CRANFIELD UNIVERSITY

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A Value-centric Decision Making Framework for Maintenance Services Outsourcing

School of Engineering

PhD
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ABSTRACT

The shift in mindset of decision makers, from maintenance being a “necessary evil” and “cost centre” to a “profit contributor” in manufacturing companies has driven outsourced maintenance suppliers to employ value-centric approaches in order to design more effective maintenance programs. A value assessment for maintenance outsourcing must facilitate the trade-off between cost-centric and value-centric approaches to enable the maintenance service providers to design more effective maintenance organizations. This assessment should also help the customers in a well informed decision making in outsourcing their maintenance function in order to add value to their businesses. Therefore the aim of this research is to develop a decision making framework for maintenance outsourcing based on the assessed customer-value of outsourced maintenance services.

In order to develop this decision making framework, the research has been performed in four phases: for the first phase of the study, repertory grid interviewing technique was applied which is an in-depth qualitative study with 33 respondents in four companies which are the customers of outsourced maintenance services. This phase resulted in 29 value dimensions of outsourced maintenance services which contributed to understanding how customers perceive value in a maintenance services context. At the second phase of the research, in order to add rigour to the methodology, based on the attributed value dimensions from Phase1, a novel multi-criteria decision making hierarchy has been developed to enhance a value-centric decision making for maintenance outsourcing. At the third phase, in a novel approach, the quantitative results from the first phase of the study have been input to the hierarchy in order to gain the respondents priorities of outsourcing their maintenance function. This approach has been further validated through its application in industry at the last stage of the research.

The results from the first phase of the study identified the dynamic nature of customer-value which changes through customer-supplier phases of relationship which pattern is also evident in respondents from different

organisational positions, namely decision makers and end-users. Also companies in different industrial sectors, have different emerging value patterns which need to be considered for designing maintenance service offerings. Also the developed novel decision making hierarchy, helped structuring the decision process for customers of outsourced maintenance services. This framework has been also helpful for suppliers of outsourced maintenance services to continuously improve their service offerings to add value to their customers. Finally combining two techniques from phase 2 and 3 created some opportunities for unbiased group decision making but had shortcomings comparing to the original method which has been identified and discussed.

In general, this research contributed to knowledge with:

- Providing a comprehensive understanding of value-in-use for maintenance services.
- Providing an AHP hierarchy based on the repertory grid technique.
- Creating of a decision making framework that helps suppliers and customers to add value through outsourced maintenance services.
- Combining the repertory grid results with AHP.

Keywords:

Maintenance Services, Outsourcing, Value dimension, In-tangibles, Multi-criteria decision making.

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Amir Toossi

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LIST OF ABBREVIATIONS

CU	Cranfield University
AHP	Analytic Hierarchy Process
BPO	Business Process Outsourcing
EPSRC	Engineering and Physical Sciences Research Council
IMRC	Innovative Manufacturing Research Centre
MCDM	Multi-Criteria Decision Making Model
OEE	Overall Equipment Effectiveness
OEM	Original Equipment Manufacturer
PSS	Product-Service Systems
Rep Grid	Repertory Grid

1 RESEARCH CONTEXT

1.1 Introduction

Intense competition in the current global business environment and the need for sustainable profit have caused companies to seek competitive advantage through the provision of services. In fact, in order to survive, companies often follow either a differentiation strategy or a cost leadership strategy. Therefore many manufacturers are lead to apply a service-oriented business logic as a differentiation strategy. In this new service-oriented world, companies are providing integrated 'Product-Service Systems' instead of selling only tangible products. In the following section, this shift towards product and service bundles will be further discussed.

1.2 Product-Service Systems

In a traditional product-oriented mindset, organisations may offer supplementary services related to existing manufactured products as add-ons, whereas in service-oriented business logic, companies move to providing integrated bundles of products and services. According to Eppientte (1997) customer service has been emerging as a competitive element for business firms, as he mentions: "it is becoming harder and harder to compete on manufacturing excellence alone. Manufacturers will compete by bundling services with products". Pine and Gilmore (1999) suggest that organizations should switch their focus on offering customer experience and need fulfillment. Auramo et al (2004) state three reasons for this shift in enterprise rationale:

1- An installed base of products with long life cycle could generate substantial and more stable revenue.

2- In many companies concentration on the core competences has resulted in demand for more services.

3- Services can create a sustainable source of competitive advantage.

Such a change, called servitisation entails suppliers "moving away from the transactional business imperative and offering more integrated and value

adding services to their customers" (Vandermerwe and Rada, 1988) which can result in sustainable profit margins higher than product sales (Patton and Bleuel, 2000; Joseph et al, 2000; Auramo et al, 2004). Baines et al (2007) also define servitisation as "the innovation of an organisation's capabilities and processes to create better mutual value through a shift from selling products to selling product-service systems". Mont (2004) also believes that "One idea that seeks to address the dilemma of economic growth and its environmental consequences is the concept of PSS." Greenough (2008) states "the complex relationship between products and services is shifting and a larger component of added value offered to the customer is now being provided by services." This new concept, referred to as product-service offerings, integrated offerings, bundles or Product-Service Systems (PSS) differentiates the market oriented value creation approach and is defined as "an integrated product and service offering that delivers value-in-use" (Baines et al, 2008). Goedkoop et al (1999) define PSS as "a marketable set of products and services capable of jointly fulfilling a user's need." Companies like Rolls-Royce and GE with their 'power by the hour' type of contracts and Xerox with their document management services are outstanding examples of this kind of approach. For example, Rolls-Royce instead of selling spare-parts and maintenance services to their customers provides a bundle of parts and services for a fixed cost over a specified period of time. In fact, Rolls-Royce by accepting the risk and maintenance function, generates revenues by making the engine available for use (Neely, forthcoming). In other words Rolls-Royce claims that "The key feature of the program is that it undertakes to provide the operator with a fixed engine maintenance cost over an extended period of time. Operators are assured of an accurate cost projection and avoid the costs associated with breakdowns."(Rolls Royce, 2007)

Applying servitised business model shifts the interaction between product suppliers and their customers from transactional to relational. In fact "the focus is shifting from the activity of attracting the customers to activities which concern having customers and taking care of them" (Ravald et al, 1996, P.19). Product-Service Systems refer to services that are on the basis of co-operative

agreements between supplier and customer, where operational risks are transferred from the customer to the supplier.

Although servitisation has been considered as a high potential source of revenue as a business model (Williams, 2007) but further research is still needed to explore PSS (Zaring and Orninge, 2001; Kanda and Nakagami, 2006). Therefore there is need to study PSS from different perspectives and in different contexts.

1.3 Product-Service Systems and Maintenance

Traditionally product support and after sales service merely constituted maintenance and repair. However, as the scope of product support has broadened over the past decade, it has also included such aspects as installation, commissioning, training, maintenance and repair services, documentation, spare parts supply and logistics, product upgrading and modification, software and warranty schemes, telephone support, etc (Blanchard et al, 1998).

As products become more advanced and complex, many manufacturers find themselves supplying more services related to product exploitation, maintenance, modifications and up-grade. In fact “Product Support appears to be important for industries where the equipment is complex, where it fails frequently or has serious failure consequences (high risk)” (Markeset et al, 2004). Indeed many manufacturers now realize that a significant part of their turnover comes from repair, maintenance and modernization/modification services. It is also to be considered that providing product-service bundles by suppliers entails the willingness to outsource the maintenance function on the customer side. In fact it is necessary to study maintenance outsourcing processes on the customer side, in order to gain holistic understanding of providing bundled products and services. But firstly we need to have a common ground on maintenance management, which we will discuss further in Chapter 2.

This research will focus on outsourced maintenance services which are a form of Product-Service System. We consider maintenance services that are delivered through a service contract. The maintenance services may be provided by the original equipment manufacturer (OEM service) or by an independent service provider (outsourced service).

1.4 Paradigm Shift in Maintenance Management

The core motivational drive for this research is the change of maintenance stakeholders in organizations from maintenance as a function that adds to the costs, to a process that can add value to the business. This shift in mindset of decision makers, from maintenance being a “necessary evil” and “cost centre” to a “profit contributor” (Al-Najjar,2007) and value-adding function in manufacturing companies has driven:

- The suppliers of outsourced maintenance services to understand what the customers mean by value and employ value-centric approaches in order to design maintenance programs which add more value for their customers.
- The customers to have value-centric decision making for maintenance outsourcing.

Moreover, keeping customers satisfied by just showing them cost savings gets more tricky and difficult in more mature phases of supplier-customer relationship (Al-Najjar, 2007). This has created a unique opportunity on the one hand for the maintenance service suppliers to survive in long-term outsourcing contracts, by understanding value and designing maintenance services, which add value to the customer throughout their relationship. On the other hand, it is essential for the customers to have a well informed decision making process for outsourcing their maintenance functions. In fact, very few efforts have been made to study customers’ decision making in maintenance services outsourcing and provide a framework to facilitate this.

1.5 Project Background

To investigate the different dimensions of product-service offerings, in August 2008, Cranfield University launched a Product-Service Systems multidisciplinary project for the duration of three years. As a result of a qualitative pre-study on PSS (Stage 00), this project was divided into five main themes; Design, Service Delivery Systems, Service Networks, PSS Customer Value and Transformation (see figure 1.2).

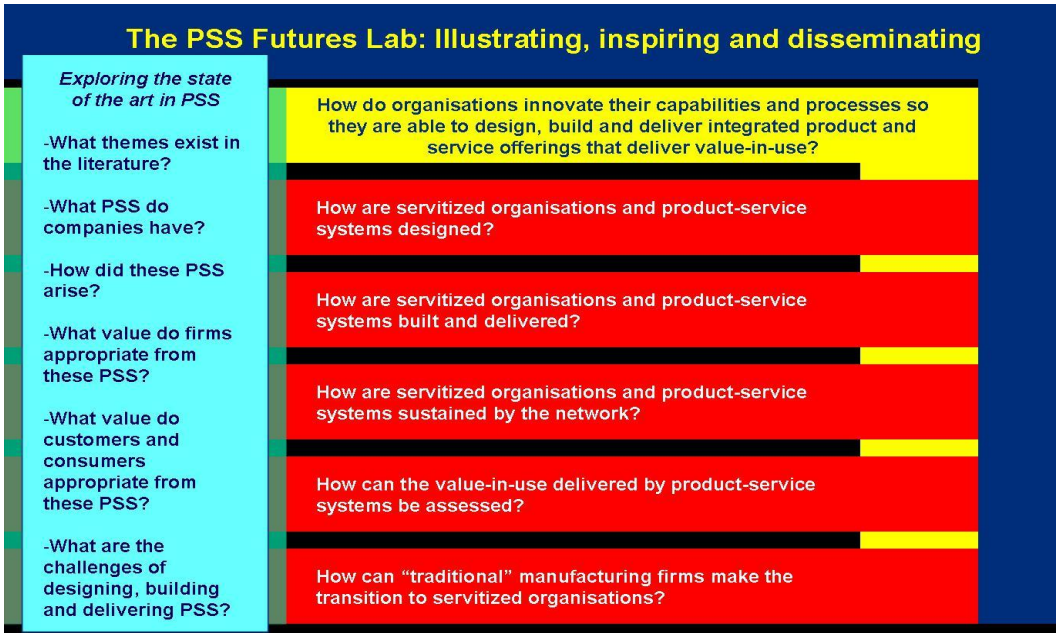

Figure 1-1 Five main themes of PSS project at Cranfield University (from PSS Community Research Outline)

As part of this PhD the author was involved as a researcher in the PSS Customer Value project. This project was conducted in the context of maintenance services, with the aim of understanding how organisations assess the value they derive from product-service systems, such as maintenance service bundles. This multidisciplinary project linked engineering, management and marketing in order to gain a useful and practical insight into the value assessment. The project comprised of 5 academics from Cranfield Schools of Engineering, Management and Applied Sciences, 1 Research Fellow from School of Management and 1 PhD Student from School of Engineering. Figure

1.2 presents the PhD research and the PSS-Value Project outlines and their overlaps.

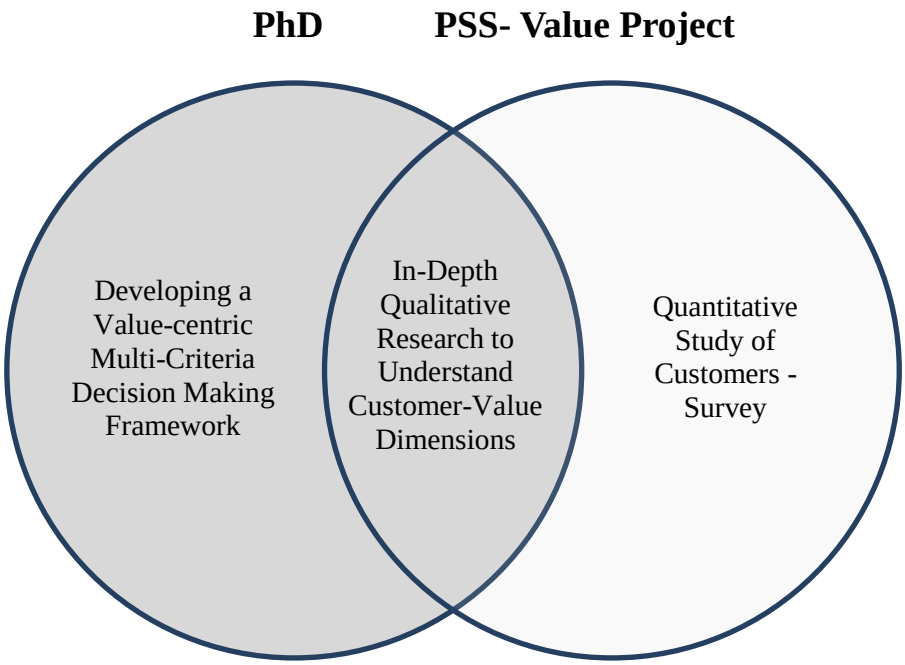

Figure 1-2 PhD and PSS-Value Project Outlines

The project was funded by Engineering and Physical Sciences Research Council (EPSRC) and Cranfield's Innovative Manufacturing Research Centre (IMRC), sponsored by Rockwell Automation as the industrial collaborator (see Figure 1.3).

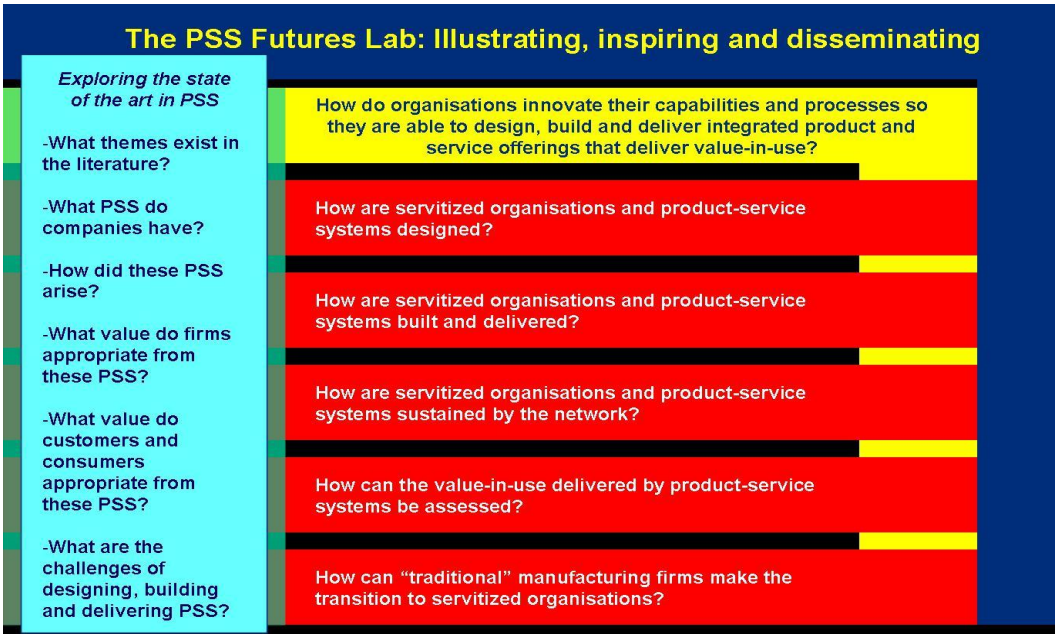

Figure 1-3 PSS Customer Value Project Structure

1.6 Research Aims

The aim of this project is to define the dimensions of perceived customer-value in outsourced maintenance services and develop a decision making framework for maintenance outsourcing, based on these value dimensions.

1.7 Objectives

From a detailed literature review it became clear that the customer value of outsourced maintenance services warrants further investigation. Also it has been identified that outsourcing decision making requires better informed value-centric basis than conventional decision making processed for outsourcing maintenance in order to add value to the customers, which is rarely studied. Therefore we can outline the main objectives of this research as follows:

1. To provide a consistent and structured understanding of value-in-use of outsourced maintenance services and dimensions of value-in-use.

