”, “service of restaurant” and “eat food” respectively.

All in all coloured petri nets can be a convenient method for describing material and information flow relationships between service systems.

Another case study was conducted by Tian et al. (2007)*. A consumer electronics rental service has been modelled using a research framework for service engineering (Tomiyama, 2001) based on the coloured petri nets method. The goal was to represent the material flow information and deal with the parameters of the receiver (RSPs). As before, they used the CPN-tools for implementation purposes.

2.7 Research Gap

From the literature search several methods, processes, techniques, etc., have been identified. Information flow and availability is important when designing a service. Cost estimation of the service lifecycle is also important for the service provider along with providing customer satisfaction. Meeting customer demands and improving the service through system/service/customer interactions is a key element for increasing customer value and profit. Below several issues that have been identified in each of the strategies are presented.

TRIZ is a theory that can tackle problems and identify solutions at the technical and system level. However there are a number of drawbacks that should be taken into consideration. The inventive principles along with the contradiction matrix have to catch up with the vast technological diversity. Moreover there are difficulties connecting the theory with current production methods. Other arguments include the number of variables it has, the frequency inconsistency of using the principles and the high complexity of creating the matrix. It is mostly oriented to tackling engineering problems and requires highly trained personnel to accomplish the tasks.

The PDD approach offers a way to make a distinction between product characteristics for structure and components, and properties which describe the product's behaviour. On the other hand there are some drawbacks of this strategy. This approach can be either service-oriented or product-oriented chosen by the provider. Therefore a problem arises for the product developer on how to work-out the needed process. It could either by contacting directly the customer or the product owner. Another issue concerns the service lifecycle which is not taken into account. Lastly it is difficult for the provider to work out the hidden customers' requirements which should be included into the product's development process and thus may provide low customer value by trying to reduce its product cost. Also complete knowledge of the situation is needed.

The modularisation-based approach lies on the mass customisation movement where its ultimate goal is to give the providers a way to offer individual customised PSS offerings. Some deficiencies of this approach include the lack of integrating customer needs into the product development process which is more efficient than trying to map them into existing architectures (product and service). Complete information of the customers' requirements is needed to produce individual PSS offerings. Changes of the PSS during its lifecycle may not be possible although modules offer some flexibility. Lastly it may not offer high customer value and cost reduction for customers and providers.

QFD is a methodology which transforms customer demands to quality attributes and properties. Engineering characteristics for service or product can be defined by mapping customer needs. Ultimate goal of the methodology is to maximise positive experiences with products and services. Nevertheless some limitations arise when looking into correct conversion of the intangible information. There is an apparent issue concerning the proper identification of customer's requests between different societies. Different environments and cultures may have other needs and desires. Another problem is with the survey establishment. Misconduct and bad data can inflict potential damage to firms. Lastly peoples' desires may change rapidly while QFD depends on costumers' decisions over extended period of time.

Service blueprint relies on the service quality and customer satisfaction. It can be used to understand and describe service processes. Although this method can provide a comprehensive description of the service process it is not without some shortcomings. It typically looks at a service from a provider's perspective rather than a customer one while the actual blueprint tells the story of the observable actions or events. The latter requires the provider to project its individual perception of service delivery in order to fill that gap.

IDEF0 is a member of the IDEF group family which is a description technique system. In particular it is a method for specifying the static functions of manufacturing systems. There is a function model that shows information flow among objects and their functions. There are some drawbacks noted using this technique. It involves a static representation of the system (dynamic aspects are excluded). Moreover it has difficulty in understanding information flow between diagrams due to ambiguities in functional specifications. Lastly there is no real-time representation of sequences and activities.

UML is a unified modelling language for modelling business processes. Using the available diagrams people can specify, construct, modify and visualise objects which can then be used by developers to produce a system's architecture. In particular a use-case diagram produces a list of steps for interaction definition between roles and the system for achieving particular tasks. Although UML as a technique is popular, it has some disadvantages. Diagrams can be overwhelming / overcomplicated in conjunction with software development processes. Another problem occurs due to the significant emphasis on the design process which makes it hard for developers to use UML for problem solving. The over-analytic diagrams may cause delays in the actual work that needs to be done to fix the identified issues.

An interaction map is a mapping method of the actors in the system using different interacting scenarios. It shows the relationships (direct/indirect) between actors and the system. Disadvantages include an increase in complexity when complex services, relationships, behaviours and other factors have to be modelled in order to get a proper analysis of the social groups. Service lifecycle is not considered nor cost from the provider's perspective. Another point of deficiency is the focus to map needs to physical/system characteristics for problem solving based only on a human-centric reference. Without a system-oriented approach some needs or problems may not be possible to solve due to system's inherent limitations.

DES method is a simulation approach for system description in specific time intervals. It models a process consisting of a series of discrete events. Multiple entities are moving between different states as time passes. This method has several disadvantages. First of all in order to create running models, it would require special knowledge of understanding simulation concepts. Thus it can be a time-consuming learning process. Moreover, possibilities of creating models are endless. Therefore it is highly unlikely that models of the same system will actually be the same. Another negative factor to consider is the process of modularisation and reusability of produced architectures. Standardised packages often include their own components. Although most of them offer extensible capabilities the process could be hindered. Lastly this approach cannot deal with systems involving continuous processes where network externalities can affect their behaviour.

A Petri net is a graphical and executable technique for analysing concurrent, discrete-event dynamic systems. It models the information flow of concurrent interacting components using a graphical language. This method has limited capabilities with the management of the dynamic objects. Due to the static nature of a petri net it is very difficult to follow the synchronisation between two dynamic processes. By adding colours to the petri net, which essentially converts it to a CPN, could rectify this issue but again the number of colours (processes) has to be a finite number.

From the previous identified and presented issues, a summary of generic gaps concerning this research is provided below:

- Difficulties during implementation phase in the service design sector (TRIZ, PDD, UML, Interaction Maps)
- Problems in dealing with the dynamic properties of the service system (Service Blueprinting, IDEF0, Petri Nets, DES)
- Requirement of complete information and knowledge about the service system over extended time period (TRIZ, PDD, Modularisation-based approach, QFD)
- Service lifecycle is not considered (PDD, Interaction Maps)

2.8 Summary

This chapter has analysed the previous work in the service design area in order to provide a better understanding of service design practices and techniques that have been applied for service development alone or as a part of product-service systems. It initially provides generic information for setting the scene of the service field and subsequently of the service system. After that a brief discussion on the construction and rationale of the methodology has been highlighted. Following that thorough discussion of the work in the area of service design has been provided. Different service design theories, process models, methodologies and methods have been discussed. Based on the literature review the research gap in the service design domain was presented and outlined. A number of research gaps, which were revealed through the literature search, have been summarised.

CHAPTER 3

Research Methodology

3.1 Introduction

The aim of this chapter is to explain how the research was conducted and the research methodology followed. There are three sections in this chapter. The first section highlights the rationale of constructing the research methodology and the second explains the adopted research methodology. Finally a summary of the chapter is provided in the last section.

3.2 Research Method Selection and Justification

There are many research methods available in textbooks where each one follows a different purpose and structure. For the purpose of this research the methodology which was chosen is based on the following components. The research methodology breaks down into four distinct categories according to the purpose of each phase which ultimately leads to producing the required novelty.

The four sections are:

- Research purpose
- Research design
- Research strategy

- Data collection techniques

For each one of these four sections there are several methods available to conduct and accomplish the required tasks needed for this research. For example the research purpose can be decomposed to explanatory, exploratory and descriptive according to Robson (2002). Research design follows the same route which can be qualitative or quantitative according to Neuman (2003) and Robson (2002). The research strategy can be accomplished by several means such as biography, phenomenology, case study, ethnographic studies or grounded theory according to Creswell (1998). Lastly the data collection techniques can be composed of literature review, surveys, interviews, observations or documents according to Robson (2002) and Blaxter et al. (2010).

Each of these methods has its strengths and weaknesses. For this reason there is a rationale of choosing the method correctly suited for each of the categories. For the research purpose the method that was chosen was a combination of an explanatory and an exploratory approach.

The exploratory approach looks into several things such as:

- To investigate current situation.
- To pursue new understandings.
- To ask questions.
- To evaluate the situation under a new perspective.
- To generate ideas and hypotheses of the upcoming investigation.

On the other hand the explanatory approach looks the situation in a slightly different way that is more into putting the research in a specific context and involves the following:

- Provides an explanation of the situation which comes in the form of casual relationships.

- Describes patterns concerning the phenomenon under research.
- Recognises interactions between different aspects of this phenomenon.

The rationale for choosing this combinatory approach is based on the fact that service design is a rather new field and processes, methods, etc. have not been researched enough for the exploratory part. Therefore it is dominant at the initial research stage, whereas explanatory part becomes more relevant at the later stage of the research, where the author is clarifying the service design system.

For the research design phase the qualitative approach was used. The process of a qualitative research includes determining the problem by studying many past theories, addressing each of the identified problems and developing individual hypotheses accordingly, collecting data from experiments, social surveys or other means of data collection, analysing the collected data in order to reject or accept the hypothesis and lastly formulating the findings and combining them into a theory for circle completion (Bryman, 2005). Moreover this kind of approach aims to sketch the nature of the experiences and actions while putting them into a contextual manner in an effort to produce a detailed and integrated analysis (Liamputtong and Ezzy, 2005). The data involved into this type of technique are understood as data enhancers. That means they give insights into the inner processes of the developed system in question (Carson et al., 2001).

The rationale of choosing the qualitative approach lies into the realm of the exploratory approach. The overall research topic calls for further exploration in order to meet the objectives stated in Chapter 1, Section 1.4. Another reason is the attempt to identify the suitable service and process development enablers, a way of making a service system to meet certain goals which are crucial to the service clients and providers. Because of this need, qualitative data provide a wider and richer description which acts as an apparent motivation. Lastly, the lack of appropriate knowledge base in the service design domain due to its apparent newness (it is only around the last 10 years), which is more profound in the current state-of-the-art service methods, gives a reason to select this approach in order to investigate the insights more clearly.

For the third category, the research strategy, the case study approach was the most appropriate choice in order to act as a validation technique not only for the developed service system but also as a side step towards conceptualising and finalising this system. It gave insights as a mean of looking into and testing other theories and methodologies derived from the literature. According to Yin (2003) a case study is "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident". In layman's terms a case study research is an enquiry which focuses on describing, understanding, predicting or controlling a process, a group and a culture (Woodside, 2010).

The rationale behind the selection of the case study was based on the fact that service design is a relatively new field and there is no strong theoretical background in the service design research. This approach is more appropriate when research and theory are at an early stage of development (Blaxter et al., 2010). Another reason why the case study approach was suitable for the author's research purpose lies on the fact that it can capture the experts' knowledge and develop/extend theories from it. Lastly since the purpose of this research laid more on the exploratory side, a qualitative method has in turn been applied.

Last category features the data collection techniques. For this purpose a literature review has been applied ((Robson (2002), (Blaxter et al. (2010)). A literature review is a clear and reproducible way for the identification, evaluation and interpretation of previously recorded work from other researchers, scholars or practitioners.

Main goals of this technique are the following (Neuman, 1997):

- Creating credibility and exhibiting awareness of the knowledge body.
- Developing a connection between old and new research.

- Integrating and summarising the acquired knowledge in a particular area unique for this research.
- Learning from others and getting motivated by their own innovating ideas.

The aforementioned goals also give the reasoning for choosing this type of approach. It is also an efficient way of testing others' experimental data into new service design systems, validate and discuss the output, or validate other methods by reaching similar results and conclusions, in order to be able to use those methods as an alternative research route. Alternate methods include surveys and interviews. A survey is an information collection method where a questionnaire is being provided and filled by individuals, which represent a distinct population. On the other hand, an interview is another data collection technique where the researcher asks interviewees questions and analyses their response.

3.3 Research Methodology based on the Selected Methods

After identifying and justifying the adopted research purpose, research design, research approach and data collection methods, this section will discuss the research methodology process which involves the use of a literature review, methodologies and case studies leading to novelty, which is the service design system in question. The research process is composed of three phases. Each phase is going to be briefly discussed and a diagram will be provided showing how all three phases interconnect (see figure 3-1).

First phase is about understanding the context and current practices. It is about gaining understanding of the current practices of the service design field and providing a view on how these current practices can be amplified by adding dynamic elements into the current state of the service design methods. For this to be accomplished an extensive literature search was established. A review process of all the current service design methods was conducted on many different method branches, deriving from a unique approach to the service design problem, to metaphors taken from other established fields, and to general methodologies and techniques which can be applied to a broad field range, thus making them multidisciplinary. In the area of the service design the main goal was to identify which, out of this vast majority of different design methods, are the current state-of-the-art and are being used into the service sector. In particular research methods that have been developed following a bottom-up approach were the ones that made it into the conceptualisation and implementation of the service design system, which will provide the novelty of this thesis. The next step was to identify a possible methodology that provides these unique and dynamic properties, which are to be included into the developed service system, which consequently enhanced the current state-of-the-art of service methods. The beginning hypothesis was to provide a system that could capture a service scenario having dynamic changes while information is incomplete. This is the basic concept of most rental services that have been deployed and are focusing into a customer centric provision.

The extensive literature search by means of providing preliminary knowledge and acquiring enough data to perform a gap analysis involved more than 100 journal papers, conference papers and white papers. In addition case studies were identified which could be used as test beds for comparison and validation purposes. Analysis of all this data gave an immense insight on the role of the service design and the methods leading to the recognition of current issues and how potential improvements could be established. A comparative analysis on a case study was performed between these research service design approaches in order to identify the specific gaps that were at first identified in a more generic terms (based on analysis of the current literature).

The second phase involved the development of the service design system including the dynamic elements as an integral part of this methodology. During the first phase it was identified that state-of-the-art approaches do not include a dynamic approach that could take into account the changing behaviour of the customers and deal with situations where complete information is lacking. It was also recognised that the potential methodology, which is called emergent synthesis, could give such a solution and thus fill the identified gaps in the service process. Now in the second phase the effort was made to discover how the service design system could be developed from the above identified service development processes, the identified gaps and the potential methodology to deal with them. At first the comparative analysis between three established ground-up service design methods (Service Explorer, ISCL and Service Blueprinting) showed that only Service Explorer and ISCL had the potential to partly address some of the initially identified gaps. A connection was made after realising how input data of these two methods can be interconnected providing partly the required dynamic elements. From the beginning (customer requirements) to end (service lifecycle), a service system was formed as a holistic approach amending the identified design shortfalls. Service Explorer was used as an input process to feed the ISCL in order to provide a service lifecycle simulation according to prioritised customers' requirements. To complete the service system, emergent synthesis was used at the beginning of the previous process, which identified the potential customer requirements that could increase customer satisfaction.

Intermediate steps were also very important. The first crucial step was to identify a new method of implementing the emergent synthesis methodology which was required to bridge the gap. The method used in the literature had some shortfalls and another broader method (agent-based simulation language) was needed. Testing this ABS language, on a case study taken from the literature, and reaching the same goals after applying the required methodology, acted as a validation method. Therefore this novel method could now be used towards the development of the unified service system. The second important step was to identify a method that could be used to achieve correct diagrammatic representation of the case studies, and the modification that needed to be applied for the developed service system. That method was called SySML, which is a modelling language, a reduced form of UML suitable for systems engineers. It was also novel using this modelling language in a service design scenario.

To conclude, for achieving the unified service system, a broader method (ABS language) of describing and implementing the needed methodology was validated and a diagrammatic representation language (SySML) for service representation was established. Apart from the final service system, both of the intermediate steps were also unique and novel.

The third phase is concerned with the validation of the system which was done by means of a case study. The validation took place in two steps. At first stage only Service Explorer and ISCL were applied on a case study to extract their outputs. In second stage the unified service system was used to form a novel design process and again the output was captured using the same case study. Then there was a comparison between these two different outputs, which was demonstrated and analysed. It was then stated that the output of the unified service system, based on the derived results, was capable of achieving the aim of this research (Chapter 1, Section 1.4). All the data that was used for the validation process, which was part of the case study, was based on the literature search and/or chosen based on common knowledge following a logical process.

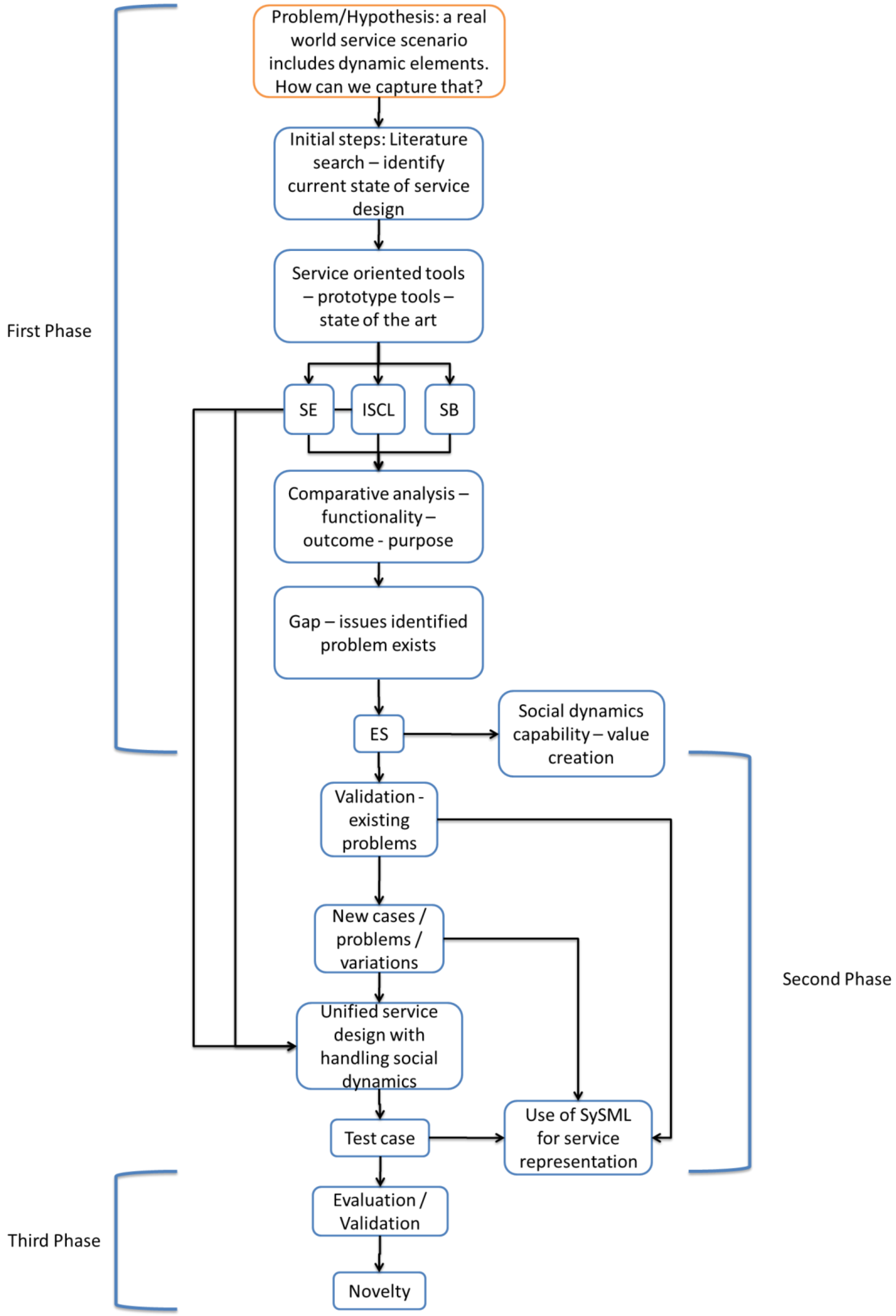


Figure 3-1: Diagrammatic representation of the adopted Research Methodology

3.4 Summary

This chapter outlines the research methodology that has been implemented to ensure that its design is appropriate to give an answer to the research questions posed at the introduction, and to attain its aim and objectives. It initially summarises the research overview which consists of the research purpose, design, strategy and data collection techniques. These four research sections have been outlined and their characteristics have been briefly provided. The chapter also presents the rationale for selecting a suitable research purpose, design, strategy and technique. Finally the adopted research methodology was explained, where each of the three phases were covered including "understanding context and current practices", "system development" and "system validation". Explanation of steps was thorough and an emphasis in the research was presented.

CHAPTER 4

Comparative Analysis of Service Design Methods

4.1 Introduction

Service provision can be seen as a complex interactive system which requires a lot of different techniques to effectively address the increasing difficulty of the system (considering the deployment scale). Many methods for this reason have been developed/ adapted (TRIZ (Low et al., 2000), modularisation-based design process (Aurich et al., 2006), PDD (Weber et al., 2004), IDEF0 (Morelli, 2006), etc.). The inherent limitations into these adapted methods lie within the constraints and metaphors that people derived in order to be used in the service domain. That is why prototype methods have also been developed in order to alleviate the limited functionality and the difficulty of addressing a variety of problems, and to increase customisation (Bullinger et al., 2003). Top-down and bottom-up approaches were used for service decomposition, identification and modelling of important service key aspects.

It is suggested that current development into these unique and prototype methods, is incomplete because they are unable to address the dynamic nature of the service within its life-cycle (Tatsunori et al., 2006), (Yuki et al., 2009), (Komoto and Tomiyama, 2008).

The aim of this chapter is to test the validity of these suggestions against current developed prototype methods and identify how well they satisfy or not the proposed dynamic features, which were gathered by looking into service building blocks, against a fundamental service scenario.

The chapter follows the structure which is mentioned below. At the beginning an introduction of these methods will take place. Because of the fact that there are no design concepts available especially for dynamic comparison, a different approach was established.

At first there is a brief discussion concerning the important generic service concepts where a service design approach should include. These have been identified by examining the literature and using all methods with different inclusive available examples (car rental service, wheel turning machine and business transaction processes). Secondly a rental service model was established to be used as a base for all methods. The application of this model showed the strengths and weaknesses of each method against the previously defined service concepts. In order to pinpoint the dynamic features of service design that were missing from the literature search, a recombination of these service concepts into higher categories took place under the premise of an emerging dynamic behaviour. These categories formed the missing dynamic features. Lastly a comparison and contrast of each method against these new features was established, ultimately showing that these methods are inadequate of capturing the dynamic role of a real-world service deployment.

4.2 Steps in Methodology

Task 1: Identify potential generic key concepts which are important and should be included in every service design system by examining the literature, methods' manuals and using the methods along with the provided examples. Moreover an explanation and description of every key concept is provided.

Task 2: Conceptualisation and design of a product/service case in order to be used as a base/measurement on how well each of the methods have implemented the above service concepts, what are the differences, the different approaches they used and if there is something missing or needs to be changed to provide better outcome (results). The need for conceptualising and designing the case reflects the metaphors that were captured from a real or reported case scenario.

Task 3: Separately identifying how a method implements a service key concept in general and what are the specifics (constraints) of this implementation according to the constructed example, and also stating the practical use and the real time outcome of that process.

Task 4: Regrouping of service concepts in a way that provides emerging behaviour to the service design. From this process four categories are formed which provide the dynamic features that form the basis of the following analysis which will be conducted. Comparison and analysis of the implementation (output) of all methods, identifying potential issues, gaps and places of improvement for a better fulfilment of these service features which will lead to a better service representation in a real world application.

4.3 Overview of Methods Specifically Developed for Services

Looking back into the literature several especially conceived ways/methods have been identified which can be used specifically for the design of services (Aurich et al., 2010). Some of them are based on the Service Engineering principles while others not (Aurich et al., 2010). The methods mentioned in the chapter are shown in table 4-1.

Service Design Methods	**Service Explorer (SE)** (Arai and Shimomura, 2004)**,** (Tatsunori et al., 2006)**,** (Arai et al., 2007)	**Service CAD - Life-Cycle simulator (ISCL)** (Komoto et al., 2005)**,** (Komoto and Tomiyama, 2008)	**Service Blueprinting (SB)** (Lynn Shostack, 1993)**,** (Bitner et al., 2008)**,** (Boughnim and Yannou, 2005)
Brief description of the methods	*Service explorer is a service design method, a service modelling method. The creation of this method took place in the University of Tokyo.*	*The ISCL is again a service design method, a service modelling method including a life-cycle simulator. The creation of this method took place in the TUDelft University, Netherlands.*	*Service Blueprinting currently is a specification standard which has been used for process analysis and modelling purposes. Currently is maintained under the Object Management Group (OMG) group.*
Detailed description of the methods	It is based on the Service Engineering concept. Service design looks into both physical and non-physical structures but the main difference from traditional design lies on the evaluation measures. The design was based on the receiver's satisfaction level that is depicted by a change in its state. Thus state changes should be expressed by the received contents. Their proposed model	It supports service design and it is also based on the Service Engineering principles. The service modelling part of this method supports the service design by finding and suggesting optimal activities (functions) for achieving customer satisfaction based on customer's requirements. The life-cycle simulator (LCS) looks into the product element of the service in order to evaluate the life-cycle cost of the service	It is a customer-focused approach for service innovation and improvement. It was proposed by Shostack (Lynn Shostack, 1993), and since then has evolved significantly and is currently been used as a useful approach for addressing many challenges concerning service design. Blueprints are mainly customer-oriented and companies can visualise service processes and customers'

	consists of receiver's state, flow model, view model, scope model scenario building and lastly evaluation process.	which would be the ultimate assessing factor judging between various different service designs. It consists of two modules: Service CAD and LCS.	interactions. They can also be extended to collect customer feedback from its service usage.

Table 4-1: Description of the Service Design Methods

Generic outcome/output and brief description of each method is being shown in table 4-2.

Service Design methods	**Service Explorer (SE)**	**Service CAD - Life-Cycle simulator (ISCL)**	**Service Blueprinting (SB)**
The outcome / output of each method.	The intended outcome for this method is to identify the most important parameters for each service interaction that would affect customer's satisfaction. It works by calculating which customer's requirements are the most important for the customer based on weight evaluation and other criteria in order for the company to provide	First of all the outcome of the service CAD is to identify/generate activities which would fulfil the specifications provided by the customer taking into consideration that the service environment is able to execute the derived activities from an available service pool. New service models can be created by combining several of the available activities which are included in a predefined pool or the designer can create new activities for future	The outcome of the SB is to show the customer/service interactions and perform analysis for potential future improvement in the process efficiency. Several extensions on this method exist which are capable of making predictions during different periods of time concerning detection of process flaws, evaluation of different process scenarios, etc. Moreover feedback from the user can be

	more of its available resources towards fulfilling these first.	integration in new service models.	expected in order to have an initial estimation of the process flow within a service system.
		The LCS is capable of calculating, by acting as a prediction method, appropriate functional upgrading service which in the end will minimise the life-cycle cost of the service. This prediction can also incorporate various market conditions and constraints representing future company needs (resource availability, profitability and cost). That also will play the assessment factor for evaluation between various service models.	

Table 4-2: Description of the outcome/output of the Service Design Methods

4.4 Results

4.4.1 Task 1: Identification of Service Design Concepts

As mentioned before, all previous methods have been used as research/especially conceived methods for designing services. First of the all service concepts that reflect a service have to be captured. These concepts are also important for service modelling purposes. By gathering information from the literature search (see chapter 2, sections 2.6.1 and 2.6.5) along with guidelines, manuals and the actual methods, which were supplied by the corresponding research teams (see section 4.3), and also by using these methods in several examples (see section 4.1) the following service concepts were identified.

Each feature and explanation of it is shown in table 4-3.

Main key features for Service Design	**Features**	**Description of each feature**
1	Modelling of agents	Agents here represent customers and customers' specifications.
2	Definition of scope	The scope involves the interactions between different entities within the service model.
3	Building of scenarios	Customers' scenarios are important within a service. These scenarios show different customer behaviour while using the service and its activities.
4	Analysis of functions	Functions here represent the decomposition of the activities, which represent the interactions of the service.
5	Evaluation of the service	Important aspect for the assessment of the service in terms of its performance, life-cycle cost, etc.
6	Simulation and prediction of the service life-cycle	This can be included in the "Evaluation of the service" feature but it is important to separate it because that will stand as the most important

		factor for deciding whether a service is better than existing models.
7	Analysis/modelling of the service processes	Every service consists of processes. These processes form a linear route within the service and must be modelled and assessed within real-time scenarios for identification of potential flaws or possible tweaks that will increase performance/throughput of them. It could be included in the "Simulation and prediction of the service life-cycle" feature but some methods lacked a lifecycle simulator thus different levels of implementation were established.
8	Interactions between customers and services	It shows in what ways customers can interact with the service. Customers can then provide feedback for service improvement according to their expectations, needs fulfilment, etc.

Table 4-3: Key service design concepts along with a brief description

These elements were identified and knowledge was gained by using all previous methods to a service model representation. The example being used is a common rental service having as a core product a washing machine. The service provision is washing clothes or purchasing washing machines.

Below a comparison of all methods will be demonstrated in terms of the previously identified service concepts. The comparison is not to identify which of these is better than the rest but only to show which of the concepts have been implemented and are included into these methods, and the difference between implementations in the case of common concepts. The outcome of this analysis is to identify potential gaps and issues in all methods that have not been encountered yet and are important during the service life-cycle.

4.4.2 Task 2: Design and Development of the Rental Service Example

The design and the development of the following example derived from a similar example that was given with the Service Explorer software and was adapted to be used with the other two methods. It is based on a real world test case scenario which is the renting of washing machines or purchasing them in order for the customer to get its clothes cleaned which is the intended outcome of the service.

In this service scenario three entities were called which consist of the machine manufacturer, the potential reseller and the customer as seen in figure 4-1. An extension would be to add the potential environmental impact of the service in order to assess the sustainability of a future scenario, or to add more manufacturers, resellers or even customers with different priorities.

The function or the functionality of the service falls into two categories again chosen having in mind minimal complexity. These consist of renting a machine to the potential customer/ user of the service or the customer purchasing the machine through a reseller. For the former, all services (e.g. maintenance) apart from the machine's utilisation are the manufacturer's responsibility. In order to achieve better clarification of these functions the customer can either use a washing machine in certain public places which are being kept by the manufacturer or taking the machine home for internal use.

In the first case the manufacturer does the service provision of washing clothes and that will be the output towards the customer. The customer pays only for accessing the washing machine and has its clothes cleaned while the manufacturer is responsible for everything else. In the second case the customer pays for having its washing machine in its own place, using it but the manufacturer is only responsible for fixing it. In the second case of course the responsibility of the customer is greater than that in the first case (where it only has to pay for the service function). On the other hand in the second case the customer may have a more customised solution for its needs and requirements.

The end goal and outcome of this service model is to increase customer satisfaction and that will in turn increase profit for the other entities of the service.

For a schematic representation of the rental service model see figure 4-1.

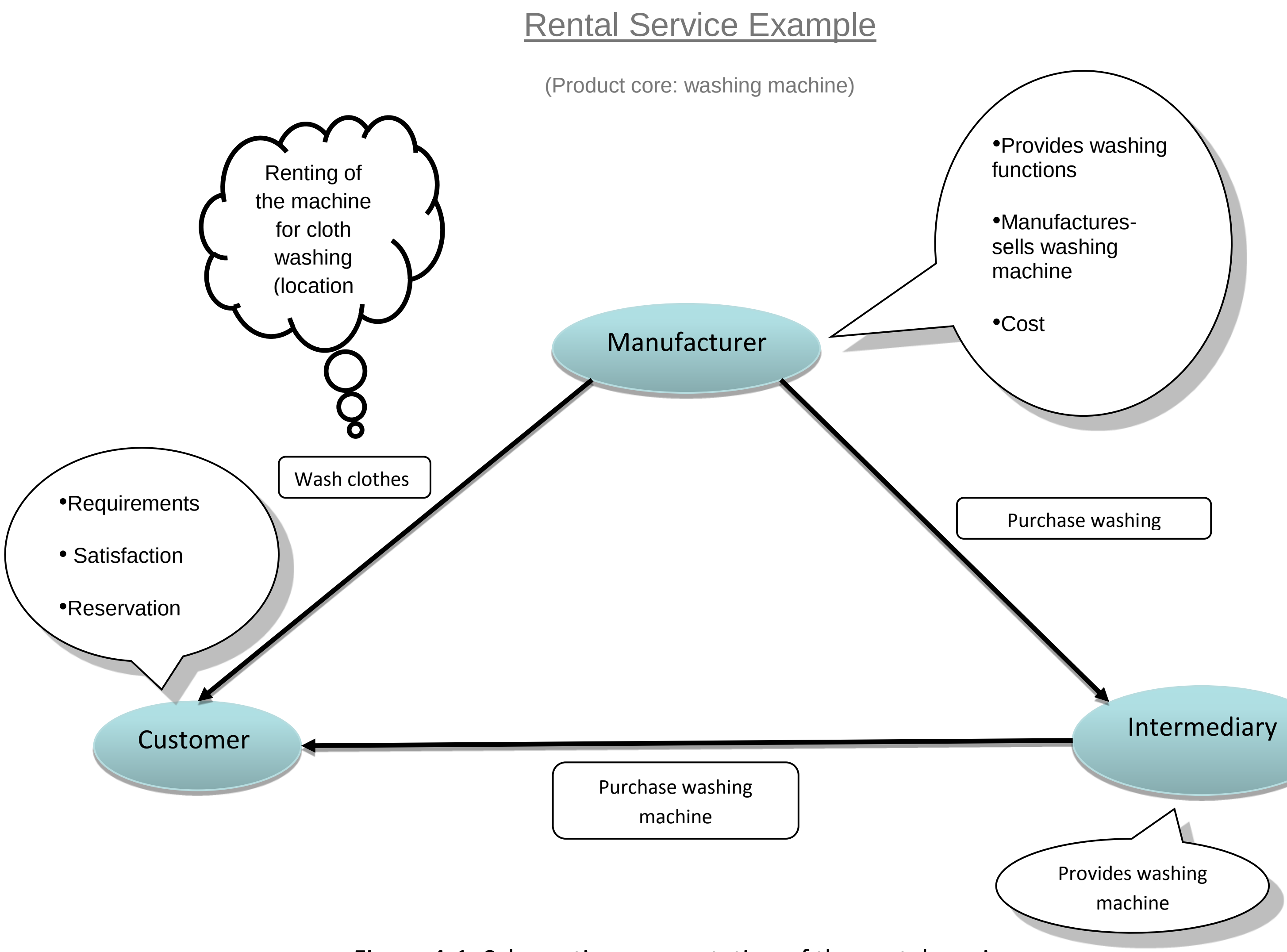
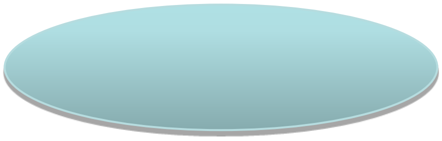
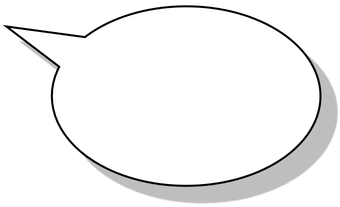
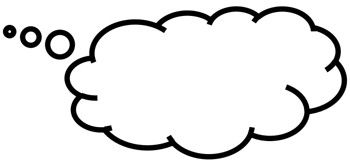


Figure 4-1: Schematic representation of the rental service

Key:

Figure	Description
	Entity
	Direction of entity interaction
	Function provision to an entity
	Available functions of an entity
	Description of a function

4.4.3 Task 3: Comparison of Service Design Methods

Feature 1: Modelling of Agents

Table 4-4 shows the comparison between different implementations of feature 1 against all methods. Figure 4-2, 4-3 and 4-4 show how each method implements and represents customer's specifications in the rental service example.

Modelling of agents	**Service Explorer (SE)**	**Service CAD - Life-Cycle simulator (ISCL)**	**Service Blueprinting (SB)**
Description of the generic modeling method	Data from the customer/agent define customer requirements. Customer requirements are parameters in the design process.	Data from the customer/agent are modeled into the service system and define the requirements that need to be met by certain activities.	People (virtual agents) are not involved in the service design process. Their only involvement is at the start/ end point of the service processes and throughout the process interaction.
Description based on the current example and how this applies	In the case of the rental service customer requirements can be the size of the washing machine, operation cost, time of washing, ease of functionality, etc. Different requirements exist for different service provisions.	More or less the same also stand for the ISCL. It has a bit different requirements like the ownership of the washing machine, the newness of the washing machine, etc.	For example customer would purchase a washing machine and wash its clothes or it would use the service provision for washing its clothes in washing machines that are available by the manufacture. This would end the service cycle for the customer.

Table 4-4: Assessment of the agent modelling feature

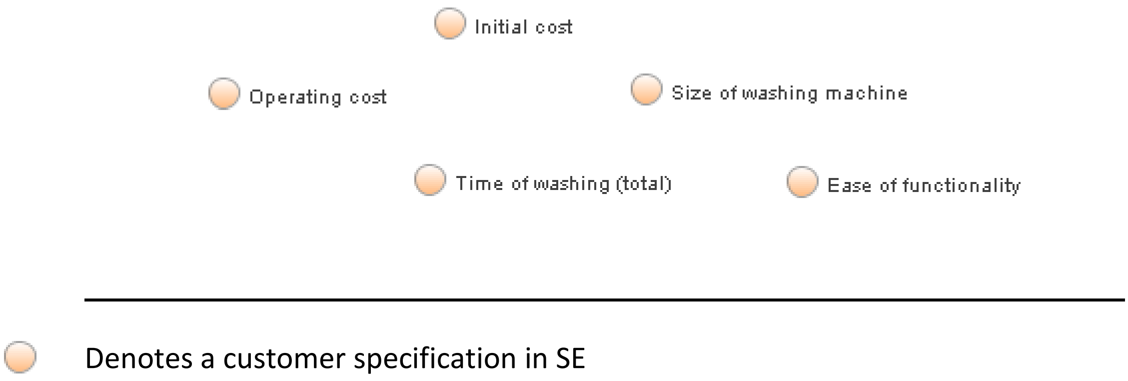


Figure 4-2: Customer requirements as shown in SE

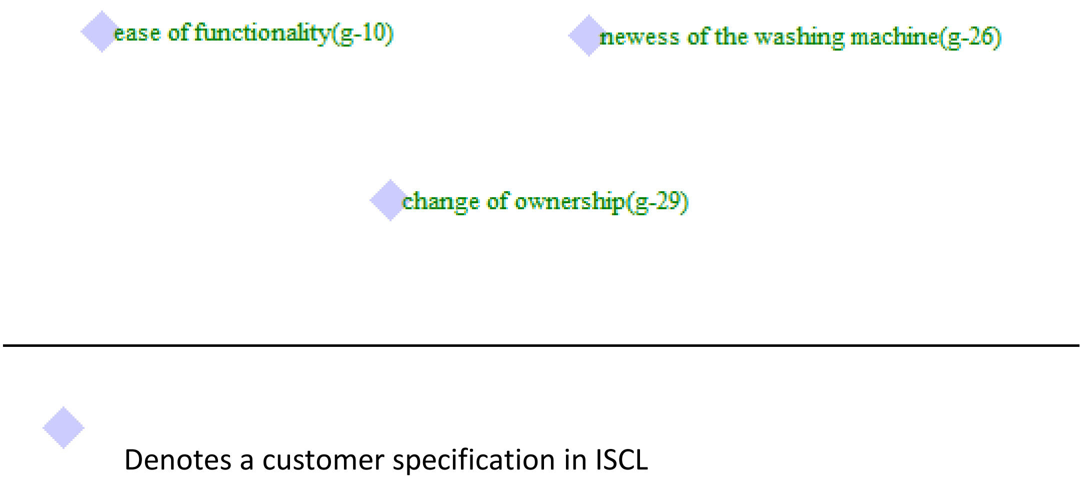
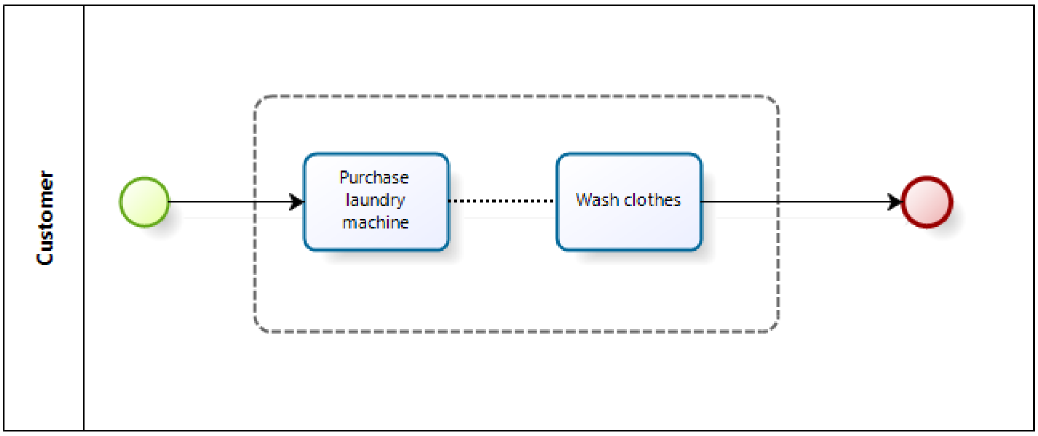


Figure 4-3: Customer requirements as shown in the ISCL



Key:

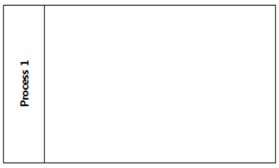
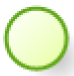
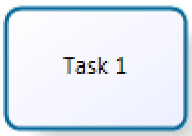
Figure	Description
	A pool represents a participant in the process (entity)
	Represents an informal grouping of entity's functions.
	Start of the process
	End of the process
	Tasks of the process represent functions
....	Denotes association between different functions

Figure 4-4: Agent representation in SB

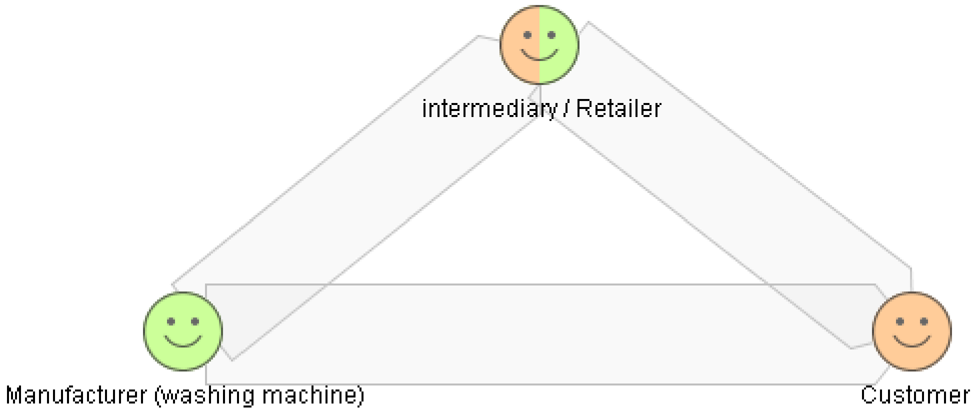
Feature 2: Definition of Scope

Table 4-5 shows the comparison between different implementations of feature 2 against all methods. Figure 4-5, 4-6 and 4-7 show how each method implements and represents the scope of the rental service which also indicates the service environment of this particular service.

Definition of scope	**Service Explorer (SE)**	**Service CAD - Life-Cycle simulator (ISCL)**	**Service Blueprinting (SB)**
Description of the generic modeling method	Defines service interactions between different entities. Entities can be service provider, receiver, intermediary, environment, etc.	Scope is defined between different entities while arcs (arrows) show the direction of the service content between entities and service activities.	There is not such clear definition of the scope and its subcomponents. The entities are composed by processes but functions are following a direct order of events from beginning to end in the form of activities, which are called pools.
Description based on the current example and how this applies	In the rental service, entities include the manufacturer, the intermediary and the customer. The representation of these relations and the interactions of the service provision are being represented in	In the ISCL the service interactions are being given in the form of activities which are the service functions and the entities with which they interact. Entities are the same seen in figure 4-1 including the labour (engineer) for the washing machine. All start from an initial state and they have a linear progression following a discrete-event simulation	So in this case one would have the customer and the manufacturer as separate entities and the interaction between them would be one way from start to end. The manufacturer would provide the service for washing clothes and customer would get its clothes washed.

	figure 4-5.	(DES) model. The included activities are the ownership, use and maintenance representing the purchase of the product or the service provision by the manufacturer (washing clothes). The inclusion of the maintenance activity corresponds to the labour entity (see figure 4-6).	

Table 4-5: Assessment of the scope definition feature



Key:

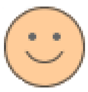
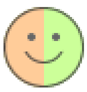
Figure	Description
	Entity (service provider)
	Entity (service receiver)
	Entity (intermediate agent) (service provider and receiver)
	Shows the direction of service interaction between different entities

Figure 4-5: Scope representation of the rental service

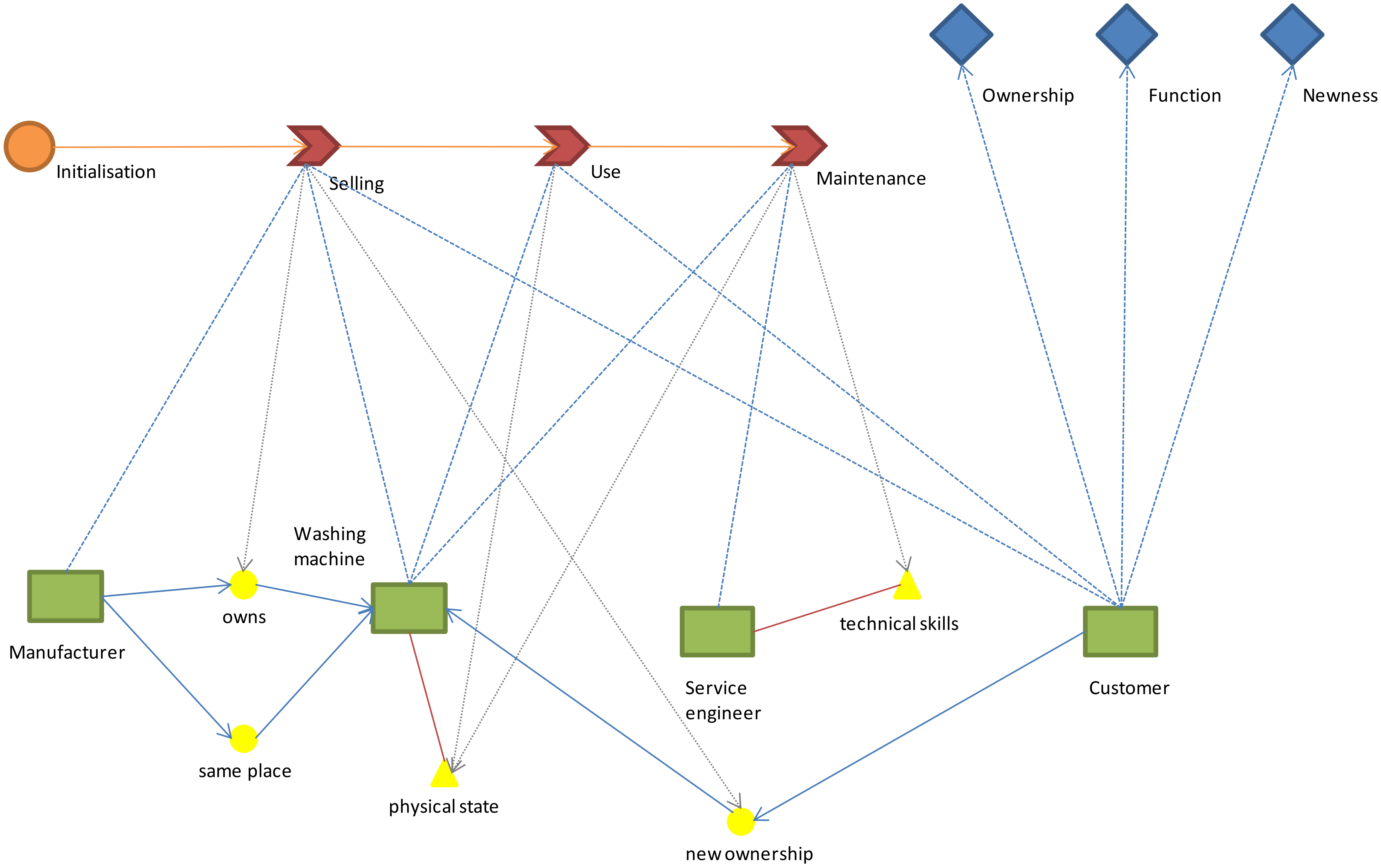
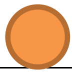
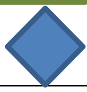


Figure 4-6: Scope representation of the rental service in ISCL

Key:

Figure	Description
	Initialisation of the service
	Activities (functions)
	Entities
	Specifications
	Properties (states)
	Attributes of entities

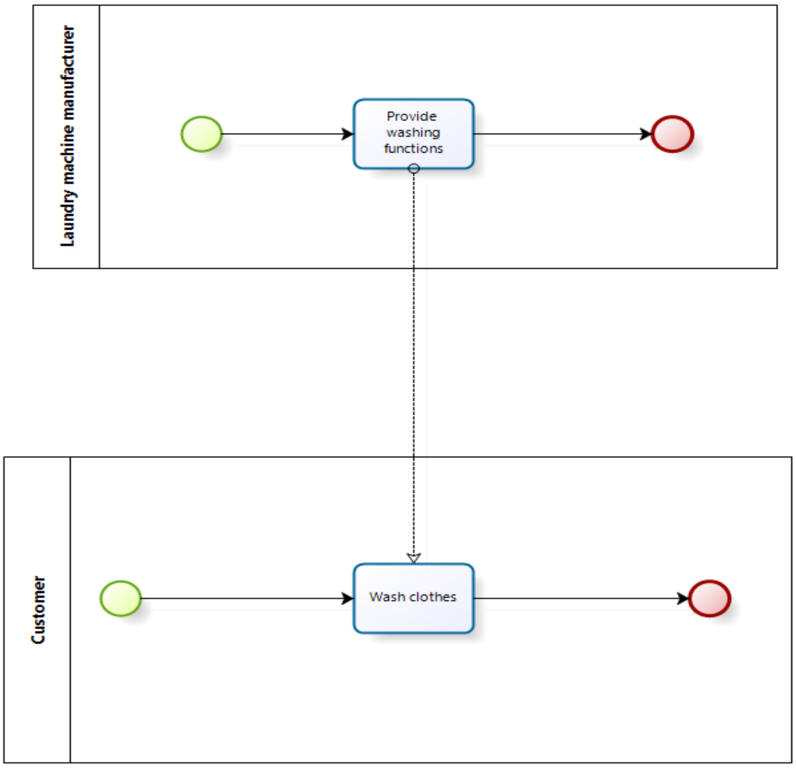


Figure 4-7: Scope representation of the rental service in SB

Feature 3: Building of Scenarios

Table 4-6 shows the comparison between different implementations of feature 3 against all methods. Figure 4-8 and 4-9 show how each method implements and represents a customer's scenario based on its initial specifications according to the rental service example.

Building of scenarios	**Service Explorer (SE)**	**Service CAD - Life-Cycle simulator (ISCL)**	**Service Blueprinting (SB)**
Description of the generic modeling method	Each agent has a scenario of sequential actions.	Activities take a sequential form from start to end and each of the customer's requirements is fulfilled in the process.	There is no such functionality. Functions are included within the entities (pools) and follow a sequential order.
Description based on the current example and how this applies	For example in this case a customer first uses the service provision of washing functionality but then it purchases a washing machine. Another case would be the purchase of the washing machine and the provision of a maintenance service by the manufacturer.	In the case of the rental service start from left to right, from the initialisation the selling, use and lastly maintenance. (This is the scenario modeled using the ISCL method)	

Table 4-6: Assessment of the scenario building feature

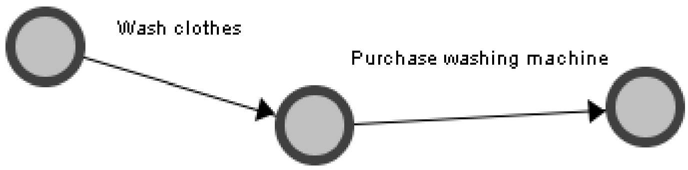


Figure 4-8: A representation of service activities deriving from customer requirements in SE

Key:

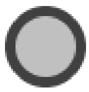
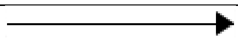
Figure	Description
	State representation of sequential actions
	Direction of customer actions

Figure 4-9: A representation of service activities in ISCL

Feature 4: Analysis of Functions

Table 4-7 shows the comparison between different implementations of feature 4 against all methods. Figure 4-10, 4-11 and 4-12 show how each method implements and represents activities (functions) in the rental service model which are comprised of sub functions. That indicates how each activity is analysed into deeper levels in order to be evaluated accordingly.

Analysis of functions	**Service Explorer (SE)**	**Service CAD - Life-Cycle simulator (ISCL)**	**Service Blueprinting (SB)**
Description of the generic modeling method	Each of the service interactions are decomposed into parameters.	Each of the activities is decomposed into smaller models which interact with the product core of the service and its properties.	Processes are decomposed to sub-processes but all are following a sequential order from start to end point. Each process is unique.
Description based on the current example and how this applies	For example in the rental service, one of the customer requirements, e.g. how easily the washing machine can be operated, is being decomposed into several functions such as the order of operation steps, improvement of the machine interface, etc. Then each of the functions has its own attribute like	So in this example if we take the service provision, purchase of washing machine, then the function decomposition again follows similar route. It decomposes in the activity of selling which connects with the entities: reseller, customer and product (washing machine). The purchase takes	So below is the analysis of the payment function to the manufacturer for using the washing machine as a service provision. First is the request of the service, then confirmation of service availability. Then there would be a transfer request of the money, approval, provision of a

	the number of the operation steps, buttons, etc. Then these functions connect with the hardware which in this case is the washing machine and its attributes.	place by changing the state of the washing machine from old ownership to new ownership.	notice that the transaction completed successfully and lastly the outcome would be the use of the service which in this case is the use of the washing machine.

Table 4-7: Assessment of the function analysis feature

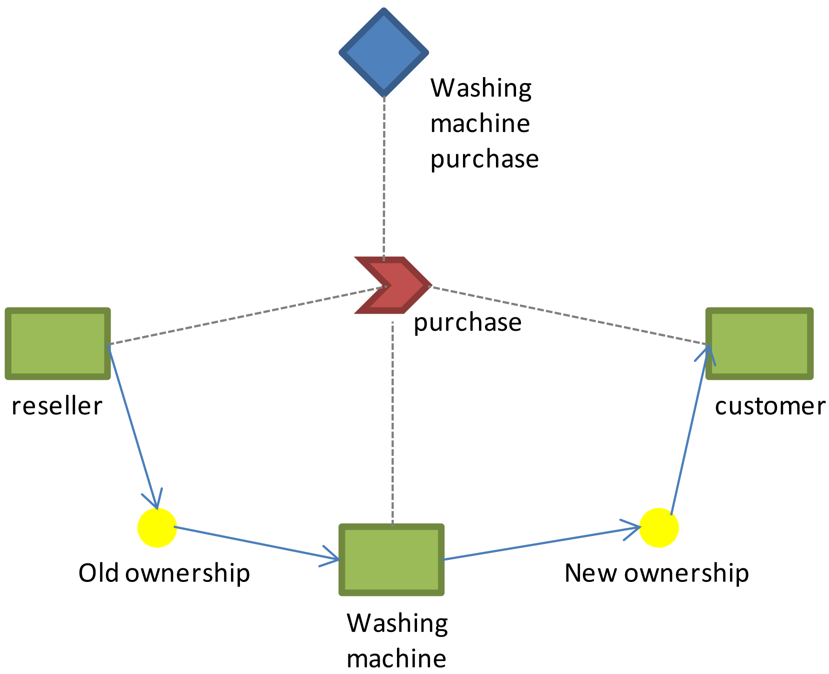


Figure 4-10: A representation of service activity (selling) in ISCL

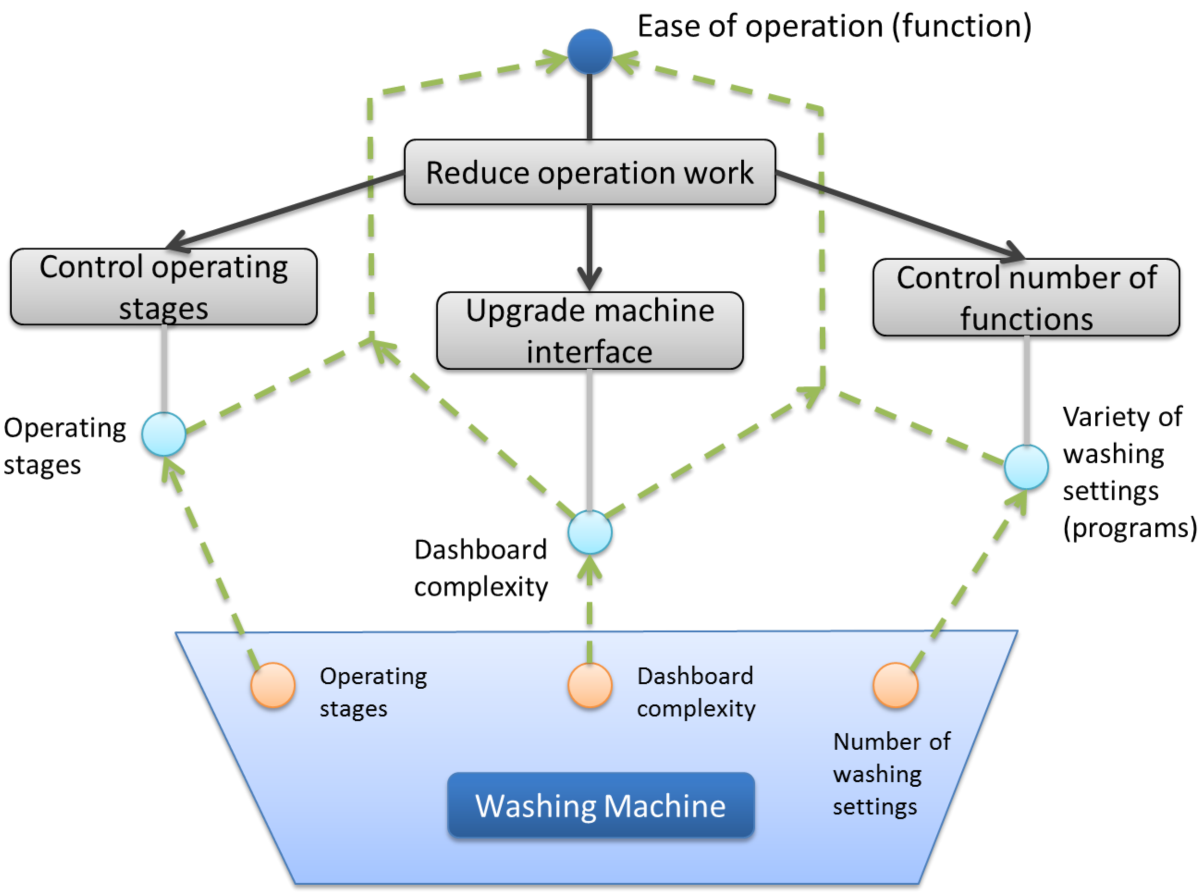


Figure 4-11: A representation of service activity in SE

Key:

Figure	Description
	Attributes of the product
Washing Machine	The product (washing machine)
	Attributes of the sub functions
Upgrade machine interface	Sub functions of the activity
	The activity (function)

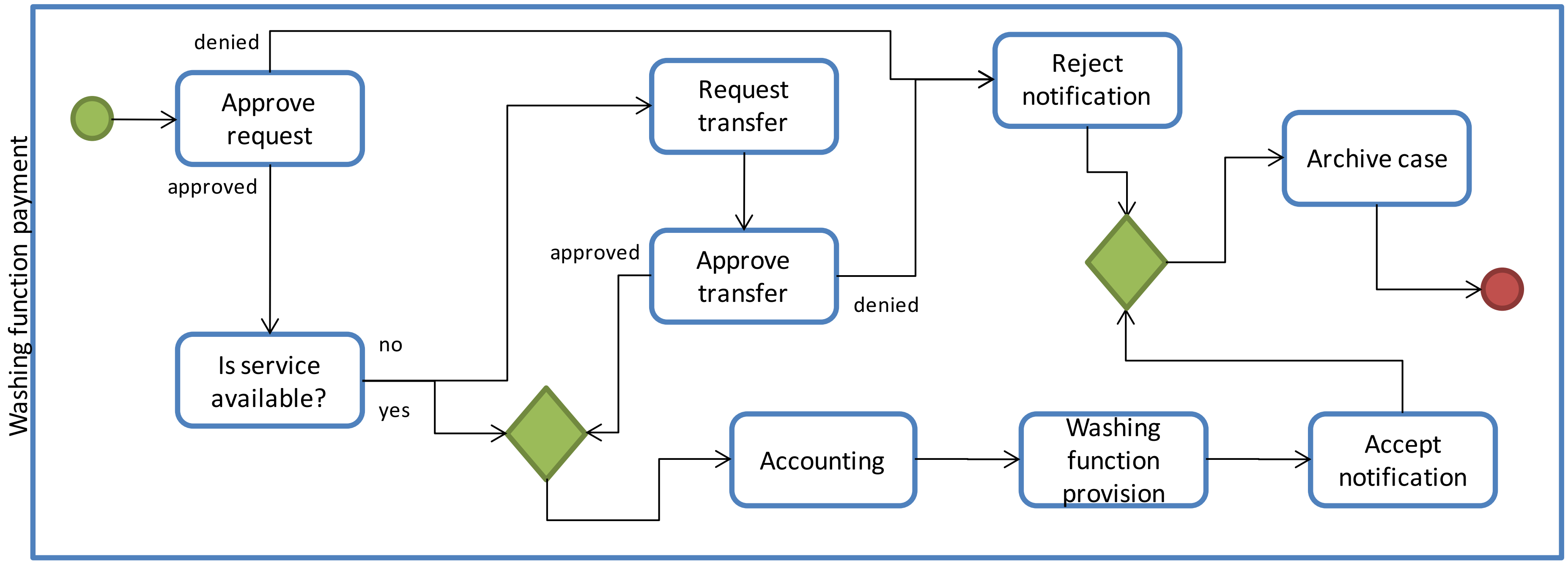
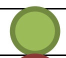
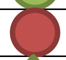
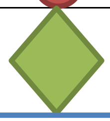
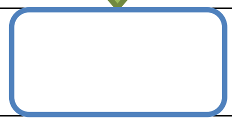


Figure 4-12: A representation of service process (transaction of the selling activity) in SB

Key:

Figure	Description
	Start of the process
	End of the process
	XOR Gate
	Tasks of the process

Feature 5: Evaluation of the Service

Table 4-8 shows the comparison between different implementations of feature 5 against all methods. Figure 4-13 show how an evaluation of the rental service in terms of customer's requirements is performed. Acquired data for implementing the service evaluation process in SE were provided by the research team which developed this method (see section 4.3).

Evaluation of the service	**Service Explorer (SE)**	**Service CAD - Life-Cycle simulator (ISCL)**	**Service Blueprinting (SB)**
Description of the generic modeling method	Through various methods (QFD, AHP, etc.) weights are being assigned to each of the parameters and a prioritisation is being conducted according to customer needs.	The evaluation procedure follows different algorithms, one which suggests the best available activities that fulfil customer's current specification and one for evaluating the current status of the service provision (detection of balancing problems).	There is no evaluation.
Description based on the current example and how this applies	After setting the weights according to what customer wants one gets a prioritisation of the requirements (specifications) in order for the manufacturer to know what is more	So here one has, for example, that in order for the service provision of purchase to get fulfilled, a selling activity is suggested by the method that will fit into the main model and	

	important for the customer and balance its resources accordingly.	accomplish that provision.	
Outcome of service modeling methods based on the current example	So one gets for example that the reliability of the washing machine is the most important parameter of the service provision.	By evaluating the current model, then after the selling activity takes place, the model may suggest that a maintenance activity has to be called upon for achieving reliability of washing machine and the service provision in general.	