2. To develop a value-centric outsourcing decision making framework, which enables incorporating both tangible and intangible value dimensions, in order to have more comprehensive decision making. It also creates the opportunity for the suppliers of outsourced maintenance services to continuously improve the

value-adding capacity of their services by tailoring it to meet customer needs and values.

3. To exemplify the developed decision making method through its application in an industrial PSS context and to further validate it through case studies.

1.8 Overview of Methodology

In order to investigate the value-in-use dimensions of outsourced maintenance services and develop a value-centric decision making framework for maintenance outsourcing, this research has been conducted in four main phases. The research aim of each phase, the methodology used and the analysed dataset are shown in figure 1.4. The detailed description of research methodology will be presented in Chapter 3.

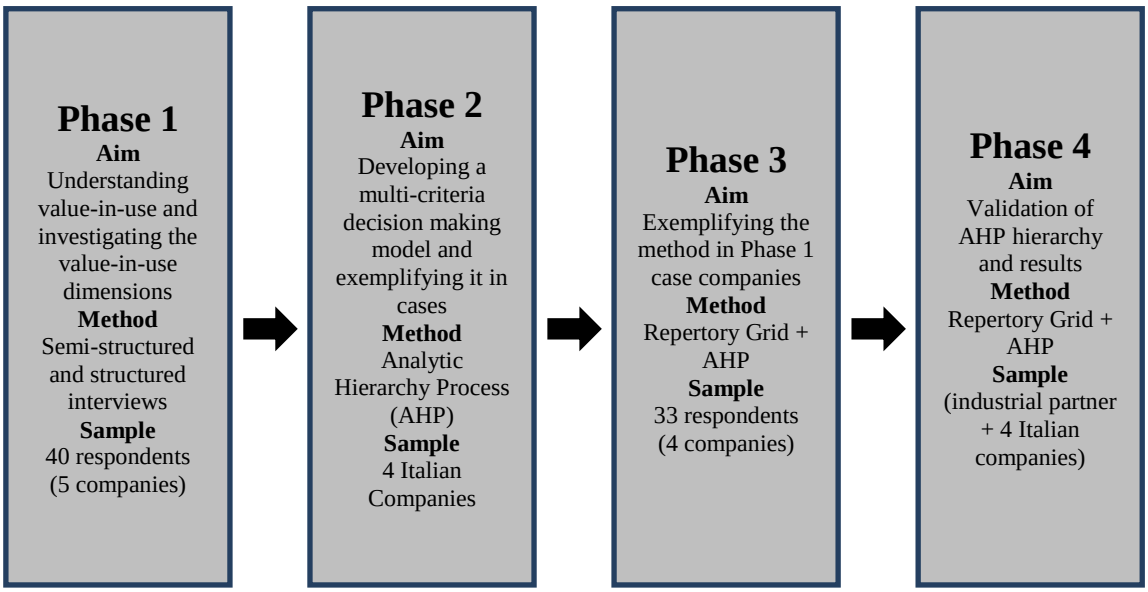

Figure 1-4 Overview of the Four Phases of the Research

1.9 Thesis Structure

This research comprises of eight chapters as follows:

Chapter 1- Introduction to the research and defining its context.

Chapter 2- Reviewing the literature.

Chapter 3- Designing the four stages of the research and the methodologies applied.

Chapter 4- The results from the first phase of the study; attributed value-in-use dimensions and their analysis.

Chapter 5- The results from the second phase of the study; the novel approach of developing a multi-criteria decision making framework based on the value dimensions of Phase 1.

Chapter 6- The results from the third phase of the study; a novel approach of combining the quantitative results of phase 1 of the study with the developed decision making framework and analysing the results.

Chapter 7- Field testing the developed decision making framework and validating numerically.

Chapter 8- Discussion and conclusions.

2 LITERATURE REVIEW

2.1 Introduction

In this chapter a detailed review of the literature for this project is provided. The review covers two main interrelated and sequential phases of the study; investigating the existing research on value-in-use of maintenance services and reviewing the literature on maintenance outsourcing strategic decision making.

2.2 Maintenance Management

Maintenance is defined by the British Standard Glossary of Terms (3811:1993) as: “The combination of all technical and associated administrative actions intended to retain an item in, or restore it to, a state in which it can perform its required function. This function may be defined as a stated condition.” As Dekker (1996) argues, the objectives of performing maintenance can be summarized under four main categories:

1- Ensuring system function; availability, efficiency and product quality which is referred to as Overall Equipment Effectiveness (OEE).

2- Ensuring system life (asset management).

3- Ensuring safety.

4- Ensuring human well-being.

The initial scientific approaches to maintenance management started in the 1950’s and the 1960’s (Kelly, 1989; Pintelon and Gelders, 1992). Traditionally maintenance was considered as a production function whose cost therefore was referred to as a “necessary evil”. Operational research techniques for maintenance planning emerged in the 1960’s and more advanced maintenance strategies like condition monitoring appeared in the 1970’s. In fact maintenance management has evolved over time from reactive and preventive to predictive and proactive approaches (British Standard, 1984; Bateman, 1995; Lee et al, 2000; Swanson, 2001 and Waeyenbergh and Pintelon, 2002). It is to be added that there are different categorisations existing for maintenance strategies in the

literature, which we have summarised in Table 2.1. One or a mixture of these approaches can contribute to enhancing manufacturing output. In other words even the oldest of approaches sometimes prove to be the most efficient depending on the situation.

Table 2-1 Maintenance Strategies

Maintenance Strategy	Definition	References
Reactive Maintenance	This approach is basically "Run to Failure" maintenance mode. No maintenance is carried out until the machine breaks down or in emergency situation.	(Swanson, 2001)
Preventive Maintenance	"The maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning and the effects limited."	(British Standard 3811, 1993)
Corrective Maintenance	Its main feature is "that actions are only performed when a machine breaks down. There are no interventions until a failure has occurred."	(Bevilacqua and Braglia, 2000)
Predictive Maintenance	"Maintenance carried out according to need as indicated by condition monitoring."	(British Standard 3811, 1993)
Proactive Maintenance	"Systematic approach that can continuously track health degradation and extrapolating temporal behaviour of health indicators to predict risks of unacceptable behaviour over time as well as pinpointing exactly which components of machine are likely to fail."	(Lee et al, 2006)

2.3 Value-in-use of Maintenance Services

2.3.1 Product-Service Systems Context

As discussed in section 1.2, Product-Service Systems are integrated product-service offerings that deliver value-in-use (Baines et al, 2007). In order to develop these product service offerings, companies can adopt different business models. Fischer et al (2010) divides these models into two 'distinct' approaches as quoted below in italics:

Exploitation: "*exploitation of service opportunities through temporal expansion of the service business along the primary customer activity chain.*" In this approach the business model becomes more service-oriented incrementally by introducing value-adding services (Möller, 2006). Rolls Royce offering integrated service offerings for their aero-engines is an example of the exploitation strategy.

Exploration: "*exploration of service opportunities through spatial expansion and reconfiguration along the adjacent customer activity chain.*" This approach is in fact discovering new service business opportunities and innovating new services e.g. Xerox's Document Management Services. Companies adopting this business model increased their share of revenue attributed to services from less than 20% to more than 40% within a period of five years. However, despite the potential profitability, the risk of failure increases in this approach (Fischer et al, 2010).

Therefore, many manufacturing companies have adopted the exploitation approach in developing their service business. Many Original Equipment Manufacturers (OEM), realised that by adding a value-creating service element like maintenance to their offerings, they can generate sustainable customer value which leads to improved revenue for the product-service provider (Gebauer et al, 2005). As we can also see in figure 2.1, the shift towards servitisation has a spectrum, in which value can be generated from pure product to pure service.

Few researches have focused on value creating capacity of PSS. Meier et al (2010) studied the architecture of value creation in the context of Industrial Product-Service Systems but less research has been focused on the value-in-use of maintenance services in the PSS context which will be more investigated in the following sections.

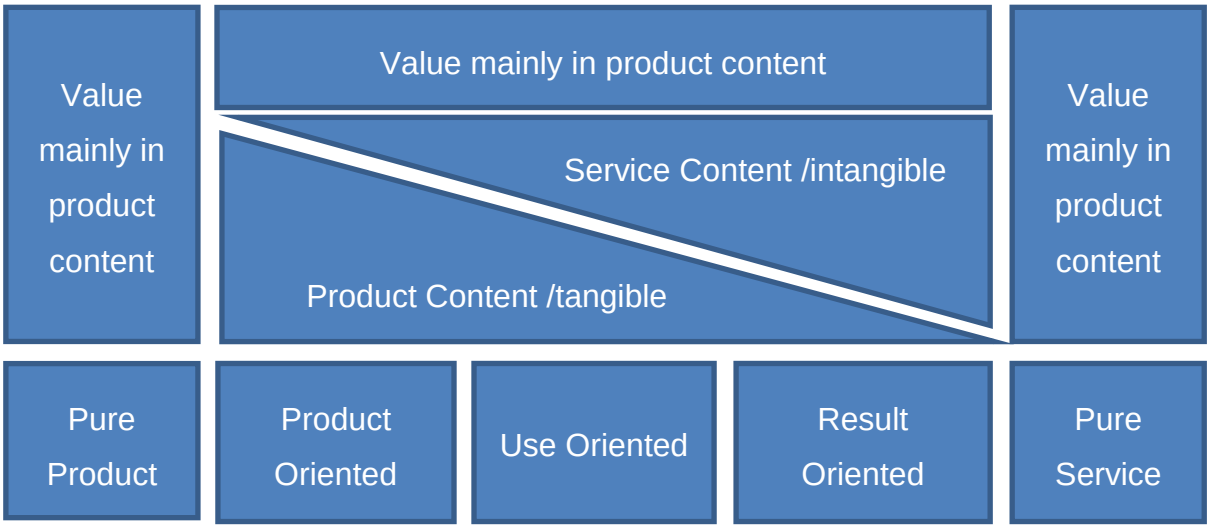

Figure 2-1 Product-Service Systems Spectrum (Tukker and Tischner, 2006)

2.3.2 Value-in-use of Product-Service Systems

The business marketing move from transactional to relational (Tuli et al, 2007) by offering Product-Service Systems has shifted the focus from attracting the customers to maintaining the relationship by increasing the customer satisfaction. This customer satisfaction is the function of the value which is created through these new offerings (Ravald et al, 1996). PSS providers add value by creating unique benefits for their customers. Not only do they take on the risk of customers' in-house activities, they develop new settings for products and services to work together as an integrated system to increase the overall value of the solution for the customers (Brady et al, 2005). In this respect, becoming "solution-focused" means that both PSS providers and customers who need to outsource their service functions, need to understand how value is created through this move from transactional to relational marketing approach. In order to gain better understanding of the value-in-use concept, in Figure 2.2 a simple example was developed by the PSS-Value project team. This figure shows the ways in which value-in-use may be co-created by the patient and the

GP service for a GP's appointment. The surgery provides a reception area, health treatment etc and the customers engage with the surgery through meeting the doctor and other patients. The value-in-use from these interactions are outcomes such as improved health, feeling secured etc which are achieved through this use process, and not directly supplied by the service provider.

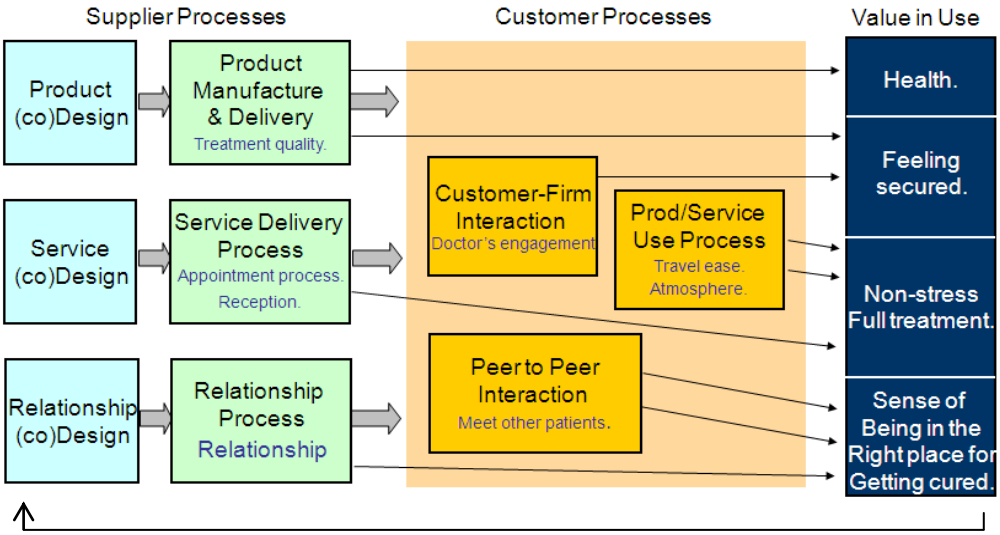

Figure 2-2 An example: Assessing Value-in-Use for a GP Appointment, developed as a part of PSS Value project (Macdonald et al, 2011)

2.3.3 Value-centric Paradigm in Maintenance Management

As stated in Chapter 1, in parallel with the trend towards servitisation, the maintenance management paradigm has shifted from viewing maintenance as a necessary evil, which "costs what it costs", to a planned and controlled part of the business process, which creates additional value, and is considered as a "profit contributor" (Parida and Kumar, 2006). Recently it has been argued that maintenance has intrinsic value (Marais and Saleh, 2008; Rosqvist et al, 2009) and there is an emerging view that maintenance not only reduces business risk, but should also be seen as a value-adding process by facilitating efficient production. This "value-centric" approach is in contrast with the traditional "cost-centric" approaches, in which the benefits of maintenance have mostly been considered as "avoiding the costs of failure" (Liyange and Kumar, 2003; Al-Najjar, 2007). It is therefore important for suppliers of maintenance services to understand and assess the value-creating dimensions of maintenance in order

to design more value adding services. In fact, according to Anderson and Narus (1998) “to persuade customers to focus on total costs rather than simply on acquisition price, a supplier must have an accurate understanding of what its customer values and would value”. This understanding would help suppliers of maintenance services to discern which areas of the provided service could be tailored and improved, in order to escalate the customer’s value perception, gain new customers by integrating value knowledge with marketing efforts (Toossi et al, 2010) and finally “better sustain customer relationships by documenting its delivery of superior value over time and by discovering new ways to update and reinvigorate those relationships” (Anderson and Narus, 1998). In order to be able to assess and improve the value generating capacity of maintenance, its definition needs to be further discussed which is presented in the next section.

2.3.3.1 Value Definition

A key point to this research is to assess the value of maintenance services. In order to understand and measure value in practice, it is essential to have a common definition of value. In the literature a range of definitions based on diverse perspectives have been proposed. These definitions can be found in table 2.2.

Table 2-2Value Definitions in the Literature

Author(s)	Year	Definition
Parasuraman et al	1988/ 2005	*“A comparison of what customers think a company should offer (i.e. their expectations) with the company’s actual performance”*
Anderson et al	1998	*“Monetary worth of the economic/social, technical, service and social benefits a customer receives in exchange for what it pays for a market offering”*
Ravald et al	1996	*Perceived benefits versus sacrifices/ perceived sacrifices including overall costs that the customer faces and perceived benefits comprising physical specifications, service attributes and available technical support as well as purchase price and other indicators of service quality*
Monroe	1991	*Defines customer perceived value as “the ratio between perceived benefits and perceived sacrifices”*
Zeithaml	1988	*defines value on the basis of benefits versus sacrifices as “overall assessment of the utility of a product (or service) based on perception on what is received and what is given”*

As we can see value has been defined based on the concept of monetary worth or perceived benefits versus sacrifices. According to Ravald et al (1996) perceived sacrifices include overall costs that the customer faces and perceived benefits comprise physical specifications, service attributes and available technical support as well as purchase price and other indicators of service quality.

Furthermore, Parasuraman brings a slightly different perspective on this by defining value based on customer's expectations versus supplier's actual performance. Parasuraman et al (1988) also have developed a tool called SERVQUAL, to assess service quality based on five service quality metrics (Reliability, Responsiveness, Assurance, Empathy, Tangibles) which is passive and is based on transactional business to customer context, although it can be used as a good comparison basis and learning source for measuring value, we will further see in Chapter 4 that this method does not cover value dimensions comprehensively and just shows a part of the value dimensions. In this research we emphasize the importance of understanding the value dimensions which create perception of benefit and/or sacrifice for the customer which may be of tangible or intangible nature rather than proposing and adding another definition to already existing literature. We used Zeithaml's (1988) definition of value in this research as a useful approach in defining value. In the next section the author will present how the value concept is shifted to the service use process rather than understanding the value that is embedded by the product-service designers at the point of sale.

2.3.3.2 Value-in-Use versus Embedded Value

According to Vargo and Lusch (2004) in traditional goods-centred dominant logic, customers are the recipient of goods and marketers try to approach the customers by segmenting, penetrating, distributing to and promoting to them, The value is embedded in the product and is defined by the producer (also known as "exchange value"). Today's business-to-business relationships and new customer-to-supplier interfaces in industrial services necessitate a more holistic approach in defining the value concept such as 'value-in-use' which

Vargo and Lusch (2004) define as “A customer’s functional outcome, purpose, or objective that is served directly through the product/service consumption”. This perspective to value is in contrast with the embedded value concept, which Vargo and Lusch (2004) define as “Performance against product/service attributes for which the customer is prepared to pay”. Table 2.3 shows the conceptual shift from embedded value to value-in-use in the literature. As we can see in this table the focus has been shifted from the value that is embedded in the service by the providers (Zeithaml et al, 1985) to the value that is co-created through the experience of using the service (Vargo and Lusch, 2004).In fact in the emerging service dominant logic (Vargo and Lusch, 2004), the customer is a co-producer of service and the value is perceived and determined by the customer in the use process. In other words customers are active participants in relational exchanges and co-production (Vargo et al, 2004).

Table 2-3 Conceptual Shift from Embedded value to Value-in-Use (Macdonald, 2008; from PSS Value project presentations)

	EMBEDDED VALUE		MOVING TOWARDS VALUE-IN-USE VIEW		VALUE-IN-USE		
1700s	Wealth of Nations: Adam Smith (1776) "services are unproductive"						
1800s					Say (1821) disagreed with Smith. Saw production as the creation of utlity, not matter.	Bastiat (1860): Economics is about people who have wants and seek satisfiers.	
1900s	Fuctional School: Shaw (1912) Value is: "The application of motion to matter to change its place and form"	Institutional School: Weld (1916): Marketing's role in production is the creation of time, place and possession utility	Lewin (1936): Looked at the instrumentality of actions and objects in achieving ends.		Barbon (1903) The "value of all wares arises from their use"		
1950s					Alderson (1957) Utility is Value-in-Use. We need: " a marketing interpretation of the whole process of creating utility".	Drucker (1958): Utility is value-in-use.	Abbott (1955) "What people really desire are not products but satisfying experiences".
1970s					Emergence of Services Marketing: Resource advantage theory; Core competency theory; Service encounter.	Nordic School: Value emerges in the customer's space, not	IMP group: Network approach
1980s		Zeithaml, et al (1985): Service Encounter evaluation - SERVQUAL.	Zeithaml (1988): Quality = Instrumentality. Perceived value = Utility based on what is given and what is received.		Levitt (1983 in Gummesson 2007): Only customers can assess the value of goods and services.		
1990s				Woodruff (1997): Product attributes, product performance and consequences arising from use.	Relationship marketing	Experience marketing	Service-scapes
2000s					Vargo and Lusch (2006) FP6: The customer is always a co-producer. FP7: The enterprise can only make value propositions.		Vargo and Lusch (2006) There is no value until an offering is used.

On top of the value-in-use concept, Markeset et al. (2004) argue that the notion of values that are critical to arrive at a commercial success today can in fact be said to be two-fold: “Accountable values” and “Non-accountable values” which are combined in complex patterns to deliver end results and subsequently business prosperity. In fact as before mentioned, due to the relational nature of offerings in new product and service settings (i.e. PSS), value is co-created between suppliers and customers as a result of this relational aspect. Also engagement of service provider with the customers highlights intangible dimensions of value rather than transactional relationships in which tangible values are more emphasized.

On one hand, maintenance as an important part of provided services in PSS settings has a major contribution in the process of value co-creation. On the other hand, offering maintenance services by providers, calls for outsourcing maintenance functions by customers. Therefore maintenance outsourcing needs to be studied in order to better understand the customer value. This is addressed in the following section.

2.4 Maintenance Outsourcing Decision Making

2.4.3 Maintenance Strategic Planning

The level of competition in the current market has driven companies to continuously improve their operation and maintenance processes (Al-Najjar, 2007). Therefore understanding how maintenance should be planned and operated as a value-adding business process is vital for both supplier and customer parties to add value to their businesses. Also, designing a maintenance organization, akin to any engineering and management system, requires comprehensive understanding of its strategic dimensions. Tsang (2002) has identified four strategic dimensions for maintenance management (see Figure 2.3):

1- Service delivery options: choosing between in-house capability of providing the service and outsourcing the service to a third party service provider.

2- Organisation: structuring the maintenance tasks and organising the maintenance function.

3- Maintenance methodology: selecting the most effective maintenance policies i.e. corrective, preventive, predictive and proactive.

4- Support infrastructure: the infrastructures that are designed to support maintenance e.g. information, training, performance management and reward systems.

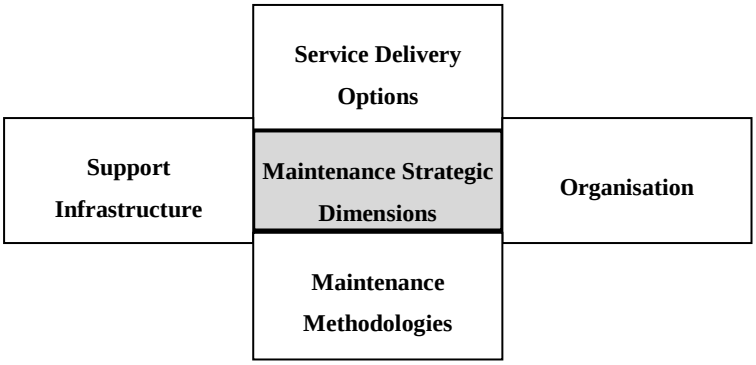

Figure 2-3 Maintenance Strategic Dimensions (Tsang, 2002)

It is to be mentioned that Organization and Support infrastructure dimensions are part of other PSS research projects at Cranfield (Transformations and Operations) and are comprehensively covered in their related work. Therefore literature relating to the Delivery options and selecting Maintenance Methodologies has been investigated extensively (see Table 2-4). As it is drawn out from the literature, most of the literature relating to maintenance strategic planning covers how to select the most effective Maintenance Methodology and less stress has been put on investigating the Delivery Options. The summary of the literature discussing these two areas can be found in Table 2.4. In fact, as we can see in the first two rows of Table 2.3 most of the literature discusses the methods to select maintenance strategies i.e. preventive, corrective, predictive and proactive and less research has been done in maintenance outsourcing. Also from the literature on maintenance outsourcing, very few discuss about the

Table 2-4 Comparing the Literature Focus on Maintenance Management Methodologies and Service Delivery Options

Subjects Discussed	Literature
Different maintenance management methodologies	British Standard, 1984; Bateman, 1995; Lee et al, 2000; Swanson, 2001; Waeyenbergh and Pintelon, 2002
How to choose the most effective maintenance methodology	Rosqvist et al, 2008; Marais and Saleh, 2008; Al-Najjar,2006; Bevilacqua and Braglia,2000; Wang et al,2006
(Business Process) Outsourcing	Kraker, 1995; Neale, 1995; Engleke, c.1996; Weston, 1996; Laabs, c.1997; Embleton and Wright, 1998; Gibson, 1996; Weston, 1996 and Yang et al, 2006
Maintenance outsourcing concept	Campbell, 1995; Levery, 1998
Maintenance outsourcing decision making	Bertolini et al, 2004; HajShirmohammadi and Wedley, 2004; Nayebpour and Shahanaghi, 2009

decision making in this area and most of the literature on outsourcing is focused on Business Process Outsourcing (BPO) in general terms (Gibson, 1996; Weston, 1996 and Yang et al, 2006). This emphasizes the importance of further investigation and research in Delivery Options and maintenance outsourcing and its decision making to cover this gap. In the next section the overview of maintenance outsourcing literature is provided.

2.4.4 Outsourcing Maintenance Function

2.4.4.1 What is Outsourcing?

Faced with intense global competition, operational risks, limited resources and new technologies, companies try to optimize their resource allocation and there

are increasing numbers of companies who would like to outsource their 'non-core' activities, in order to reduce the risk of operation. These are activities where the risk of losing know-how by outsourcing them is low. Outsourcing results from an economic climate, where the emphasis is on cost savings and increased profits where it can reduce costs and increase quality (especially for lean operations). In other words, outsourcing is another approach leading to greater competitiveness (Weston, 1996). This is achieved by concentrating on companies' core competences and outsourcing all activities for which the company has neither a strategic need nor a special capability, which results in increasing their return on internal resources. Embleton and Wright (1998) summarise the outsourcing definition as in Table 2.5, whose common theme is transferring the management and risks of an internal function to a third party company.

Table 2-5 Outsourcing Definition [created from data in Embleton and Wright (1998)]

Definition	Resource
"The transfer of routine and repetitive tasks to an outside source."	Gibson, 1996
"...having an outside vendor provide a service that you usually perform in-house."	Laabs, c.1997
The decision to obtain selected goods and service from outside your company	Engleke, c.1996
Finding new suppliers and new ways to secure the delivery of raw materials, goods, components and services, by utilizing the knowledge, experience and creativity of new suppliers not used previously.	Kraker, 1995
"The practice of handing over the planning, management and operation of certain functions to an independent third party"	Neale, 1995

2.4.4.2 Why Outsourcing Maintenance?

As Embleton and Wright (1998) assert, none of the outsourcing definitions (see Table 2.5) deal with the issue of timing of switching from in-house to "external sourcing" (outsourcing) or the identification of functions which could become outsourced. In fact, once a company's readiness to outsource has been

established, as the next step those operational functions and activities that offer the most potential have to be identified. These are usually support services which are not part of the organization's core competences. Support services are routine, well defined, can be measured and managed "at arm's length" and are provided by the suppliers in the marketplace, in a competitive atmosphere which may include services that are critical and specialized (Campbell, 1995). Not surprisingly, some maintenance activities (see Figure 2.3) are good candidates for outsourcing such as specialist equipped maintenance. This is more apparent where uptime, capacity and precision of equipment are critical and there is a shortage of skilled and experienced maintenance engineers (Campbell, 1995).

As we can see in figure 2-4 traditionally, the decision to outsource maintenance can rely on the ability to define maintenance requirements and the ability to relate asset performance to maintenance effectiveness.

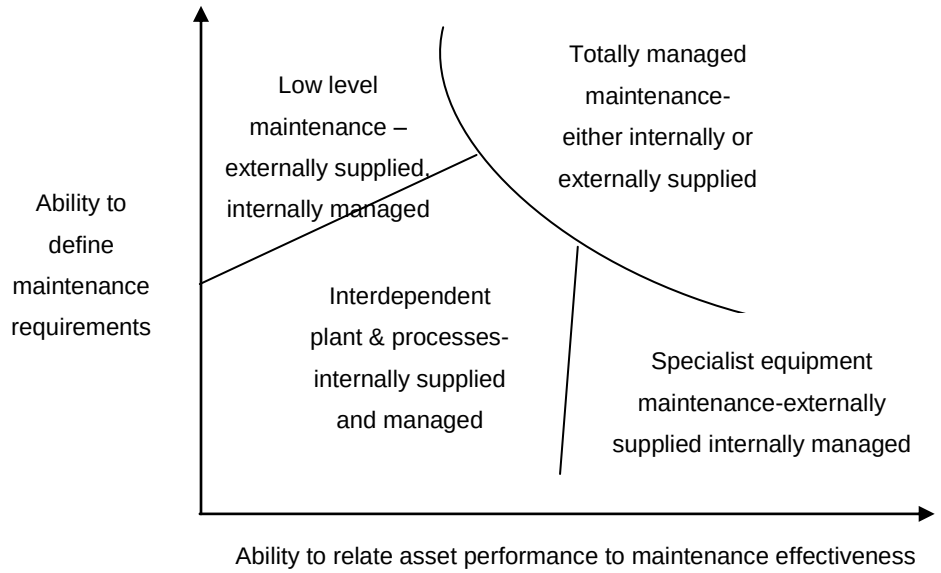

Figure 2-4 Maintenance outsourcing strategy (Levery, 1998)

2.4.4.3 Maintenance Outsourcing Decision Making

As discussed earlier, delivery options and outsourcing is one of the four strategic dimensions of maintenance. The "make or buy" philosophy is the process that decision makers undergo when considering outsourcing (Embleton and Wright, 1998). Similar to all other changes conducted in organizations,

there are 3 key steps to be taken in order to achieve a successful decision making in maintenance outsourcing: Strategic and financial analysis (feasibility analysis); selecting the providers; and managing the relationship (Embletom et al, 1998). In order to do the feasibility study, the company's readiness to implement outsourcing should be assessed as the initial step (Bertolini et al, 2004). In this respect maintenance managers should review internal structure, processes and management procedures, personnel capability and their responsiveness to change (Bertolini, 2004).

Today the business relationship shift towards supplier-manufacturer partnerships clearly signals a managerial transition to adopt a new decision-making criterion. (Liyange et al, 2003). It has been argued that most successful outsourcing arrangements are those who bring "partnership philosophy" into their businesses (Judenberg, 1994). Wolff et al. (2000) reveal that the currently adopted criteria for investment decisions are not exclusively economic in nature, but also take into account social and environmental considerations in appraisal of the security of investments. Similarly Lemke et al (2003) emphasise that "the role of price has diminished in evaluating supplier performance in many sectors." According to Keeney (1994) values are fundamentally important in any decision situation. Anderson et al (1998) assert that "many customers understand their own requirements but do not necessarily know what fulfilling those requirements is worth to them". In fact they are more fundamental than alternatives and they should be the basis for our decision making. In other words alternatives are means to achieve values. Keeney (1994) refers to this kind of thinking as "value-focused thinking". The fundamental role of value-focused thinking is shown in figure 2.5. Therefore a better understanding of maintenance value will help customers to have reliable decision making criteria for outsourcing their maintenance functions.

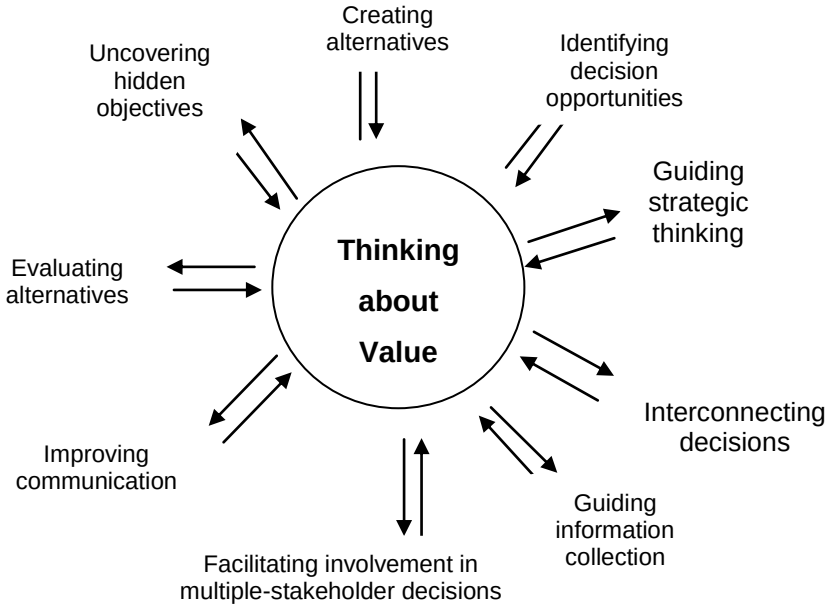

Figure 2-5 Quality decision making by value-focused thinking (Keeney, 1994)

In this respect we need to understand the value that customers perceive from outsourcing maintenance. Like any business process, outsourcing of maintenance activities can result in both benefits and drawbacks at the same time. If we look at the literature there are a few efforts to elaborate the value of maintenance. Plant Maintenance Resource Centre (2001) [www.plant-maintenance.com] has identified the benefits of outsourcing maintenance activities as follows:

- To increase labour productivity and work quality
- To reduce maintenance costs
- To allow in-house personnel to concentrate on ’core’ activities
- To reduce management effort
- To obtain specialist skills not available in-house
- To level fluctuations in workload
- To reduce risk
- To increase access to specialist equipment

- To increase equipment uptime/performance
- To keep pace with rapidly changing technology

Whereas Bertolini et al (2004) lists a set of drawbacks of maintenance outsourcing which need to be taken into account by the customers:

- Loss of control and loss of a learning source, because an internal activity is externalised
- Loss of knowledge of the plant
- Possible dependencies on the supplier
- Variations in the quality of the product given to the customer
- Problems among personnel, since they lose their functions

Dekker (1996) believes that “the main question faced by maintenance management, where maintenance output is produced effectively, in terms of contribution to company profits is very difficult to answer”. Much of the extant literature in maintenance value details the technical and financial benefits of maintenance (Al-Najjar, 2007; Marais and Saleh, 2008). However, Embleton and Wright (1998) emphasize that “more variables are brought into play when management considers outsourcing a product or service that is currently being produced internally”. Current research also argues that there are elements of intangible and soft values that are as important and effective in decision-making as tangible values (Bowman and Ambrosini, 2000; Liyange and Kumar 2003 and Markeset et al, 2004). According to Marr (2006), “whereas identifying and managing traditional financial and physical value drivers are difficult enough, identifying and leveraging the intangible value driver is still seen as the holy grail of management”.