Table 4-8: Assessment of the service evaluation feature

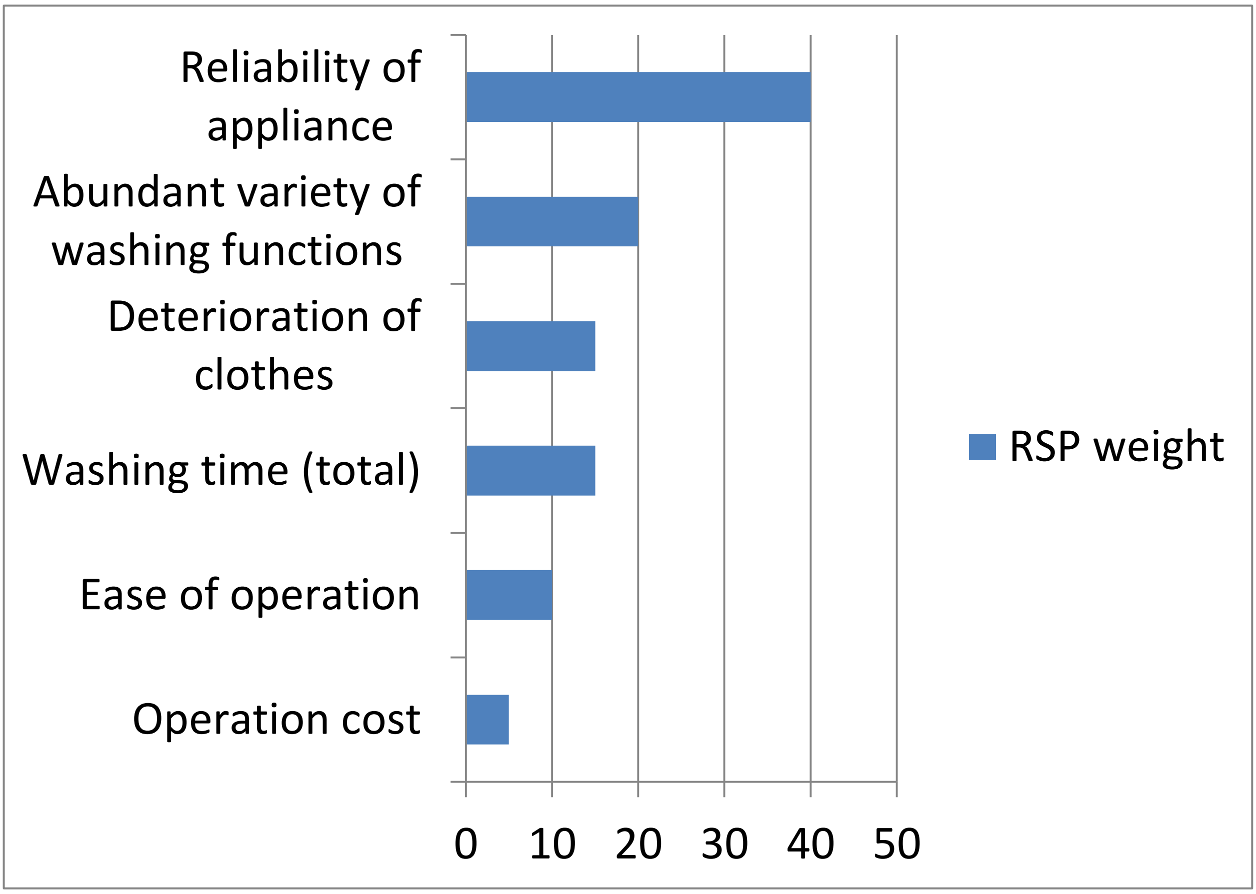


Figure 4-13: Evaluation of individual customer requirements and identification of the most important one in SE

Feature 6: Simulation and Prediction of the Service Life-Cycle

Table 4-9 shows the comparison between different implementations of feature 6 against all methods.

Simulation and prediction of the service life-cycle	**Service Explorer (SE)**	**Service CAD - Life-Cycle simulator (ISCL)**	**Service Blueprinting (SB)**
Description of the generic modeling method	There is no such module available.	LCS provides a holistic view of the service as a service model because it integrates a life-cycle simulation into the service design process. The evaluation gives a performance measure of the service model.	There is no such module available (although using extensions, simulation of the processes for a certain period of time is possible for process improvement).
Description based on the current example and how this applies		In the rental service, it calculates the need for the maintenance activity to be called upon and the spare parts that may be needed for fixing the machine, etc., and gives a prediction of the life-cycle cost in a period of time. Then one may change some variables in order to try to decrease that	

		cost or assess this model against current or predicted economic situations.	

Table 4-9: Assessment of the service life-cycle simulation feature

Feature 7: Analysis/Modelling of the Service Processes

Table 4-10 shows the comparison between different implementations of feature 7 against all methods.

Analysis/modelling of the service processes	**Service Explorer (SE)**	**Service CAD - Life-Cycle simulator (ISCL)**	**Service Blueprinting (SB)**
Description of the generic modeling method	There is no such functionality.	There is no such functionality.	Processes are thoroughly analysed and are checked for consistency through a web or other interface (using extensions) and can be analysed in terms of identifying which of them are at risk.
Description based on the current example and how this applies			For checking the transactions within the service provision the processes can be visualized and evaluated in terms of consistency,

			customer feedback, etc., and thus improved incorporating knowledge from pilot programs and test cases.

Table 4-10: Assessment of the service process analysis feature

Feature 8: Interactions between customers and services

Table 4-11 shows the comparison between different implementations of feature 8 against all methods.

Interactions between customers and services	**Service Explorer (SE)**	**Service CAD - Life-Cycle simulator (ISCL)**	**Service Blueprinting (SB)**
Description of the generic modeling method	It does not show how the customer interacts with the service in the level of function/ implementation of customer satisfaction.	It does not show how the customer interacts with the service in the level of function/ implementation of customer satisfaction.	There is customer interaction with the service because the whole process involves the customer in various steps and it gives one the ability to see the interaction as the process progresses.
Description based			Interactions of customers and

on the current example and how this applies			other entities (manufacturers, resellers, etc.) can be represented (for communication purposes) in a visual way through an interface, which involves some processes of the service, while having actual customers using the pathways for sending and receiving information. One can also depict the information flow and test the validity of the actual process.

Table 4-11: Assessment of the customer-service interaction feature

4.4.4 Task 4: Analysis outcome

After the analysis of the concepts and their implementation, a summation process was conducted for the creation of the needed dynamic features. This process involved regrouping/recombining the tested concepts into 4 categories where each one represents a dynamic feature and better depicts, according to the author, the dynamic side of a service (table 4-12). The rationale behind this is to bring forth specific dynamic features of the service design which previously were missing from the literature. This will give the ability to assess the capabilities of the methods in a higher service level, which represents dynamic behaviour. Individual service concepts are too generic but merging them together, one could see the dynamic features in the service design process.

Service dynamic categories	**Service features**
Multiple customers-interaction modelling	Building of scenarios Interactions between customers and services
Capability of dealing with external parameters / factors	Definition of scope Modelling of agents
Automatic reconfiguration according to current needs and available resources	Evaluation of the service Simulation and prediction of the service life-cycle
Generation of models capability	Analysis of functions Analysis/modelling of the service processes

Table 4-12: Regrouping of the previous 8 service concepts into 4 categories (features) where dynamic service representation emerges

From the above summation of the concepts and their implementation, in each method, a comparison was conducted according to the level of implementation of each feature which pinpointed possible open issues as shown in table 4-13.

Open issues	Service Explorer (SE)	Service CAD - Life-Cycle simulator (ISCL)	Service Blueprinting (SB)
Multiple customers-interaction modelling	Unable to model multiple customers (service receivers) to a certain degree. In SE one assesses individually each of the customers for a prioritisation of its specifications. Although this is true, specifications from multiple customers can be combined together and assessed as a whole, and therefore achieving in prioritise them. The problem lies that these are known a-priori and can be applied only to a few. Also service scenarios are fixed.	Again In ISCL one takes all customers' specifications and tries to fulfil them without any prioritisation. Requirements are known a-priori and few stakeholders participate. Also service scenarios are realised from the beginning.	Having multiple customers interacting with each other, and with the service itself, is something that is currently lacking. In SB one also has a linear process for each customer without any other interaction. In fact processes follow the same principles and thus are considered the same for every customer.
Capability of dealing with external parameters / factors	External parameters which can indirectly affect the service are not included. The service environment is considered as a closed one.	In all cases the service environment is considered semi-open. That means that everything is known from the beginning but the service can deal with sudden changes during its lifecycle process. The scope of the service is fixed. One may have	None

		external factors which can expand this, like other customers using the service, other entities approaching, which can then connect to the network, etc.	
Automatic reconfiguration according to current needs and available resources	Lack of addressing dynamic changes in terms of automatic reconfiguration/redesign. The evaluation that takes place is only for identification of the most important customer requirement but there is no other means of evaluating the service in a long term scenario.	There is an evaluation function of the service current state and a simulator during a pre-defined time period but the initial resources are fixed. Also there should be a way to handle changes automatically by reconfiguring itself or service redesign in such a way that will satisfy more customers. Moreover there may be increased competition for multiple resellers or other manufacturers of the same service provision.	None
Modelling generation capability	Lack of model generation capability	Generation of models from a predefined activity pool reduces the space of possible solutions. In ISCL, the models are suggested from a model pool, which is predefined. Although	None

		one may create new activities it would be preferable for an automatic suggestion method that would help creating new activities by analysing the available block elements (although these elements are defined in the initial resources).

Table 4-13: Assessment of the service design ability on how effectively the aforementioned dynamic features are dealt with

4.5 Summary

We tested prototype methods developed specifically for service design to see what the limitations in this particular area are. The outcome of this comparison can be summarised below:

Service Blueprinting does not address any elements that can change through time.

Service Explorer can provide multiple customer interactions by combining all customer requirements and identifying the most important of all, thus giving a prioritisation element. Moreover, it has the ability of evaluating a service when current requirements change. However, there is no way to automatically assess current state of the service and adjust the resources according to new prioritisation rules. For every change that is employed, there must be a reassessment of the service to seek the most important requirement that needs satisfaction. Moreover, there isn't a lifecycle simulator that could help the service provider to increase its service efficiency and deal with other changes, apart from these related to the customers. Lastly, there isn't any assistance for model generation based on previous models or existing functions that could be recycled to provide a modular service design process.

Integrated Service CAD and Life cycle simulator provides multiple customer interactions which are treated in the same way as in SE. Dealing with sudden changes and external factors is possible through the lifecycle simulation process, and resource distribution according to current needs, is accomplished. Moreover, there is capability of generating service models through pre-established sub-models/functions. However, there is no prioritisation process at the beginning of the service design. Therefore service efficiency through resource/cost balancing is achieved only by the lifecycle simulator, excluding the customer part. Moreover, the resources that a service provider has are stated as static. Complete knowledge of the initial service state is required.

CHAPTER 5

Conceptual Development of the Solution through a Generic Agent-Based Modelling Language

5.1 Introduction

In Chapter 4 we established a specific gap of current research methods which involved the lack or difficulty in capturing the dynamic nature of the service in terms of analysing the social groups and their interactions. Through the extensive literature review which was presented in Chapter 2 we have also identified a methodology which could bridge this gap and proposed it as a solution to this problem. The methodology in question is called "Emergent Synthesis".

In addition Sections 5.2, 5.4, 5.5, 5.8 and 5.9 are referring to literature search which was mandatory to be conducted as part of the scope of this chapter and was not included in Chapter 2 due to the fact of being part of a different research area other than the service design, which is the main theme of this thesis.

Ueda et al. (2008a) has used agent based modelling software in order to model the emergent synthesis methodology in a service market. They developed specific tool for this purpose. It is not open source tool therefore is not possible for researchers to incorporate changes or extend it (i.e. including more features or making modification according to their needs).

There is a fundamental problem with this approach. Using proprietary software to implement agent-based modelling (see section 5.2), the system is in a closed environment, which means that people will be unable to use the software if they want to model other areas of research or plugging it into other data or being part of a bigger framework.

The approach by Ueda et al. (2008a) lack some important valid points which we think it could provide a better agent-based modelling experience, and in return would give more assistance to the researcher to create an accurate modelling representation of its strategy.

- The need of an agent-based modelling environment that could be used as a generic approach for implementing the emergent synthesis methodology.
- The availability of a programming environment capable of minimising syntactical errors and providing better error handling, which could be used as a platform for rapid application development. That would give rise to rapid prototyping where researchers can issue quick models and test them. Moreover, researchers could learn quickly the programming principles of this environment.
- The incorporation of a flexible 3D world which acts as the interacting environment of the agent-based model. Rapid change of the 3D world would incur different behaviours of the model and that would give rise to new scenarios to explore. A 3D implementation is required due to the fact that environmental changes cannot be accomplished in a 2D plane (i.e. differences in the terrain structure could affect agents behaviour)
- The benefit of a 3D perspective within the agent's eyes. That would give the service world a very alternative view angle which gives the sight of the entity while the researcher can see the interactions as they are occurring.

5.2 Emergent Synthesis

Increased complexity and uncertainty arising from various sources and factors, like cultural diversity, different lifestyles, globalisation of the industrial markets, and a complete change of attitude toward the environment, is observed. For describing this approach, first a definition of synthesis and emergence is required. An important component of problem solving processes is called synthesis. It is almost required in all phases of an artefact's lifecycle. Emergence, on the other hand, has a key role in solving difficult problems which arise through synthesis.

Synthesis is related to human activities for creating artificial things. Novel artefacts are required to satisfy specific requirements and functions corresponding to human needs. The problem of synthesis lies within the creation of an artifactual system. In general, such a system is created by a specific purpose in mind and is related to a particular environment which is supposed to work. Ueda (1998) proposed a framework to solve the problem of determining a system's structure for function realisation in order to achieve a specific goal under a particular environment. The main concern of this framework is the completeness of the information concerning the environment and the specification of the artifactual system. According to the incompleteness of the information Ueda (Ueda, 2001) proposed three distinct classes:

- Class 1: Problems that have complete description (i.e. optimisation problems in manufacturing). The problem is completely described when total information about the environment, specifications and the artifactual system is provided. In general, this class of problems is often difficult to be accomplished and thus identify an optimal solution.0020
- Class 2: Problems with incomplete environment description (i.e. reinforcement learning problems). In this case the available information about the environment is incomplete but the specification is complete. Thus the problem is not wholly described and for this reason it is difficult to cope with the dynamic properties of this unknown environment.

- Class 3: Problems with incomplete specification (i.e. incorporating information management methodologies to manufacturing solutions). Last category involves problems that have neither specification not environmental description complete. Thus the problem solving process has to start off with an ambiguous purpose while human interactions play an important role through this process.

The traditional methods (analytic/deterministic approaches, decomposition principles, etc.) are not suitable for solving these problems. On the other hand, emergent approaches seem more likely to get solutions. Emergence in this particular context means “the global order of structure expressing new functions formed through bi-directional dynamic processes; where local interactions between elements reveal global behaviour resulting in new constraints imposed on the elements” (Ueda, 2001). The crucial part in this description is that global order is not fixed, chaotic or periodic but actually forms a complex structure. New functions will rise from this order and if they meet the specified purpose people can use them as valid solutions.

The approaches of the emergent synthesis are being developed with bottom-up and top-down characteristics. They include soft computing methods, such as evolutionary computation, self-organisation, behavioural methods, reinforcement learning, multi-agent systems, etc. All of these techniques can offer efficiency, robustness and adaptation to synthesis problems. For each of the previously mentioned classes some of these methods may be better than others. Therefore before applying any method, one must first identify how much suitable this method will be to provide feasible solutions.

Emergent synthesis is a new methodology proposed by Ueda (Ueda, 2001) which tries to deal with the current uncertainty and complexity identified within the stages of design, manufacturing, utilisation and interaction with users. It has strong correlations with the field of soft computing. It can provide an efficient, robust and adapted service system dealing with the aforementioned problems.

This methodology is a possible way to deal with the issues mentioned in Chapter 4. It has already been tested and applied in several cases towards manufacturing systems and its benefits have been demonstrated.

- It has been shown to increase value creation which involves adjusting a manufacturing system to a new standstill having a win-win situation for the manufacturer and the customer (Ueda et al., 2008a), (Ueda et al., 2008b).
- Also it has been used and provided more efficient results in optimisation problems where the fitness landscape has been significantly increased (Ueda et al., 2004), (Ueda et al., 2007).
- Another test case scenario involved the adjustment of a supply network while introducing dynamic elements (Ueda et al., 1999).

For these reasons the emergent synthesis approach could potentially benefit service design and represent the complex nature of the system along its service life-cycle by increasing customer satisfaction, while pinpointing the provider's cost for this to occur

5.3 Aim and Purpose of this Chapter

The aim of this chapter is to use an agent-based modelling language to simulate a service design scenario based on the emergent synthesis methodology. For this reason, a service market model derived from the literature has been used as a baseline scenario and a validation method of the results, gathered by the simulation process. The baseline scenario was modified accordingly to the modelling language requirements. The rationale behind this is to establish a widely used research method for simulating social phenomena, for use in the service systems design area and emergent synthesis simulation. Also the different design principles based on the modified service scenario may also be used as a guideline to modelling future service design systems.

5.4 Multi-Agent Systems

Multi-agent Systems (MAS) nowadays have been used in various fields and in a growing number of areas as a technique to support simulation of complex systems. Fields that are becoming more and more appealing for MAS include sociology, biology, physics, chemistry, ecology, economy, etc. Defining a model in MAS poses some difficulties due to the variety of the representation that the simulation design allows. The knowledge transfer to computational terms is rather dependent to the platform, architecture, or language that is being used. The negative effects are the discrepancies that occur between design and implementation goals where agents are defined in rather "weak" terms. The agent's description such as proactive, interactive, autonomous, etc. does not reflect the computational properties that the agent really possesses (Drogoul et al., 2003).

In the implementation phase a multi-agent based simulation (MABS) widely differs from all other simulation techniques, in that the entities are being modelled through agents. The collective specific behaviour (interactions) of those agents (individual entities) can be viewed to form structures that are part of an emerging process. This is the fundamental difference from the macro-simulation techniques where the characteristics of the population are averaged together, and the model itself brings forth changes that would affect those characteristics, which underlie the whole population (Davidsson, 2001).

The agent-based modelling and simulation (ABMS) is rather a new approach for complex system modelling, which comprises of interacting, autonomous agents as said before. The agents' behaviour is based on rules, whereas the interaction between them produces a collective organisation and behaviour, due to the fact that each agent affects and influences all other. The diversity of the agents provides the emergent action of the system as a whole. An increase of the diversity in the attributes and behaviour of the agents makes the system less predictable and more dynamic. Self-organisation is being reported in such systems which have individual agents modelled from the ground-up, and patterns, structures and behaviours rise without being explicitly coded into the system. Two factors that diversify this approach from other modelling and simulation methods are the heterogeneity of the agents and the emergence of self-organisation. This aspect of modelling offers a way to simulate social systems by having agents interacting with each other, learning from the environment and having behaviour adaptability, so that to achieve a better adaptation in their environment, providing that they end up exploiting the knowledge they gathered (Macal and North, 2005).

There are a lot of applications in which such simulation systems have been deployed. These range from modelling agents' behaviour in the stock market, supply chains to the spread of epidemics, bio-warfare threats, to the adaptive immune systems and understanding consumers' purchasing behaviour (Macal and North, 2005). And there are plenty of others. Some are small and elegant models, which include only the basic components of a system and give insights into the social fabric, and how certain behaviours are being developed. Others are of a large scale based on the system's nature they try to model, due to the need of large sum of data. These kinds of models have gone through validation process, and are being used into the policy formation and decision-making fields.

A structure of an agent-based model comprises of the following elements (Macal and North, 2005):

- A set of agents, with their attributes and behaviours.
- Another set which represents the agent's relationships, methods and interactions: there is an underlying topology which defines how and with whom the agent's interaction takes place.
- The environment of all agents that are subject to interact with and thus gain knowledge, which would in turn alter their characteristics and in the end the whole system.

A certain developer must identify, model and code all of these elements in order to create its own agent-based model. For simulation purposes there is a computational engine which is responsible to give the output of the agent's behaviour in a visualised form. As for the programming language that is required, a toolkit is provided or other implementations which provide such capability. By running such simulations, agents get repeatedly enact and are executing behaviours and interactions with all elements of the system. This process can be indefinite but most of the time it is operated in a certain timeframe over a specific timeline, by which the developer will get the output it needs, to extract valuable information for the particular system it modelled. Time-stepped, activity-based or discrete-event simulation, are the most common forms of implementation.

The most important defining characteristic of the system is the agent and its ability to operate autonomously. What that means is to act on its own without any influence by external factors according to the situation it encounters. They have inherently independent behaviours, and their actions are based on the fact that they try to satisfy their internal goals and form a collective response, involving all agents.

Some of the areas that such systems have been deployed have already mentioned previously (physical, biological, social, management services, etc.). The fields span from modelling ancient civilisations to the design of unknown markets. In such real-world systems the agents are a combination of physical components and social agents, which go by the term "socio-technic" systems. Examples of such systems include traffic, air traffic control, command and control of the military, net-centric operations, physical infrastructures and last but not least markets (electric power, integrated energy markets, etc.) (Macal and North, 2005).

5.5 Agent Based Social Simulation

The research area of agent based social simulation (ABSS) is defined by the intersection of three distinct scientific fields the social sciences, the agent-based computing and lastly the computer simulation. (Davidsson, 2002)

- Agent-based computing, as said before, is a research topic within the computer science field, and includes agent-based modelling, design and programming.
- Social sciences refer to a large set of different scientific areas, and the purpose of this field is to study the interactions between social entities. Examples are, but not limited to, psychology, management, policy, areas in biology, etc.
- Computer simulation is all about the study of different techniques and methods for simulating phenomena on a computer. Examples of these processes are discrete-event, object-oriented and equation-based simulation. The phenomenon that is being simulated constitutes of an event or a sequence of events either in a natural or an artificial system (or combination of both), which could be present or not during the runtime of the simulation. The rationale behind computer simulation usually is to gain better knowledge and understanding of the occurring phenomenon, like predicting future behaviours or performing experiments that are very difficult or unreal to be carried out in reality.

A pairing matrix can be created from the previous three scientific fields. There are other fields derived from the intersections of this pairing matrix and much work is being done on those areas. The social sciences area along with agent-based computing forms the social aspects of agent systems. That area includes the study of the activities of competition, cooperation, organisation, etc. The combination of computer simulation and agent-based computing forms the area of the multi-agent based simulation. This involves the study of how agents can be used for simulating any phenomena on a computer. Lastly, the third pair, social science and computer simulation is called social simulation and leads to simulations of social phenomena on a computer using any simulation technique (Davidsson, 2002).

Based on this view the ABSS can be called upon as use of agent technology, having as goal the simulation of social phenomena. The main role of ABSS is models and tools provision for agent-based simulation of social phenomena. This can be applied to many different areas.

Service design can be considered as having a social infrastructure according to the design of products and processes which lead people to participate and contribute in the development of the service process. Feedback and interactions between service users can offer a clear and productive outcome to the provider. Three elements can be interconnected in that sense: behaviour (people), process (actions), outcome (product). Thus services would be inexistent if people were not involved by any means (using, contributing or participating). Therefore there is a need to model this aspect of the service using ABSS approaches.

5.6 Methodology of this Chapter

The methodology follows the steps below:

1. Identification of an agent-based modelling language for service implementation.
2. Identification of a service scenario to be represented and implemented by the agent-based language.
3. Explanation of the service scenario and its changes that went through to the implementation phase.
4. Use of a diagrammatic modelling method for representation of the previous service scenario.
5. Simulation of the service scenario using the identified agent-based modelling language.

6. Validation of the agent-based modelling language by contrasting the findings from the model to that of the literature that will show the dynamics of the class 3 in the emergent synthesis methodology against class 1 and 2.

5.7 Selection of the Agent-Based Modelling Language

In MAS there may be simple or complex entities supporting the levels of representation of a system. It all depends to the modeller and its ability to handle those levels within a unified conceptual framework (Drogoul et al., 2003). Using MAS do not always provide the same level of success due to the ambiguity of the semantics within each modelling method. There are various implementations such as Swarm, Madkit, Starlogo, Netlogo, Repast, etc. which implement the same specifications using different approaches. This fuzziness at the computational level trying to identify and understand what a particular agent really is, and what is supposed to do, spans in all other levels which are required to complete a simulation design.

Based on these different architectural designs we identified an approach which supported the initially stated requirements (see section 5.1). The rationale behind the selection was based on the literature and also practical reasoning. First we identified the advantages and disadvantages between widely used approaches such as NetLogo, RePast and Swarm (Robertson, 2005). Secondly we used and tested these methods with their provided cases and examples to see their inner workings in practice. This two-fold process provided the required knowledge to understand their operational characteristics, differences and modelling processes. The outcome of this procedure led to the conclusion that the appropriate approach/method for modelling emergent synthesis methodology was StarLogo.

StarLogo, an open source framework for implementation of agent-based modelling systems which provides solution to this problem and it incorporates most of the stated requirements (points) in a package form, friendly to the researcher.

5.8 StarLogo

StarLogo is a programming modelling environment where the design is based on the premise to help non-expert users, to model and explore decentralized systems (ant colonies, market economies, etc.). Due to the complexity of such collective systems it is difficult for people to understand their inner workings. With StarLogo people can try to escape the centralised mind-set in a way that would give rise to understanding the principles of emergent behaviour. This behaviour is what makes the system dynamic and is based on patterns emerging from the decentralised interactions as opposed to the dictations of a centralised authority (Resnick, 1996).

History of StarLogo and other various decentralised programming environments started with a paradigm shift after scientists experienced with a wide range of programming paradigms such as object, orientation, logic, constraints, parallelism, etc. Each of these paradigms offered new design abilities (new ways of object creation using computers). But the most important thing among these paradigms was the new logic behind computation and other world phenomena. Explicitly, StarLogo is a rather new modelling environment which is based on the massive parallelism paradigm (Resnick, 1994). This paradigm enables the execution of multiple processes simultaneously regardless of the underlying implementation. Users can write their own code using rules for thousands of objects and then observe how patterns emerge from the objects' interactions.

Ant colonies are one of the many true examples of a decentralised system. Ants forage for food forming trail patterns which are determined from the local interactions among thousands ant workers. Then there are macroeconomic patterns, where one has millions buyers and sellers and these patterns emerge from their interaction. Another example could be found by looking at immune systems, where you have hordes of antibodies seeking out bacteria in a coordinated attack without any organisation planning from a single entity. It is the action of each antibody which produces the formation of the collective behaviour. For any of the systems above and other systems too, StarLogo is especially designed for tackling the difficulties of such modelling processes.

An example of how a model is implemented in StarLogo is being given by the slime-mold model. StarLogo was used for modelling the aggregation behaviour of the slime-mold cells. Each of the cells follows its own rules which are trivial. This is transferred to the programming environment by using agents. Each of these emits a chemical pheromone while covering the area it passes with gradient colourisation, according to the colour of the emitted pheromone. The existence of these pheromone trails, which they get diffused and evaporate slowly, is the core element that forces clusters of creatures to emerge after several dozen steps into the simulation process. This reorganisation strategy accurately models the aggregation behaviour of the slime-mold cells (Resnick, 1996).

5.9 StarLogo the Next Generation

StarLogo the next generation (TNG) is based on the StarLogo tradition of providing an easy method for agent-based modelling for various people, (researchers, students, teachers, etc.) having added the features of a graphical programming interface along with a three dimensional world. The graphical programming environment makes it easier for mastering the programming skills required for this language. The 3D graphics makes an immersive and engaging experience for people to see and understand the basic principles of the model in development. One last element is that this version of StarLogo is a fundamental change to the virtual machine which makes it more transparent. (Klopfer et al., 2009)

The original StarLogo version had some apparent limitations in developing new models. Several barriers had to be surpassed such as the time for someone to learn the programming basics and acquire the necessary skills for model development. So in order to acquire deeper learning on the model creation side StarLogo TNG was created.

StarLogo TNG holds the basic language and processes of StarLogo intact so the transition from one to the other is trivial. Deployment of StarLogo TNG, as used by researchers and various people that are in need of designing complex social systems, has shown that it promotes and engages people to complex model creation by making learning programming easier. Moreover it alleviates peoples' anxiety while trying to be syntactically correct. The 3D world is rather unique and gives a visual impact of the running model to non-scientific persons. Therefore it can be used not only as a programming environment to developers but also as a method to present complex models to laymen (Klopfer et al., 2009). It is for these reasons that it was chosen as the appropriate method to establish the social aspects within a service design system.

5.10 Service Market Scenario

The service scenario is based on a service market model where there are multiple customers and one manufacturer which produces a single service (Ueda et al., 2008a). The manufacturer has the ability to produce multiple levels of this service. Each level consists of different service functions. At any given time the manufacturer can produce only one service level. Customers interact with the service producer in order to check if they are satisfied by this. Customer's decision on utilising this level is based on its demand and the cost of the offered level at that time. If a service level is not meeting its demands and the cost that it is willing to pay, then there is no customer satisfaction and no profit is gained by the producer. There are three different customer groups with different demand and cost each.

The aim of the producer is to satisfy as many customers as possible which translate to maximising its profitability. In addition customers have different service needs so finding a niche between customers, service provision and the service provider is difficult.

In this market model there is also one network externality which plays a crucial part of the modelling process. In a real world market the more people that are using the service the higher the service value is, which ultimately helps attracting more people. That scheme is also transferred in this market model. To achieve this there is a customer parameter, unique for every customer which changes customer’s demand according to the sum of customers who are currently using the provided service level.

5.11 Market Service Representation

Various models for modelling services have been proposed but as of yet there is no standard definition and universal method for accomplishing that (Durugbo et al. 2010a). There are specific methods to design services, methods adapted from the manufacturing side, etc. but they all have something in common. They are not standardised and each company or manufacturer, when it needs to create a service, relies on specific oriented methods tailored to the required problem.

Systems engineering is a field that has to deal with complex, dynamic, multidisciplinary systems, which may be adequate to capture and model a service system due to the fact that the service itself has similar properties. The SySML technique is a formal modelling method in the systems engineering field which benefits systems engineers because of its simplicity. It is based on the minimal set of the well-known UML technique, specifically adapted to offer capabilities such as analysis, design, verification and validation processes covering a wide range of systems. Moreover it has been shown that SySML could be used for requirement mapping of PSS models (Durugbo et al. 2010a).

5.12 SySML

The SySML is a general purpose modelling language used for representing systems engineering applications (Friedenthal and Wolfrom, 2010). It has the ability to offer a variety of specifically designed diagrams for this purpose. It was evolved from the Unified Modelling Language (UML) and is considered to be an extension of it or a subset. Because of that, not only it shares similarities with UML but also employs different diagrams and notations to form a stricter and simplified representation (Friedenthal and Wolfrom, 2010). SySML consists of nine diagrams (Friedenthal et al., 2008). These are:

- Behaviour diagram
  - Activity diagram, Sequence diagram, State Machine diagram, Use Case diagram
- Requirement diagram
- Structure diagram
  - Block Definition diagram, Internal Block diagram, Parametric diagram, Package diagram

For the purpose of this service scenario seven out of nine diagrams will be used. The excluded diagrams are the block definition and internal block diagram because they are looking into the structure and components' interconnections of the product core which is not related to the intangible elements of the service system.

The behaviour diagram consists of four diagrams as a set and describes the interaction of the entities in the model. In particular the purpose of the activity diagram is to represent the behaviour of the system in the form of sequential actions based on available input and output. These actions can modify both of them.

The sequence diagram also represents system behaviour but in a different way. Messages are exchanged sequentially between different parts of the system. In this case, time can also be depicted whereas the activity diagram lacks this property.

State machine diagrams represent entities' behaviour by showing their transitions between states which have been triggered by events. Lastly the use case diagram shows the functionality of the system in terms of how it interacts with external entities in order to fulfil a task.

The requirement diagram shows requirements and their relationships between them. These are being represented using a text-based method. In addition this diagram also gives a means of traceability by providing a tree-based top down visualisation scheme.

The structure diagram also consists of four other diagrams and describes the inner workings of the system using a decomposition process. The block definition diagram represents the structural components of the system, which are called blocks, and their composition. The internal block diagram gives the interconnections and interfaces between parts of a block.

The parametric diagram gives the constraints on property values which are used in the engineering analysis process.

Lastly the package diagram shows an overview of the system model by organising the previous diagrams into high level abstractions called packages, where each one contains model elements.

5.13 Results

5.13.1 Diagrammatic Modelling of the Service Market

The following SySML diagrams based on the previous market model represent an instance of this model (e.g. a stand-alone customer) and how this instance interacts and affects the whole service environment (e.g. other customers, service provider, service). The service scenario, which was taken from Ueda, Takenaka, and Fujita (Ueda et al., 2008b) used a neural-network based learning method within its simulation process. As access to this method was unavailable a different approach was used consisting of heuristics components.

The use case diagram (figure 5-1) shows the entities of the service model and how they interact with the service environment. The service level represents the current state of the service which the service provider produces. The service environment consists of different functions such as production and selling of the service, profit for the service provider and utility gain for the customer. Utility gain represents customer's satisfaction stemming from service utilisation.

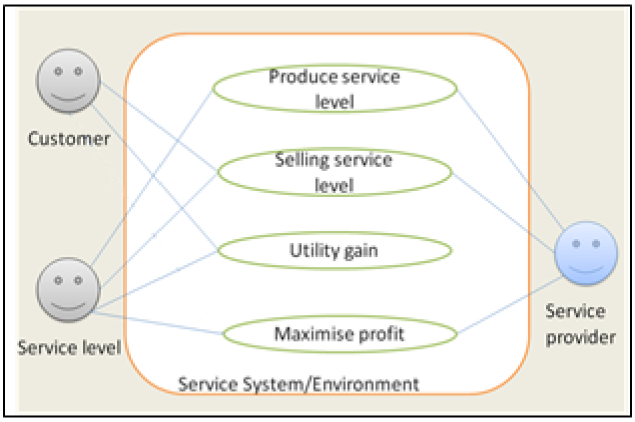


Figure 5-1: Use case diagram

Figure 5-2 (activity diagram) shows the procedure of the customer purchasing a service. There are a number of actions that take place within this process. Before any purchase, customers must be capable of purchasing the service. This is represented by a demand factor which needs to be fulfilled according to the current provided service. The customer can then buy the service which also increases its satisfaction and gives profit to the service provider. Otherwise there is no purchase. The total satisfaction value shows how many customers were actually satisfied by the current service provision and thus gives rise to its popularity.