Useful conventional approaches to outsourcing decision making have been discussed in the literature (Campbell, 1995; Harkins, 1997; Embleton and Wright, 1998; Levery, 1998 and Fill and Visser, 2000). However cost-centric processes have been the most applied decision making methods for maintenance outsourcing (Bertolini et al, 2004; Sunny, 1995). In fact outsourcing should be considered as a strategic planning process, whose

dimensions should be carefully analysed, rather than just an exercise to reduce cost. Therefore in order to have a well informed decision making process, there is a need to develop a value-centric decision making framework for maintenance outsourcing.

2.5 Summary and Conclusions from the Literature

As discussed in this chapter, strategic decision making in maintenance management is mostly based on the cost effectiveness of maintenance operations. The literature review identifies a shift from cost-centric to value-centric approaches. In addition, most of the emphasis of current research has been placed upon creating a decision making support system for designing a maintenance programs based on its technical and financial impact at strategic and operational level, in order to select maintenance strategies applied to a specific part of operation (Al-Najjar, 2007). In fact much less effort has been put in decision making for service delivery options or outsourcing decision making.

Therefore there is a need to:

1- Assess the perceived value of outsourced maintenance services which the PSS Value project members argue for the need to understand it in use context (value-in-use) rather than the value which is perceived at the point of sale(embedded value) (Macdonald et al, 2011), and

2- Develop an outsourcing decision making framework based on the assessed value dimensions. In fact, customers who have outsourced their maintenance activities need to reassess their decision based on their experience in a value-centric framework, in order to make sure that outsourcing is adding value to their business. This framework obviously needs to be able to capture and incorporate both tangible and intangible value. Additionally, Customer Company employees at different levels need to have input into this decision making framework (HajShirmohammadi and Wedley, 2004). It also should be able to evaluate the company's resources for outsourcing or continuing the outsourcing process. This decision making framework should also help maintenance services suppliers to continuously

improve their offered services by tailoring it to the customer needs and adding value to their businesses.

3- Value-in-use needs to be assessed in such a way that it can be used as an input to design and improve the value adding services to boost customer satisfaction, rather than as just another quantitative performance indicator which could not effectively improve the provided maintenance services. The methodology for this assessment and developing the framework is described in the following chapter.

3 RESEARCH DESIGN

3.3 Introduction

This Chapter explains the applied methodology for this research. The successful fulfilment of the research aims and objectives stated in chapter 1 is the final result of a structured research methodology. In summary, the research design:

- Addressed two research questions which stemmed from detailed literature review as stated in the previous chapter:

  1- What are the dimensions of value-in-use in outsourced maintenance services?

  2- How to perform value-centric decision making in maintenance outsourcing?

- Divided the research into four phases which were addressed by sequential research questions (see Figure 1.4). Phase 1 identified the dimensions of value-in-use perceived by customers of outsourced maintenance services. In Phase 2, a decision making hierarchy for maintenance outsourcing based on Analytic Hierarchy Process (AHP) was developed on the basis of the resulting value dimensions of Phase 1. In Phase 3 quantitative results from Phase 1 has been fed into the Phase 2 hierarchy and finally in Phase 4 the results were validated by their application in test cases.

- Studied eight case companies in different industrial sectors, from data collection to the validation stage.

  In the next section an overview of the methodology is presented which is followed by detailed review of applied methodologies in subsequent sections.

3.4 Overview of Methodology

As mentioned earlier, the research in this thesis was performed in four Phases. The details of the adopted methodology are as follows. The methods outlined below have been selected to facilitate the research aim:

- *Systematic literature review.* Literature research has been extensively carried out and reported in Chapter 2. The literature review has contributed to establishing a solid knowledge basis on the advancements in the relevant research area. The literature survey has mainly focused on techniques of assessing the value of maintenance and further included state-of-the-art research in product-service offerings, maintenance strategic planning, maintenance outsourcing, decision making.

Phase 1

- *Exploratory study* has been used to elucidate the value-in-use process (Miles and Huberman, 1994). At this stage, value dimensions of an outsourced maintenance service provided by our industrial collaborator to their customers have been assessed by extensive qualitative research. Value-in-use and the product/service attributes which will enable adding value to customers' businesses have been explored in the first instance by two techniques:

- Semi-structured interviews to uncover the participants' understanding of value adding capacity of maintenance services. This stage has been performed with a major customer of our industrial collaborator, in collaboration with PSS value project.

- The repertory grid technique (rep grid) based on Kelly's personal construct theory (Goffin, 2002; Goffin et al., 2006), a structured interviewing technique to uncover the often tacit constructs by which customers distinguish the relative value offered by different PSSs (In collaboration with the PSS Value project).

Phase 2

- *Maintenance strategic design method selection.* Based on the resulted value-in-use dimensions from phase 1 and their specifications, different methods of maintenance planning have been compared and Analytic Hierarchy Process (AHP) was selected as the most appropriate method (see Section 3.5.1). This method is capable of being fed by attributed value-in-use dimensions identified in Phase 1(Individual PhD research).

- *Developing value-centric maintenance outsourcing decision making model*. A decision making hierarchy based on AHP has been developed. This hierarchy incorporates value-in-use dimensions identified from Phase 1 of the research (Individual PhD research).

- *Exemplifying and validating the hierarchy*. The AHP based decision hierarchy has been presented to a group of maintenance specialists in an Italian maintenance and mechatronics consultancy company to gain feedback and improve the hierarchy. Also the hierarchy has been applied in three Italian companies, in order to validate its applicability in industry. The details of this Phase will be further discussed in Chapter 5.

Phase 3

- *Developing an novel AHP based maintenance outsourcing decision making framework integrated with repertory grid.* As it will be explained in the next section, repertory grid technique provides useful quantitative measures along with the qualitative results. These quantitative results from the Phase 1 of the research have been used as an input to the AHP model to facilitate the decision making for maintenance outsourcing (Individual PhD research). The details of the results and analysis have been presented in Chapter 6.

Phase 4

- Validation of the decision making framework (Individual PhD research). The details of the validation stages will be further discussed in Chapter 7.

In the following section, the case studied in this research is described.

3.5 Case Description

An exploratory qualitative approach has been adopted in order to investigate the dimensions of use value for outsourced maintenance services. We conducted an in-depth case study research with customers of one of the global leaders of automation and control Original Equipment Manufacturer (OEM) with 20,000 employees in more than 450 sales/support locations in approximately 80 countries that will be referred to as Service World. This company has a business stream specifically dedicated to engineering and asset management services. The UK services division is responsible for managing the entire maintenance function for customers and has more than 150 employees and £28 million sales (2008 figures). The services offered include asset management, integrated condition monitoring, remote monitoring, onsite support, phone support, repair services, training and service assessments.

This study investigates four different customers that have outsourced their maintenance operations. These manufacturing companies range across different sectors: medical equipment, pharmaceutical manufacturer, insulation material and a specialist metal products manufacturer. It is important to mention that the length of customer companies' relationships with the service supplier ranges from one to four years. In other words, they are in different phases of their relationship with the service supplier. For confidentiality, these companies are named; Medica, Pharma, Insula and Metal, respectively. The details of case companies' relationship with Service World can be found in Table 3.1.

The focus of this research is on maintenance management services which include data administration (parts renewal plan), calibration of equipment, inventory management, warranty tracking, systems integration and repair management. This service offering also provides a permanent on-site engineer who deals with technical and administrative aspects of the contract with the customer. This on-site representative is referred to as Service Representative [SR] in this thesis.

Service World's marketing approach to the new customers is to offer value adding services, which promise to decrease costs, optimize assets and improve productivity. In this research we will also see that value-adding dimensions of

maintenance services go beyond the technical and financial benefits, which accentuates the need to consider them by maintenance service providers. In the following section the data collection process is described in detail.

Table 3-1 Case Companies' Relationship Details

Company	Length of relationship (year)	Range of services
Medica*	3-4	Asset Management, phone support, repair services
Metal**	1	Asset Management, phone support, repair services
Pharma*	1-2	Asset Management (focus on inventory management), phone support, repair services, condition monitoring
Insula*	1-2	Asset Management, phone support, repair services

*Private sector

**Public sector

3.6 Phase 1: Investigating Value-in-Use Dimensions

3.6.3 Data Collection

In order to gain deep understanding of maintenance outsourcing value a range of different qualitative methods (structured, semi-structured interviews and survey) were considered (Miles and Huberman, 1994). Due to the exploratory nature of this Phase of the research, interviewing was chosen as it gives the opportunity to the researcher to dig deeper through the subject area, instead of surveys, which need prior structuring and limiting the responses to the pre-designed questions. Also among interviewing techniques, repertory grid was chosen. One of the advantages of this technique is that it allows for a deeper

exploration of the subject matter, whilst restricting interviewer bias (Goffin et al, 2006). Also as it will be further discussed in the following sections, repertory grid not only provides a rich pool of qualitative data but its ability to analyse the data quantitatively offers a strong advantage over other interviewing techniques.

Therefore structured interviews (Repertory grid) were conducted with interviewees from different backgrounds and varying degrees of seniority within the respective customer organisations. In total, 33 repertory grid interviews were conducted, lasting between 45 and 90 minutes. The breakdown of interviews can be found in Table 3.2. Each interview started with open ended questions in order to understand their role in maintenance department, maintenance management organization and the history of using Service World as the automation equipment and subsequently maintenance service provider. These lasted 15 to 20 minutes with each interviewee before we stepped into the main interview (repertory grid). All interviews were recorded and transcribed verbatim. The interviewees included both maintenance personnel (maintenance engineers, technicians, and operators) and managers (procurement managers, engineering managers, finance managers) of four customer companies. These interviews were followed by repertory grid interviews as described below. In this thesis, the findings from the repertory grid study are reported which was applied to understand and articulate the dimensions of use value of outsourced maintenance services.

Table 3-2 Sample for Repertory Grid Interviews

Customer companies	Hands-on maintenance personnel	Managers	Total
Medica	6	3	9
Metal	5	2	7
Pharma	7	2	10
Insula	5	3	8
			33

3.6.4 Repertory Grid Technique

Repertory grid is an in-depth interviewing technique which is used to elicit the personal perceptions about an aspect of the reality or phenomena (Jankowicz, 2003; Fransella et al, 2004). This technique is useful especially for situations where it is hard for interviewees to articulate their ideas and experiences with clarity and is "a powerful research tool for probing interviewees' understanding of complex topics" (Lemke et al, 2003). This technique is based on Kelly's (1955) Personal Construct Theory (PCT), which assumes that people construe internal representations of the reality they experience. In other words, it is based on Kelly's main belief that people, consciously or sub-consciously develop categories in the situations they face (Lemke et al, 2003). As Kelly was basically a clinical psychologist, the technique has been traditionally used as a means to improve psychologists' understanding of how the interviewee views the world (Fransella et al, 2004). Although this technique has been later used in several areas such as business and management studies in order to understand people's perception of organisational problems (Stewart et al, 1981). The technique enables the researcher to capture the mental map of how the respondent construes the world; through constantly comparing and contrasting how respondent interprets and re-interprets that which is important to them in their lives (Kelly, 1955).

In order to understand this interviewing technique, one of the grids elicited in our research (see Figure 3.1) will be described. The detailed interview protocol can be found in Appendix A. This interview has been conducted with a maintenance technician of Pharma Company. The repertory grid interviewing technique consists of four main components: topic, elements, constructs and ratings (Jankowicz, 2003). To commence, the interviewee was asked to consider a phenomenon or situation under study (in this case maintenance and repair operations). The interviewee was then asked to name at least 6 suppliers of maintenance and repair services that they were familiar with, including the focal firm Service World. These companies are referred to as elements. The elements were noted on postcard sized cards, which were already numbered by the random order of elements. These were also noted on the grid (see Figure

3.1). In the next step, the elements (names of suppliers) are compared in triads (random set of three cards) using the post cards (Fransella et al, 2004; Goffin et al, 2006) by asking the question which was tailored to our research: “Can you think of any ways in which two of these suppliers are similar to each other and different from the third in terms of the outcomes you get?” It is important to mention that from the possible combinations, triads should be selected in a way to present clearly contradistinctive elements (Bender, 1974; Goffin et al, 2006). The response is captured as a construct in the words of the interviewee e.g. one of the suppliers has “good quality of repairs” versus the other two suppliers which provided repair services are of “poor quality”. The interviewee is also asked then to rate all the suppliers on a scale of 1 to 5 against the elicited construct (Tindall, 1994; Gammak and Stephens, 1994 and Goffin et al, 2006). This process is then repeated using another randomised combination of triads until no more meaningful constructs can be elicited. The elicited constructs are to be unrepeated in an interview; therefore the respondent is encouraged to think more deeply. Also to obtain an accurate understanding of the constructs, laddering questions (e.g. ‘How, in What Way?’) were asked, which also in many cases resulted in eliciting new constructs (Jankowicz, 2004).

Order of personal elements: 5;1;6;4;3;2

	..1.. Constructs	Elements-suppliers: Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Supplier F	..5.. Poles
1	Good quality of repairs	2	2	4	2	2	3	Poor quality of repairs
2	Being local	3	3	1	1	2	3	Distant
3	Specialist Knowledge	1	1	2	1	2	1	General Knwoledge
4	On-site representative	4	5	4	2	1	5	Off-site
5	Good response time	2	2	1	1	1	2	Poor response
6	Good relationship with supplier	1	2	1	1	1	2	Not so good
7	Transparency in cost	4	4	2	3	2	4	Not so clear in cost

Figure 3-1 Example Repertory Grid (Interviewee: a maintenance technician in Pharma company)

Due to complexity of conducting this interview method and different ways to approach to this method, it was needed to get to a certain level of confidence and common understanding in defining and conducting this method in our research area. Aside participating in Cranfield School of Management's repertory grid training session (conducted by Prof. Keith Goffin), this method has been piloted several times in different topics and respondents (IT Dept, researchers etc). In order to finalize the method protocol (see Appendix A), the final pilot test has been performed with one of the case companies' maintenance manager. The maintenance manager participated in a pilot rep grid interview which was performed by 3 researchers from Cranfield University (including the author) in order to validate the method protocol in an actual industrial environment before interviewing the main cases.

The interviews were undertaken by 5 researchers over periods of 2-3 days in each company. The author personally has been actively present in conducting 7 semi-structured and 20 of the repertory grid interviews.

3.6.5 Data Analysis

Based on the interview transcripts and grids, which provide a valuable source of qualitative and quantitative information, data analysis was conducted in two main following steps (Goffin et al, 2006). Further details of the data analysis and results will extensively be explained in Chapter 4. However due to the inter-relation of the phases of the research, initial results have been briefly provided here, which will be useful for understanding the next section of this chapter.

3.6.5.1 Qualitative Analysis

This stage of analysis was undertaken by the project researchers. Following Table 3.3 is the process defined by Jawwad Raja (Goffin et al, forthcoming).

***Table 3*-3 Stages of Repertory Grid Qualitative Analysis (Toossi et al, 2010)**

Analysis Stage	Description
Initial Coding (Categorisation) Process	All the individual constructs elicited across all the interviews were listed on to 3x3 inch cards (See Figure 3.2) including the names of the construct, pole and the counter pole (e.g. good quality versus poor quality); the company name; the code identifying the company; interview number and construct number; the name of the participant; and lastly, the description/quote describing the meaning of the construct in the words of the respondent or a concise summary was used from the interview transcript. Additionally, different coloured cards were used for the different organisations. This was followed by researchers A and B examining in detail the interview transcripts and interview grids. Following this, both researchers independently grouped common constructs into categories. All 272 constructs were categorised. Researcher A grouped the 272 construct cards into 46 categories. Researcher B grouped the 272 construct cards into 43 categories.
Reliability table	The next step involved producing a reliability table (See Appendix B) showing the independently coded categories to emerge represented across two axis in an excel sheet. The cells of this 46 x 43 table were annotated with the code identifying the company, interview number and construct number. Those areas of the reliability table that clearly showed agreement were shaded. A further step was taken to reorganise the rows and columns to group cells were agreement existed into a diagonal (Jankowicz, 2004). The remaining constructs that sat above or below the diagonal indicated differences in opinion between researcher A and B.
Initial inter-coder reliability check	The initial coding process showed an inter-coder reliability of 48% for all the constructs. According to Miles and Huberman (1994), this figure is representative for this stage of coding and demonstrates the need to clarify the definitions of the categories (See Table 3.5).
Enhanced category definitions	The next stage involved the lengthy process of the two researchers discussing the constructs that sat outside the diagonal of the reliability table. These discrepancies highlighted by the reliability table were thoroughly discussed and debated vigorously, with clear definitions agreed upon (Miles and Huberman, 1994) as to what the category included. In order to ensure content validity, researchers A and B constantly referred to the interview transcripts in informing agreement over category definitions.
Re-coding the constructs	In line with Jankowicz (2003), researchers A and B repeated the process of coding the 272 constructs into one of the enhanced categories. This process was conducted independently and without discussion or debate. The outcome of the re-coding resulted in a second reliability table (Jankowicz, 2003; Miles and Huberman, 1994). The re-coding process showed an inter-coder reliability of 86% for all the constructs.

The process of categorisation has been repeated with two other independent researchers at two different stages, whose results have been compared with the initial researchers'. The inter-coder reliability for these two re-coding stages has been 78% and 83% which shows a reasonable degree of agreement among the researchers in categorisation (Jankowicz, 2003; Miles and Huberman, 1999). Further details of this analysis can be found in Goffin et al (forthcoming).

This stage of analysis led to the coding of 29 enhanced categories shown in Table 3.4a, representing the value dimensions identified by customers in using outsourced maintenance services. The categories have been subdivided into tangible and intangible values. In Table 3.4b we can also see the example of respondents' quotes, defining each category (value dimension).

As mentioned earlier, the detailed analysis of the enhanced categories will be further touched on in Chapter 4.

Company/Interviewee: *Insula/Anonymous*
Construct (code*): *Fast speed of response vs. Slow speed on response (K5-4)*
Quote: *Very good, very obliging if we need them. We had a breakdown on Friday night, they phoned them and two boys were on site within 2 hours.*

*code: Company/interviewee (grid) number- construct number

Figure 3-2 Sample Construct Card

Table 3-4a Customer Value-in-Use Dimensions

Tangible Values	**Intangible Values**
Ability To Source	Communication
Accessibility (of Service Provider)	Convenience
Cost Savings	Control
Delivery	Detailed Analysis
Feedback And Reporting	Innovation
Good Administration	Proactiveness (of Service Provider)
Inventory Management	Relational Dynamic
Locality	Risk Averse
Nature Of Contract	Service Orientation
Pricing	Understanding Customer Business
Quality Of Equipment	Urgency
Quality Of Repairs	
Range Of Product And Service Offerings	
Reliability (of Service Provider)	
Responsiveness	
Specialist Knowledge	
Support Systems	
Traceability	

Table 3-4b Value Dimensions and example quotes

Category (Value Dimension)	Interviewee (Company/Position)	Example of respondents' quote
Ability to source	Pharma/Calibration Team Leader	*We have some obsolete equipment and then I face the situation of quality and a change control, so if a company can get me something that's five years old, I'll take it.*
Accessibility (of service provider)	Medica/Maintenance Coordinator	*We are on 24/5 here so you don't want a motor sitting on the floor for 12/14 hours just because somebody can't ship it out to a plant that is only 20 miles away, so it gives us quick turnaround time.*
Cost Savings	Medica/Engineering Manager	*They're motivated to drive cost down to get us better value than if we did it ourselves*
Delivery	Pharma/Maintenance Technician	*They might take 24 hours for you to get a delivery date. The one thing I will say for them is when they give you that delivery date it is held to.*

Feedback and reporting	Metal /Engineering Coordinator	*I've got to go into our path, I've got to find out what's happened, it's almost like that Service World are dealing with it in the background and no one is aware of it.*
Good Administration	Insula /Maintenance Manager	*Some soft issues like invoicing, paper work…*
Inventory management	Insula/Purchasing Manager	*When a piece of equipment becomes obsolete you should go through the stores to remove the parts, but that hasn't been done over the years.*
Locality	Medica/Maintenance Coordinator	*They are local, they are in the UK.*
Nature of contract	Insula/Purchasing Manager	*Contract is a fixed price to come in a set number of times per year, but any extra work that is required is charged on top. Service World is also a contract, but we pay for the services per month, depending on what they do.*
Pricing	Pharma/Maintenance Manager	*It's difficult to negotiate pricing with them.*
Quality of equipment	Insula /Engineering Manager	*I think their equipment is built cheaply and at least cost.*
Quality of repairs	Insula/Engineering Manager	*It's fault rectification versus recurring problems. I mean that if you've had an issue, they will get to the cause and solve it, it doesn't keep coming back.*
Range of product and service offerings	Metal/ Central Stores Manager	*[Service World] could probably cover 95% of all repairs, In house can't cover as many I would say to be fair.*
Reliability (of service provider)	Insula/Senior Electrical Engineer	*He is a type of person that you can rely on. If he says the part is gonna be there next day or whatever, the parts arrive on time.*
Responsiveness	Insula/Maintenance Planning Engineer	*Very good, very obliging if we need them. We had had a breakdown on Friday night, they phoned them and two boys were on site within 2 hours.*
Specialist Knowledge	Pharma/2nd Line Maintenance Technician	*They'd come on site, he's a one man job, he'd come on site and tell you look that'll be very helpful to the machine, you'd be better off if you did this or that.*
Support Systems	Insula/Electrical Engineer	*He hasn't got fax machine and alike and you have to do electronically where these two if we need them you fax them and send info direct by photo and stuff. That's a complication on its own.*

Traceability	Medica/Maintenance Technician	*When you're ordering the parts yourself you know when the part is going to be in, you have better traceability of the part but when it's third party you're just relaying on them to let you know when the part is in.*
Communication	Insula/Stores Controller	*[Service World] communication is basically between [SP] and I. We have to know what we are going to repair, how the repair is progressing when we deal those items back.*
Convenience	Pharma/Facility Technician	*They come on site and they make it easy for me because they are familiar with the site and the more familiar they are and the more knowledge they have of the plant, it's easier for me you know.*
Control	Metal /Maintenance Manager	*Because it's under my control, once you go to Service World it's out of my control.*
Detailed Analysis	Medica/Engineering Manager	*I think if you had a supplier who's very proactively managing your spares and making sure you have the right mix of spares and do a statistical analysis and saying we need to hold more of these and less of these, that's where I would see someone adding a huge value to our business because the maintenance guys we have they are out there to fix machines*
Innovation	Pharma/Procurement Manager	*Innovation doesn't have to be about technology it can be about just billed process.*
Proactiveness (of service provider)	Pharma/Procurement Manager	*It's quite reactive, they needed to become proactive, they needed to free up their time*
Relational Dynamic	Medica/Maintenance Engineer	*But then that's because I'm dealing with them every day and it took me nine years to mould them the way I like.*
Risk Averse	Pharma/Facility Technician	*The less risk we would carry I think the better*
Service Orientation	Medica/Maintenance Coordinator	*They've got good phone and feedback and they show they care and there's a good relationship with the individuals.*
Understanding customer business	Insula/Electrical Engineer	*I use the suppliers who know what I'm talking about because I use them so that I know they can supply.*
Urgency	Pharma/Maintenance Technician	*If I needed something urgently I know that these guys would do everything in their power to get it for me.*

Tale 3-5 The Reliability Checks Table (Goffin et al, Forthcoming)

Measure	Stages of the Coding/Reliability Checks			
	Initial Coding	Re-coding	Independent Check	Independent Check
	(Researcher A vs. Researcher B)	(Researcher A vs. Researcher B)	(Researcher C vs. Researcher A/B)	(Researcher D vs. Researcher A/B)
Time required for each stage	10 hours to prepare construct cards	16 hours to prepare the enhanced coding definitions	8 hours for coding	10 hours for coding
	8 hours for the coding by each researcher	8 hours for the coding by each researcher		`
	10 hours for the reliability table	6 hours for the reliability table	4 hours for the reliability table	4 hours for the reliability table
Inter-coder reliability	48%	86%	78%	83%

3.6.5.2 Quantitative Analysis

At the final stage of analysis in order to identify the key constructs (value dimensions), a quantitative measure of the importance of each value category has been performed using two parameters, Frequency and Variability as proposed by (Goffin et al,2006). The ***frequency*** is defined as the percentage of respondents who have mentioned constructs in a category. Frequency is used to identify a “common” construct (Lemke et al, 2003: Jankowicz, 2003; Goffin et al, 2006). ***Variability*** is a mathematical measure of the spread of ratings for a construct (Goffin et al (2006). A higher spread of elements’ ratings for a construct shows that the interviewee perceives it as a more important dimension. Further details on these two parameters will be described in chapter 4.

In the following section the methodology used for developing a value-centric decision making model for maintenance outsourcing has been described. As

mentioned earlier the results of Phase 1 of the study have been used as a basis to develop this model.

3.7 Phase 2: Developing a Decision Making Model for Maintenance Outsourcing

3.7.3 Maintenance Strategic Planning Models

According to Tsang (2002) maintenance systems decision making is of strategic nature which is discontinuous, complex and unstructured. It is discontinuous because it cannot be treated like inventory ordering and once we make a decision we have to commit to it for a long time, due to its costly process in terms of both capital and human resources. Also it is complex because we need to consider multiple criteria and perspectives. Finally it is unstructured "in the sense that organized decision models with a single dominant criterion or a few well known criteria are not readily available" (Hajshirmohammadi and Wedley, 2004). Therefore we need to look at maintenance from different perspectives for a better design of maintenance system that satisfies the diverse and dynamic nature of its strategic dimensions.

As previously mentioned, in the past few years, the strategic decision making mindset has changed from maintenance being a "cost centre" to a "profit contributor". Moreover where the benefits of maintenance are considered, it is usually in the sense of avoiding the costs of failure. This explains why the existing methods of maintenance strategic planning are mostly operations research problems in which the main objective is to reduce maintenance costs. Unfortunately these models can only be applied in hypothetically simplified cases, which reduces their applicability (Bertolini et al, 2004). By this cost-centric approach, as we have seen briefly in the analysis of interview data (which will be discussed in details in chapter 4), many of the attributes of maintenance valued by customers are not considered. As we can see in table 3.4 and further explained in Chapter 4, intangible sides of the provided maintenance services also play an important role in adding value to their businesses. Value dimensions like Communication, Relational Dynamic and Understanding Customer's Business are examples of intangible dimensions

which need to be incorporated for a better informed strategic decision for maintenance systems.

As it is seen in Figure 3.3, the desired maintenance strategic planning model would incorporate avoiding the costs of failure with the value creating capacity of maintenance. It would also capture intangible values as they play a key role in satisfying the customers.

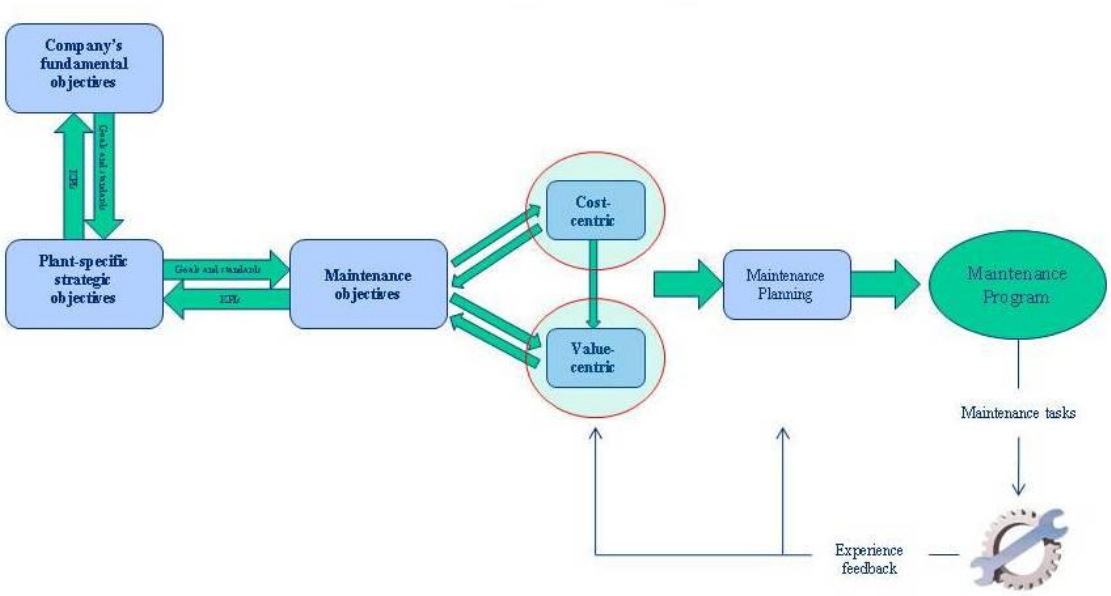

Figure 3-3 Maintenance planning model (after Rosqvist et al, 2007)

Designing maintenance programs has been extensively discussed in the literature. Different approaches can be found, ranging from methods based on reliability to net present value. The major existing models have been summarized in Appendix D. The columns in the table in Appendix D show the inputs that are used in different major maintenance design models i.e. Failure data, Repair Data, Process Data and/or KPIs. The last four columns indicated if the method designs maintenance program from operational level or strategic and whether it is considered as cost-centric or value-centric approach. As we can see in Appendix D Reliability Centered Maintenance (RCM), Failure Mode and Effect Analysis (FMECA), Value Driven Maintenance (VDM) and Al-Najjar's (2006), Rosqvist et al's (2007) and Marais and Saleh's (2008) models of maintenance strategic planning have been compared against each other.

As we have previously discussed briefly, the intangible dimensions of maintenance value shape an important part of customer's perception of value. As per Appendix D, from the existing models mentioned only Analytic Hierarchy Process (AHP) has the ability of incorporating intangible data. One of the unique advantages of this model is that different tangible and intangible attributed values can be fed into this multi criteria decision making model (MCDM). It also is able to get used for decision making in maintenance outsourcing. The details of the Analytic Hierarchy Process (AHP) will be presented in the next section.

3.7.4 Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) (Saaty, 1980) is one of the most popular Multi Criteria Decision Models (MCDM) which enables the user to solve decision problems based on both quantitative and qualitative decision criteria. Also it has the ability to handle multiple conflicting objectives while giving the opportunity to deal with different perspectives of decision stakeholders. These specifications very much satisfy the requirements for a value based decision making system. On top of all these, value is very difficult to quantify as a standalone figure and it is easier to compare the individual value dimensions against each other for a maintenance service system. AHP also gives us the capability to compare value dimensions, as will be further discussed in Chapter 5.

AHP has been applied in various areas such as: social science, politics, engineering, education science, government and manufacturing. It has also been used in maintenance management (Bevilacqua and Braglia, 2000; Emblemsvåg and Tonning, 2003 and Wang et al, 2006) and specifically in maintenance outsourcing decision making (Bertolini et al, 2004; Hajshirmohammadi and Wedley, 2004 and Nayebpour, 2009). Wang et al (2007) also lists a few advantages of applying AHP in the maintenance area:

1- The only MDCM model that inconsistency of respondents' judgments can be calculated in.

2- The decision criteria can be organized in a structured hierarchy.

3- This method enables pair-wise comparisons which is mostly preferable for the respondents.

Making the decision with AHP generally involves four steps (Saaty, 2008). After defining the problem we need to structure the decision hierarchy from the top down. Structuring has to start with the goal, lead to criteria and/or sub-criteria and lead to decision alternatives. A simple example of a hierarchy has been presented in Figure 3-4.

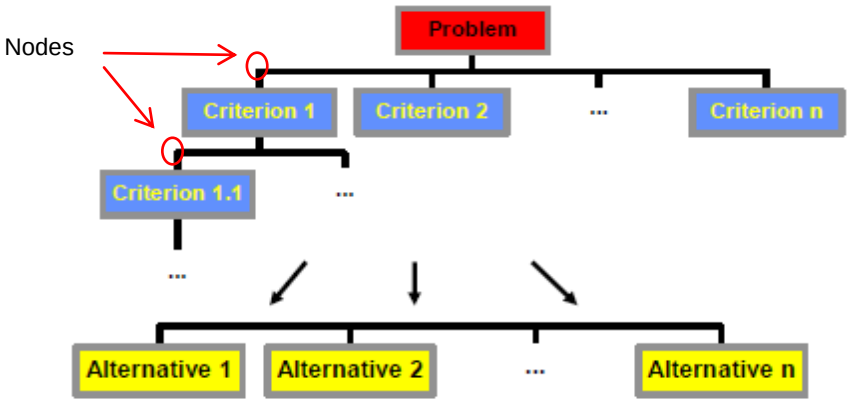

Figure 3-4 An AHP Hierarchy Example

After structuring the hierarchy, a set of pairwise comparison matrices (see matrix A) need to be constructed using Saaty's nine point scale (Saaty, 2004) as per Table 3.6. Saaty (2004) suggests using this scale to transform verbal judgments to numerical values. In the comparison matrix A, each entry a_{ij} of this matrix is formed by comparing the row element A_i with column element A_j where a_{ij} is the relative importance of the criterion i with respect to the criterion j. This matrix is a positive reciprocal pairwise comparison. The comparison of elements is made by using questions like: "which one of the two elements A_i and A_j is more important with respect to the higher level element?"

$$A = \begin{vmatrix} a_{11} & a_{12} & A_{13} & \dots & A_{1n} \\ A_{21} & A_{22} & A_{23} & \dots & A_{2n} \\ A_{31} & A_{32} & A_{33} & \dots & A_{3n} \\ \vdots & \vdots & \vdots & & \vdots \\ A_{n1} & A_{n2} & A_{n3} & \dots & a_{nn} \end{vmatrix}$$

$a_{ij}>0$; $a_{ij}=1/a_{ji}$; $a_{ii}=1$ for i,j=1,2,3,...,n

Table 3-6 The Fundamental Scale of Absolute Numbers

Intensity of importance	Definition	Description
1	Equal importance	Elements A_i and A_j are equally important
3	Weak importance of A_i over A_j	Experience and judgement slightly favour A_i over A_j
5	Essential or strong importance	Experience and judgement slightly favour A_i over A_j
7	Demonstrated importance	A_i is very strongly favoured over A_j
9	Absolute importance	The evidence favouring A_i over A_j is of the highest possible order of affirmation
2,4,6,8	Intermediate	When compromise is needed, values between two adjacent judgements are used.