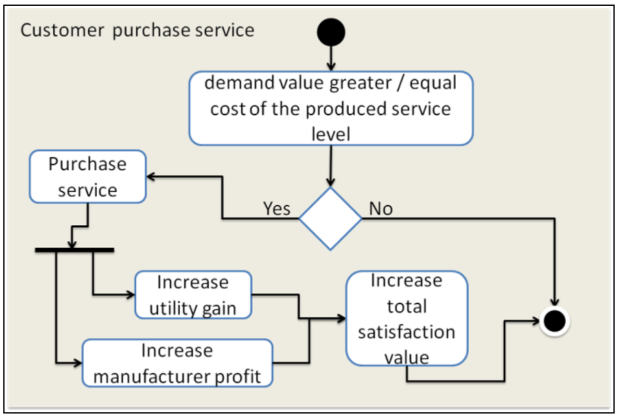


Figure 5-2: Activity diagram

Figure 5-3 (sequence diagram) depicts the flow of the service by giving the time and succession of different events. The customer interacts with the provider asking to purchase the provided service. The provider checks the service cost, checks customer's demand factor (which also shows current purchasing ability) and service is delivered to the customer.

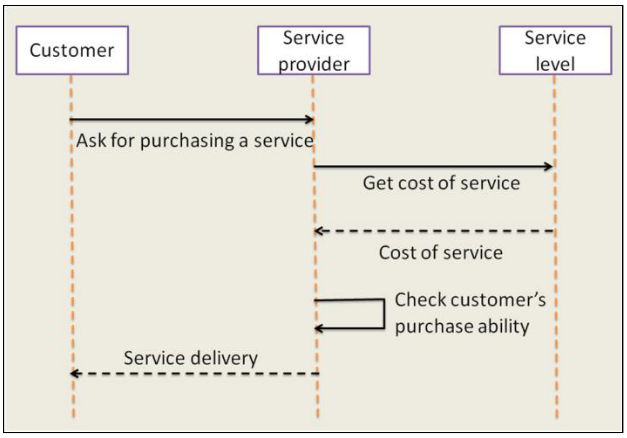


Figure 5-3: Sequence diagram

In figure 5-4 there is a representation of the customer as an agent in the model. Customers can only have two states, either they are moving trying to get served or they have been served and their quest ends. When a customer reaches the service provider, it interacts with him. A service request is being sent with all the additional parameters and if it is successful then it gets the service and stops or becomes obsolete. Every customer can only be satisfied once as it was mentioned in the service overview (see Subsection 5.9). Otherwise it moves around for another customer to take its place (random movement was employed so that all customers have equal chance of interacting with the provider, reflecting the service at the macro scale).

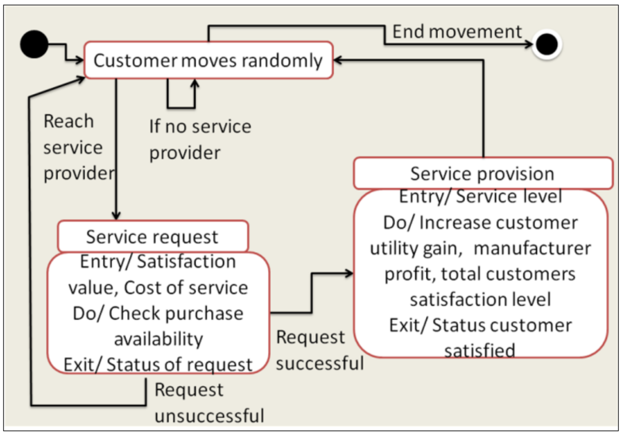


Figure 5-4: State machine diagram

The service requirements of this particular market model are represented in figure 5-5. Requirements of the provider include maximising its profit while producing the most cost-effective service. From the customer's point of view, total customers satisfaction is required to increase, which is dependent on the satisfaction of the individual customer. That gives value not only to the customer but also to customers as a group.

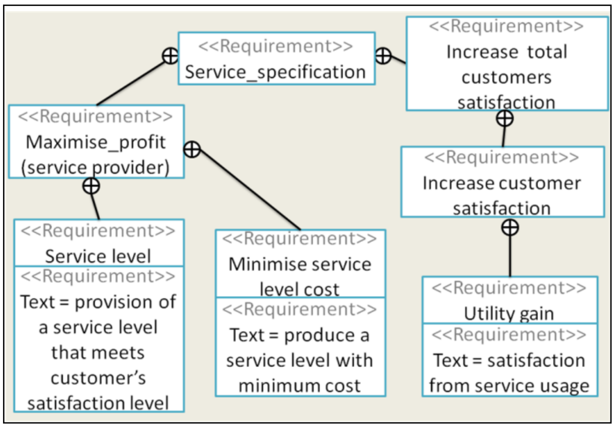


Figure 5-5: Requirement diagram

The penultimate diagram in figure 5-6 shows all the service parameters and their interconnections. It also gives an insight in which values are real or integer, which act as input, temp data and output of the model. Every customer has two parameters, a demand level and a reservation value (how much money a customer is willing to pay according to its demand). "Total customers" is the sum of all customers which interact with the service provider trying to purchase the available service level. Total utility gain represents the gain of all customers. Service usage acts as a network externality to individual customer's reservation value. This creates a social pressure to customers which is reflected by the increase of the spending money.

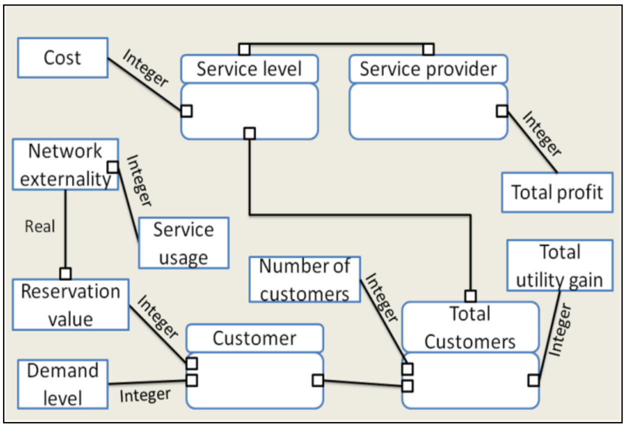


Figure 5-6: Parametric diagram

Last diagram (figure 5-7) gathers all previous diagrams (figures 5-1 to 5-6) in a coherent way which reflects the organisation as a holistic entity of the service model within higher building blocks (requirements, structure, behaviour).

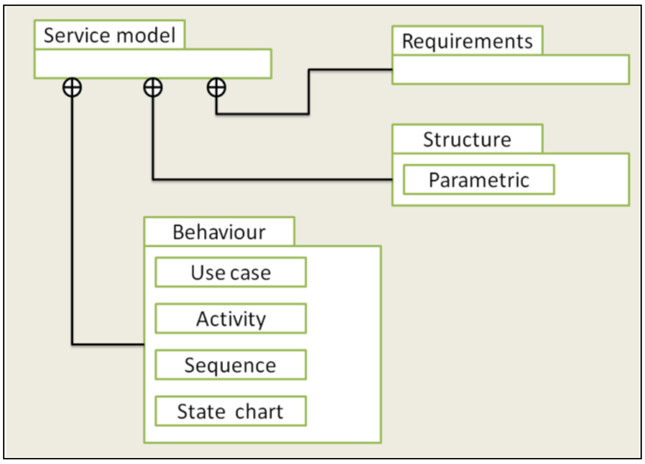


Figure 5-7: Package diagram

5.13.2 Service Market Simulation

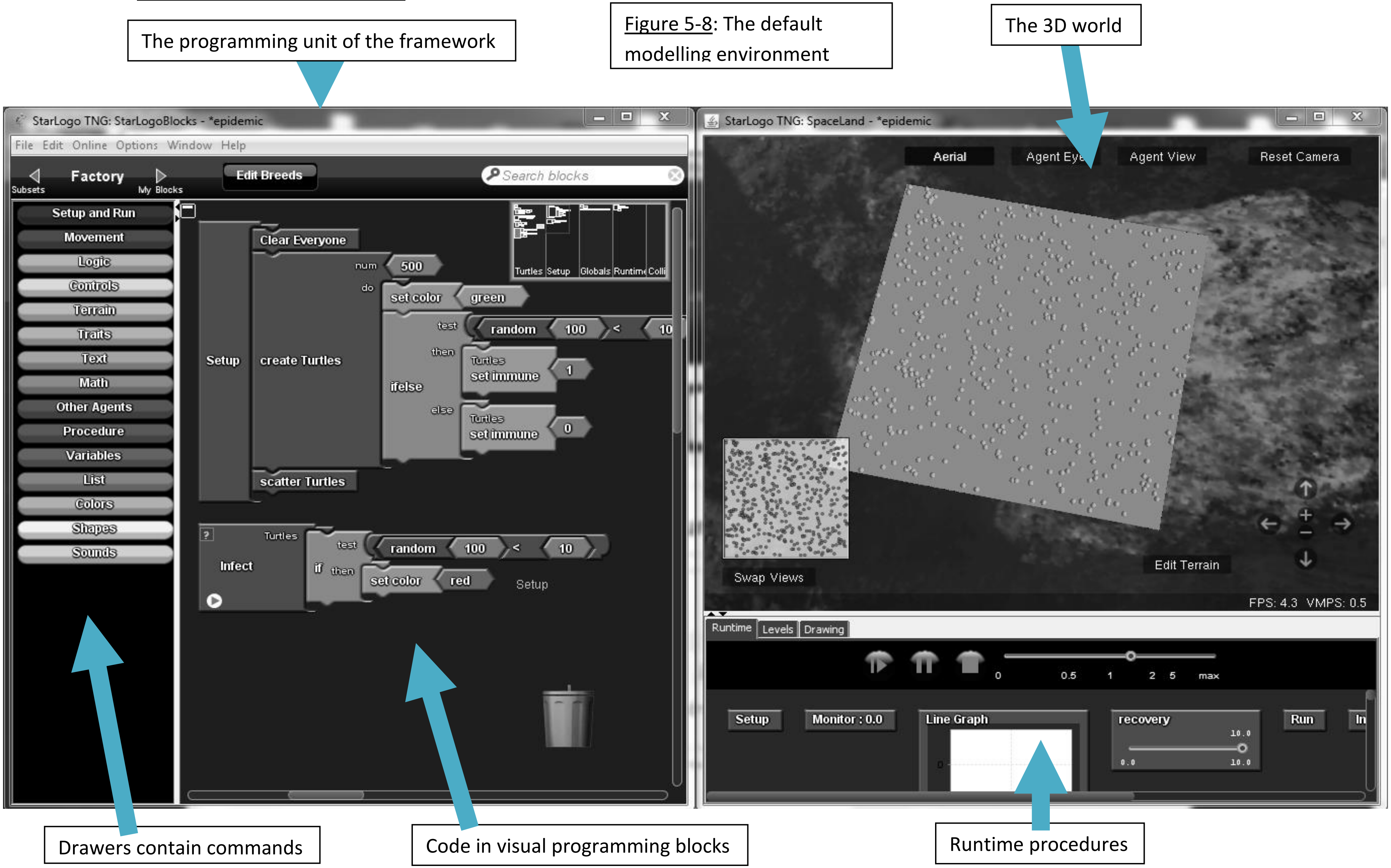


Figure 5-8: The default modelling environment

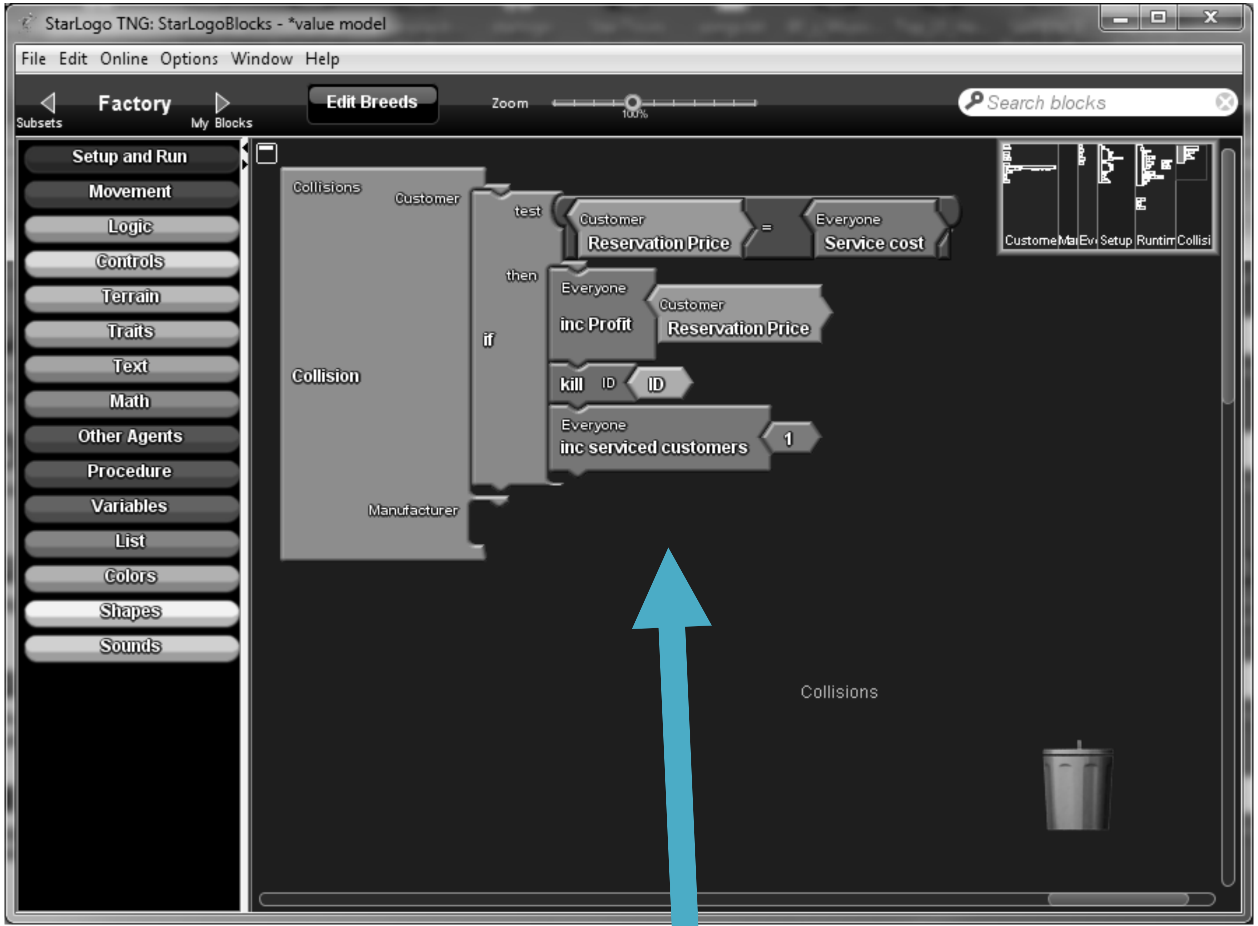
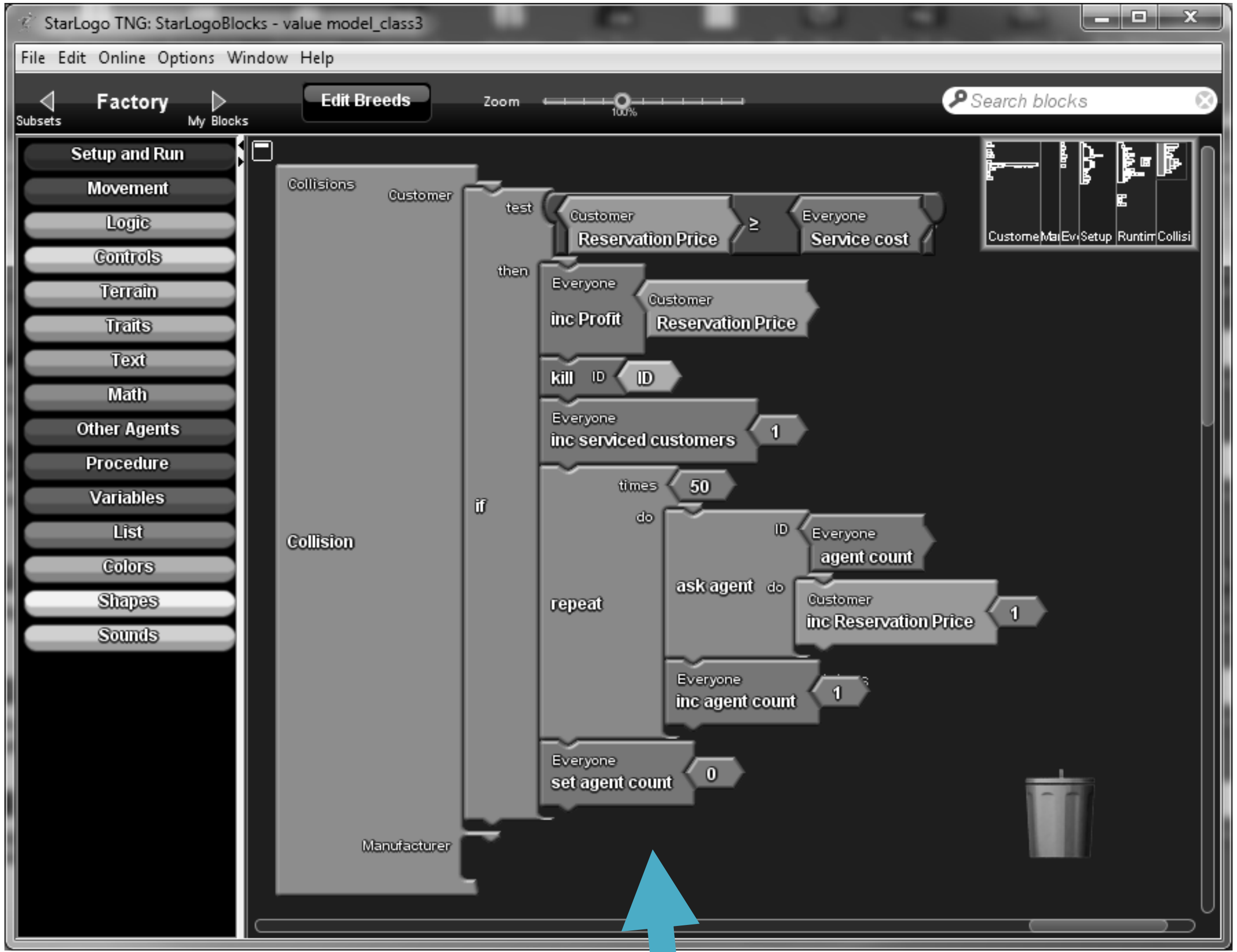


Figure 5-9: The implementation of class 1 and 2 in the programming framework

Part of the model for class 1 and 2

It shows how agents interact and get service provision by encounter the manufacturer in a collision based process.

Within the collision block the following procedures occur. The customer (agent) contacts the manufacturer. Then the manufacturer checks customer's available funds for a specific service level. If the customer can afford the service which is provided by the manufacturer then the customer gets served and is being killed of the customer population. At any time every customer can be served only once.



Drawers contain commands

Code in visual programming blocks

Figure 5-10: The implementation of class 3 in the programming framework

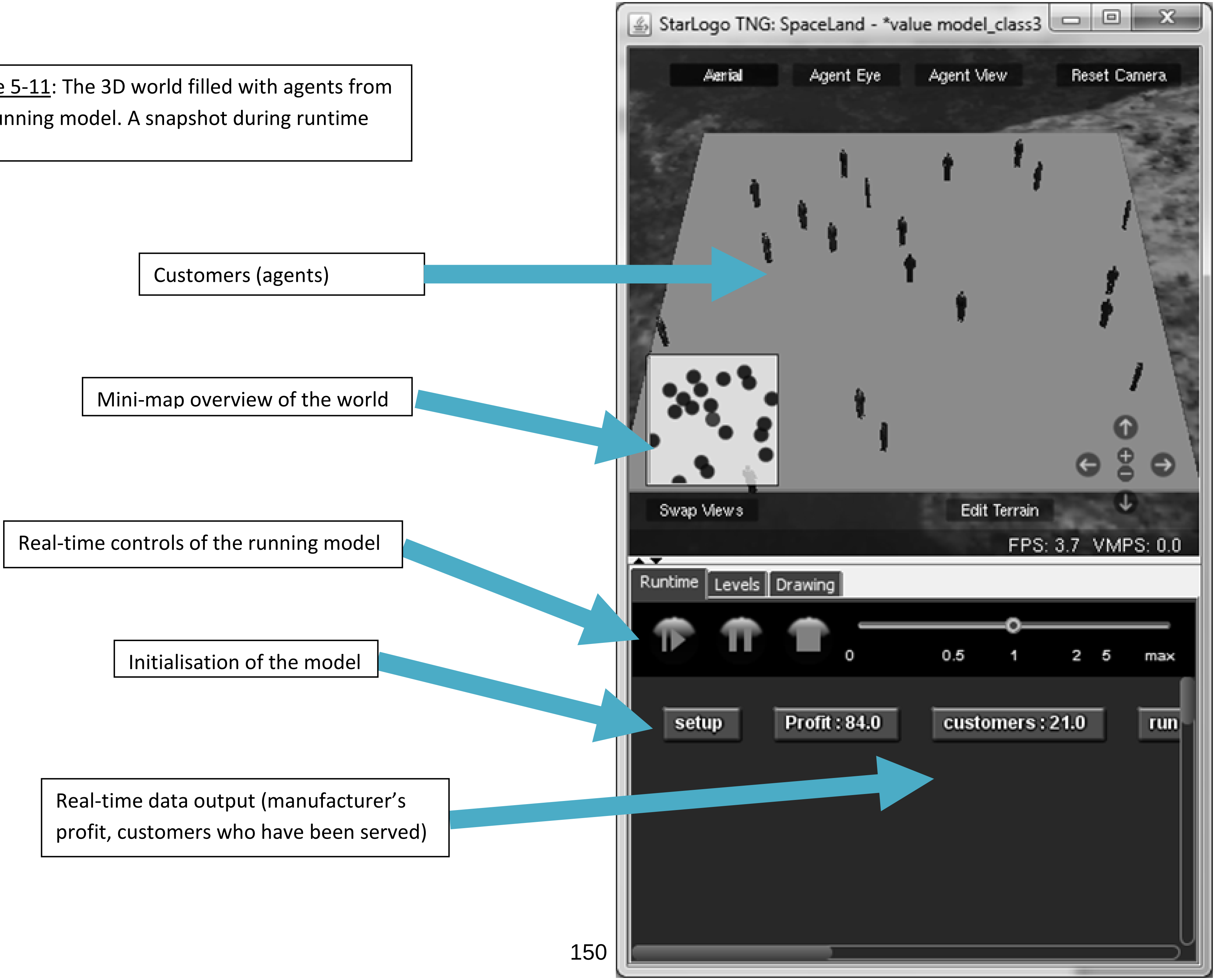
Part of the model for class 3

It shows how agents interact and get service provision by encounter the manufacturer in a collision based process.

Within the collision block the following procedures occur. The customer (agent) contacts the manufacturer. Then the manufacturer checks customer's available funds for a specific service level. If the customer can afford the service which is provided by the manufacturer then the customer gets served and is being killed of the customer population. At any time every customer can be served only once.

The difference from class 1 and 2 is that after the customer gets killed all other customers have an increase in their individual reservation values by one. Therefore they gain in customer value due to the fact that the customer preferred the manufacturer's current service provision.

Figure 5-11: The 3D world filled with agents from the running model. A snapshot during runtime



5.14 Summary

We proposed emergent synthesis as the methodology which would provide solution to the research gap identified in Chapter 4.

We showed that SySML can be used for analysing systems consisting of intangible elements which could provide a standardised way to support service design.

We also showed that an open source agent-based modelling language can be used to model services and in particular the emergent synthesis methodology. At first a service scenario was identified by the literature to be used as a test bed for the agent-based modelling paradigm. The next step was to analyse and briefly discuss the modelling method that is going to be used for this purpose. The rationale for choosing the correct modelling method was also explored. In addition there was a brief walkthrough on the emergent synthesis methodology that was deployed for the purpose of service simulation. A literature-based service market scenario was used for this reason. Apart from that, there was also a diagrammatic representation of the service scenario in a higher level perspective of the simulated model. Differences from the literature in the implementation phase were acknowledged, notified and thoroughly discussed in Chapter 7. Results showed that by using an agent-based modelling environment, which has been used for research purposes in a variety of fields, one can also achieve service modelling through the emergent synthesis process (which was accurately implemented).

CHAPTER 6

Development of the Unified Modelling System and its Validation

6.1 Introduction

In Chapter 4, important service key aspects, valuable to service modelling, were identified. Consequently, a comparative analysis of state-of-the-art, prototype and unique, ground-up developed, service design methods was conducted. According to that chapter several service categories were formed by recombining the previously identified key aspects. Some of these categories were tackled by the individual methods that took part in the comparative analysis. In particular, three individual and unique methods couldn't effectively tackle all of the categories of the service. These methods were:

- Service blueprinting: offers a flat view of the service flow considering that the service and customer requirements stay the same.
- Service explorer: can deal with the service requirements by prioritising them.
- Sevice CAD with integrated lifecycle simulator (ISCL): deals with the service lifecycle by modelling cost and other variables which can change through the service lifecycle.

By exploring these three individual methods for designing a service, several problems emerged:

- A service does not split into three areas individually. It is a combination of many factors. Therefore all service aspects must be tackled at once.
- It is difficult for someone to assess a service only by using one of the methods due to the limiting nature of each individual method.
- For an accurate service deployment in a real system they are missing data and a service optimisation is not feasible.

It is important to look into an effective way of dealing with all the service aspects at a time due to the nature of the service which requires a multidisciplinary approach. The missing link requires rendering an approach that would incorporate the following points:

- Why: In order for someone to look, design and simulate a service as a whole entity it is mandatory to use this combinatorial approach to establish a connection between customer needs, the dynamic nature, and the lifecycle of the service.
- How: In order to combine the previous aspects of the service one must look into individual inputs, and in order to create an optimised service process, would require the inputs to be added in a sequential order, which would benefit the customer and manufacturer in such a way that would increase profit and value within the service lifecycle. On top of that, it is required to include a new methodology to make the connection feasible. This methodology is mentioned below:

- Emergent synthesis: on a service model can tackle with the dynamic nature of the service involving internal and external interactions with customers and providers.

The unified modelling system which is going to be discussed and thoroughly analysed in this chapter, illustrates and implements the missing link, and includes the aforementioned points to provide a new level of service design experience. It also looks into the service modelling from a customer-centric view. SB was not used as part of this modelling process due to the fact that it relies on a flat view of the service whereas the service can be thought as being a social environment.

6.2 Methodology of this Chapter

The methodology follows the steps below:

1. Identify a suitable methodology that would represent the complex nature of the service, which lies between the design and its lifecycle.
2. Identify from the literature a potential case study to be implemented which consequently will show how the identified methodology is mapped into this.
3. Conceptualisation and explanation of the unified modelling system's data flow.
4. Explanation of the service scenario taken from the literature, the reasoning of its choice and diagrammatic representation of the model.
5. Simulation of the scenario using the unified modelling system.
6. Contrast the findings with the output of the ISCL method stating the differences and the reasoning for a designer to use the unified modelling system.

6.3 Data Flow of the Unified Modelling System

In figure 6-1, a diagrammatic representation of a high level abstraction of the unified modelling system is being shown. It starts of the emergent synthesis methodology process, then followed by using the method provided by service explorer and lastly ends with the ISCL method. For its one of these steps a set of goals is being provided thus it is trivial to realise the structure, flow and the interconnections of the service system. What is of particular interest in this specific diagram is the initialisation method. Emergent synthesis can be seen as a process which constantly evolves and changes because of the interactions taking place within the system. That is why there is a recurrence arrow to show this capability.

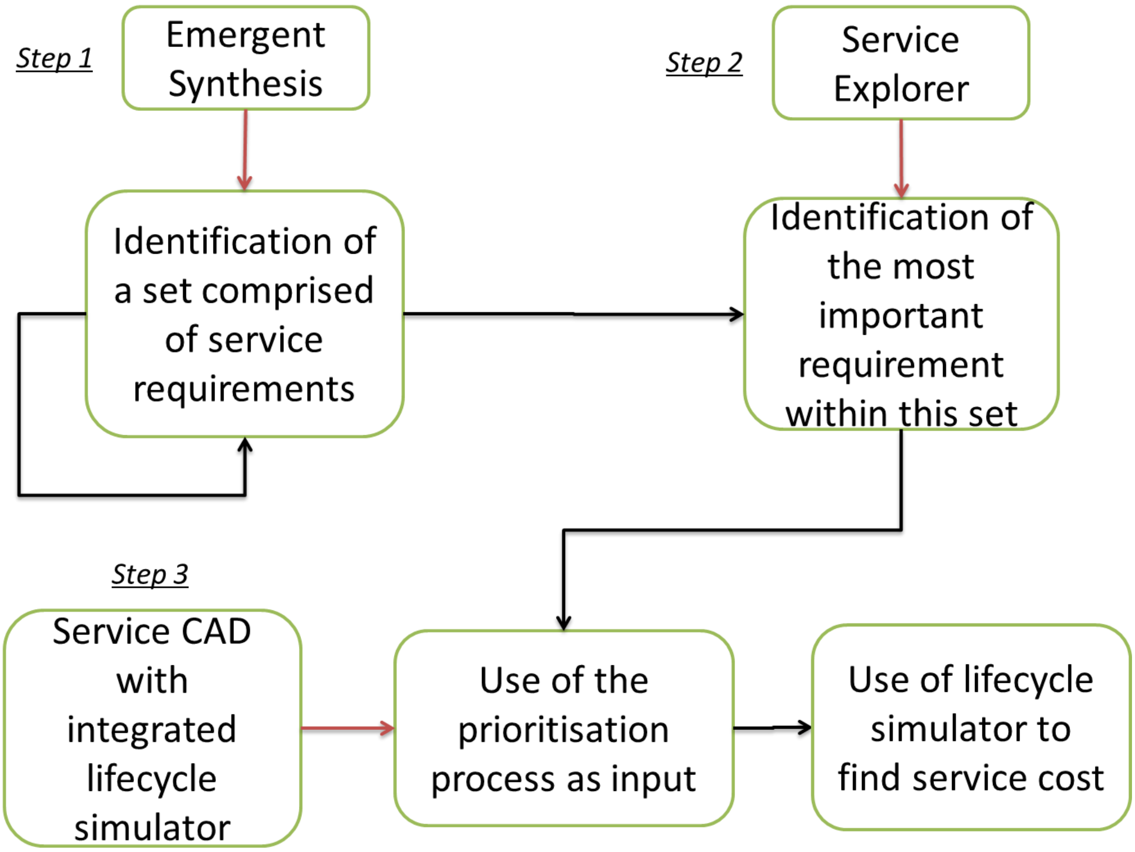


Figure 6-1: Conceptualisation of the Unified Service Modelling System

1. Emergent Synthesis approach (step 1)

- Simulation of the methodology using the Agent-Based Simulation Language identified and validated in Chapter 5 (StarLogo)

  - Customers' interaction with service provider is modelled (social dynamics)
  - Each customer has its own requirements
  - Each customer has its own demands and cash availability

Figure 6-2 and 6-3 visualise the search element of the process. The initial state is shown in figure 6-2 and the findings / output after the end of the process is stated in figure 6-3. The output is based on the customers' reservation value and the cost of the service provision.