So after we have compared each element in an upper level with the elements in the immediate below level and once we have captured sufficient comparisons for each node, they are standardized so that it sums to one. The so called

principal eigenvector (Saaty, 1990) of the comparison matrix becomes the ratio measure of the relative importance of each item. These local weights represent the relative importance of just items below a parent node.

At the last stage, the local weights need to get combined into a composite priority that incorporates the impact of all factors. Based on the principle of hierarchic composition, the local weights are multiplied by the product of all higher-level priorities joining to the target node to the top-most node. This process gives us the global weights from local weights which represents the importance of each node in the hierarchy. The global weights need to get summed up to give us the overall priority for each alternative at the bottom most level (Saaty, 2008; Hajshirmohammadi and Wedley, 2004).

It is important to mention that inconsistency of comparisons for each matrix needs to be verified, which according to Saaty (2004) needs to be less 0.1 for a valid comparison. In chapter 5, developing the AHP hierarchy based on the articulated value dimensions from Phase 1 of the study will be presented. Also this hierarchy's practicality in industry has been validated through a feedback session with 6 maintenance specialists from 2 Italian companies. Finally the developed AHP hierarchy has been applied in 3 Italian case companies. How we have managed the criteria weightings, comparison matrices and the results will be discussed in detail in chapter 5.

3.8 Phase 3: Exemplifying the AHP method with Repertory Grid Data

As reviewed by Vaidya and Kumar (2006), AHP can be combined with some other methodologies like linear programming, artificial neural networks, fuzzy set theories, etc. This trend is more seen in current research than in its initial applications after Saaty (1999), although it does not mean that AHP is no longer used on its own. In fact, AHP provides the flexibility to be combined with so many different techniques effectively (Vaidya and Kumar, 2006).

In phase 2 of our study, therefore to create a value-centric hierarchy we used repertory grid data to provide the comparison values. The repertory grid

technique also provides quantitative measures (frequency and variability), which create a rich pool of data to measure the importance of the value dimensions for the respondents. Therefore it is proposed in this research to perform criteria comparisons in Analytic Hierarchy Process (AHP) we have used these quantitative measures. We have used frequency, variability and also their product separately for this purpose. As it will be further discussed in Chapter 6, the product of frequency and variability has been used for this purpose as it has enabled us to have more precise and meaningful comparisons.

3.9 Phase 4: Validation of the results

At the final Phase of the research the results from previous phases of the research have been validated through feedback sessions and test cases involving the project's industrial partner and four Italian companies to test the applicability of the framework. Also special numerical validation for Phases 2 and 3 of this research has been performed. More details on the validation will be presented in Chapter 7.

3.10 Summary

In the first phase of the study in order to understand the dimensions of customer's perceived value from outsourced maintenance services, repertory grid which is an in-depth interviewing technique has been used. The rich pool of data helped to understand the value of outsourced maintenance services. The 29 emerged categories (value dimensions) have been used as the basis for developing a value-centric decision making framework. This technique also gives the user to benefit from both qualitative and quantitative data analysis.

As the nature of the value dimensions are of both tangible and intangible, from the existing maintenance strategic design methods, AHP was chosen. This method is able to incorporate the tangible and in-tangible value dimensions into a single decision making framework. Therefore AHP hierarchy has been developed on the basis of these dimensions. As it will be discussed further in chapter 5, this hierarchy has been validated by a group of maintenance specialists and applied in 3 Italian companies.

In the third phase of the study, a novel approach has been developed in which the quantitative measures resulted from repertory grid data analysis; frequency and variability have been to perform weighing the comparison criteria in the AHP hierarchy. In fact as these two parameters indicate the importance of the value dimensions in repertory grid analysis, they can be a useful source for weighing the decision criteria.

Finally, the framework has been validated through a series of industrial cases and some suggestions have been provided for the users. In Figure 3-5 the general framework of the research has been presented.

The results of the phases of the phases have been presented in the following Chapters 4 to 6.

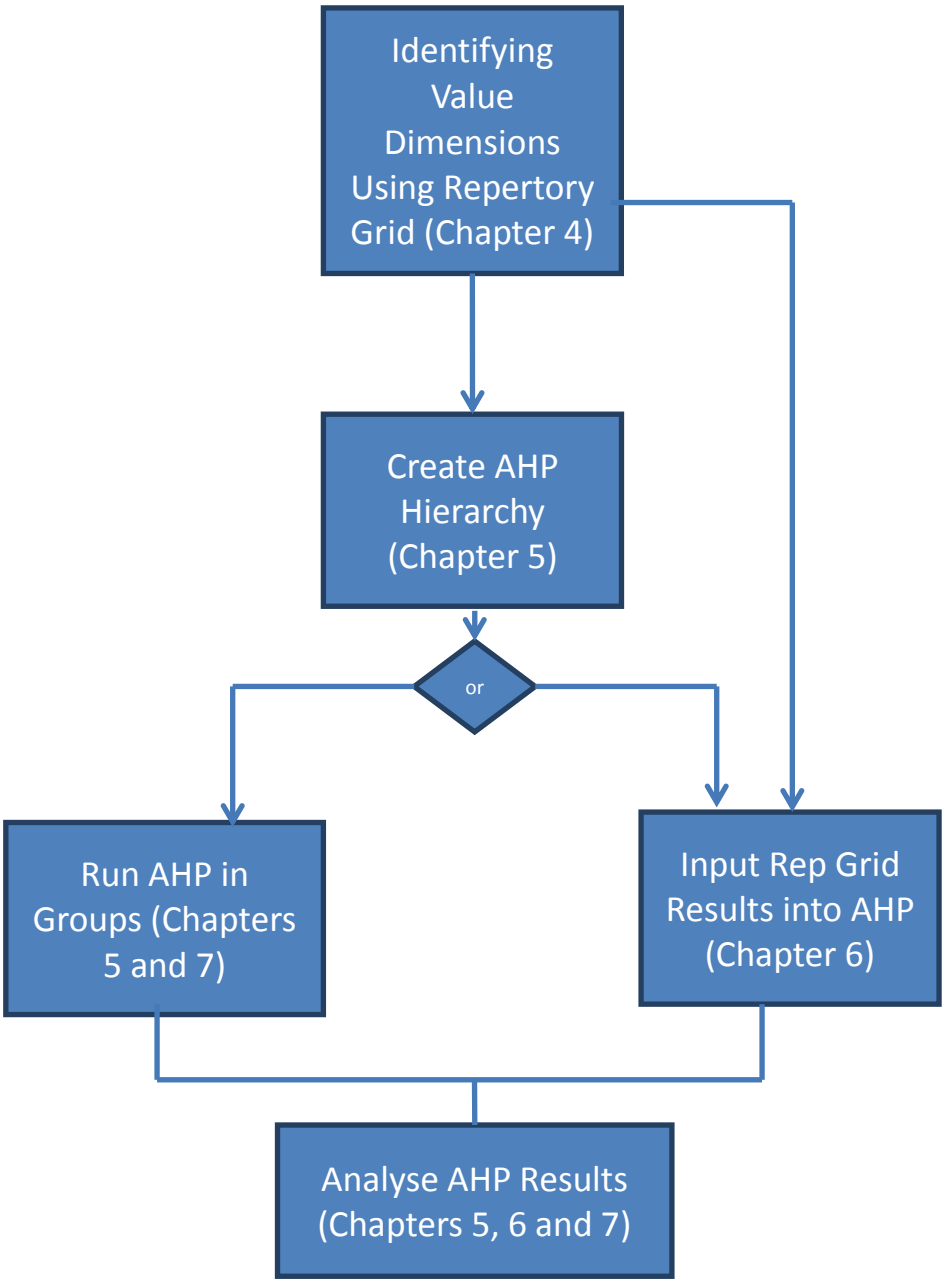

Figure 3-5 General Research Framework

4 RESULTS OF PHASE 1: VALUE-IN-USE DIMENSIONS OF OUTSOURCED MAINTENANCE SERVICES

4.3 Introduction

The aim of this phase is to understand the value-in-use dimensions and develop a basis for value-centric decision making for outsourced maintenance services. Repertory grid interviews have been conducted with 4 case companies in different sectors who outsource their maintenance function to Service World. Figure 1.4 demonstrates how Phase 1 is embedded into the whole research project. In summary Phase 1 had the following key characteristics:

- Repertory grid interviews with 33 respondents in four of Service World's customers.
- Qualitative and quantitative analysis of repertory grid data.

This chapter first describes the analysis of the repertory grid data. It also elaborates on the quantitative and qualitative results of this analysis. It further investigates the patterns of value-in-use in case companies and describes how these value dimensions are inter-related in enhancing customer satisfaction. The tangible and intangible nature of the dimensions will also be discussed and the basis for developing the value-centric outsourcing decision making will be set. Finally the different patterns of perceived value dimensions for decision makers and end-users will be discussed which emphasises the importance of considering contrasting value patterns at different organisational levels for an effective and better informed decision making.

4.4 The Analysis and the Results of Repertory Grid Interviews

The aim of the following data analysis is to investigate the dimensions of value for maintenance services from a customer perspective and to explore the differences between customer values in different customer companies. The initial data analysis has provided 29 value categories from the collected data as

it has already been presented in Table 3.4 representing the value dimensions identified by customers in using outsourced maintenance services. This analysis has been performed based on the analysis method described in Chapter 3.

4.4.3 Quantitative Analysis of Repertory Grid Data

A quantitative measure of the importance of each value category has been performed using two parameters, Frequency and Variability as proposed by Goffin et al (2006). The ***frequency*** is defined as the percentage of respondents who have mentioned constructs in a category. Frequency is used to identify a "common" construct (Lemke et al, 2003: Jankowicz, 2003; Goffin et al, 2006). ***Variability*** is a mathematical measure of the spread of ratings for a construct (Goffin et al, 2006). It is calculated as the percentage of total sum of squares of elements' ratings for each single construct in a grid. A higher spread of elements' ratings for a construct shows that the interviewee perceives it as a more important dimension. In line with Lemke et al (2003), value dimensions with a frequency value of at least 25 percent are identified as being of high importance. However, Goffin et al (2006) caution that a high frequency may indicate that a category is obvious to respondents, without being important, and a combination of frequency and variability will therefore be used to measure importance. In this section we will investigate these parameters in more details for the four case companies.

The frequency and variability for each construct has been calculated for each of the case companies and are presented in Tables 4.1 to 4.5. Table 4.5 shows the combined results for all four companies and the results for each individual company are shown in tables 4.1 – 4.4.

The frequency of mention has been calculated by manually counting the number of respondents who have mentioned constructs that belong to a category. Also the variability was calculated by using Idiogrid 2.4 software. In this software the grids are analysed individually.

The variability measure is dependent on the number of constructs in a grid which is different across grids. For example, if 8 constructs have been elicited from a respondent, the average variability would be 12.5% (i.e. 100/8), whereas if 5 constructs have been elicited in a grid, the average variability would be 20% (i.e.100/5). Therefore following the method proposed by Goffin et al (2006) the variability calculated for single constructs has been normalized across the grids by multiplying the variability of each construct by the number of constructs in that individual grid divided by the average number of constructs across all of the respondents for that company. The normalised variability has been calculated for Pharma, Insula, Medica, and Metal as 8, 7.1, 9.2 and 8.7 respectively.

At the next step, in order to calculate the average normalized variability (ANV) for each category, we need to take the average across the normalized variability of the constructs that belong to that category.

Finally, to obtain the importance baseline for the ANVs (Goffin et al, 2006), we have to calculate the average variability per construct which is the average number of constructs across all of the respondents in each company expressed as a percentage. The average variability per construct has been shown as BL (abbreviated for Base Line) in the tables 4.1 to 4.4 for each company. This means that for instance in Medica Company, the categories with an average normalized variability (ANV) higher than 10.8(BL) are considered to differentiate more strongly among the elements and therefore indicates higher importance for respondents. In tables I to IV the categories (value dimensions) that have a frequency greater than 25% and an above average variability are highlighted. The categories have been sorted firstly by frequency and secondly by variability.

Also in the right hand side column of tables A to D the categories that are mentioned by End-users (EU) and/or Decision makers (DM) have been identified. This would help us understand the differences in value perception in various organizational levels.

The overall results in Table 4.6 show for example that *Specialist Knowledge* was mentioned by 75.8% of all respondents and that the variability of their

responses was 13.24 (which is higher than the Baseline overall average variability of 12.09). This indicates that *Specialist Knowledge* was an important category because it was mentioned by three quarters of respondents and their responses for this category ranged widely. In contrast *Responsiveness* was mentioned by 66.7% of respondents but the variability was low (9.62), indicating that all suppliers are relatively similar in this regard, perhaps because all suppliers are responsive to their customers to some degree.

Table 4-1 Value dimensions (Categories) for Medica Company (9 respondents)

Category	*Frequency of mention (%)*	*Variability (BL 10.8)(%)*	*Stakeholders*
Specialist Knowledge	56	13.4	**(**DM/EU)
Delivery	56	10.3	(EU)
Support Systems	56	7.7	(EU)
Pricing	44	10.3	(DM/EU)
Feedback and reporting	44	10.5	(DM/EU)
Responsiveness	44	8.4	(EU)
Reliability (of service provider)	44	6.5	(EU)
Accessibility (of service provider)	33	13.6	(EU)
Understanding customer business	33	12.8	(DM)
Service Orientations	33	12.6	(EU)
Cost Savings	33	11.8	(DM)
Detailed analysis	33	8.7	(DM/EU)
Convenience	33	8.5	(EU)
Innovation	33	8.1	(DM/EU)
Inventory management	22	18.1	(DM/EU)
Range of product and/or service offerings	22	14.7	(EU)
Nature of contract	22	14	(DM/EU)
Risk adverse	22	12.9	(DM)
Urgency	22	9.6	(EU)
Relational Dynamic	22	7.6	(DM/EU)
Traceability	22	4.7	(EU)
Control	11	31	(EU)
Communication	11	23	(EU)

Locality	11	16.9	(EU)
Quality of repairs	11	10.7	(EU)
Ability to source	11	8.5	(DM)
Proactiveness (of service provider)	11	4.84	(DM)
Good Administration	11	3.9	(EU)

Table 4-2 Value dimensions (Categories) for Pharma Company (10 respondents)

Category	*Frequency of mention (%)*	*Variability (BL 12.5)*	*Stakeholders*
Accessibility (of service provider)	56	18.2	(EU)
Specialist Knowledge	56	16.8	(EU)
Relational Dynamic	56	12.1	(DM/EU)
Understanding customer business	56	9.7	(DM/EU)
Locality	44	17.3	(DM/EU)
Range of product and/or service offerings	44	15.8	(DM/EU)
Responsiveness	44	9.6	(DM/EU)
Control	33	15.1	(DM/EU)
Cost Savings	33	13.2	(DM/EU)
Pricing	33	12.7	(DM/EU)
Service Orientation	33	8.8	(DM/EU)
Ability to source	33	8	(DM/EU)
Innovation	22	14.6	(DM/EU)
Convenience	22	13	(EU)
Proactiveness (of service provider)	22	10.7	(DM/EU)
Quality of repairs	22	9.3	(EU)
Communication	22	5.1	(EU)
Delivery	22	3.4	(DM/EU)
Risk adverse	11	24.5	(EU)
Reliability (of service provider)	11	12.4	(EU)
Urgency	11	11.9	(EU)
Good Administration	11	7	(EU)

Table 4-3 Value dimensions (Categories) for Insula Company (8 respondents)

Category	*Frequency of mention (%)*	*Variability (BL 14)*	*Stakeholders*

Responsiveness	88	13.1	(DM/EU)
Accessibility (of service provider)	75	14.4	(DM/EU)
Range of product and/or service offerings	50	16.9	(DM/EU)
Specialist Knowledge	50	13.4	(DM/EU)
Relational Dynamic	38	21	(DM/EU)
Locality	38	16.2	(DM/EU)
Good Administration	38	14.8	(DM/EU)
Convenience	38	9.9	(EU)
Inventory management	25	16.2	(DM/EU)
Service Orientation	25	14.5	(DM)
Communication	25	12.7	(DM/EU)
Pricing	25	12.5	(DM/EU)
Reliability (of service provider)	25	12.2	(DM/EU)
Feedback and reporting	25	11.7	(DM/EU)
Quality of equipment	25	11.2	(DM)
Support Systems	13	21.7	(EU)
Nature of contract	13	16.5	(DM)
Urgency	13	14.3	(EU)
Proactiveness (of service provider)	13	13	(EU)
Understanding customer business	13	12.2	(EU)
Control	13	12.1	(EU)
Quality of repairs	13	6.8	(DM)
Delivery	13	4	(EU)