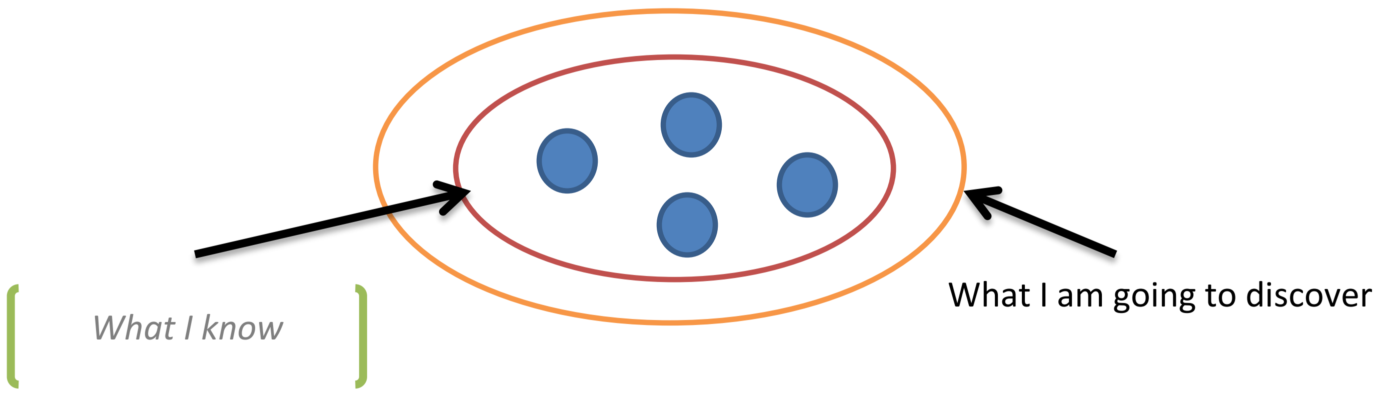


Figure 6-2: The known search space

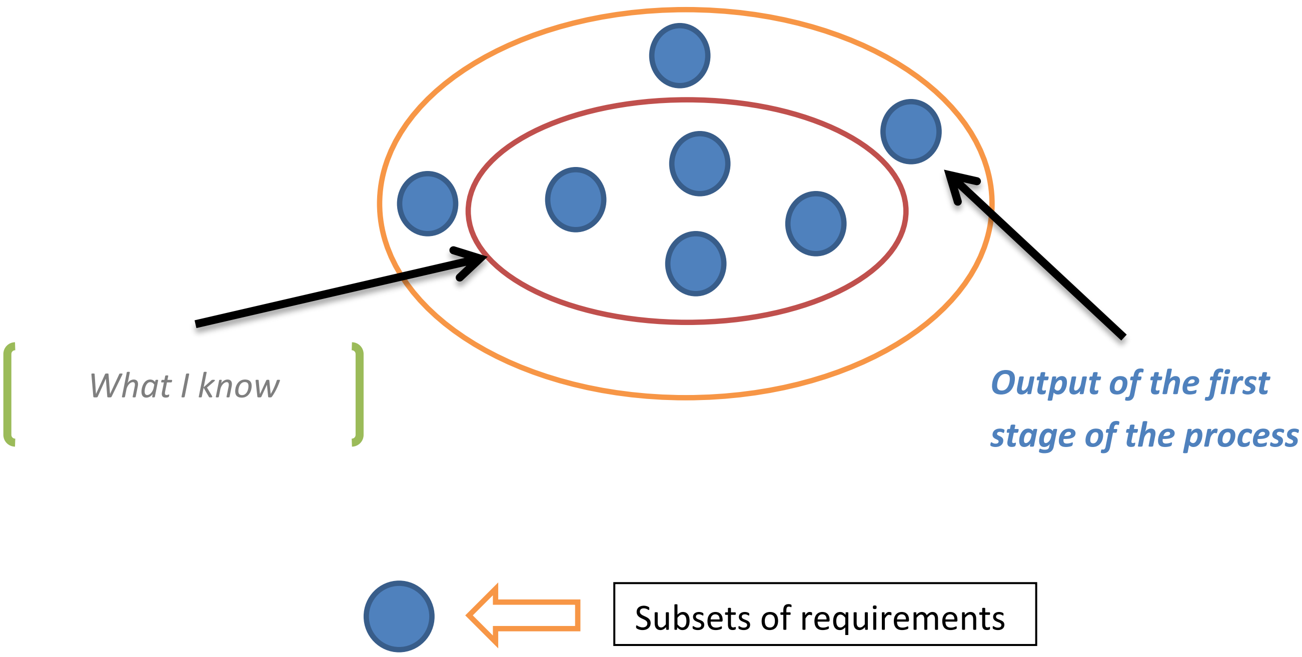


Figure 6-3: Probing the unknown search area

Output of the Process

To identify which subset of requirements satisfies most people which in turn would bring customer value to them.

- Modelling the implications of network externalities being depicted as social effects and social pressure (social drive to requirements that were not previously predicted)
- Increased profitability for the service provider benefited by this social effect
- Ultimately win-win situation (everyone is satisfied fulfilling their goals)

2. Prioritisation approach (step 2)

- Simulation using Service Explorer

In the second phase of the approach we use service explorer to try and prioritise the selected service requirements from first stage according to customer's importance.

<u>Output of the Process</u>

The end goal from this stage would be a hierarchical order of the assessed requirements from the most important to the least.

3. Lifecycle Simulation approach (step 3)

- Service Cad with Integrated Lifecycle Simulator

In order to complete the process of assessing the service system we would need a simulator concerning the lifecycle of the service from beginning to end.

This is very important for the service provider and also for the customers. The service provider would have finite resources that would need to spend for service provision, and thus it is imperative to know how to adjust them to provide the customers' requirements according to their importance.

In other words, the service provider should take into account the prioritisation of customers' requirements, so that it would increase their satisfaction and also increase its profitability. Higher satisfaction rates along the service lifecycle would increase future customer awareness towards future services, lay down by the service provider and thus potentially attracting more customers.

<u>Output of the Process</u>

The main output of the ISCL and in particular the simulator module is the provider's cost required to fulfil and satisfy the requirements that are dictated by the users of the service. This cost spans from the initiation of the service till its termination. It is a very important output which must be taken into account during the service design process. Finding a way of reducing it without hindering users' satisfaction is where the unified modelling system actual targets.

6.4 Service Scenario

The design and the development of the following scenario derived from a similar case study that was taken from the literature where the Service Explorer method has been tested and was adapted to be used with the unified modelling system. The path of changes that were passed through can be seen in the previous chapter, Chapter 5, delving into the SySML diagrams. That was a mandatory intermediate step for achieving the first step of the service system.

This service scenario which is described below is similar to the one mentioned in Chapter 4. Nevertheless this does not bring any bias to the side of modelling and results because in the first case, in Chapter 4, the goal was to identify through a comparative analysis specific gaps of prototype service methods, while in Chapter 6, the goal is the validation of the unified modelling system. In the first case service methods were against each other whereas in the second case service methods were included as parts of the unified modelling system. It is for these reasons that there is no correlation between these two sets.

It is based on a real world test case scenario which is the renting of washing machines or purchasing them. The intended outcome of the service is twofold: for the customer is to have its clothes cleaned, while the cost reduction of the lifecycle of the service is from the provider's view.

In this particular service scenario three entities were called which consist of the machine manufacturer, the potential reseller and the customer as seen in figure 6-4. A possible extension of this service would be similar to the one mentioned in Chapter 4, Section 4.4.2.

The functions or the functionality of the service falls into two categories again chosen having in mind minimal complexity for a better evaluation of the unified modelling system. These consist of renting a machine to the potential customer/ user of the service or the customer purchasing the machine through a reseller. For the latter, all services (e.g. maintenance) apart from the machine's utilisation are the manufacturer's responsibility. In order to achieve better clarification of these functions, the customer can either use a washing machine in certain public places, which are being kept by the manufacturer or taking the machine home for internal use. This separation was mandatory in order to decouple the customers' requirements into basic components with no interrelations whatsoever. There are two possible cases that define this particular rental service scenario which have already been mentioned briefly in Chapter 4, Section 4.4.2.

The primary end goal and outcome of this service model is to increase customer satisfaction. The secondary goal is to achieve this while trying to increase provider's profit. Thus a win-win situation would be reached. The previous two cases were from the customer's viewpoint and by having this as a mind-set, a total of six customers' service requirements were proposed. In addition provider's cost was also introduced as an element of each identified requirement. For a schematic representation of the rental service model see figure 6-4.

Rental Service example
(laundry machine service)

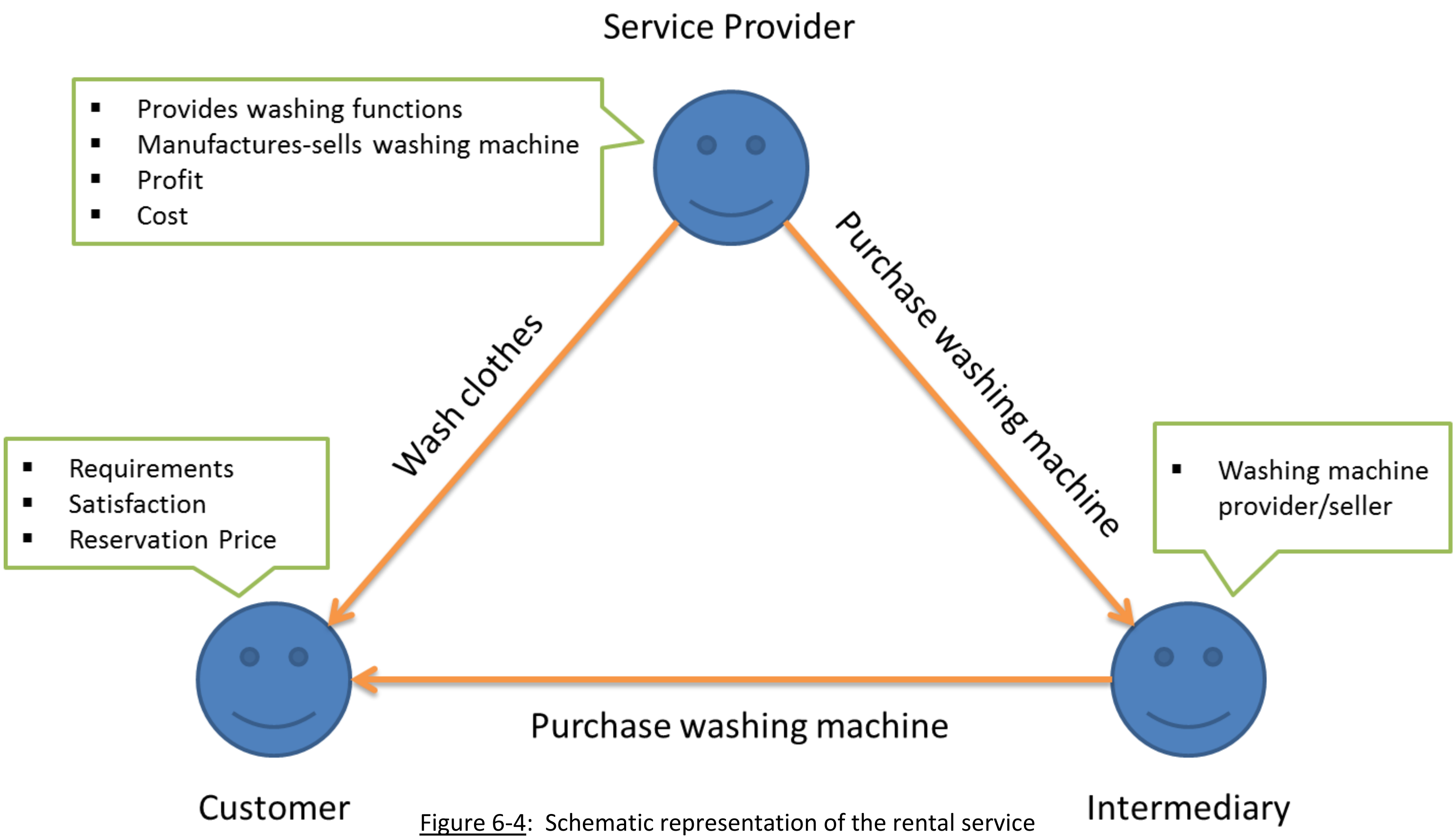


Figure 6-4: Schematic representation of the rental service

Key:

Figure	Description
	Entity
	Direction of entity interaction
	Available functions/properties of an entity

6.5 Results

Explanation and justification of the rationale and decisions for creating table 6-1 are provided in Chapter 7, Section 7.2.3.

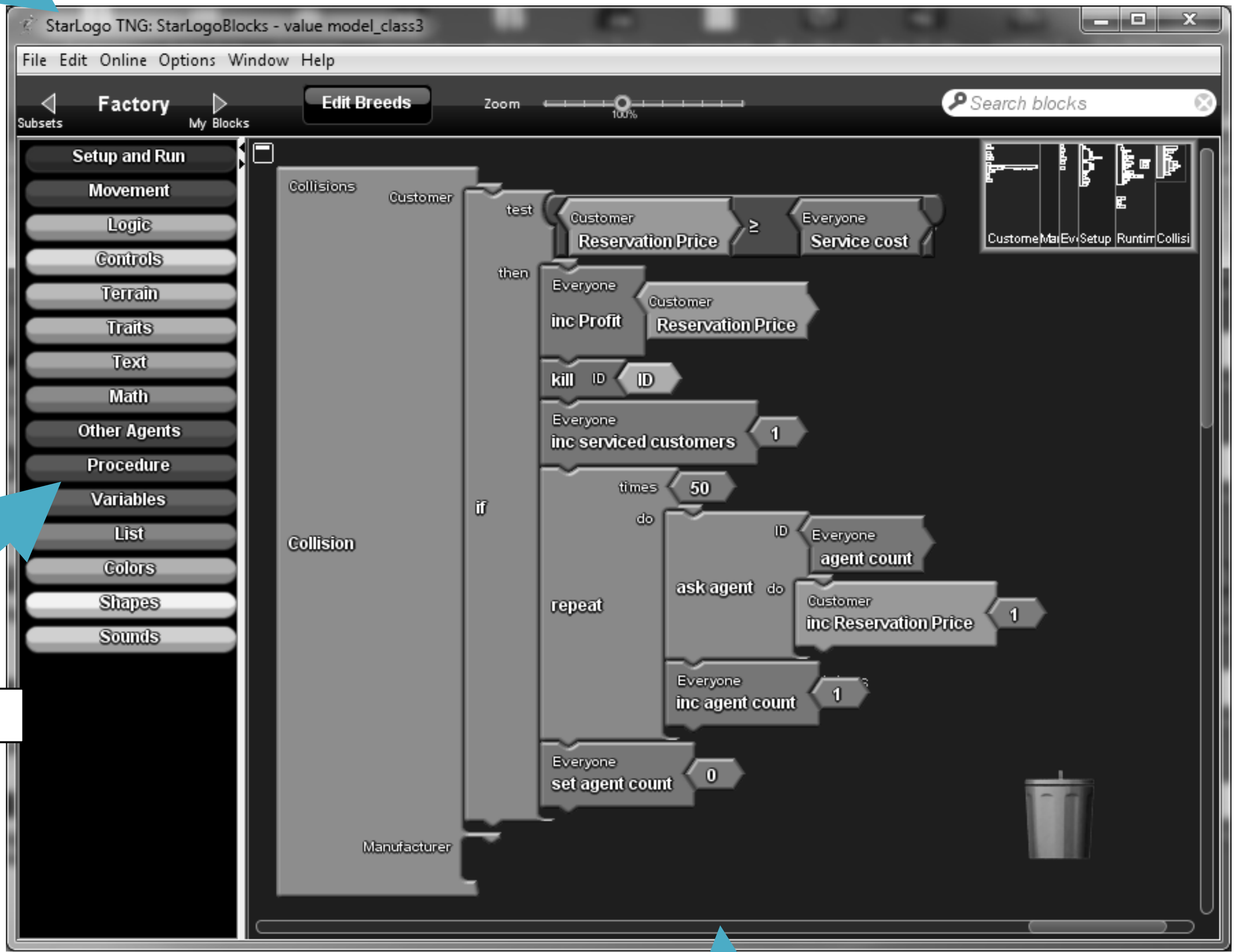
Service Levels	***Customer Requirements***	***Provider's Cost***
2	Reliability of appliance	200
1	Washing functionality improvement	300
2	Reduction of cloth deterioration	150
3	Reduction of washing time	100
3	Simplistic operation	50
1	Reduction of maintenance time	250

Sensitivity analysis

		Cost Function					
		50	**100**	**150**	**200**	**250**	**300**
Customer Importance (%)	**10**	5	10	15	20	25	30
	20	10	20	30	40	50	60
	30	15	30	45	60	75	90
	40	20	40	60	80	100	120
	50	25	50	75	100	125	150
	60	30	60	90	120	150	180
	70	35	70	105	140	175	210
	80	40	80	120	160	200	240
	90	45	90	135	180	225	270

Table 6-1: Parameters and data which were used as input as part of this service scenario. A sensitivity analysis is also provided.

The programming unit of the framework



Drawers contain commands

Code in visual programming blocks

Figure 6-5: The implementation of class 3 in the programming framework (step 1)

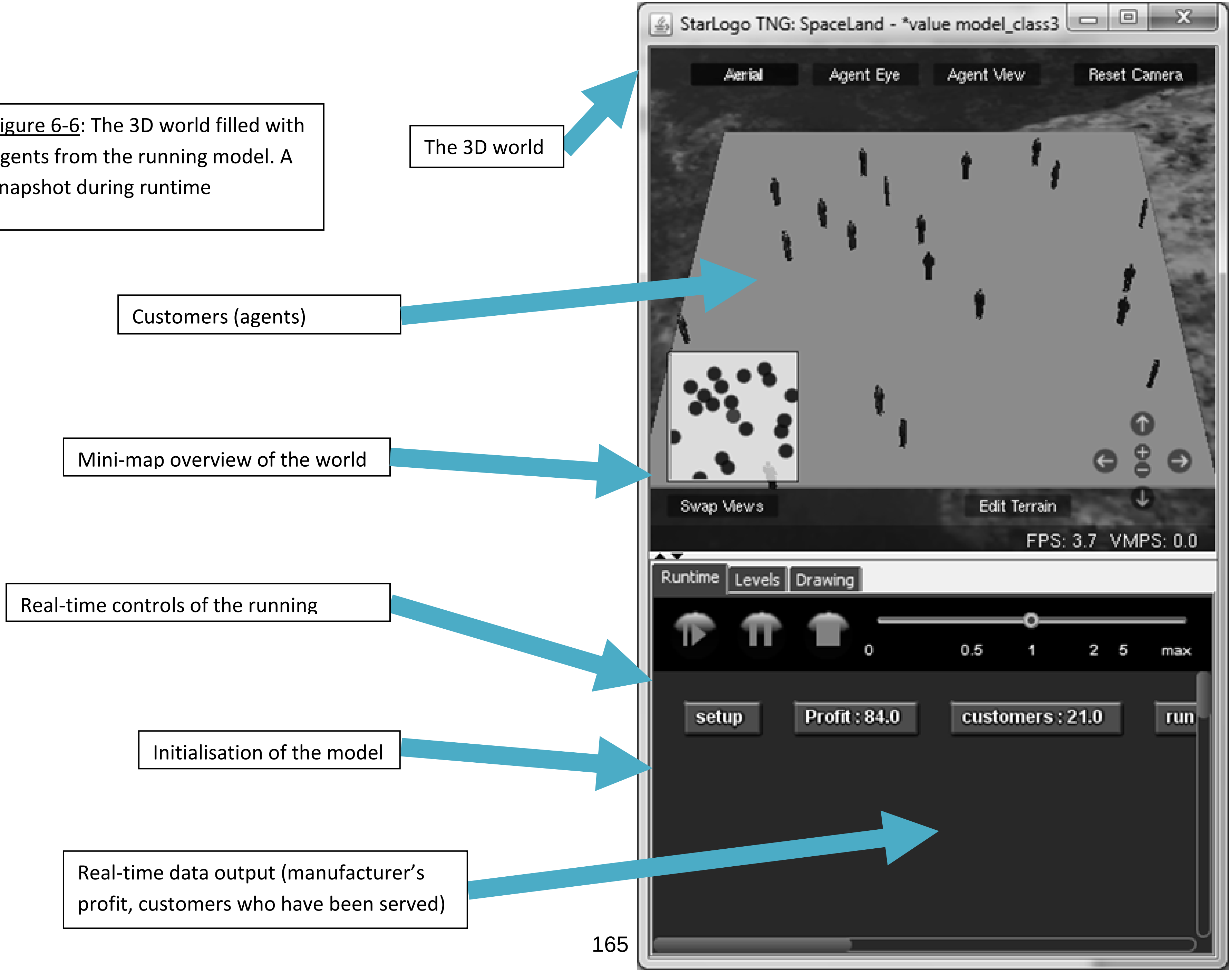
Part of the model for class 3

It shows how agents interact and get service provision by encounter the manufacturer in a collision based process.

Within the collision block the following procedures occur. The customer (agent) contacts the manufacturer. Then the manufacturer checks customer's available funds for a specific service level. If the customer can afford the service which is provided by the manufacturer then the customer gets served and is being killed of the customer population. At any time every customer can be served only once.

The difference from class 1 and 2 is that after the customer gets killed all other customers have an increase in their individual reservation values by one. Therefore they gain in customer value due to the fact that the customer preferred the manufacturer's current service provision.

Figure 6-6: The 3D world filled with agents from the running model. A snapshot during runtime



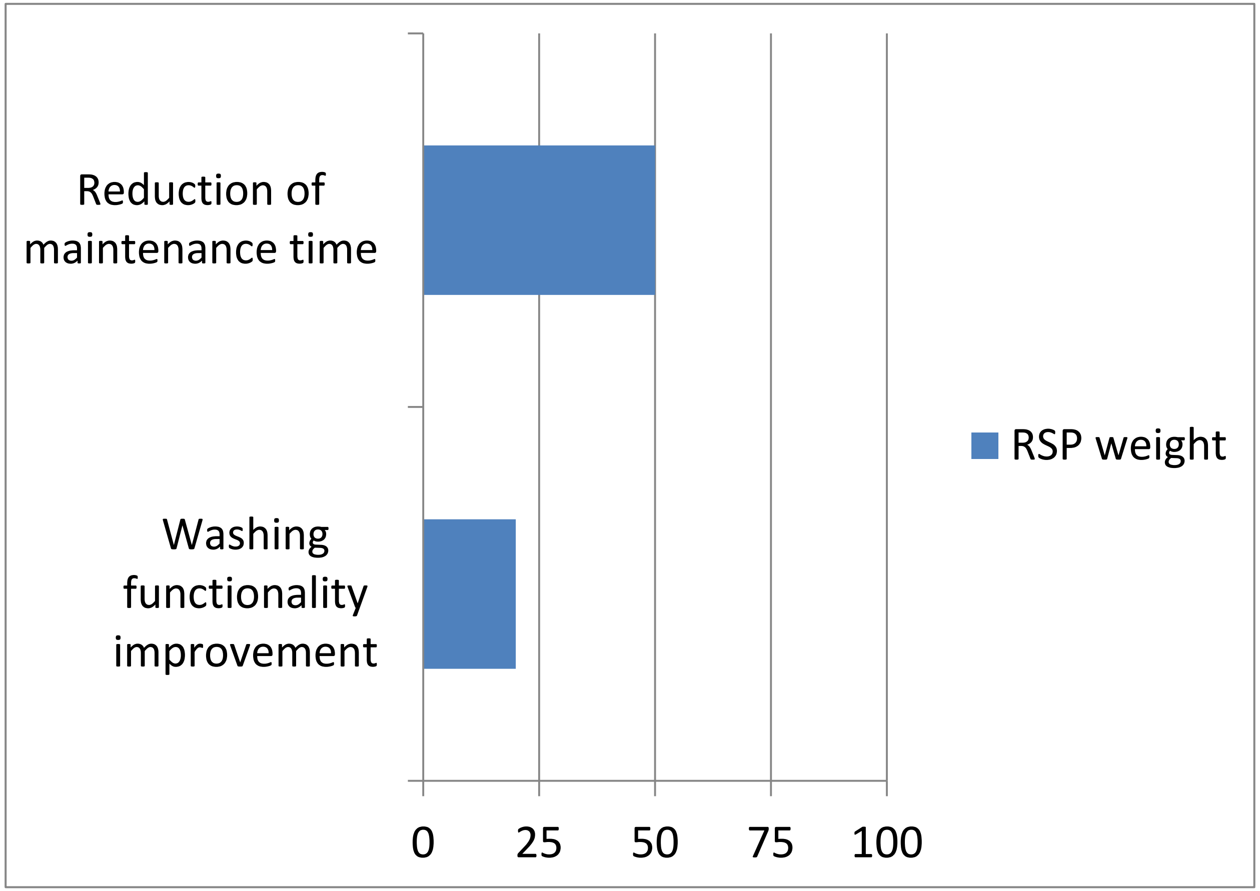


Figure 6-7: Evaluation of individual customer requirements and classification according to importance in SE (step 2)

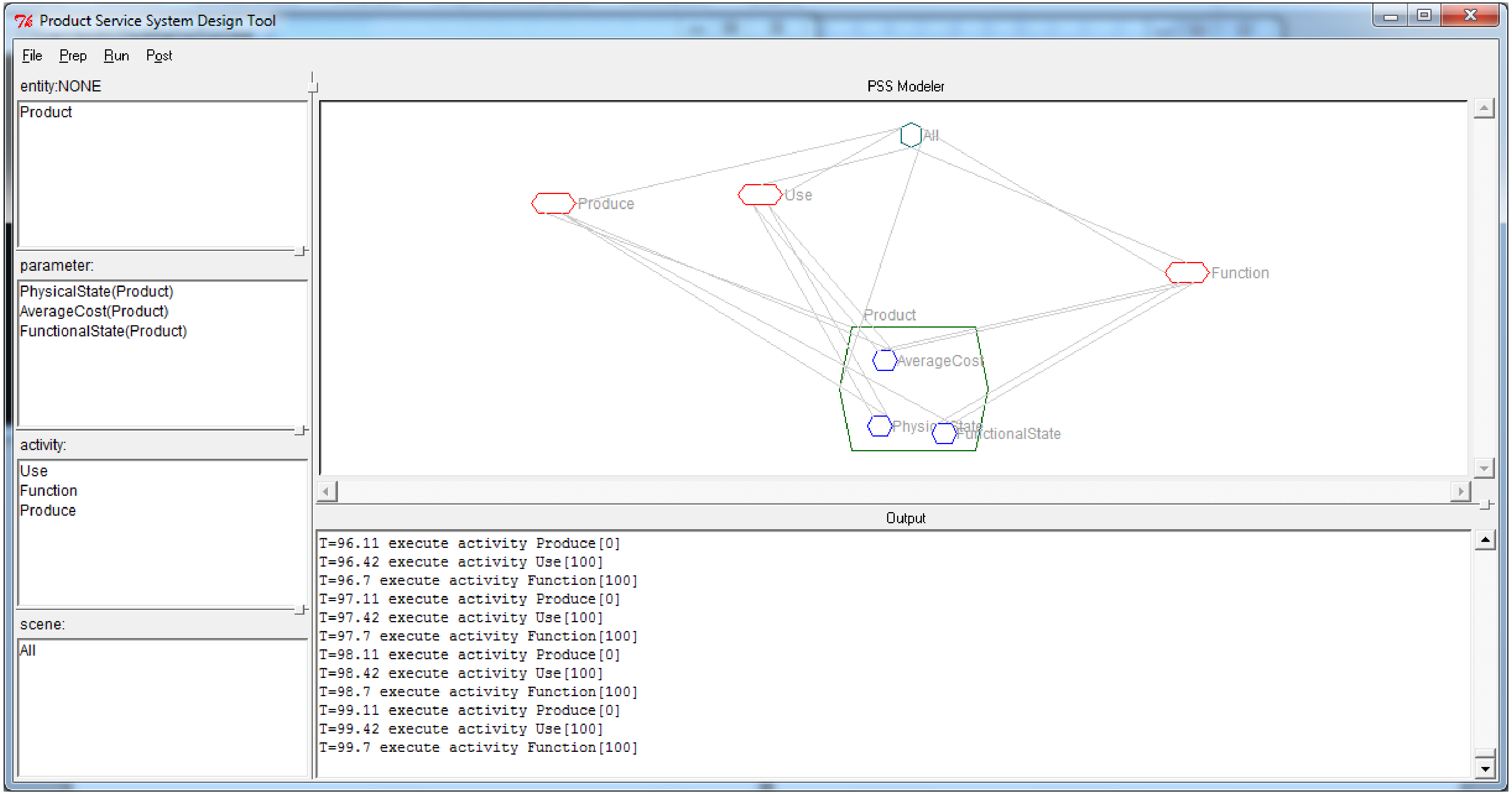


Figure 6-8: Model representation of the laundry service using the lifecycle simulator as the final step of the unified modelling system (step 3)

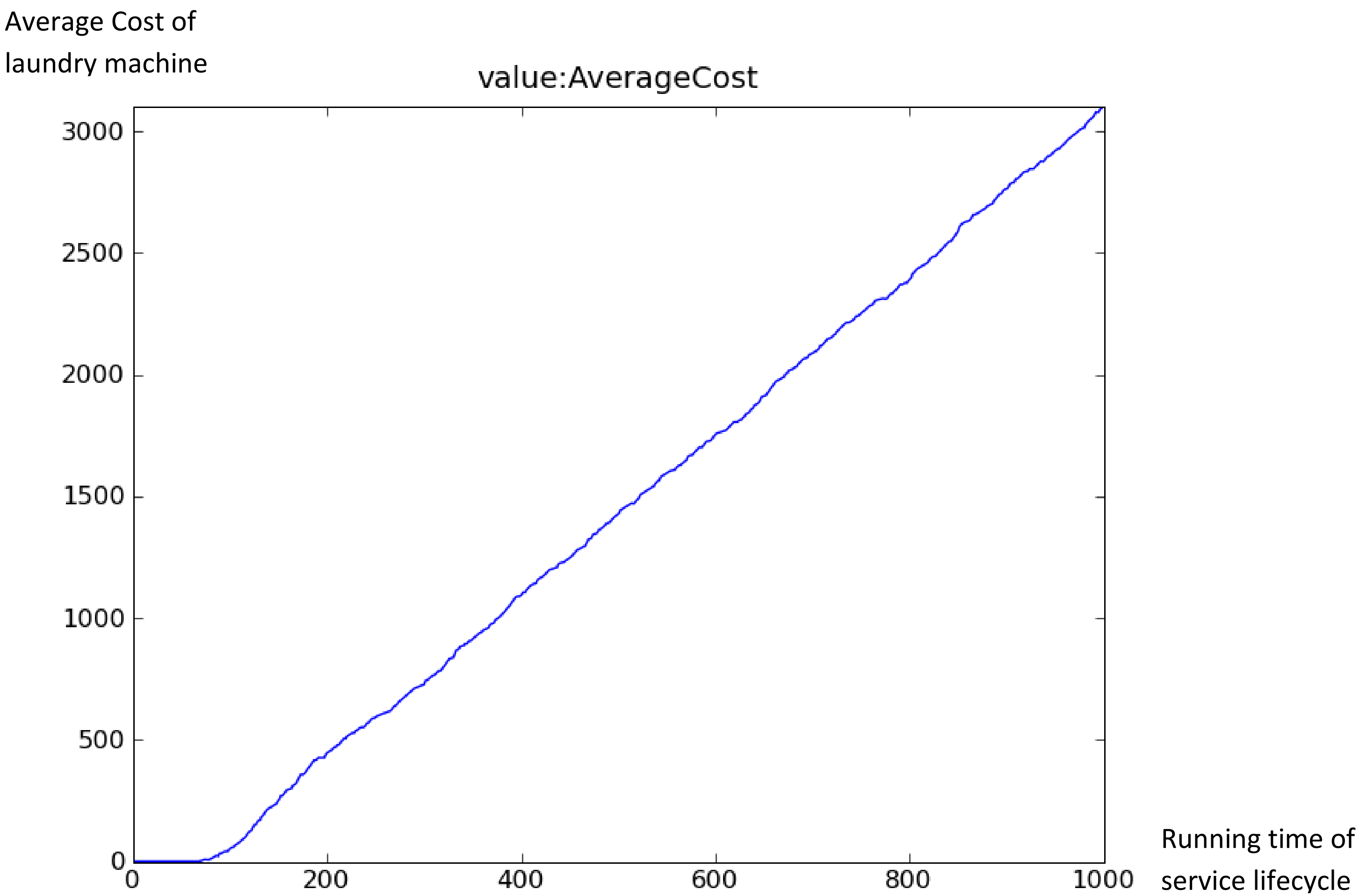


Figure 6-9: Average provider's cost for the laundry machines used in the whole service lifecycle

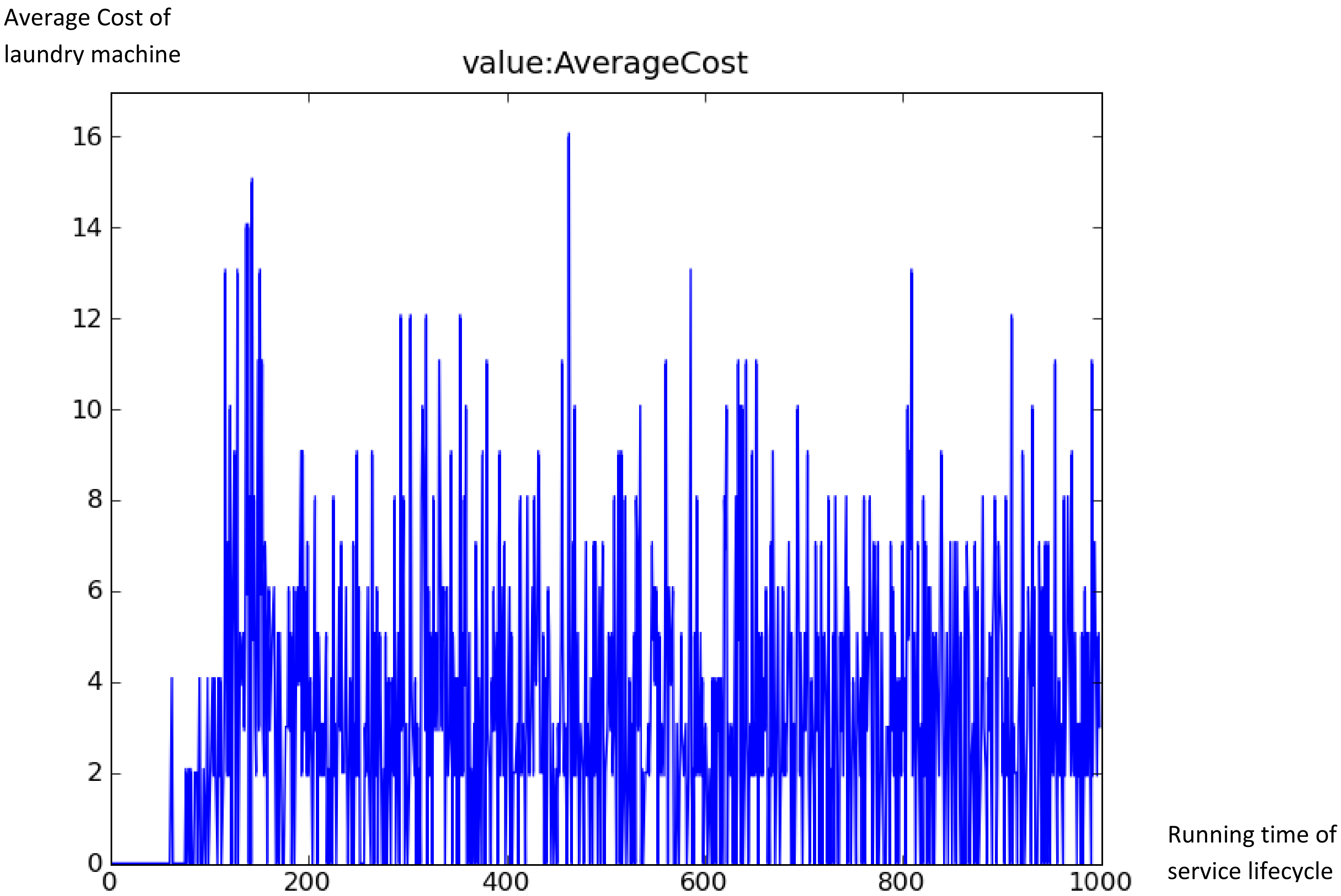


Figure 6-10: Average provider's cost for the laundry machines used for each step of the service lifecycle

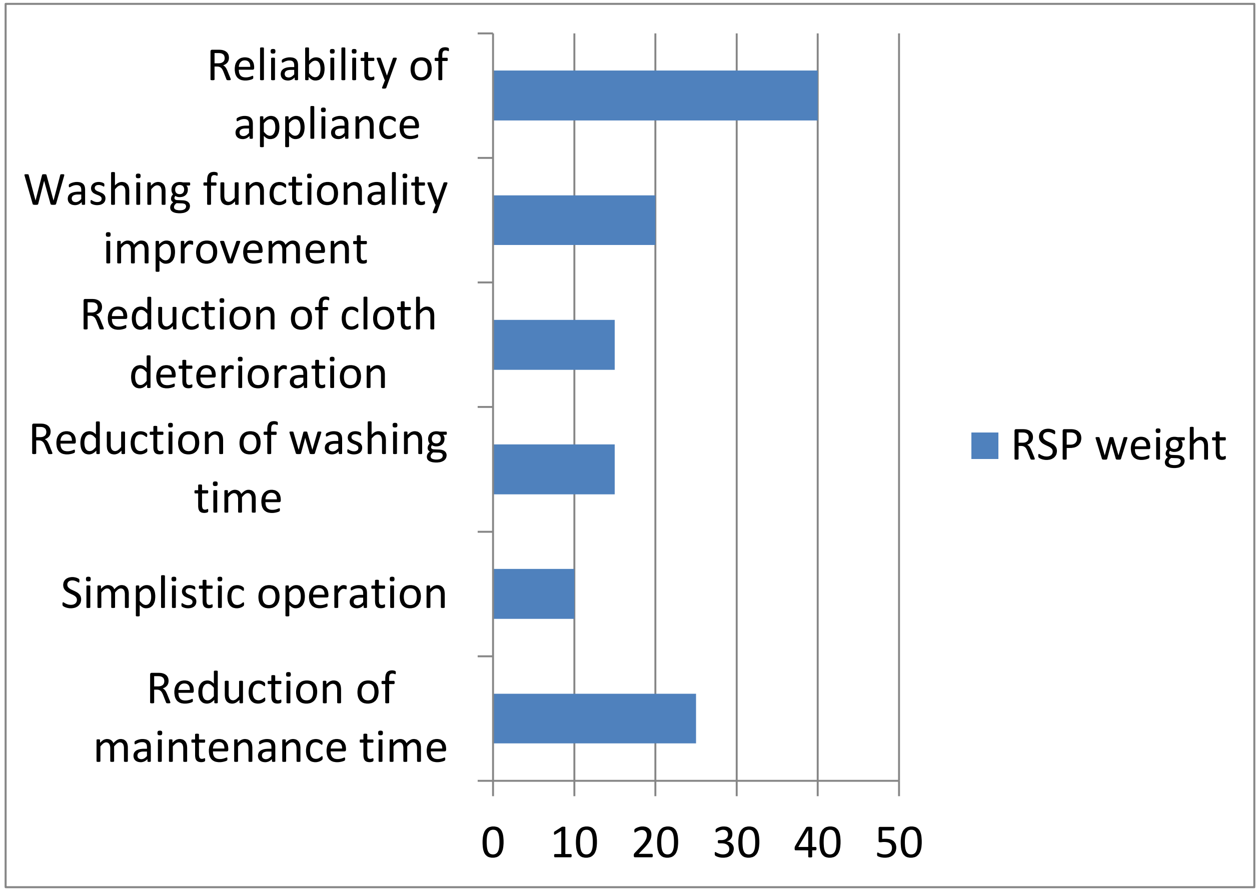


Figure 6-11: Evaluation of individual customer requirements and classification according to importance in SE for all customers' requirements

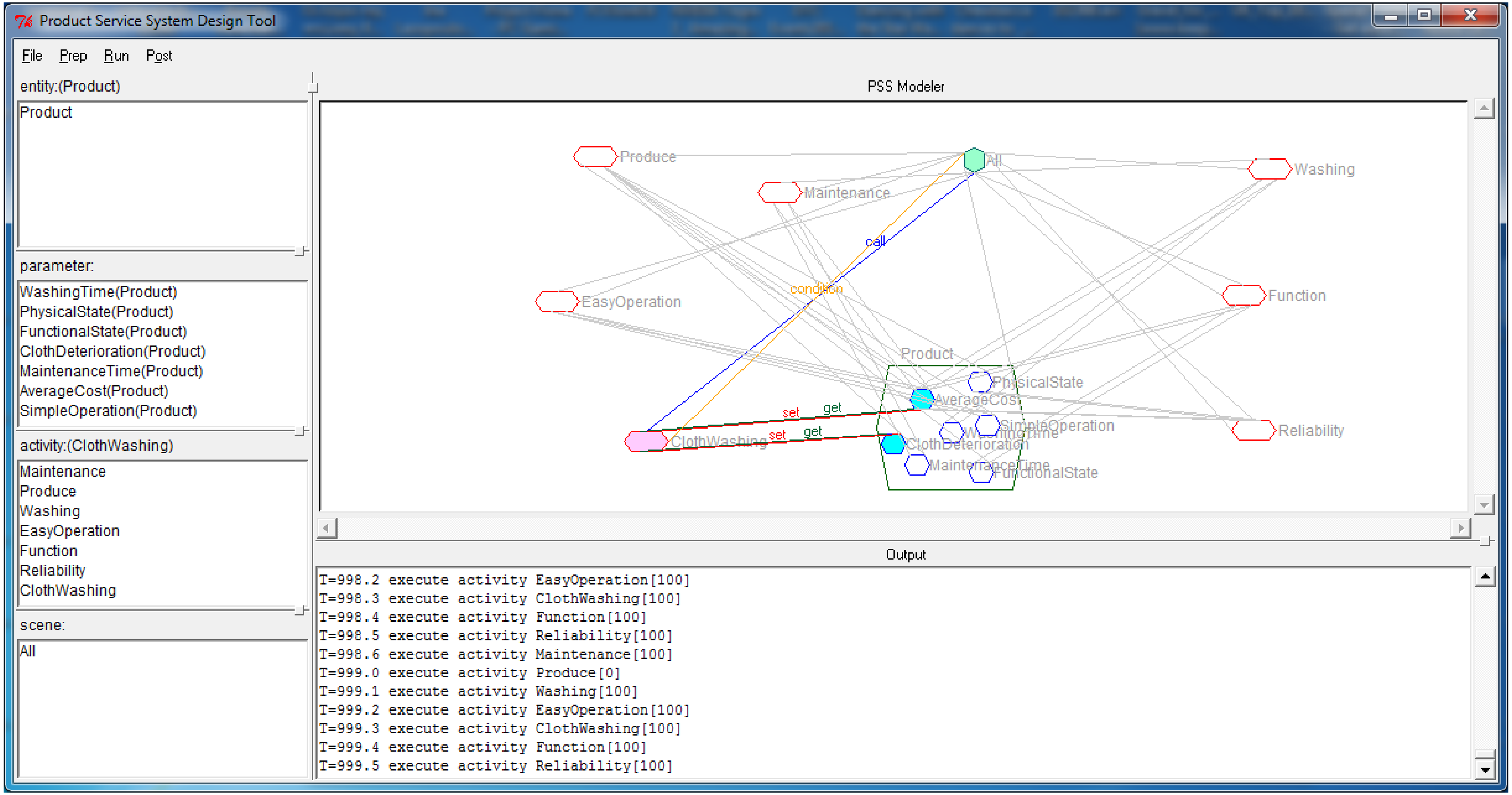


Figure 6-12: Model representation of the laundry service using the lifecycle simulator for all customer requirements

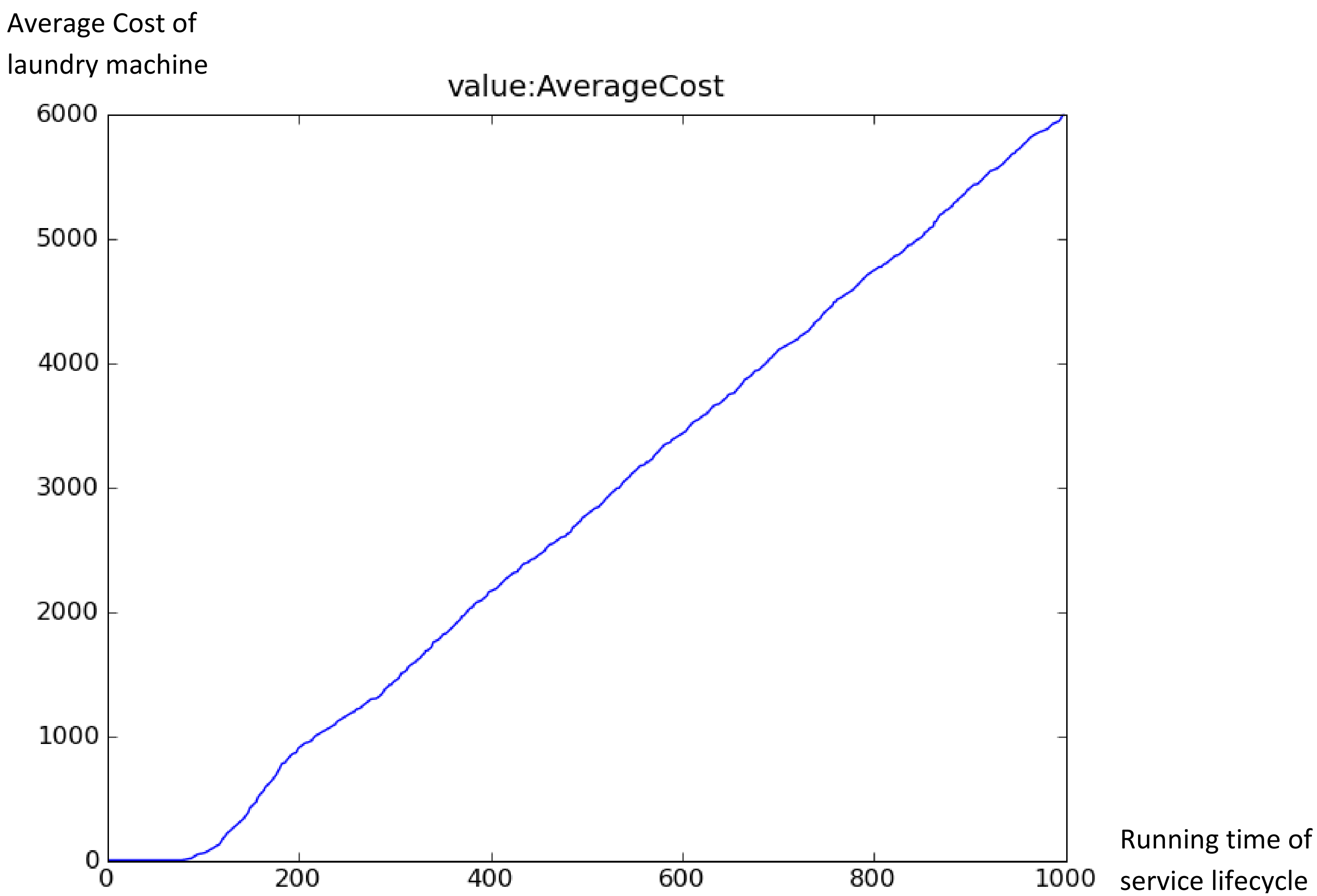


Figure 6-13: Average provider’s cost for the laundry machines used in the whole service lifecycle satisfying all customer requirements

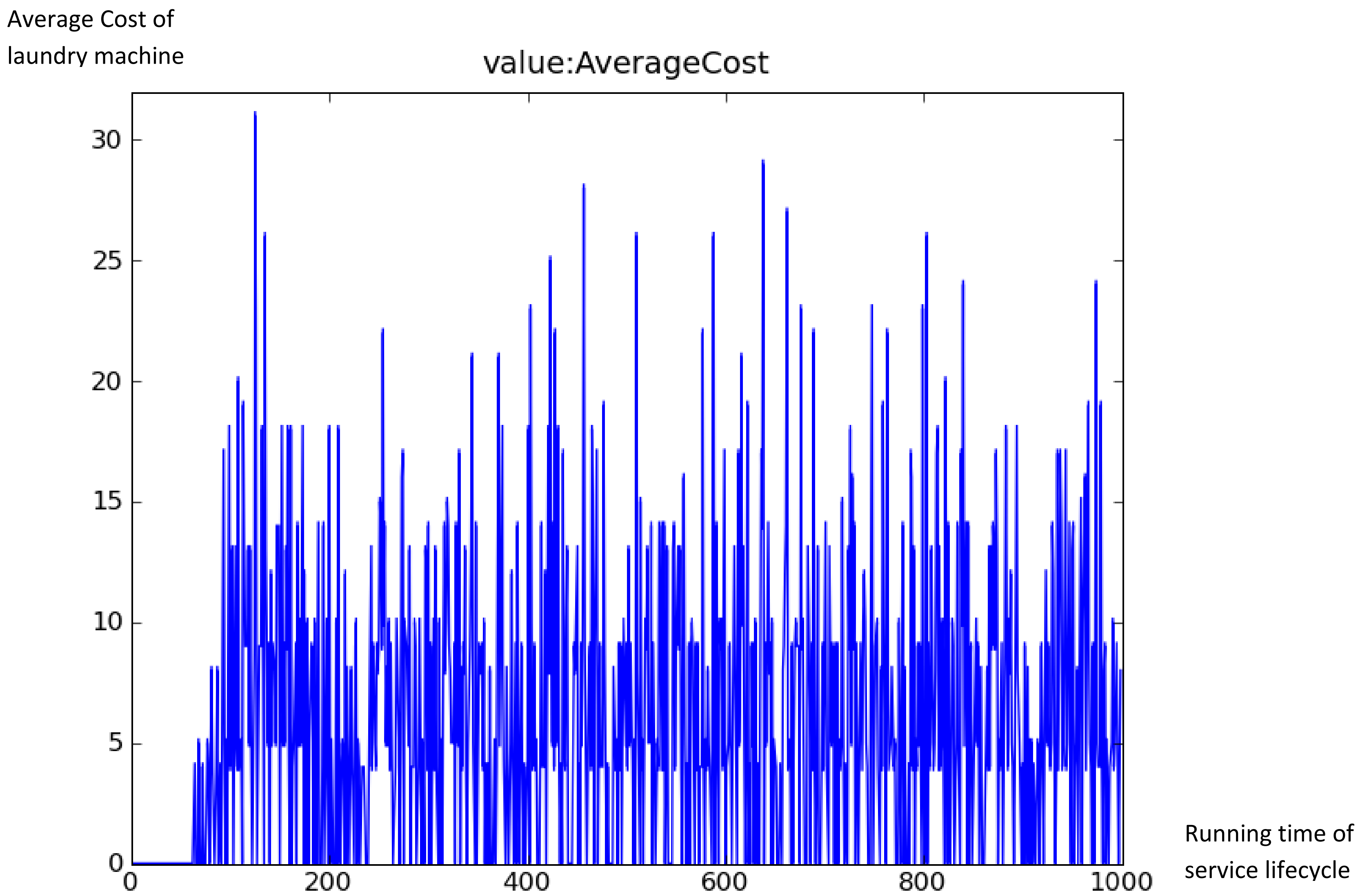


Figure 6-14: Average provider's cost for the laundry machines used for each step of the service lifecycle

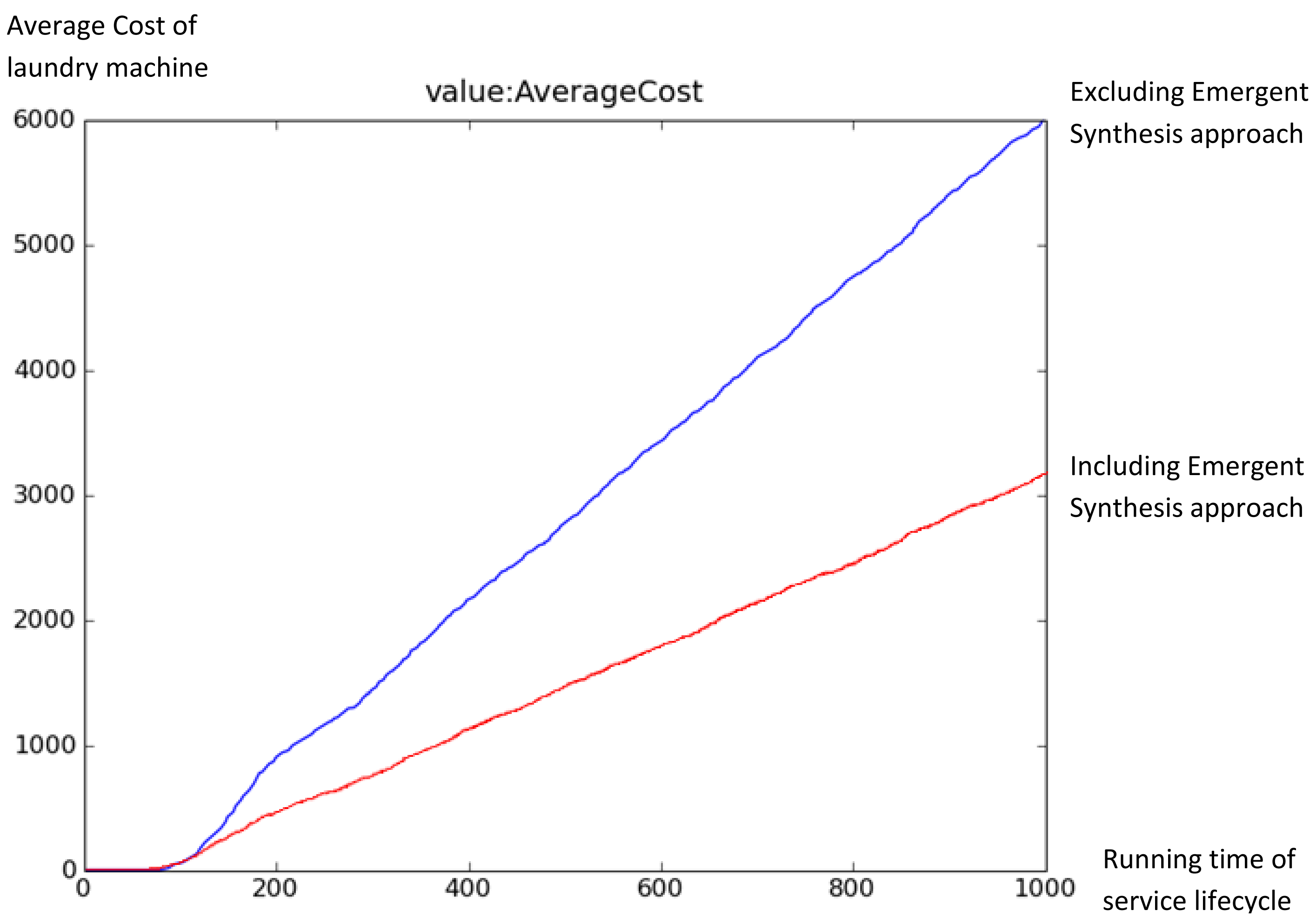


Figure 6-15: Contrast of the previous two different outputs (see figures 6-9, 6-12)

6.6 Summary

We developed the unified modelling system. In order to accomplish this task we combined and interconnected existing methods and methodologies which would give solution to the previously identified gap that we detected in chapter 4. At the beginning we provided the rationale behind the initial conceptualisation of this system. The purpose for pursuing such a course of action was also explained. In the next section the data flow of the unified modelling system was provided. Using several figures it was shown how the interconnections will work, their purpose and output of each one, and how the combinatorial process is achieved, to form the holistic view of the unified modelling system. Next in line was the statement of the service scenario, which was used as a case study to validate this system. A rental service was picked up to form the test case for such a system. Details explaining the rationale behind this decision were also provided. Last section was the formulation of the results which were indicative of the unified modelling system's success.

CHAPTER 7

Discussion and Conclusions

7.1 Introduction

In Chapter 6, the development of the unified modelling system for representation of services was presented and validated through a case study, a service scenario of laundry rental services. The development was based on the observations which emerged from Chapter 2, Chapter 4 and Chapter 5. The purpose of this chapter is to present a discussion of all the key themes considered throughout this thesis. Additionally this chapter includes and presents the conclusions drawn from this thesis.

7.2 Discussion of Key Research Findings

This section discusses the key research findings achieved from this research. The discussion follows the sequence in which the thesis has been presented. It has to be mentioned that limitations of the methods and results that are going to be presented and discussed were the outcomes of the specific cases that were presented and analysed in previous chapters. It cannot be excluded that these could be potentially valid to other cases as well but it has to be researched further.

7.2.1 Comparative Analysis of Service Design Methods

There are 4 main research findings presented in this section based on the analysis of the results at the end of Chapter 4.

1. From the analysis, we can see that previous methods lack when there are multiple types of customers interacting with the service and service provider, creating different scenarios. Methods don't have capabilities of dealing with those issues. In a typical real world service scenario the interactions are many and the system tends to be rather chaotic. In a closed (fixed input-output) environment there isn't this dynamic fluctuation because the service environment is closed. Moreover the modelled interactions are few. This is a constraint that methods apply for a reduction in complexity.

2. In a service environment there are not only the interactions within the service but also other interactions outside that can cause disruption and interference (maintenance, market competition, resource handling, etc.). The service scope changes and the service network can expand or contract. It is difficult to deal with these situations in the long term.

3. To cope with a huge number of interactions within a service and expansion of the service environment itself, there needs to be a reconfiguring mechanism that could change the way the service provision is modelled. As a future extension, that could lead to an automatic method for dealing with sudden changes.

4. Lastly, there should be a functionality to create novel solutions through model generation, taking into account the available resources of a service provider, which could lead to providing potential solutions to unexpected situations / problems.

All of the above depict the dynamic nature of a real world service system which underlies within the initial identified service features. All methods have difficulty, to a certain extent, in dealing with all of these issues. In particular, SE can partly address only the first one, while ISCL covers partly the first, third and fourth. SB has issues with all of them.

The limitations in evaluating current methods include limited testing with a rental service scenario. This was done to provide an assessment of the methods. Moreover, it cannot be considered as a general statement involving all kinds of service scenarios. However, it gave a first insight on the methods against several dynamic features, but for a more thorough examination it would need multiple testing on different cases to provide a more generalised view.

7.2.2 Conceptual Development of the Solution through a Generic Agent-Based Modelling Language

In this section, research findings of Chapter 5 are presented based on the analysis of the results at the end of that chapter.

SySML diagrams can be generated to support service design and act as a service representation method. For analysing and conceptualising a service, a company would need to capture the key components of the service system (customer, service provider, service) and the interactions between them. These are then implemented into SySML diagrams accordingly. Applying SySML for designing a service can be beneficial in terms of developing models that could aid systems engineers to transform captured data (service requirements, interactions, system organisation, etc.) into functions and components. All SySML diagrams are equally important for describing a service scenario because each one is functioning at a different level and represents a unique view of the service as demonstrated by the diagrams (figures 5-1 to 5-7).

Moreover SySML as a technique gives the ability to understand decisions made during service design and development, and act as a guide for testing a service by building up different service scenarios. The diagrammatic notation can also help designers to maintain traceability during a service reconfiguration. This is possible mainly because it offers components that could enable them explaining the rationale behind their decisions during the design phase.

The default programming environment and its characteristics can be seen in figure 5-8. In the model implementation there were 50 customers and one manufacturer (figure 5-11). The manufacturer was in the middle of the world in order to be equally accessible to all agents and being able to get served. All agents were performing random walks on the world until they reached the manufacturer. When a collision took place the manufacturer checked at the customer's reservation value and if it could buy a particular level of service, customer got satisfied and also got deleted. Therefore every customer could be satisfied only once. In order for all customers to get satisfied the model was running through a predefined but large period of time for acquiring around 90% satisfaction rate. Every simulation run took around 60 minutes to be concluded. The manufacturer's profit and the customer's value (in terms of satisfaction rate) was calculated for each emergent synthesis class in terms of which service level according to cost is being selected by the customers. In particular, in this model there are three different service levels implemented, each with different price values for the customers. Among the 50 customers, 1/3 of these were given a specific value. So basically there were three groups of customers that could buy one out of the three service levels. One group with low expectations thus lower reservation value, one with medium and one with high. The goal was the maximisation of the profits which in addition also offered value creation for the customers.

The implementation modelled all three classes of emergent synthesis.

- Class 1 (figure 5-9) is when everything is known, from the agents to the environment. In the model, implementation took place in the form which the reservation values, which also define the customer's value, are fixed and known prior to running of the model. It is defined during the setup and initialisation phase. By running the model most of the time, a service level having a medium price point was selected.

- Class 2 (figure 5-9) is when the environment is unknown and can change. In this particular situation, the selected reservation values were not fixed for each customer as per class 1, but were rather random numbers selected from a predefined integer number space. Therefore the values for each customer were unknown while running the model. The outcome was similar to class 1. That was sort of to be expected, because of the nature of the random process and the modelling choice of implementation.
- Class 3 (figure 5-10) is when both customers and the environment are unknown. In this case the random reservation values of the customers as occurred in class 2 were combined with the interactions of the colliders with the manufacturer. Each customer that got served, it gave rise to the reservation values of all the remaining agents on the world. That was to show how a network externality affected customers' choice on level of servitisation. Therefore more agents were prone to ask higher priced service level satisfaction in accordance to the preference of the majority. In this case more people preferred service level 3 in contrast to the other two classes where the majority of customers' were satisfied by service level 2. Higher manufacturing profit and an increase of customer's value was reported, in terms of higher satisfaction rates, because of the customers' preference of a more costly service level.

The results from class 1 and 2 were expected to be rather similar because of the fact that in the fixed reservation customer's value, regime customers' were split into three individual groups of different purchasing power. Thus, the outcome was balanced into mostly the service level 2 which offered a medium price point. The same occurred to class 2 even though the reservation values were randomly distributed. The randomisation distribution produced similar classes of customers with approximately 1/3 distinct groups across a range of reservation values. Therefore, even though individually the customers' reservation values were unknown, the total customers' group output was similar to that of class 1.

The acquired results from the agent-based modelling environment that was used, and the output of the three distinct emergent synthesis classes, along with the service market scenario obtained by the literature, show the similar trends that were justified in the literature. By referring to trends we mentioned on the differences of the three classes and how they are defined in a service market model according to output. By using another research method we also affirm that other agent-based modelling methods, which are available and have been demonstrated effectively to various other fields, can also be applied to the service design domain and effectively model and simulate the emergent synthesis methodology.

7.2.2.1 SySML Limitations

It should be noted that careful understanding of the service and a clear path for producing the mapping with the SySML notation is needed. It is much counter-intuitive while trying to adapt the notation to a service system, because systems engineering field deals with analysing products, hence it includes mostly tangible components. The notation is thus engineering-oriented and the differentiation in levels from the decomposition process is blended for service systems.

7.2.2.2 Limitations of the Programming Environment

There are some limitations or better say lack of strong points in this environment. First of all one would need to be acquainted with the programming skills in writing such service models. One would need to analyse the models from the agent-based perspective, then to understand how objects interact with each other and how the connections among all things are being established. That would give the understanding needed to model service scenarios in an agent-based fashion.

Another more or less critical point is the lack of collecting and storing large sum of data for further analysis. This occurs due to the lack of data manipulation functionality within the programming environment. Saving data is not a strong point of StarLogo TNG. There are some ways of getting passed this obstacle (i.e. using tables), but not completely (system can run out of memory due to continuous data sampling). It is not straightforward and requires some non-trivial thinking. For complex service systems this may prove a deterrent to potential future researchers. Other methods, though, some of which were mentioned in the introductory section, may prove better suited. Every programming environment has its pros and cons and one must decide what is best in the situation it should face.

7.2.3 Development of the Unified Modelling System and its Validation

This section presents the research findings of Chapter 6 based on analysing the results at the end of that chapter.

The unified modelling system that was deployed for this particular service scenario showed that it is possible to reduce the cost of the service provider based on fulfilling only the most important customers' needs, which have been identified using the emergent synthesis methodology (see figure 6-15).

For this to be realised important stages needed to be carried out that would follow the steps of the conceptual data flow that was presented in Chapter 6, Section 6.3. At first several assumed values and parameters were needed to be used in order to represent the initial input of the unified modelling system. These values were presented in table 6-1. Six different customer requirements were identified by the literature that customers may need during this service lifecycle. "Reliability of the appliance" refers to how much reliable is the washing machine or in other words the fault tolerance level. Another one is the “lack of washing functions”. That refers to customers who may need more functions to be included in their appliance. “Cloth deterioration” takes the fact that an appliance may need fixing because it gradually deteriorates clothes while washing them. “Washing time” may be another customers’ need because they would expect faster washing of clothes as a requirement. “Simplistic operation” can also be a plausible requirement if an appliance is so complex to operate that one would ask for a trivial approach. Lastly the “maintenance time” refers to the time that one has to wait in order to get its appliance on service maintenance or fixed. It is important as a requirement that less time duration makes the customer more satisfied.

The decisions behind the perceived cost that was required for all these customer requirements to be met were based on how much the service provider has to spend for each one of them. Change of the appliance layout to provide a trivial operation had the lowest cost impact on the provider. Reducing washing time by making the appliance operation to spin faster was second from the lowest cost. Reducing cloth deterioration would need specific measures to be applied and is a more complex solution than reducing washing time. That is why it came third from the bottom. Making the appliance much more reliable would require extensive tests and time and many different conditions for someone to benefit and reduce maintenance time or fixing. Therefore it costs more than the previous requirement. Reducing maintenance time or fixing would require an essential upgrade to machinery, tools and personnel and that would cost even more than increasing the appliance’s reliability. Lastly the most expensive of these requirements would be to invent, create and deploy new functions and functionality to the appliance because of the increased R&D costs. Apart from giving the rationale and justification behind each decision, a sensitivity analysis was presented showing how service provider‘s total cost for each customer’s requirement is affected by the individual customer’s importance.

After setting the values and parameters of the service scenario, next is to form several service levels, which the provider would offer to the customers. Three service levels were created, according to cost, a low cost service provision, a middle one and an expensive one. Each of these service levels consist of two separate customers' needs which in turn can fulfil. So for example a customer who will buy a low cost service level knows the provider's offering and is satisfied from its purchase.

We feed those parameters and values to be used with the emergent synthesis methodology according to the first step of the unified modelling system diagram. For the simulation to be conducted we used the open development environment which we also used in Chapter 5. This agent-based modelling environment has been validated as an appropriated method to be used in the service design field. The validation process targeted a simulation of the emergent synthesis methodology thus the same environment can also be used to model this particular service scenario following the same or similar principles. The modelled emergent synthesis methodology for this scenario, using the data available in table 6-1, can be seen in figures 6-5 and 6-6. Figure 6-5 shows a partial code of the simulated emergent synthesis methodology, which in particular, is the simulation of a class 3 environment, the one which has the highest value for this process. In figure 6-6 the modelled world environment can be seen along with the agents to form the customers and the service provider. After running this simulation for an appropriate length of time, in order to reach the highest possible number of agent interaction, the obtained results showed a unique preference of the customers towards the more expensive service level. That means customers who are not capable or not wiling of buying a more expensive service, changed their mind set dramatically. They were driven by other customers who purchased the expensive service level because of their perception of higher value. Therefore the total customer value, the value that customers perceive by acquiring a service, increased. Because of that, now we have identified the service level which transfers the highest value to customers and the next step is to prioritise the needs that this service level satisfies. Although there is a defining rule that individual customer's value would increase due to external influences of others, it is not guaranteed that it will come into effect either at all or towards a particular service level. It depends on two factors, the initial reservation values and the number of people that got satisfied by the current provider's service level.