Table 4-4 Value dimensions (Categories) for Metal Company (7 Respondents)

Category	*Frequency of mention (%)*	*Variability (BL 11.2)*	*Stakeholders*
Responsiveness	86	10.1	(DM/EU)
Quality of repairs	86	5.9	(DM/EU)
Specialist Knowledge	71	8.8	(DM/EU)
Feedback and reporting	71	12.1	(DM/EU)
Accessibility (of service provider)	57	18.9	(DM/EU)
Communication	57	8	(DM/EU)
Delivery	43	20.1	(DM/EU)
Pricing	43	18.9	(DM/EU)

Urgency	43	13.1	(DM/EU)
Locality	43	10.7	(DM/EU)
Understanding customer business	43	7.4	(EU)
Service Orientation	29	12.5	(EU)
Range of product and/or service offerings	29	11.8	(EU)
Control	29	9	(DM/EU)
Convenience	29	6.7	(EU)
Traceability	14	31.5	(EU)
Proactiveness (of service provider)	14	21.8	(EU)
Cost Savings	14	16.3	(EU)
Inventory management	14	13.6	(EU)
Good Administration	14	4.25	(DM)
Relational Dynamic	14	4.1	(DM)
Quality of equipment	14	0	(EU)

Table 4-5 Value dimensions (Categories) Overall (33 Respondents)

Category	*Frequency of mention (%)*	*Variability (BL 12.09)*	*Stakeholders*
Specialist Knowledge	75.8	13.2	(DM/EU)
Responsiveness	66.7	9.62	(DM/EU)
Accessibility (of service provider)	54.6	16	(DM/EU)
Relational Dynamic	45.5	12.4	(DM/EU)
Range of product and/or service offerings	42.4	15	(DM/EU)
Understanding customer business	42.4	10.63	(DM/EU)
Delivery	39.4	12.5	(DM/EU)
Service Orientation	39.3	11.9	(DM/EU)
Convenience	39.3	9.63	(EU)
Pricing	36.7	13.7	(DM/EU)
Locality	33.3	17.7	(DM/EU)
Feedback and reporting	33.3	11.9	(DM/EU)
Quality of repairs	33.3	7.2	(DM/EU)
Communication	27.3	10.11	(DM/EU)
Control	21.2	15.3	(DM/EU)
Innovation	21.1	12.73	(DM/EU)

Cost Savings	21.2	12.14	(DM/EU)
Urgency	21.2	12.07	(DM/EU)
Reliability (of service provider)	21.2	10.1	(DM/EU)
Support systems	18.2	10.25	(EU)
Good Administration	18.2	9	(DM/EU)
Proactiveness (of service provider)	15.2	12.7	(DM/EU)
Inventory management	15.2	15.4	(DM/EU)
Ability to source	15.2	8.1	(DM/EU)
Risk adverse	9.1	17.45	(DM/EU)
Traceability	9.1	14.1	(EU)
Nature of contract	9.1	13.9	(DM/EU)
Detailed analysis	9.1	9.6	(DM/EU)
Quality of equipment	9.1	6.71	(DM/EU)

Table 4.6 summarises the value categories with higher importance, (as defined previously based on the combined frequency and variability ratings). It can be seen in the table that some categories are important to all respondents e.g. *accessibility* (*of Service Providers)* whereas some others just exist in one case e.g. *Feedback and Reporting*. It can also be noted that Cost Savings and Pricing are not important in all companies. In fact different companies have contrasted patterns of value-in-use dimensions. These ratings help to differentiate the needs and expectations of different companies.

Table 4-6 Value-in-use Categories of Higher Importance Based on Frequency and Variability

Ranking	Overall	Medica	Pharma	Insula	Metal
1	Specialist Knowledge	Specialist Knowledge	Accessibility (of service provider)	Accessibility (of service provider)	Feedback and reporting
2	Accessibility (of service provider)	Accessibility (of service provider)	Specialist Knowledge	Range of product-services	Accessibility (of service provider)
3	Relational Dynamic	Understanding customer's business	Locality	Relational Dynamic	Delivery
4	Range of product-	Service-driven attitude and	Range of product-	Locality	Pricing

	services	quality of service	services		
5	Delivery	Cost Savings	Control	Good administration	Urgency
6	Pricing	--	Cost Savings	Inventory management	Service-driven attitude and quality of service
7	Locality	--	Pricing	Service-driven attitude and quality of service	Range of product-services

It should also be noted that, identifying categories with higher importance, based on frequency and variability (Goffin et al, 2003) does not have to make us neglect the remaining categories which do not come up as the important categories. In fact the categories with lower variability (of ratings) might just mean that the respondents have the same perception of the category for the rated elements (suppliers) and does not necessarily mean lower importance in terms of variability, although it has to be mentioned that we still consider variability as a useful parameter for identifying the importance but encourage observing the whole picture of how customers perceive value-in-use which is essential and more useful in practice rather than just focusing on top categories. In Table 4.7 we have summarized the top 7 value dimensions based on frequency for separated case companies and in overall.

Table 4-7 Value-in-use Categories of Higher Importance Based on Frequency

Ranking	Overall	Medica	Pharma	Insula	Metal
1	Specialist Knowledge	Specialist Knowledge	Accessibility (of service provider)	Responsiveness	Responsiveness
2	Responsiveness	Delivery	Specialist Knowledge	Accessibility (of service provider)	Quality of repairs
3	Accessibility (of service	Support Systems	Relational Dynamic	Range of product-	Specialist Knowledge

	provider)			service offerings	
4	Relational Dynamic	Pricing	Understanding customer's business	Specialist Knowledge	Feedback and reporting
5	Range of product-service offerings	Feedback and reporting	Locality	Relational Dynamic	Accessibility (of service provider)
6	Understanding customer's business	Responsiveness	Range of product-service offerings	Locality	Communication
7	Delivery	Reliability (of service provider)	Responsiveness	Good administration	Delivery

As we can see Responsiveness has come up as an important category based on frequency, which does not appear as an important one based on both frequency and variability. This would show that by just considering important dimensions based on frequency and variability we might lose some valid insights into the provided services which in this case (responsiveness) plays an important role based on feedback discussions with the industrial partner (Service World). Also, as mentioned earlier in order to utilize the full potential of the results for improving the provided services, the whole picture of value dimensions should be considered and not only the most important ones. That is why as explained in Chapter 3, we have chosen a multi-criteria decision making model which enables us to feed in all the dimensions which results of using it will be further discussed in the following Chapters 5 and 6.

Aside from the quantitative data from repertory grid interviews, this technique has provided us with a rich pool of qualitative data, which complements these quantitative data. In the following section the results of Phase 1, will be discussed in the context of the qualitative data that was gathered from the case companies.

4.4.4 Qualitative Analysis of Repertory Grid Data

The analysis of enhanced value dimensions have been carried out with respect to their relating interview transcriptions in order to identify the patterns (Cassel and Symon, 1990). Quantitative repertory grid data have also been used to understand the value patterns in our case companies. We have tried to focus on the dimensions that follow a meaningful pattern through our cases which could help enhance our understanding of value-adding process through maintenance services. The diverse nature of dimensions shows the necessity of taking into account more comprehensive value adding dimensions in order to survive in customer bases. The results have been grouped into common themes in the following sections to allow for comparison between categories.

4.4.4.1 The Need for Specialist Knowledge and Control

Specialist Knowledge is one of the most important categories to emerge from our research (overall frequency 75.8% and Variability 13.24) and highlights that customers of maintenance services expect their suppliers to have an excellent knowledge of their service offering. Similarly, *Understanding Customer's Business* (overall frequency 42.4% and Variability 10.63) has a relatively high frequency for all companies and a high importance for Medica, which highlights a desire for the service provider to engage with their customer's business needs. An Insula Electrical Engineer comments on the importance of supplier specialist knowledge and understanding:

"I use suppliers who know what I'm talking about because…I know they can supply"

However, the customer's desire for suppliers with good *specialist knowledge* competes with their fear of losing control and losing their own specialist know-how. It can be seen in analyzed data, that the category of *Control* has a high variability (15.3) and is mentioned by at least one respondent in all the case companies. The maintenance Manager for the Metal Company highlights the problem:

If it's something that I've sent out through [Service World] etc I have no control. The only control I've got is phoning [Service World's on-site representative] or whoever, I don't know who [Service World's on-site representative] has sent it to.

The Engineering Coordinator in Metal Company elaborates his frustration for outsourced repair jobs:

I don't know where it's gone, I don't know how long it's going to be out for, how much it's going to cost, I don't know anything.

It is clear that in many cases issues associated with loss of control could be managed by better feedback and reporting. The issue of *Control* has an even greater effect for end-users who have even less visibility of feedback than the decision makers. The Facilities and Utilities Team Leader in Pharma Company states:

With [Service World] I'm not exposed to what their service level deliverables are, they would have a report … on a monthly basis, further up the line than me where they would present their deliverables and their performance.

The issue of *Control* continues into the mature phases of customer-supplier relationships and we can see that for instance in the Metal Company, which is in a mature phase, *Control* is still considered as an issue and can cause friction between the customer and supplier. The Maintenance Manager of Metal Company articulates:

When it's under my control if something goes wrong my shoulder's are big enough I've got to take the blame but I'm not prepared to take the blame for somebody else's – if it's outside of my control.

In summary, customers of maintenance services value the *specialist knowledge* of the service providers, but fear the loss of *control* to a supplier. Outsourced maintenance service suppliers therefore need to manage their customer's perception of losing control through better *feedback and reporting*.

4.4.4.2 Financial Imperatives

As we can see in tables 4.2 to 4.6, the *Cost Savings* category has a relatively low importance (overall frequency 21.2% and Variability 12.14); it is moderately important in Pharma and Medica companies, less so to Metal company and not even mentioned in Insula. This is in contrast with the commonly held cost-centric approaches to maintenance management where "avoiding the costs of failure" is considered the main source of value for customers (Liyange and Kumar, 2003; Al-Najjar, 2007). On the other hand, *Pricing* (overall frequency 36.7% and Variability 13.7) is perceived as more important than *Cost Savings*. In fact, being able to negotiate spare parts and service prices is more valuable for customers than the overall cost savings. Whereas negotiating prices is usually impossible with fixed prices of outsourcing as a Maintenance Technician in Medica Company emphasises:

when it's in-house you can shop around and you can basically get the best bargain but when you're dealing directly with companies that have their fixed bases you can't go and negotiate on the price, you just have to basically take what they give you.

Despite the moderate importance of *Cost Savings*, more customers have mentioned the *Feedback and Reporting* (overall frequency 33.3, variability 11.9) on the cost savings as of high importance. In fact giving customers more perception of control over costs and financial aspects by proper and consistent feedback and reporting system can sometimes be more valuable than the cost savings itself. For instance, in Metal Company, even though Cost Savings category was of low importance its feedback and reporting is important as their Engineering Manager mentions:

We don't get a lot of feedback of the repair costs from [Service World], obviously that's what they do, they give an overall cost to us of what certain items cost to repair but that's not always fed back to us.

This accentuates the importance of customers feeling in-control with better financial reporting and opportunities to negotiate prices of products and services.

4.4.4.3 Understanding Quality

Based on the responses from our case companies, we can divide quality to three subcategories: *Quality of Equipment*, *Quality of Repairs* and *Service Orientation*. *Quality of Equipment and Repairs* refers to the technical aspects of the provided services such as reliability, Accessibility and the ability of maintenance service provider to repair and restore equipments to as good as new condition. Whereas *Quality of Service* is related to the soft side of provided maintenance services and the human interfaces involved.

Interestingly *Quality of Repairs* is not perceived as an important dimension (overall frequency 33.3% and Variability 7.2) except by the Metal Company. This may indicate that in general all suppliers are able to deliver high quality repairs so it is not a differentiator between suppliers. Similarly, *Quality of Equipment* is even less important (overall frequency 9.1% and Variability 6.71) whereas *Service Orientation* is articulated as one of the key dimensions of value. The Senior Procurement Consultant in Pharma Company highlights the importance of the suppliers' attitude:

suppliers can easily turn a negative into a positive by the way they handle the issue, so if there's a service failure and they handle it extremely well, often the client feels very positive about them bizarrely, missing the point slightly that they should have been an issue in the first place and that doesn't always happen.

This shows that the soft side of the quality which incorporates human interactions and relationships can be as important as the tangible side of maintenance services and can create more customer satisfaction. This is evident in companies that are in more mature phases of their relationships with Service World (i.e. Metal and Medica) where service quality is identified as being important only by end-users who have closer interfaces with suppliers. This also shows the relatively higher importance of focusing on service quality

in longer relationships to sustain this value adding dimension and not making the mistake of forgetting about customers in longer established relationships. The Maintenance Coordinator in Medica reflects on this as:

They've got a good system, that they've got very fast – in getting spares and service to you, they've got good phone and feedback and they show they care and there's a good relationship with the individuals.

Lack of consistency can have a negative impact on the customer's perception of service as commented by Metal's Engineering Manager:

Service World, there's no consistency in the response, some things take longer than we feel they should, some things exceed our expectations but overall things take longer than we would like.

It is clear that *Good Administration*, *Delivery* and *Feedback and Reporting* all contribute to the customers' experience of service quality, and they can be seen as supporting elements which ensure that the customer is kept informed about the quality of the overall service. In summary, the consistency of quality over time is essential, particularly for customers who are in the mature phases of a supplier relationship.

4.4.4.4 The Importance of Intangible Value

As can be seen in the results tables 3.3 and 4.7, intangible value can be as important as tangible value which is in line with the maintenance literature (Liyange and Kumar,2003; Markeset et al., 2004; Lemke et al, 2003;Wolff et al.,2000). In fact, due to closer partnerships in the service setting, soft values emerge which must be taken into account in designing more value-adding services.

At the end-users level we can see that *Convenience* (overall frequency 29.3, variability 9.63) was mentioned by all companies, but with a relatively low variability. The Stores Controller in Insula Company explains as the value of the on-site Service Representative provided by Service World:

[SR] specifically makes my job easier, you might well see that. Whereas I interacted probably the same way with our crafts people as I do with [SR], face-to-face. These guys [competing service providers] are just customers, they just go, I call them the takers. They just go. Whereas [SR] is really assisting me.

Relational Dynamic (overall frequency 45.5, variability 12.4) is perceived as an important value category especially for the companies in their initial phases of relationship. The Planning Engineer in Insula Company (1-2 year old relationship) reflects on this:

Usually once we got a company working for us they are here for a long time. We tend to stick with the same people.

This softer side of the business relationships can also be clearly seen as the Maintenance Manager in Pharma Company says:

In fact they actually knew him outside the company and they dealt with him the whole time and they just made their phone calls when they wanted parts that were not available here, they went down by car and collected the parts. That's just a good relationship.

Interestingly in more developed phases of the relationship the service supplier is expected to have a strategic approach in managing the relationship with the customer. This is clearly apparent in lines of the Engineering Manager of Medica Company (3-4 year old):

Certainly I would see relationships are developing as strategic relationships, [we] have had to have a relationship with [Service World] but I would see [competing service supplier] having put considerable effort into developing the relationship in the last 12 or 18 months as our business requirements and expectations have changed, they really stepped up their game and came with us.

These findings are in conformance with Judenberg (1994) as he believes that most successful outsourcing arrangement are those in which supplier brings a "partnership philosophy".

4.4.4.5 Accessibility and Responsiveness

Accessibility and *Locality of Service Provider*, *Urgency* and *Responsiveness* relate to the physical presence and direct interactions between the service provider to the customer. As would be expected *Accessibility* (overall frequency 54.6, variability 16) is one of the most important categories. As previously mentioned, Service World assigns an on-site service representative (SR) in order to manage the customer-supplier relationships and act as the single point of contact for provided maintenance services. Although by *Locality* (overall frequency 33.3, variability 17.7) respondents mostly mean a company that is geographically local or at least in the country but the perception of locality can also be satisfied by the on-site SR.

Having an on-site SR who daily deals with the customers face-to-face, can contribute to *Service Quality* perception as the Maintenance Manager of Insula Company articulates:

I guess the Service World team are in advantage such as. That's almost their role in life to give quality service. It's all channelled through one person who is on site, so you play the right game; you got the consistent result from a guy

It is evident in our four cases that the companies in initial phases of their relationships tend to perceive *Locality* as of higher importance rather than the company (Medica) that is in a longer relationship. In fact this trend shows the importance of locality and on-site representative in building the trust between customer and supplier companies.