The second step according to the unified modelling system diagram involves the use of the service explorer method as a simulation process with end goal to prioritise individual service requirements which are components of the service level. In this particular example we use this method to establish weights according to customers' input for each of the requirements of the chosen service which was the output of the first step. In figure 6-7 we can see the weights for the specific components of the selected service level. Maintenance time is much more important than inventing, creating and deploying new washing functions. These weights are going to be used as inputs to the third step of the unified modelling system which deals with the simulation of the service lifecycle in order to simulate the provider's cost according to customers' needs.

Third step involves the use of the ISCL which consists of the service design model and the lifecycle simulator based on that model. In figure 6-8 it can clearly be seen the model based on the service scenario. It consists of the appliance at the centre which has some attributes and the activities surrounding it. There is another one component which is called scene and is being used by the activities to call the appliance's functions and change its attributes. At the initial step the produce activity creates the size of the market model, which in this case is 100 and sets up all of the attributes' variables. This phase is called initialisation. Subsequently all of the other activities are called in a sequential order which has been defined before running the simulation. The attributes are parameters which are modified by the activities. When an activity satisfies a condition then the parameters are changed. Those conditions rely to the weights that have been identified during the second step of the service system. Each activity represents one of the customers' requirements and in order to be activated and fulfilled it must meet the demand of the number of customers they need it. To take a satisfying measure which is plausible it has been set up initially into the simulator the number of customers that would want a specific requirement. In this case that measure is approximately 1/10. Therefore at each time only 1/10 customers would actually ask for a specific activity to be satisfied. The simulation was timed at 1000 runs. When there is an appropriate demand based on the customers' weights, defined in second step, the activity would be triggered and the provider would bear the cost. The required costs were defined in table 6-1. Based on all of these factors the simulation for this service scenario run for a long time (1000 times) and the cumulative average cost for the provider was produced. Figure 6-9 shows that result. The line is gradually increasing because the cost of each run is added to the next one in order to acquire the provider's average total cost during the lifecycle of the service. At the end it has been found that for the whole lifecycle of the service the provider would have a cost of around 3000 based on the activities it offered. It must be noted that an activity can be triggered more than once by different customers or even by the same customer. Figure 6-10 shows a different representation of the acquired result. It gives the potential range of values for each simulation step.

In order to do a comparison without using the initial step, the emergent synthesis methodology, we established the service model while taking into account all of the available customer requirements. Now we don't have any specific service levels and the provider is offering satisfaction for all customer needs. Therefore the first step of building a model according to this type of service scenario is to use the service explorer again to establish the weights for each of the customers' needs. As we can see in figure 6-11 weights are completely different to the one we calculated when we had one two available customer requirements. Even weights for the same requirement have changed due to the apparent influence of all the other. We can see that the most important requirement to customers is the reliability of the appliance while the maintenance time comes second. The reason for this discrepancy is the increase in customers' choice. Now customers have assessed the whole pool of requirements rather than a subset of them which was presented in figure 6-7.

ISCL method was again used to formulate the model under this new service scenario and all of the requirements were presented in the form of activities. Similar principles were followed as in figure 6-8 to establish the new version of the service system which is shown in figure 6-12. As we can see this model is more complex and has a lot more parameters than before. Again, for each requirement an activity was set up consisting of its own weight following the results which were given in figure 6-11. The provider's costs related to each of the activities were provided in table 6-1. The results are shown in figure 6-13. We can see that at the end of this service lifecycle the cumulated average cost for the service provider reached 6000 nearly double than the previous established cost (figure 6-9) which was the output of the unified modelling system. The reason for this is because the cost is much higher when a service provider tries to satisfy all of the service requirements with no apparent value for the customers. Of course some customers would be satisfied by such course of action but the majority would only want specific requirements to be fulfilled through which they would receive higher value. Figure 6-14 shows again the acquired result with a different representation. It gives the potential range of values for each simulation step for the comparative case, which shows the difference from figure 6-10.

The unified modelling system resulted in showing that a service provider is better suited to shift its spending towards satisfying only the requirements that are perceived by the customers to have higher impact on the value they receive. This approach would lower the costs of the service provider, thus raising its profit, in addition to an increase in customer value. By establishing this service scenario as a case study we pinpointed the need of creating a new service system for designing services based on the emergent synthesis methodology. In particular this methodology dealt with the need to perform analysis of the social dynamics of the service and identify the correspondent relations between requirements and customers' values. It has been demonstrated and validated that by combining the three aforementioned methods a new service system has been established by the name "unified modelling system" which could help service designers to perform performance improvements to their service models.

7.3 Main Research Contributions

The contribution of this research led to a better understanding of customer value and how this reflects to customer requirements and cost for the service provider. It has introduced a novel approach on how to conceptualise and design a service having those characteristics. Moreover the presented novel unified modelling system could enable designers to take the right decisions and resolve issues related to perceived customer value and provider's profit while attaining a win-win situation for all of the entities (customers, provider) involved.

The key contributions of the research are summarised as follows:

- A novel method for representing a service (SySML) has been explored. This method could well aid system designers to capture the key elements of a service system along with their interactions. They could transform them into functions and components and thus acquire the ability of understanding the system in a deeper level. System designers can then collaborate with service designers based on the different views of understanding and exchange the rationale of their decisions on a common platform.
- A novel method for service simulation has been investigated based on StarLogo TNG, which is an agent-based modelling language. An open-source environment has been established to be appropriate for service simulation where emergent synthesis methodology was used for validation purposes. Although the scope of this research was the initial motivator leading to this method, which would be suitable to formulate and simulate the emergent synthesis methodology, it is not limited by it. A method involving an open source, generic modelling language for services could benefit immensely researchers and designers in capturing an integral part of the service, the social dynamics.
- A new and novel system called "unified modelling system" was developed. It can relate value perceived by customers in the form of satisfaction and fulfilment to the actual cost required by the provider to meet those needs. It

could help service providers to identify the lifecycle service costs targeting on specific service provisions which would increase customer value.

7.4 Main Research Limitations

This section presents the limitations of this research. These limitations are related to the unified modelling system.

In order for the unified modelling system to work properly there must be a modelling of the service prior to the initialisation of the system. SySML can work for this purpose but there are limitations on the scope of the modelling procedures. Although it provides relatively good performance when services are trivial enough, like when entities and service operations are limited, when a service is a multiple of many interactions and the end result has to include many parameters, SySML is rendered inadequate for a service representation at a higher abstraction level.

Limitations of the agent-based modelling language that was used for simulating the emergent synthesis methodology involve data storage and manipulation when a service involves many parameters and variables. Thus the ability of a designer who wants to conduct complex operations during testing phase of its service model based on the social aspects of the customers is limited. Moreover modelling social behaviours based on different interactions and environmental changes may not be trivial and one has to find a way to map those changes to be reflected in the opened 3D world.

Using QFD techniques to prioritise customer requirements by adding weights is a good way of identifying function importance of the service but other techniques for value analysis and value of information may be proven better candidates to extract and associate customers' qualitative data into quantitative. That would provide better support to decision analysis leading to a more accurate decision-making function.

7.5 Future Research

The literature review showed that service design is a key research area. The current research focused on two unique and state-of-art service methods and tried to give a different perspective and output of a service by reaching specific goals. A unique modelling system was developed for that issue which connected those two methods with a methodology designed for the manufacturing field. In the future it should be possible for other techniques in other areas to be identified to be used as key components to attain certain goals which would be beneficial not only for service providers but also for customers too.

In the developed system a solution for the selection of service levels and customer requirements has been provided through the use of an agent-based modelling language along with the QFD techniques applied in the service explorer method to establish decision making capability. However other optimisation methods have not been considered in this research. In the future it may be necessary to compare other methods and tools in order to improve this area.

7.6 Summary and Conclusions

This section aims to illustrate the outcome of this research which spans in three chapters, Chapter 4, 5 and 6.

A service consists of intangible elements such as customers, resources, etc., and may also include other sub-services such as maintenance or expansion of current services to satisfy future changes and trends. Therefore, a service is a multidisciplinary system and it is very important, during the lifecycle of the service, to try and capture this nature.

In Chapter 4, we tested prototype methods developed specifically for service design to see what the limitations in this particular area are. The outcome of this comparison can be summarised below:

- Service Blueprinting does not address any elements that can change through time.
- Service Explorer can provide multiple customer interactions by combining all customer requirements and identifying the most important, thus giving a prioritisation element. Moreover, it has the ability of evaluating a service when current requirements change. However, there is no way to automatically assess current state of the service and adjust the resources according to new prioritisation rules. For every change that is employed, there must be a reassessment of the service to seek the most important requirement that needs satisfaction. Moreover, there isn't a lifecycle simulator that could help the service provider to increase its service efficiency and deal with other changes apart from these related to the customers. Lastly, there isn't any assistance for model generation based on previous models or existing functions that could be recycled to provide a modular service design process.
- Integrated Service CAD and Life cycle simulator provides multiple customer interactions which are treated in the same way. Dealing with sudden changes and external factors is possible through the lifecycle simulation process and resource distribution according to current needs is accomplished. Moreover, there is capability of generating service models through pre-established sub-models/functions. However, there is no prioritisation process at the beginning of the service design. Therefore service efficiency through resource/cost balancing is achieved only by the lifecycle simulator excluding the customer part. Moreover, the resources that a service provider has are stated as static. Complete knowledge of the initial service state is required.

It can be seen that a real-world service scenario is not accurately represented by current prototype methods due to a number of constraints in the service design and lifecycle process.

In chapter 5 we proposed emergent synthesis as the methodology which would provide solution to the research gap identified in Chapter 4.

We showed that SySML can be used for analysing systems consisting of intangible elements which could provide a standardised way to support service design. The advantages of using SySML include maintaining traceability in service reconfigurations, providing rationale behind decisions during design phase and describing a service in multiple layers giving invaluable insight to designers. Disadvantages include the need of a careful understanding of the service and a clear path for producing the mapping with the SySML notation.

We also showed that an open source agent-based modelling language can be used to model services and in particular the emergent synthesis methodology. At first a service scenario was identified by the literature to be used as a test bed for the agent-based modelling paradigm. The next step was to analyse and briefly discuss the modelling method that is going to be used for this purpose. The rationale for choosing the correct modelling method was also explored. In addition there was a brief walkthrough on the emergent synthesis methodology that was deployed for the purpose of service simulation which the paper from the literature used. Apart from that there was also a diagrammatic representation of the service scenario in a higher level perspective of the simulated model. Differences from the literature in the implementation phase were acknowledged, notified and thoroughly discussed in the appropriate section. Results showed that by using an agent-based modelling environment, which has been used for research purposes in a variety of fields, one can also achieve service modelling through the emergent synthesis process (which was accurately implemented). Advantages of this method include a unique way of programming through graphical programming blocks, which can help the researcher to efficiently code the model in question, and a 3D world which depicts the environment where the simulated model runs. Disadvantages include a fairly steep learning curve of this unique programming process and the lack of efficient data collection and retrieval for further analysis where complex services models have to be dealt with.

In Chapter 6 we developed the unified modelling system. In order to accomplish this task we combined and interconnected existing methods and methodologies which would give solution to the previously identified gap that we detected in Chapter 4. At the beginning we provided the rationale behind the initial conceptualisation of this system. The purpose for pursuing such a course of action was also explained. In the next section the data flow of the unified modelling system was provided. Using several figures it was shown how the interconnections will work, their purpose and output of each one and how the combinatorial process is achieved to form the holistic view of the unified modelling system. Next in line was the statement of the service scenario which was used as a case study to validate this system. A rental service was picked up to form the appropriate test case for such a system. Details explaining the rationale behind this decision were also provided. Last section was the formulation of the results which were indicative of the unified modelling system's success. It was shown that it is possible for the service provider to reach higher profits by lowering its lifecycle provision costs while boosting perceived value of the customers.

Below are provided the main findings/ learnings of this research:

- Recognition of the fundamental research issues
- Analysis of the background research in the service design area and Identification of research gaps
- Adoption and implementation of the research methodology

- Identification of the limitations of current prototype service design approaches (SB, SE, ISCL)
- Proposal of the emergent synthesis methodology as the solution to the identified limitations
- The use of SySML for analysing systems consisting of intangible objects
- The use of an agent-based modelling language for simulating the proposed solution
- Development of the unified modelling system and its validation through a case study

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Appendix

TRIZ

Reference to Zhang et al. (2003) and Chai et al. (2005)

In a more detailed manner, stage 1 is responsible for collecting and identifying problems within services. A preliminary analysis is then conducted in order to capture information about the situation. A set of questions is being used to accomplish this task. The questions have been structured in such a way to provide an in-depth analysis of the problem and stimulate the following stages.

Through stage 2 the TRIZ technique of problem formulator (PF) (Zlotin and Zusman, 2001) is being used for modelling and formulating the problem in question. Function analysis builds a function diagram while PF generates a pool of problem statements based on this diagram. The creation of the function diagram involves realisation of basic function components and establishes function relationships between those. One way to achieve the former is by asking specific questions to consumers (Berkley, 1996). A two-type classification system, between harmful and useful functions, is being adopted for function identification. Functions are then connected in a cause-effect manner forming a network. In continuation to the previous step problem statements must also be formulated according to the function diagram. This procedure narrows the solution generation due to the fact that function relationships can easily be observed in contrast to a single problem structure (Terninko et al., 1998). By decomposing a complex problem into correlated small ones it produces more straightforward solutions.

PF is a good approach of analysing and generating preliminary results for function diagrams. However building such diagram for a complex problem is a rather tedious process which is also very costly. An alternative way for problem analysis involves the elimination of the inherent contradictions which will lead to addressing superficial problems. An inherent contradiction defines a key problem that lies deep within the system. The transformation of the problem into a form of contradiction is achieved by identifying two conflicting components in the system or two opposite requirements for the same component. This comprises stage 3.

Stage 4 deals with eliminating the formulated contradictions by using powerful methods from TRIZ theory such as inventive principles, contradiction matrix, etc. The inventive and separation principles are one of the most useful TRIZ problem resolution techniques. Empirical evidence has shown that these principles are equally effective concerning non-technical problems (Mann et al., 1999), (Terninko, 2001), (Retseptor, 2003), (Hipple, 1999).

In the last stage a pool of solutions should be generated from the outcome of stage 4. The main purpose of this evaluation is to identify which of these are the best ideas. The technique that is frequently used for solution evaluation is called ideal final result (IFR). According to Domb (1997) IFR is a description of the situation derived from the resolved problem without any additional cost. An ideal solution is one that meets all desirable benefits without producing any negative effects while being cost-free in implementation. After finishing this step solutions can be evaluated against the law of ideality. The closest solution to this should be the best one. The law of ideality states that any technical system through its lifetime tends to be become more reliable, trivial, and effective. Selected innovative service concepts would be the outcome of this framework.

Reference to Zhang et al. (2003)

Stage 1: an increasing amount of cars at Sentosa Island is the direct impact of lowering the entry fees. Although people from the local island welcomed this change it also brought some negative outcomes. At first the system can be decomposed into several subsystems such as visitors, cars, operations, staff, available resources, etc. The ideal solution should eliminate all of the negative effects while being able to attract visitors without creating new problems. So for this case the goal is to derive an effective solution that will eliminate the side-effects from the lower car entry fee while keeping the system at its ideal state.

Stage 2: a function diagram is constructed by using the preliminary analysis from previous stage. Finding the primary useful function (PUF) is the first step towards building such diagram which consists of increasing the tourists of the island so that the company responsible for lowering the fees can establish a brand name among the Singapore leisure industry. Improving the accessibility to the island acted as the useful function (UF) in achieving the PUF. Thus the company lowered car entry fees (UF) to make PUF a reality. By eliminating the harmful function (HF), people's perception of an inconvenient and expensive driving experience, led to new problems about the Island environment (HF). The formulated statements are being constructed from the function diagram. Initial analysis on these may provide some indications about the usefulness of each statement.

Stage 3 and 4: looking into finding a contradiction, a service capacity problem could act like one because it is difficult to accommodate so many cars simultaneously. Therefore an inherent contradiction would take a form of accommodating all entry cars in line according to the policy of lowering car entry fee. On the other hand it seems difficult to accomplish such task due to limited capacity and lots of negative impacts as a direct result of car increase. In order to provide solution to the contradiction two extreme situations must be taken into account: "many cars" versus “few cars”. In the “many cars” view, all cars are allowed entry and be well accommodated. In the “no car” view, entry cars should be separated from the island’s natural surroundings. Based on these indications and analysis, according to TRIZ separation and inventive principles, possible solutions may arise.

Stage 5: from stages 1-4 a list of possible solutions to address the initial problem has been formulated. The ideal final result would be to open a special channel for car entry in order to decrease car’s noise damage and gas pollutants to reach the lowest level. That would be the closest to the state of ideality. Constructing a sea tunnel can be very costly so an alternative route would be more acceptable to solve this situation. There are also many visitors who don’t like driving to the Island. Therefore more access options should be provided to cater needs of all visitors. A combinatorial effective strategy might be needed to provide a sufficient final solution to the initial problem.

Reference to Zhang et al. (2005) and Chai et al. (2005)

Stage 1: capturing the situation information by using several questions was a first step towards preliminary analysis. The questions were specifically selected and modified by the innovative situation questionnaire (Terninko et al., 1998). By interviewing food-outlet operators, canteen staff and consumers along with investigating canteen operations and interactions, useful information was gathered and structured for further processing using TRIZ methods and tools. The purpose for this study was meeting the dining needs of all customers while finding effective measures for improving canteen operation. The centre of the operation system is the canteen which includes physical facilities, operators and other resources. The super-system that involves the canteen is the entire university. The ideal solution would eliminate all existing problems while maintaining low cost.

Stage 2: based on the interview information, the problem formulator method (Terninko et al., 1998) analysed the problem deriving with a set of events. By looking into the formulated problem statements, lots of possible solutions could be realised.

Stage 3 and 4: apart from the previous technique (PF) another way to conduct investigation is through the contradiction analysis. It is easy to identify two conflicting aspects in the original system. These two aspects involve the opening hours of the canteen and meeting customer demands. The contradiction is then structured in the following way: the operation hours should be long enough to meet demands from staff and students while operation time should be kept to a bare minimum due to cost-ineffectiveness among the food-outlet operators. In order to eliminate this, effective measures that will either stretch the operation time or concentrate customers' demands into shorter period times must come into force. Using separation and inventive principles, again a number of solutions are proposed.

Stage 5: a number of possible solutions that address the problem with the canteen operation hours were demonstrated from previous stages, 3 and 4. The evaluation of these using a customer workshop resulted in identifying the feasible ones. Food outsourcing or setting up new outlets for night operation were amongst them. Support by the university is required to actually implementing one of those. Another solution would be the establishment of a food-outlet service on campus where staff and students could use different contact means (telephone, internet, etc.) for placing orders. Food preparation could be either from existing canteens or off-campus restaurants. The ordered food could be delivered to designated collection points.

Reference to Chai et al. (2005)

Stage 1, 2: some people might like sightseeing while cycling especially the youngsters. But for the majority of visitors exercising might not be what they had in mind and thus not be pleased by this enforcement. The added cost of bicycles is another drawback. The system of operations consists of several components such as visitors, booth renting, staff, bicycles and cycling paths. To solve this situation, effective strategies might be needed to provide a new approach on redesigning the current program or developing a new one that could eliminate the existing drawbacks without creating new ones. Based on the preliminary problem analysis a function diagram of the cycling problem was constructed. The analysis of the formulated statements could provide some indications on possible solutions.

Stage 3, 4: looking into the contradiction analysis the problem could be interpreted by the following statement: the travelling path should help and direct the visitors with their vehicle of their choice and also it should decrease their own path choices, lower the cost and minimise the environmental impact. In order to eliminate the contradiction, two extreme situations must be taken into account. The first one is a very well designed path and has a lot of functions apart from cycling usage. The second extreme has no path provided for cycling and it encourages visitors to make their own paths. By using the inventive and separation principle strategies several solutions to this problem could be found.

Stage 5: looking into the ideal final result, a solution closer to ideality would be joining in an event, like excursions or parties, which takes place in new areas and work their way out to further destinations. Freebies or rewards may also motivate visitor's adventurous curiosity.

Reference to Lin and Su (2007)

The first stage, definition of the problem, occurs on about 90% of the problems which also defines the problem. Mann (2002) recommends four activities that would help finding the right answer to the problem at hand. Apart from, Lin and Su (2007) suggested two separate stages that form the first basic stage. First is identification of the problem's scope and second definition of the problem's ideal final result (IFR).

The former consists of collecting information based on current problems between service operation and environment. Then the problem must be analysed from customers' feedback in order to reach its core requirements. One of the most commonly used methods to achieve this is through survey conduct of a focus group. There is also another way to collect information. It involves consulting operators of the targeted service operation.

The latter is achieved in two steps. At first the problem has to be dissolved into its most basic parts and conceptualise its components. This is achieved by expressing them into their most fundamental form. Next the IFR represents the ideal situation that can be achieved without using any more resources after eliminating the contradictions. In order to proper define the IFR, seven questions should to be used (Lin and Su, 2007).

The second basic stage, the generating one, is one of the most important aspects of the TRIZ theory. The solution generating methods are many and include inventive, separation principles, physical contradictions, etc. The TRIZ toolset gives more than one route to follow for problem resolution. These depend on the facing problem therefore solving methods must be properly selected. Lin and Su (2007) suggested in utilising one of the most common methods for problem solving, the contradiction matrix with inventive principles. They split up the generation process in 4 steps.

First step is contradiction analysis. Conflict points that could prevent finding the ideal solution must be identified. Then each of the components must be examined to check whether it contradicts with other parts and then see if solutions can be derived to eliminate these. Second step is to identify the relative TRIZ parameters and improve upon those that get worse. Third step is to examine the contradiction matrix and look for the corresponding inventive principles. Forty principles can be gathered from the intersections of worse and improved TRIZ parameters based on the content of the problem. Last step involves the generation of specific solutions. Following the previous derived principles, discussion meetings may be used to help generate all possible solutions.

The final basic stage is the evaluation of the solutions. Various specified performance criteria are necessary to evaluate these before the implementation process actually starts. Another reason for conducting evaluation is to see whether this new solution can actually bring the system closer to the IFR. Feasible solutions must be evaluated in terms of several criteria like cost, time, resources, etc. The derived confirmed feasible solutions can then be implemented. In the unlikely case that conflicts have not been resolved by the specified feasible solutions, the evaluation method should be repeated to identify the problematic step.

Reference to Lin and Su (2007)

The first step was identifying the scope of the problem. The function and attribute analysis (Mann, 2002) was used for problem definition. This process gives the ability to users to perform analysis on the functional relationships of a physical object between components and components' attributes. The outcome of this process is a function description of the components and attributes that would help finding the root of the problem. The primary useful function (PUF) was customers' satisfaction which became companies' goal. The PUF is acquired from useful functions (UF) such as improvement on software availability and enhanced software's online usability. However the harmful functions (HF), increased system maintenance cost and technical support, inflated total operation cost. Due to this inherent contradicting relationship the scope of the problem was defined within the areas of software availability, online usability, system maintenance and technical support cost.

In step 2 the IFR was defined as providing an easy and user friendly operating environment based on the principle of ideality and the focused areas from previous step.

In step 3 a contradiction analysis is performed. The company provided newly developed services in order to reach the IFR by updating and upgrading software services to customers. It also changed the application system to provide easier access for the users. By this approach the users' benefits will increase and new customers will sing-up. The problem lies within the complexity of the overall system. The design complexity of software and application environment and the technical training will inevitably increase the operational costs of the company. Thus a contradiction element occurred by noting down the issues of cost increase as a direct impact of benefit increase.

Within step 4 TRIZ parameters should be identified. In order to give rise to new approaches for improving the service provided by the software application environment, company's responsible division tried to enhance the web design of its site, make the online service system more reliable and increase the availability of the new software application system. Based on this fact the following parameters should be improved: shape, reliability, ease of manufacture, ease of operation, adaptability or versatility. The increase in the total operational cost and difficulties in repairing the system provided the parameters that became worse: amount of substance, ease of repair, device complexity.

In step 5 the contradiction matrix is created and inventive principles are identified. Based on the occurring frequency the following inventive principles were denoted: segmentation, parameter changes, equi-potentiality, copying, and mechanics substitution/ another sense.

Step 6 is considered to be the solution generator. After conducting discussions with the managers of the related divisions and analysing each of the previous principles and examples, the following ideas were generated for each of the principle.

Segmentation: an idea was to provide clients with a live representative to talk in contrast to a trivial communication with the service provider through the phone. As an outcome the interface between service representatives and clients becomes friendlier.

Parameter changes: the idea was an online training program provision to a client company instead of sending people for on-site training. By doing this, cost reduction is possible. Moreover the proposed training service scheme could also be accessed easily any time and place at the client's convenience.

Equi-potentiality: no idea was created

Copying: the suggestion was to use outsourcing companies for designing parts of new software systems. These companies would be located in mainland China and India thus reducing the expensive labour costs in Taiwan. Cheaper software designers would bring reduction to the software design costs. The purchase of commercial software packages from other companies and integration onto the main software framework posed as another viable solution. This would also reduce costs of R&D.

Mechanics substitution/ another sense: the last idea was about providing an online chat session on its website for satisfying its customers. An informal channel could also be used for advertising new policies or products. This approach would enable customers to give feedback on these enabling the company to realise their needs. Also valuable information exchange from customers' response could help on improving the advertised elements.

Step 7 or last step concerns the evaluation of the previously generated solutions/ideas. Company's personnel prioritised the ideas based on criteria imposed by the president of the company. After the evaluation of these four ideas the solutions were further prioritised in terms of feasibility. Final results were proposed to company's president.

Reference to Yang and Hsiao (2009)

They followed five pillars of service innovation described in the service engineering method:

- Initial phase
- Management of ideas
- Analysis of requirements
- Service development
- Trial of the service

During the initial phase they established a multi-discipline experts' team in order to plan and examine the complex development processes involved such as consumer research, service design and service trials construction. During the "management of ideas" phase they collected data and information about service features, business models, types of marketing, survey results, related companies, etc. The goal was to gather ideas and identify which of these would get the highest appraisal. For creating new innovative ideas they used the TRIZ method which is an effective method for addressing technical issues. For the "analysis of requirements" phase they identified customer requirements and consumer views, and opinions through systematic consumer surveys. During service development they applied service specifications and process modelling to form a proper description of the service they wanted to design. They formed individual service scenarios and based on those they designed a community healthcare network system. In the last phase, the "trial of the service", a pilot system and a service experiment laboratory was used. They analysed the feedback from the service output of multiple service trials to improve and enhance the design of the service itself.

User-Oriented / Modularisation-Based Design Process

Reference to Auric et al. (2006)

The technical service model consists of the following components:

- Description component provides general information about the technical service. The objectives of the technical service are also covered in addition to the service and product strategy. It also represents all related entities and interactions that are involved in the implementation.
- Reference component talks about how to describe products, components or profile of the users that are dealt with by the technical service together with their effects on them.
- Function component provides the details of the previously mentioned service functions for a special test scenario. As a result, description of the measures for implementation purposes is needed.
- Last component is resources. Physical and non-physical resources, which are mandatory for service implementation, are covered. Equipment, supplies, spare parts, vehicles, etc. are some of the physical resources. Non-physical resources consist of descriptions about servicing and information exchange, instructions, guidelines, forms, databases, etc. Users' qualifications such as expert knowledge and social skills are also included.

The derived systematic process which follows the above service model description interrelates between tangible and intangible components of a technical PSS. This systematic process tries to adapt existing product design processes for gaining highest acceptance towards application within the enterprise. The goal is to identify specific service properties within the enterprise as well as determine corresponding design activities for future integration within the product design process. Last part would be the definition of several organisational standards for designing services. The technical service process that has been established consists of six phases:

- Phase 1: identify customer demands: market surveys help analyse existing products and their usage. Customers often give their feedback and express their ideas or complaints to staff from the service provider. Service provider conducts thorough analysis on the received information and identifies market potentials, solutions feasibility upon existing resources, etc. Initial objectives can be specified. Next phases are going to deal with fulfilling these by developing new ideas.
- Phase 2: analysis of constraints: the analysis starts off by first by identifying the service target group. A cost-benefit-analysis is then conducted. The cost involves necessary resources for service realisation on demand. The second part refers to the technical feasibility. Analysis of the interactions between physical products and service give rise to potential product improvements. This is a necessary step due to the product and service design problematic integration. It is not required when product and service are designed in an integrated way. A service design project is decided as a conclusion of this phase.
- Phase 3: development of the concept: there must be a definition for project times, budget and staff responsible for the service design. Next step is identification of potential solutions which meet customer demands as a result from first phase. A service is then drafted using a selection of solutions which consists of the most promising ones. Description about service operation, realisation principles along with corresponding product users and products are defined. Also an information exchange concept must be developed due to information constraints posed by the identified solutions.
- Phase 4: modelling of a service: service modelling refers to construction and details of a product. It uses all the information that describes the design of the

object. Manufacturer staff and customers counter interact ideally and this represents the service system. The technical service model gives information about the service under investigation taking into account the basic model of a technical service. All activities, which are mandatory for a technical service implementation, are correctly described by specifying servicing and information exchange processes.

- Phase 5: planning of service deployment: the actual planning, physical and non-physical layer, is covered as it has been specified earlier by the service model. For the non-physical service resources service staff qualification must be ensured (initiation of trainings). In addition, development of deployment plans concerning guidelines, checklists, etc. should be available for direct application by the service staff. Last step is calculating service cost and setting up market prices.
- Phase 6: testing of service prototype: the service design project ends by testing a service prototype together with important customers from the company. Customer feedback should help identify service improvements. It is likely that this step needs repetition. Lastly, the service project team is disbanded and the responsibility of the service is passed to the service network partners holding them liable for its market success. Usually the deployment plans are required to de adapted judging by the cultural frames of the specified area. Servicing starts at the end of this phase.

For the integration of a product and a technical service process a modularisation process is being introduced. The need for such a process is based on the fact that reference process models, which in turn are rely upon generic process models, have rather limited application into the industrial sector. The problem lies to the individualisation within this sector. The process reference models turn out to be either generic or too confined to limited domains. By introducing the concept of the modular design the ability for increased adaptability of product-design processes is apparent.

The idea behind this unique process lies into building a “library” of basic building blocks for PSS design and realisation. Partners can specify their own rules for assembling their own unique process as required. The outcome would be the development of a PSS integrated design process for the service provider as well as equivalent building blocks to reflect customer’s requirement of the intangible components. A process module is stated as a logically process building block which represents a “black-box”, by having a generic character, which gives widespread usage, and inputs/ outputs along with corresponding states according to these (Wagenknecht and Aurich, 2004). Different process modules can be linked together and reused. This linage combined with the generic character of these modules can allow the assembly of a number of process models for applications in different areas and enterprises. The only necessary step for this task is the activities to be adapted according to specified inputs/ outputs. Process modularisation is the outcome of process decomposition. Individual processes are analysed into their modular sub-processes. It would be useful this analysis be performed on a low hierarchical level, and elementary modules on that level be identified for achieving broader applicability and higher level of transparency (design tasks, deliverables, etc.). Although the modularisation process provides a systematically way of describing state changes and necessary input/ output information, it needs decomposition itself. This is rather important for setting coherent design activities along with corresponding input/ output information. The latter is a result of the synergy between different design activities and in particular their impact on the physical layer (corresponding products).

Modular PSS design is realised by linking, parallelising and integrating PSS design process modules in terms of matching inputs and outputs (information, resources, etc.).

- Linkage is the structuring of PSS design modules in a sequential way providing staff responsibility for performing specific tasks according to the input information.

- The goal of parallelisation is to provide a rigorous process for identifying separate design tasks with no correlation whatsoever. Tasks that do not rely on each other in terms of common information, completely independent and thus can be performed at the same timeframe.
- Integration aims to combine those design tasks that could performed simultaneously and rely on the same resources.

A process library, which was mentioned previously, is required for realisation and usage of this modularisation process. This library supports modelling generic processes for technical PSS design which is a core element, by giving the capability of adapting individual processes to applications. Warnecke et al. (1996) proposed a reference process model which in turn was modified by Aurich and Wagenknecht (2003). The integrated production process model (IPPM) has been created using object-oriented modelling structure which gives the ability of defining processes, objects, structures, relations, etc. The modified version employs the modular design concept giving access to predefined process modules concerning life-cycle oriented design. It also supports modelling of processes that belong to different scopes (i.e. value creation) which are related to the technical PSS design and implementation. Application of this model for designing and manufacturing products from a life-cycle perspective can thus be reached and as an outcome a process module library can be established for future usage.

Reference to Auric et al. (2006)

1. Description of the basic object (i.e. product core, service shell, etc.) is highly important. Also network partners should agree on the common objectives as well as for any individual role they take up concerning the design and realisation process.

2. The modified IPPM is used for selecting corresponding process modules following top-down decomposition.
3. Process modules are assigned to network partners. For making this task possible several criteria can be thought in order to find the best fit for each of the partners. Criteria such as individual roles, market power, or organisational competence can help work out the splitting.
4. A second adaptation of the process modules maybe necessary due to the fact that IPPM provides a sort of generic degree of specification which may no be suitable for application within enterprises. There is more than one way to adapt a process module. It can be either disassembled into two processes modules or on the other hand two modules can merge together into a single one. A third solution would be to adapt the activities as required which follow the state of changes of a process module leading to a new module. It should be noted that in all cases, input/ output information, resources, etc. must be left unaltered according to the black-box principle (i.e. leading to the same output).
5. A simplified version of the derived process might be useful. It is an optional step because an applicable process is already available (steps 1-4)

Reference to Auric et al. (2006)

Phases “identification of customers’ demands” and “project study” were combined in order to address all activities including preliminary activities such as market survey conduct, strategic planning, finding service requirements, etc. By using methodological tools support is provided by combining a service QFD method and a known portfolio technique for measuring the impact of new ideas about services, how these map to service objectives and what are the gaps in the existing service portfolio (Fuchs et al., 2003). For the concept development and service modelling phase common methods were applied for representing main characteristics of the new service together with the service blueprinting technique (for representing information exchange) (Shostack, 1984). Realisation planning and prototypical service testing phase were also combined to show emphasis to the iterative process of testing the service. An additional phase with the purpose of adapting developed technical services was created due to the need of enforcing new service implementation on different markets. This activity was supervised by the service managers on each area.

Next stage was the adaptation of a modular design approach that would systematically align tangible and intangible PSS elements towards a better customer solution. The use of a product-service design with a modular approach concluded in four steps and an example was given for replacing a hydraulic system.

- A process module “specifications of product characteristics” is responsible for bringing product characteristics from previous product concepts that have been developed, while imposing current restrictions (i.e. environmental impact). For the hydraulic system, that would be the design specifications of the system.
- Next a “service for finding solutions” aims at bringing solid solutions, which are necessary for fulfilling the previously specified functions of the service (i.e. preservation a level of maintenance for the hydraulic system).
- Now, the outputs from both of the processes mentioned before can be used as inputs for another process module called “construction of a hydraulic system" along with other corresponding designs such as pumps, tubes, etc.
- Last step of the process is to use the hydraulic system layout along with the technical specifications of its components as inputs for a module “servicing process specification”. In addition the maintenance process mentioned in step two is designed by the staff of field service. From the derived modules and layout of the hydraulic system, homologous maintenance tasks and guidelines can be specified.

Reference to Yu et al. (2008)

The industrial service design consists of four distinct aspects which are defined below:

- Product information: the information is critical when considering of a hybrid offer like product and service.
- Flexibility: the entire process is related to customer demands, production planning, maintenance, etc. The difficulty in prediction should respond to a flexible environment that is capable of undergoing rapid changes.
- Co-operation: service processes maybe carried out not only outside of the departments' boundaries but also organisational ones. The service process then should also address the distributed process parts. Also transparency is required to all members involved.
- Participation of the customer: customer has a significant impact on the service because not only it provides feedback for improvements but also helps product innovation from information exchange.

Based on the previous analysis the proposed method for a systematic industrial service design consists of the following phases:

- The analysis phase collects and examines information concerning customer demands, markets, etc. for producing valid concepts and strategies for the service. First step for building specific services according to customer needs is to identify the critical points of the customer's requirements and use information from customer's site in a beneficial way. A method to surpass the emerging complexity that the service provider has to encounter is by performing a market and a competitive analysis.
- Next in turn is the concept phase. The goal is to find solutions for the generated problem of meeting customer demands simultaneously with fulfilling business objectives, which are related to evaluating customer's perception, and identify

any opportunity available based on the demand of the service. Customers and service providers have different targets therefore solutions must satisfy all.

- Strategy phase builds up on the previous two, establishing an optimal business model considering product, service and the dimensionality of the co-operation. First of all product dimension brings important data to the service process, like thermal or mechanical properties, which are necessary for maintenance of the service. Service dimension expands the traditional service lifecycle by looking into the product's one. The benefit lies into enhancing the customer-provider relationships from ensuring service availability, optimisation, productivity, etc. The co-operation dimension sets some rules and policies to ensure co-operative service delivery.
- Focus of the phase "module design for services" is a modularisation-based service modelling taking into account the storage and classifications, for implementation purposes of customers' specific configurations. Emphasis is given to the co-operative environment and to an interactive platform for implementing an industrial service using commercial infrastructure (tele-services, CRM, SCM, MES, etc.).

Reference to Yu et al. (2008)

- The first one splits into four steps. First is the identification and extraction of the processes that comprise each of the service modules. Synchronisation and collaboration of information flow among networked enterprises can realise competitive advantages. Also transparency of the service such as delivering process, knowledge, cost, material flow, etc. can reduce coordination costs. Second step is to standardise and modularise the process. The former has to do with the reusability of preliminary and reference processes, while the latter takes the decomposition method to identify the elementary sub-processes of the initial process. Third is the definition of the interfaces and attributes of the modules. Then service testing is done by the customer and manufacturer for validation purposes according to customer's needs. A service catalogue is created for storing the service modules establishing a repository. Last step is retrieval and selection of the optimal service modules from this repository.

- Classification of these service modules is important for configuring and adapting individual service packages for meeting different customer's needs. Three types have been created according to frequency of use, complexity, and customer, partner and product level: 1) Core service module groups all fundamental processes which are critical to an enterprise success, and have a major impact on cost or play an important role in the company. They are generally found within the service lifecycle, and in particular are related to the customer in terms of maintenance and repair. 2) Controlling service module assists and controls the service process for accomplishing tasks and business goals. It is more related to partners. 3) Supporting service modules can support two categories of modules. Its use is to increase value of the service and help enterprises to differentiate themselves from other competitors. Due to its simplicity it can also be replaced with other modules.
- The industrial service model is responsible for building customised services. Each of the modules contains an external shell and internal meta-model, which defines the core of the service module. The module shell has IDs and names of the selected individual modules, parameterised interfaces defined by programming languages, and restrictions that are used for properly selecting these. The parameterised interface gives the ability of changing module's properties according to the specified parameters, and has its focus on various communication and semantic aspects. Four parameters have been defined: state (declaration of module's state), function (description of service functionality), output (definition of the event or result to trigger other modules) and input (the output of one module). Restrictions provide definitions of the relationships among service modules. There are three types: sequence (ensure that the process is logical and can prevent deadlocks), co-operative

(emphasise on the human coordination and increase service efficiency) and cost (deals with cost and profits of the service process). The meta-model includes seven types of sub-models which express the service module thoroughly. First the goal is all about identifying why this particular service exists during the service delivery process. It satisfies all business objectives and their use in general, and is related to identification of the customer and business requirements. The co-operation sub-model defines co-operative policies and rules between modules. It is accomplished through goal, inputs and outputs exchange for all modules. The organisational sub-model expresses the structure of the organisation within the service delivery. It includes roles of the organisation units and resources. The process sub-model links all other sub-models and uses a series and sequence activities especially designed for providing a specific output which will in turn enable business goals to be met. The information sub-model expresses structure, flow state and information flow which describe completely or to an extent service activities. Customers and organisational units provide the needed information. The products sub-model expresses type, structure and properties of products. Because of the interrelationship between service and product, different types and structures of products will bring about other processes and service models. Last is the quality test sub-model which is used for testing the various modules against their specifications, content and formal correctness using quality criteria. These criteria include business (cost, location, usability, efficiency, etc.) and software aspect (functionality, reliability, maintainability, etc.).

Reference to Yu et al. (2008)

First different customer requirements were analysed through contact and communication with the customers. Then strategies, plan supporting methods, etc. were established for supporting the service design process. Service modules were selected or re-modelled for specific adaptation on the company. If a service module met the requirements then it was selected from the repository. In general the selection process starts off from the core elements and then continues up to controlling service modules. If there is a problem in the selection process variations or new designs can be used by replacing existing modules from the repository. The rules for the combination and arrangement of the service modules were given in the service delivery process.

<u>QFD</u>

Reference to Shimomura et al. (2008)

The proposed method consists of seven steps:

- Importance of the receiver is set
- Service quality table is created
- RSPs are structured and importance is obtained
- Using the Dematel method (Warfield, 1976) indirect interactions are taken into account
- ChP importance is obtained
- Functions/mechanisms are deployed

Step 1 considers service design also from the viewpoint of changes on the RSPs which affect different customers. Customers are represented by agents. Agents are then extracted from the scope model of the targeted service (Arai and Shimomura, 2004). Then AHP method (Saaty, 1980) is applied to the individual agents and importance of service receiver is established from the viewpoint of the service provider. This method has been widely used as a decision making technique.

For step two the service quality table is created by listing the quality items on the vertical column and functions on the horizontal one. With this differentiation, RSPs are placed on the vertical side because these represent how customers evaluate individual components. FPs are placed on the horizontal axis. So the target service corresponds to RSPs - FPs pairs.

For step 3 structuring of the previous table according to RSPs is required if there are different levels of abstraction within the target service. There must be coordination between abstraction levels on RSPs and table representation. After finishing this step RSPs on the same level are compared and weights are calculated.

In step 4 CoP importance is obtained. Using a binary table RSPs importance is converted into FPs importance. The binary table shows the degree of association. The CoP importance is obtained by evaluating the FPs that have a direct effect on the RSPs. That means only the FPs that belong to CoPs will be directly defined.

Following step is the consideration of the indirect interactions using the Dematel method. The interactions can be quantitative weighted according to the state of these and to a matrix called Direct Influence matrix, which describes the direct influence of the FPs. Applying the Dematel method to the direct influence matrix the entire influence matrix is defined. It represents how much influence FPs have to the particular RSP concerning all direct and indirect interactions of all the other FPs. These indirect interactions are called function influences (FI).

From the entire influence matrix, which defines FPs and FIs, the ChP importance is obtained. It is based on the following hypothesis that ChP is more important than CoP.

Last step is the deployment of the function/ mechanism. From the QFD method detailed design indicators can be derived from the importance of the quality elements correlated with function/ mechanism importance. From the extracted functions and mechanisms two tables can be created, a function and a mechanism deployment table. Using these charts, transformation of FP importance to either function or mechanism can be achieved. The result is the following service design indicators: 1) FP importance can be derived from the concept of service channels / concepts, 2) by looking at the FP influence matrix an overview of the interactions between FPs is easy to see and grasp the interfering relationships, 3) design operations can be performed by looking into the information of function/ entity importance such as addition, deletion or replacement.

Reference to Shimomura et al. (2008)

Service provider is responsible for clothes-washing functions through the supply of laundry machines. There are four agents: the laundry machine manufacturer, retail store, a customer using the service and the environment. The purpose of the environment is for evaluating the environmental impact of the service. In service explorer the flow model and four scope models represent the interactions. Three scope models are with the manufacturer and one with the retailer. For each scope, weights of the RSPs and the receiver have been performed. Then a table is created having FP in the left column while the right column shows the FP importance. Taking the receiver and the RSP as an input through the proposed method FP importance can be derived within the service framework. The construction of the table takes the degree of RSP influence, which is computed by the AHP method, and the degree of FP importance, which is determined by the RSPs weights. The weights have been calculated in numbers using the Dematel and QFD method. Conversion from RSP to FP importance requires only the strength of the direct influences to be shown thus makes it easier to get the FP importance. In addition function and entity importance in the channel is also calculated.

Service Blueprinting

Reference to Bitner et al. (2008)

Yellow transportation is a multi-billion dollar trucking and logistics business. In 2007 was ranked first within the trucking industry among the most admired companies by Fortune magazine, though this wasn't always true. Back in 1997 the company was at the bottom of this list. By using this technique it managed to overcome all the obstacles and rank first in the following years. New services for customers were developed using this method, services that created value for customers and make Yellow to growth. Exact express was a first sign of such kind of service. It was a premium service that could guarantee on-time delivery of goods within a specified time frame. This became the most profitable service for the company. All started by blueprinting an ideal guarantee service looking into from customers' perspective and comparing this to blueprints from competitive companies. A need for customisation in terms of customer access and few things that mattered to customers were revealed. Communication channels from marketing, operations and delivery were clearly defined to create this highly valued new type of service. Moreover Yellow blueprinted existing services to assess and improve their performance. An innovative step the company took was to carefully examine its core service by getting feedback from its business customers and its employees on improving it. Some of these insights visualised and recognised the importance of "driver touch points". Yellow's truck drivers interacted with its customers and an opportunity for building loyalty and brand reinforcement was apparent. Yellow saw how critical internal customer service, terminal personnel and team sales were for supporting its core service delivery. Every party related was able to see its role on the blueprint and improve upon.

Aramark leads the global professional services by outsourcing almost anything and is working with many organisations. Fortune magazine ranked it first on its most admired companies list. One of its divisions provides services for major park destinations within the US. Some years back, marketing director of this division faced a challenge. Businesses for parks started to decline. Traditional, visual blueprints were needed to remedy this fact. By helping the company to identify specific changes for service improvement resulted in an increase of repeated businesses. The first step was the development of a typical hotel/resort experience from a customer's point of view. Then a blueprint of a company's particular resort was established. By comparing and contrasting these two blueprints revealed the differences in terms of services, upgrade on facilities and service key elements. Also need for service upgrades became apparent by looking into photos and videotapes from the visual blueprint. Among all, an interesting fact was revealed concerning customer experience and satisfaction. Customers were asked to work very hard for their vacations. The blueprinting exercise made clear to all staff that a lot of factors combined together made bad impact to customers' experience after having their first vacation. Top management started the production of new services, facilities renovation and staff training to meet these new service standards. New measurement and reward system was also employed.

IBM contributed in a service innovation. An IBM service research employee deployed a service system analysis based on the blueprinting technique. The set of goals included identifying important lessons to learn, which would transform IBM's service innovation process to a better, faster and effective model. The superiority of the method proved important based on the following abilities. First, by clarifying the time dimension and seeing how multiple tasks were connected together to produce a sequence. IBM's innovation lifespan of four years was the main requirement for this kind of representation. Second, a hidden but vital part of this process was revealed by analysing backstage and supporting stages. Third the nature of some iterative tasks was possible to analyse by looking into new ways for viewing activities which could provide future innovations. As a final ability it enabled a cleaner view of how research and consulting units co-produced innovation and created business value. Apart from these abilities IBM was to realise that the innovation part was only just a small fraction of the whole process. The major part was all about exploitation and adaptation of the process. Particularly emphasis was given on those activities responsible for disseminating innovation. In general blueprinting indicated a potential roadmap for future innovations while augmented the process by revealing important lessons to be learned.

Marie stopes international (MSI) is a health information service provider. A consultant for this provider worked with MSI directors and used a modified blueprint for this purpose. The goal for this blueprinting initiative was improving upon quality of services provided by the MSI centres. Modifications of the blueprint were necessary because virtually all of the service is onstage. These were done in order to link human resources and operations to customers' moments-of-truth. For each of these moments, customers' contact points, physical evidence and measurement standards, which are used for tracking service quality, were all specified in the blueprint. Moreover involved parties examined who was onstage and what the customers wanted as a communication standard. Next step was to develop a script for assessing the outcome of a person's communication with the service encounter. In addition participants examined onstage, outside firm, technology and office supplies communications in order to identify potential critical points from an operational perspective. After pointing out the key elements each of these were properly prepared to meet customers' requirements and needs. In the Marie Stopes case blueprinting identified implementation issues that were very important for improving quality. All of these modified blueprints which incorporated the previous mentioned parameters helped and improved the service offerings at the clinics.

Guest services for the San Francisco giants created a blueprint of customer contact and service delivery by brainstorming and documenting their existing customer service, client service and guest communication plan. Through this process it became apparent where their separate areas should be integrated and proved beneficial for Giants organisation and future customers. Since the implementation of these improvements, strategic plans were created documenting the existing points of integration. A lot of these changes enhanced communication between areas that focus on the customer and ballpark experience.

Reference to Hara et al. (2008)

The proposed framework consists of four layers: receiver state, function, activity and attribute layer. Following this model, functions are mapped into and interconnected with related activities in the activity model. In addition activities on the activity layer are evaluated from a functional point of view. First step is to define the basic service provision. Basic customer actions needed for a service are mapped on the activity layer. Personas (Sakao and Shimomura, 2007) or service scripts from marketing field (Fisk et al., 2003) may be used for obtaining these actions by creating different scenarios. State parameters on the receiver state layer are measured based on the particular scenario. A set of receiver state parameters (RSP) are identified and thus the targeted customer value is determined. Next step is the construction of service functional structures. From the previous step customer value has been identified as a set of RSPs. On the function layer service functions that affect each of the RSPs are described by a tree structure representation (Sakao and Shimomura, 2007), (Arai and Shimomura, 2004). The relation between customer value and concrete functions on the function layer is established by providing a functional structure and detailing the upper functions. Thus a static evaluation of customer satisfaction can be achieved by looking into function performance. On the other hand little information can be obtained regarding service delivery only by looking into the function structure. As a result the lowest functions are not clearly visible. Further step involves constructing the actual delivery process. Service blueprinting acts as a guide in order service activities to be constructed. The basic steps that customer performs are partially being selected from the activity layer. Then actors are being chosen as BPMN pools on the same layer. Other systems such as mechanical/information are also represented by actors on the layer. Next the construction of service encounters takes place and customer actions are being modified. The lowest functions are mapped into series of activities. These activities not only involve the service provider but also customer actions as well. After concluding the activity layer on the service blueprint all activities presented there must ensure the whole delivery process. An organisation structure is required to accomplish this task. Some examples of such operations include classification, additions/ deletions, divisions and grouping. There is also a possibility of a certain activity not being able to interconnect with functions on the function layer. These activities do not have any impact on the customer state although it is a necessary component for service execution. In the end BPMN flow figures are added. Final step of this framework consists on describing the entities that comprise the service. On the attribute layer entities, such as resources, objects, activities products, etc., are arranged. These entities are from both the functional viewpoint and the physical environment which surrounds the customer. Moreover they have their own attributes. As a result they can be visible to the customer in a similar way to activities.

Reference to Hara et al. (2008)

The blueprint involved four actors: the elevator user, the elevator, the company responsible for the elevator, and a security company. The elevator was configured as a BPMN pool because of the frequent interaction with the user. A scenario that was depicted involved service activities when a specify event occurred, like earthquake or fire detection. These activities provided functions influencing the user's RSPs concerning security and safety of the service. The activities were split into two parts: activities of the elevator were visible to the user while activities of the elevator company were invisible to him. The activities were realised by interactions between actors. For example, in a case of emergency the starting point of the activities is when the elevator has an emergency stop. The user calls from the intercom and the company receives the call. Staff of the company watch the user while checking images from the camera inside the elevator. Then the personnel from the security company arrive to the elevator and solve the situation after being contacted by the company.

The integration of the function-attribute and activity model on service explorer was done by relating the activity nodes to corresponding functions in the view model. For instance the activity of emergency stop was related to the functions that would respond to the situation quickly and efficiently. The user's RSP "security and safety of the service" is shown as a tooltip on the specific activity and also highlights related functions in the view model. On the other hand functions in the view model are related to activities and behaviours.

As a result of this interconnection, one can understand for example that the function of receiving calls through the intercom is related to the user action of picking up the intercom in order to answer the call. Therefore the function requires user actions apart from activities of the service provider. This brings up the possibility of analysing and evaluating service activities while viewing the user interactions and how the function affects him.

Reference to Shimomura et al. (2009) and Hara et al. (2009)

After this connection takes place there must be an evaluation method of the service. Quality function deployment (QFD) has been proposed as a good method for this purpose (Shimomura et al, 2008). Using this method, designers can determine importance between RSPs and functional parameters (FPs). This can help for a better and effective PSS design. The evaluation consists of the following three steps: first is obtaining RSP importance by calculated RSP weights using the AHP method (Shimomura et al, 2008). Next step is obtaining influence of FP to RSP by using a correlation matrix table to calculate the degree of association. The RSP importance is converted to FP importance. Last step is obtaining the importance of processes. A similar correlation matrix to step 2 is created having FPs in a vertical and processes (from extended blueprinting) in a horizontal column. The evaluation method helps designers to find out which of the processes contribute most to the customer value of a specific RSP.

Reference to Geum and Park (2011)

The conceptualisation of such a distinctive blueprint derived from the service blueprint. They took the notion of the service blueprint and extended it to bring a product-service blueprint by adding areas, lines and appropriate symbols that are new and reflect the PSS characteristics. Service blueprinting is a good method for two reasons. First because it focuses on the service side of a PSS, and that is what delivers its value, and second because it provides a clear and reliable representation of a service system in terms of behaviour, progress and relationships. They employed it as a starting design method and in addition they added a new area and relevant symbols to this which led to proper illustration of a PSS. It is for these reasons that they used the title “product-service blueprint”. It defines “a map that portrays the product-service system where products and services are systematically integrated to deliver both sustainability and increased customer value” (Geum and Park, 2011). This concept was used as a proposed approach to illustrate the effectiveness of the PSS representation on two cases, a car-sharing and a water purifier service. Moreover Geum and Park (2011) report that an additional implication was obtained by the in-depth investigation of the product lifecycle, the service flow and the relationships between products and services. A valuable insight was provided to managers who needed to be in charge of the PSS design.

DES / Simulation Methods

Reference to Arai and Shimomura (2005)

The evaluation procedure consists of the following steps:

- First weight evaluation is being conducted using AHP for all the receivers in the flow model under provider's viewpoint.
- RSPs of each receiver are also evaluated using AHP finding their weights.
- For each RSP the weight is split among its FPs with DEMATEL.
- From the obtained weights correlation matrix is created between RSPs and FPs for each receiver.
- Scores for all FPs are calculated from two vectors of the matrix, weight and relational-strength.

Service quality is evaluated based on three criteria. First criterion is based on the importance of the requirements, which will give the importance of each RSP. Second is the service evaluation itself, based on the current state of the provider. Third and last is the service evaluation from competitors' point of view.

Reference to Arai and Shimomura (2005)

The model which was defined for this case followed the steps below:

- First service agents are selected and their functions are expressed.
- Then weights are determined for all agents and their RSPs.
- A QFD matrix is generated for this service as mentioned previously.
- Design solutions that will reinforce current service are being searched.

It should be noted that weights in step 2 are being given by the service providers and a clarification is required between weights from both receivers and their RSPs to be used as a design strategy. Following the previous procedure the defined service agents are: a hotel, hotel guests, a bed linen rental company, a power supplier and environment. The environment is a representation of a virtual hotel service receiver from the environmental impact scope. RSPs for evaluation of service qualities are developed. Accordingly RSPs from other agents were also prepared. Based on the interview investigation, function structures for each RSP were developed. These structures describe and give details of the hotel service from the service receiver standpoint.

The evaluation of the service started by calculating RSPs importance quantitatively based on the on-site survey. CoP and ChP weights for each RSPs were also determined according to RSPs using the DEMATEL method. This resulted in evaluating each entity, which plays the role of a medium for the service. The model serves as a visualisation method for showing the importance for each entity, a green arrow to show the relationship strength and the customer's requirements, which are integrated with it. Service receivers are influenced by service activities. For this study the environment plays the role of a virtual receiver. The designer of the service needs to allocate a requirement to the receiver. Service strategy determines this allocation. For the hotel service two redesign options that would enhance it were proposed by Arai and Shimomura (2005) and Sakao et al. (2006); use of a sun-lighting system and renting various goods in the hotel (ie. cash-back system for not using towels).

Reference to Yoshimitsu et al. (2006)

The proposed model by the authors consists of five steps.

- The designer writes a hypothetical service in the view model, makes decisions on the RSPs and the relationships between FPs and how they affect the RSPs.
- The designer adds weights to each of the FP in order to know the degree of influence for each RSPs. This is being done using QFD and DEMATEL method.
- For each of the FPs a satisfaction-attribute value (S-AV) functions must be set. These functions represent the function relations between satisfaction of the service receiver and the FPs which constitute the service. The designer also provides relationships for each RSP and FP value. Each FP has only one S-AV function.
- The designer sets attribute values for each FP. That gives him the ability to know the degree of satisfaction which is given by each FP.
- In the last step the designer can calculate customer's satisfaction acquired from the whole service.

The S-AV functions have being defined and calculated using the Kano model and Prospect theory. An experiment was performed to verify how the proposed evaluation method can practically be used. A survey for "in-flight service" was conducted which described the service on the view model. The process took two steps. First was the verification of the method used for finding the S-AV functions and second the testing of the calculated satisfaction between business and economy class models. By applying this method to the example service it was proved that it is possible to predict changes on customers' satisfaction by altering attribute values on FPs.

Reference to Shimomura et al. (2007)

The design procedure concluded in seven steps:

- Creation of the flow model which represented the target service.

- A customer survey was created from the design team in collaboration with the company sales department which resulted in identifying the RSPs included in the flow model.
- Description of the realisation structure based on the existing service.
- Feasibility of the previous structure was confirmed which included connections between supplier activities, RSPs and other parameters.
- No new RSP was identified by assessing the service so far.
- No need of placing new agents or determining its position.
- Using the results from the previous customer survey helped the design team to identify the most crucial function by evaluating the RSPs. Function availability proved to be the most important one thus the design team focused on improving this by choosing the RSP view model. Most important functions including malfunctions and maintenance had four FPs: time for malfunction detection, time sending spare parts, time for maintenance and malfunction frequency.

Based on the results from the previous procedure, the design team developed design solutions which would further increase the warehouse owner’s function availability.

- Active monitoring
- Parts selection based on a broader life-cycle perspective
- Easy access of service
- Simplify access to testing points
- Ensure a robust electrical system

All of the previous design solutions were independently applicable but they could also be combined to increase total potential impact on function. Therefore this method along with the CAD method could support innovative design processes.

Reference to Komoto et al. (2005)

The proposition of such a method, for a systematic generation of service designs and the analysis of current conditions through simulation processes, leaded to the creation of ISCL. For the first module, the service design CAD, it follow and implements the concepts and specifications proposed by Tomiyama (2001) under his definition of the service engineering concept. Therefore it is similar to Service Explorer at this level. As said before adding a simulator for counting the overall impact of current conditions on the service brings the benefits of having the designer to test different service configurations as well as systematically optimise its designs through a lifecycle simulation process. Thus the method described above brings an essential way of evaluating a service based on the designer's scenario while prohibiting him of overlooking potential solutions (Komoto and Tomiyama, 2008)

Reference to Hara and Arai (2011)

Service blueprinting semantics have been widely used by marketers for a visual description of the service activities in a sequential and dynamical manner. Flowcharts have been used for depicting interactions between providers and customers. In order for the authors to use the BPMN specification they introduced a novel simulation method for describing the design process and they converted this method using the BPMN graphic notation. This was achievable by exposing the underlying structure of the execution language that simulates the described business process.

The applied signposting model (ASM) was introduced as a requirement to formulate the simulation of the design process. This method emphasises the dependencies and precedencies between tasks during the design process. These come in the form of interactions with the design parameters. The ASM framework can incorporate uncertainties and unpredictable events into the process models. Because of that they could form the test bed of a better and more effective planning as a formal practice by researchers.

In order to make all of the above work together they proposed a novel mapping of BPMN, similar to the Business Process Execution Language (BPEL), to the ASM method. This enabled the authors to evaluate the parameters of the design process. Events in BPMN such as message flow and message trigger have been mapped to ASM's interaction with parameter. A rule trigger event has also been mapped to an interaction as well. An iterative task in ASM was mapped for a looping task in BPMN. Similarly a data object in BPMN has a function which resembles to a parameter in ASM. Therefore any change during the design phase of the product or process can be directly referred to by them. By using this conversion service designers can have an immense help due to the ability to parametrically analyse and simulate the delivery process of services. That also includes product manufacturing.

Reference to Makino et al. (2009)

The computer simulation used an agent-based modelling approach in order to replicate the dynamic service processes. The model they built had a microscopic view so that they could assess and design the service system taking into account, in a more detail fashion, all of the dynamic processes involved. These were microscopic aircraft interactions such as delays due to problems in the ordering of pushback operations during departure. These considerably influenced aircrafts' efficiency according to field experts. The method consisted of three phases, service modelling, service simulation and service planning.

The service modelling phase was initiated by recording tasks, decisions and other behavioural patterns of service staff within the actual service operations. By interviewing the staff and analysing the collected data enabled the knowledge of the field experts to be embodied into the service model. That was the key element of a human-centric service design approach.

During the second phase all of the service processes were replicated inside a virtual environment having a timeframe shorter than the real time. After collecting all of the data needed to have an understanding of the problem situation they asked the field experts' views on the visualised simulation results. They extracted a comprehensive solution due to this interactive and cooperative process which was followed by the appropriate decision-making technique which made the service design model complete.

In the last phase all possible solutions, derived from the simulation results, were assessed and appropriate design decisions were made. The assessment process looked at customer and staff satisfaction, costs, difficulty of tasks, etc. The outcome of this process was again reviewed by the field experts. It is because of this open-ended cycle that the method was stated as interactive.

Coloured Petri Nets

Reference to Tian et al. (2004)

First the evaluation of the restaurant to the wholesaler is modelled. If the restaurant requires some raw materials then it will give out some information about quantities and qualities of the goods, perhaps along with price. So actually using definitions such as "a piece of", which represents the raw material for food, and tokens with different colours, they managed to model the decision making process concerning purchasing of goods. In more details they used different variables for showing the different pieces of food-goods that the restaurant wants to buy. They also used other colours/tokens for showing the goods/foods quality requirements for the restaurant provided by the wholesaler. Also a third variable, for showing the price in the same way as quality has been used. Therefore quality and price requirements for foods/goods have been established. Then the wholesaler makes the food/goods provision. The goods have as attributes both price and quality while different colours have been used for depicting these into the model. There is also another colour for representing the available stock of food/goods in the storeroom.

The decision making process starts by placing initial values to the restaurant requirements for quality and price. These values can only be changed by the restaurant itself taking into account customers' dissatisfaction. If the wholesaler's price and quality value meets the restaurant's values then it will buy food/ goods, which will then be deposited into the storeroom. Otherwise the restaurant will go to evaluate the next wholesaler in line. In any case both quality and price must be met. Next time the restaurant will assess the number of pieces it wants to buy and the purchasing process will start again.

Next in the evaluation process is the relationship between customer and restaurant. The restaurant provides some service conditions like price and quality of the food, environment, food quantity, etc. Then the customer has specific requirements for each of the conditions. it will then decide if it is going to have its dinner or not, based on the satisfaction offered by the restaurant. If the restaurant can provide the same conditions and meet its requirements, then the customer will decide to order food and wait. Otherwise it will leave without eating any food.

Next in line is the service of the restaurant to customers. After having food ordered by the customer, the restaurant will initiate the service according to the first-in first-out rule. The restaurant will take food from the storeroom and cook food for the customers.

Last process is the customer who will eat and pay for its food. It will eat the food if a tidy table and clean dishware are available. After finishing it will pay, release the resource (table, dishware) and leave.

Reference to Tian et al. (2007)

The development procedure will be analysed below.

First of all the framework consists of the service provider, service receiver, service contents and service channels. The service model is the same as mentioned before. There are three sub-models: scope, view and flow model (Shimomura, 2003).

The consumer electronics rental service can represent a new paradigm by leasing instead of selling goods. Transferring from product-selling to function-selling can reduce cost and trouble of customers (buying, operation, and disposal), and increase productivity through reusability. The process from production to consumers is rather a complicated and large system. Therefore it is better to describe it in a hierarchical and modular method achieving better analysis. This decomposition process will be analysed below.

There are many intermediate agents between the electronic producer and the consumers (wholesalers. Lease companies, etc.). Each role is different but they carry out similar activities. If details for each activity are excluded then the product-receiving service relationship can be represented using a flow model. This also forms the top level of the hierarchical coloured petri net structure. In this structure the service provider has only outgoing arcs while service receiver only ingoing. The progress of the system is controlled using only one token. Transitions on this top level are all of substitution transition type and by looking to the scope model sub service activities can be determined.

For the rental service the sub service "leasing" was more important thus in the scope model (second level of decomposition) activities, caused by the lease company to consumers, are depicted as a matter of reference. The same procedure stands for all other sub services. In this activity the lease company will provide the consumers with electronics rental service. Next step is the evaluation of the service by the consumers using four RSPs: rental expenses, installation trouble, maintenance and, repair and disposal trouble. Four places are then defined representing these four RSPs. Each one has a colour which represents the satisfaction degree on each RSP. A particular transition within the scope model represents the rental service provision. There is also an evaluation criterion which is used by the consumer to judge the service according to its needs. The scope model cannot only describe whether a consumer can receive the material contents but also if it is satisfied with the service contents (RSPs definition within the model).

Last level comprises of the view model. In the scope model there is no consideration about how the lease company will manage the rental service or how service management can influence these four defined RSPs. Therefore the details of the substitution transitions, which influence these four RSPs provided by the scope model, will be depicted by the view model. Each of the RSPs is influenced by many factors which are represented using places within the view model. Four view models, each one for evaluating the corresponding substitution transition which influences each RSP, are created.