It is also to be mentioned that for companies that *Urgency* and *Responsiveness* are important dimensions, locality can contribute to this perception as the Engineering Coordinator in Metal Company says:

Because they're closer and their turnaround time, they'll come in, they'll collect the parts, they'll take it away, give you an update, repair the problem, get the part back to you, whereas [competing service company] obviously you have to arrange carriage to send it out to Germany, you've got all the running to do.

On top of this, having an on-site representative can enhance perception of *Accessibility* of service provider (a key category in all four cases). This trend is seen especially at the end-users level as the Engineering Contractor in Medica highlights:

Well Service World would have [SR] on site every day, so it's a lot easier to deal with [SR]...So he's on site and easy to deal with.

In fact, having an on-site representative gives the customer the feeling of being taken care of and the perception of service provider's accessibility even though the on-site representative only acts as a point of contact for the supplier's services and the actual job may be undertaken elsewhere.

4.4.4.6 Innovation

A value dimension which is often ignored but can play a key role in adding value to the businesses is *Innovation* (overall frequency 21.1, variability 12.73). This category has been mentioned by both Pharma and Medica Companies' decision makers who are obliged to meet tight regulatory requirements for their processes. The Senior Procurement Consultant in Pharma Company highlights the importance of service providers engaging with his company's primary objectives:

In a healthcare it's all about regulation and you work out which ones are not constrained... we're engineering the process, changing the garments, changing the way we do things on our side, if they can't help to deliver those changes then I only get a part of the benefit.

Although these process and technological changes and innovation are valuable for the customer they have to be in line with the financial benefits of the business as he further says:

So in the next year and the next year you kind of look at innovation and working supplies to find cost opportunities …

By providing a wide *Range of Product and Service Offerings* (overall frequency 42.2, variability 15), which is perceived as a key value category in almost all cases, a maintenance service provide can contribute to creating sense of innovation for the customers. In fact, using the opportunities for being innovative also shows customers how flexible the supplier is, and ready to add value to the customer's processes.

4.5 Summary

This phase of the research has investigated the customer-value dimensions of outsourced maintenance services through repertory grid interviewing technique. Quantitative and qualitative results have been applied in order for a better understanding of value dimensions and the patterns in which they emerge. It has shown that customer companies' expectations from provided maintenance services are not only based on financial and technical attributes but also a wide range of intangible value dimensions also play a key role in sustainable supplier-customer relationships. It has also been shown that the value dimensions are diverse for different companies and in order to improve the provided services, suppliers need to study different sectors' needs and values. Value dimensions may also change in different phases of the customer-supplier relationship from the initial honeymoon stage in which Cost Savings are easier to show to the customers, to more mature phases in which intangibles like Innovation are expected from the suppliers. It has also been seen that value dimensions diversify at different organisational levels, namely decision makers and end-users. Furthermore, value dimensions are often interrelated and a supplier may find that by improving one measure of value another is reduced. In Chapter 8, these will be further discussed along with the results from the rest of the phases of the study.

4.6 Next Phases

This phase of the research has identified a range of value-in-use dimensions in outsourced maintenance services. The next phases of the study need to help customer and supplier companies to assess the value of outsourced

maintenance services. In the following chapter it is presented how we have developed a multi-criteria decision making framework to help customer companies perform more informed decision making for maintenance outsourcing and continuously improve the value they receive through maintenance services. This framework will also help suppliers to improve the value adding potential of their maintenance services through redesigning based on value-in-use.

5 RESULTS OF PHASE 2: Developing and Testing Analytic Hierarchy Process (AHP) Hierarchy

5.3 Introduction

After Phase 1's investigation of the value-in-use dimensions of outsourced maintenance services using repertory grid interviewing technique, the aim of phase 2 of the research is to develop a value-centric decision making framework for maintenance outsourcing. Therefore, attributed value dimensions from Phase 1 have been used as a basis for developing the decision making framework using AHP. Figure 1.4 demonstrates how Phase 2 is embedded into the whole research project. In summary Phase 2 had the following key characteristics:

- Developing a decision hierarchy based on AHP by using value dimensions resulted from Phase 1.
- Getting feedback on the developed hierarchy from a group of maintenance specialists.
- Using the hierarchy in 3 Italian case companies to test its applicability and validity.

This chapter first describes developing the AHP hierarchy. It further describes how the hierarchy has been improved by specialist feedback sessions. Finally application of the hierarchy in 3 cases will be demonstrated and the results will be described.

5.4 Developing the AHP Hierarchy

In order to develop the hierarchy, we firstly need to define the decision goal. As discussed earlier, the goal is for the maintenance decision makers *to choose the most value adding outsourcing alternative.*

After defining the decision problem and its goal (see Section 3.4.2) we need to structure the decision hierarchy from the top down. Structuring has to start with the goal, lead to criteria and/or sub-criteria and lead to decision alternatives.

The analysis of repertory grid interviews resulted in 29 categories representing the dimensions of customer value-in-use, as per Table 3.4.These value dimensions have been used as the basis for structuring the hierarchy criteria. For this purpose two researchers clustered these value dimensions into the following groups based on the definition of dimensions as Table 4.1:

1- **Quality**-incorporating three different quality measures; Service orientation, Quality of equipment and Quality of repair.
2- **Resources**- this group consists of the dimensions that help to assess the availability of service providers' resources at different levels; Human resources, Structural resources and Relational resources (Marr, 2006). The value dimensions belonging to this group are: Specialist knowledge, Ability to source, Locality, Support systems, Good administration, Feedback and reporting, Detailed analysis, Traceability, Inventory management, Understanding customer's business, Communication and Relational Dynamic.
3- **Benefits vs. Sacrifices**-including both qualitative and quantitative benefits and sacrifices of maintenance outsourcing; Cost savings, Control and Convenience.
4- **Solution Expectations**- representing the dimensions that the customers expect which increases the customer's value perception including; Responsiveness, Urgency, Accessibility (of service provider), Delivery, Reliability (of service provider), Proactiveness, Range of product-services and innovation.
5- **Contractual Considerations**- standing for the customer value dimension at the contracting and negotiations phases and level of service providers' obligatory performance including; Nature of contract, Pricing and Risk adverse.

These five groups define the decision criteria at the first level of hierarchy and are further divided into sub-criteria consisting of the value dimensions at the second level. The proposed hierarchy can be seen in Figure 5.1.

Also based on our case companies' experience with different types of maintenance organization and the maintenance management classification proposed by (Gerosa et al 2006) we have chosen three alternatives for the hierarchy:

1- In-house: own maintenance personnel taking care of the maintenance function.

2- Outsource: third party Company providing maintenance services.

3- Extended vendor: an OEM that offers maintenance services on top of their products.

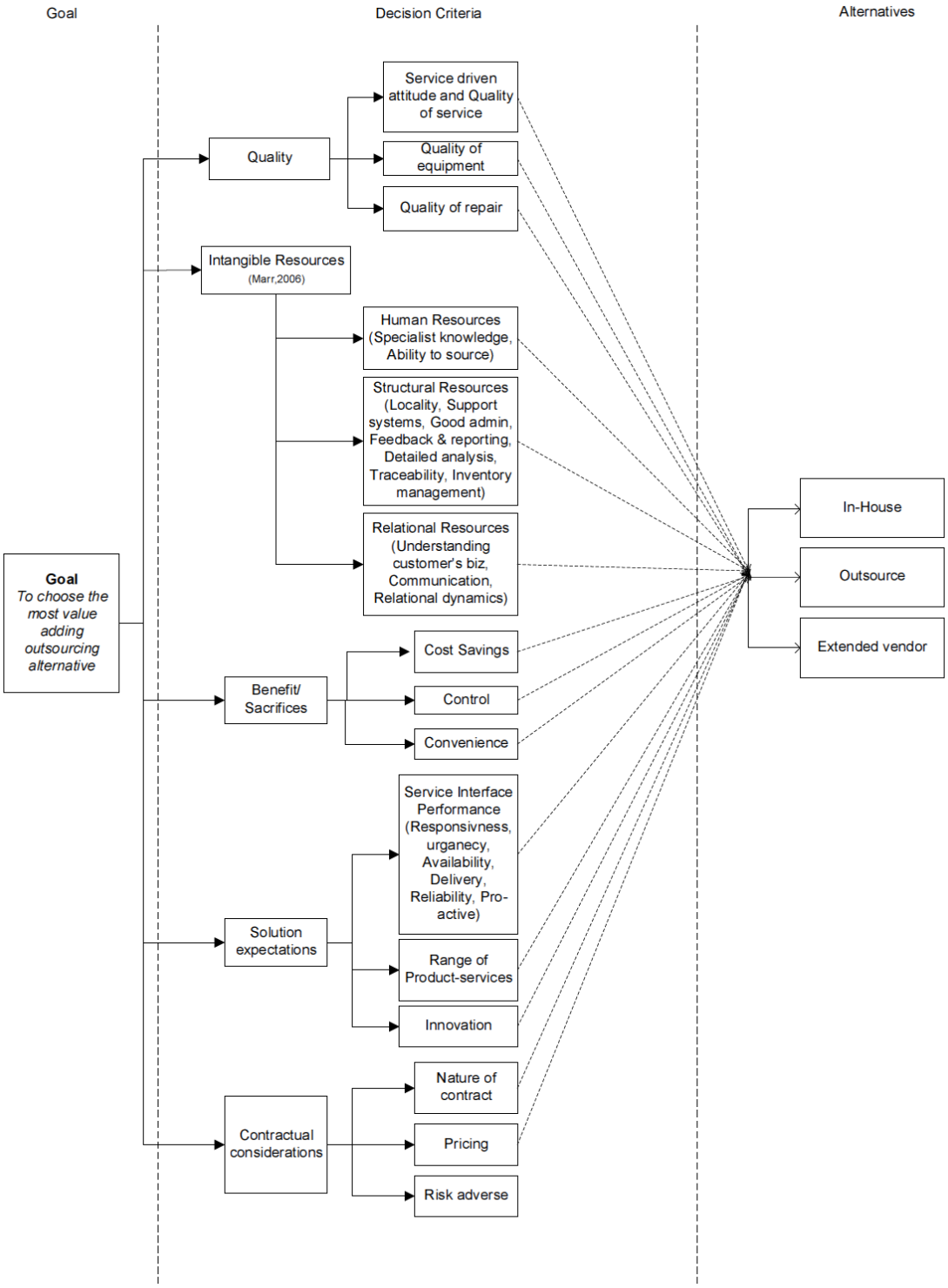

Figure 5-1 Developed AHP Hierarchy Based on Rep Grid Results

In order to test the applicability and validity of the developed hierarchy, it has been applied in cases which will be described in the next section.

5.5 Testing the Applicability and Validating the Developed Hierarchy

In order to test the applicability and to validate the hierarchy we have conducted a two-stage validation approach:

1- Feedback session with maintenance specialists on the developed hierarchy and revising it.

2- Applying the revised hierarchy in 3 case companies.

In the following sub-section these stages will be further described.

5.5.3 Feedback Session

Before applying the hierarchy in test cases it was described and presented in a 2 hour feedback session to a group of 6 maintenance specialists from two Italian companies in Italy: a maintenance management and mechatronics consultancy, in this research referred to as Italiatech; and a public company responsible for water distribution and sewage management in an Italian city referred to as Aqua. In this session the specialists were asked to participate in an open discussion and brainstorm on the developed hierarchy in order to investigate if there were any missing aspects of the maintenance outsourcing which needed to be taken into account.

The participants were generally happy with the structure of the hierarchy but their only concern was on the type of operations which needed to take into account standards such as environmental, security and regulations. The Standards criterion was therefore added to the hierarchy for the operations that follow special regulations and security measures. In these types of operations, the service provider's ability to apply these regulatory and security measures has to be taken into account, thus their proposal to add another criterion under the name of Standards to the hierarchy. The revised hierarchy has been shown in Figure 5.2. As we will see in the following sections, none of our cases needed

to use this criterion, as they did not follow any restrictive standards. Although in order for the hierarchy to be comprehensive, we need to consider this criterion. Apart from the comment on the Standards criterion, the respondents were happy with the hierarchy to be applied in actual cases as the next stage.

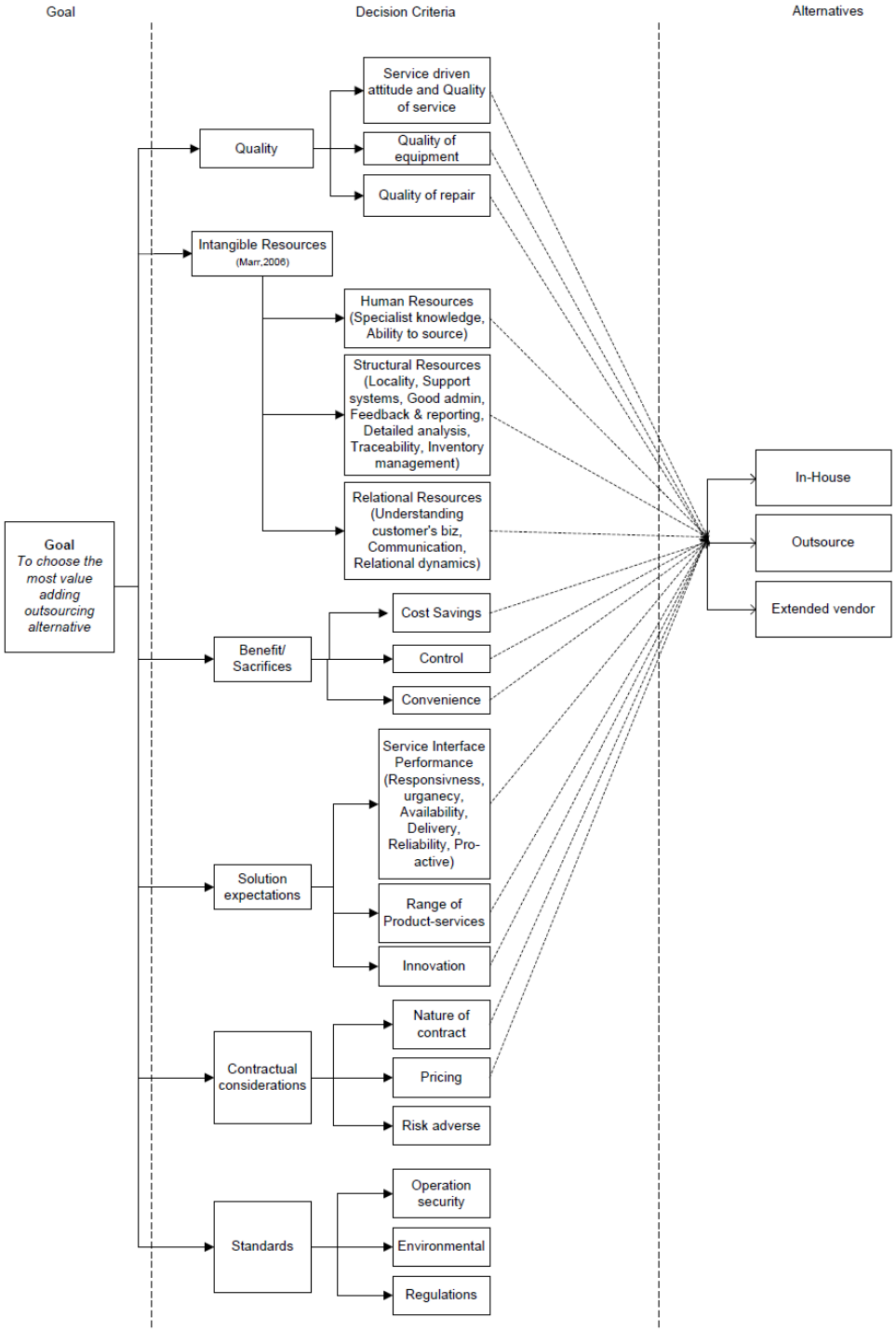

Figure 5-2 Revised AHP Hierarchy after Feedback Session

5.5.4 Test Cases

In order to validate the developed hierarchy and test its applicability, it has been tested in three Italian case companies which for confidentiality are referred to as Aqua, Brake and Balance. Aqua is a customer of outsourced maintenance services. Also to acquire a better understanding of the practical perspectives of companies from both customer and supplier sides, we have chosen Brake Company, which is a customer of maintenance services offered by Balance Company, which is the supplier of maintenance services. This will help us understand how different users from supplier to customer sides can benefit from this method. It will also demonstrate how the perception of value for customers differs from suppliers on a provided maintenance service.

As previously discussed in detail in Chapter 3 (Section 3.4.2) and as you can see in Figure 5.3, this method is based on pairwise comparisons, in which the respondents need to consider the maintenance of a particular piece of equipment or production area in which the criticality of equipment is the same. The respondents were required to:

1- Compare first level criteria (See Figure 5.2) with respect to the goal (*choosing the most value-adding outsourcing alternative*),
2- Compare second level sub-criteria with respect to the criteria they belong to and
3- Compare alternatives with respect to each sub-criterion.

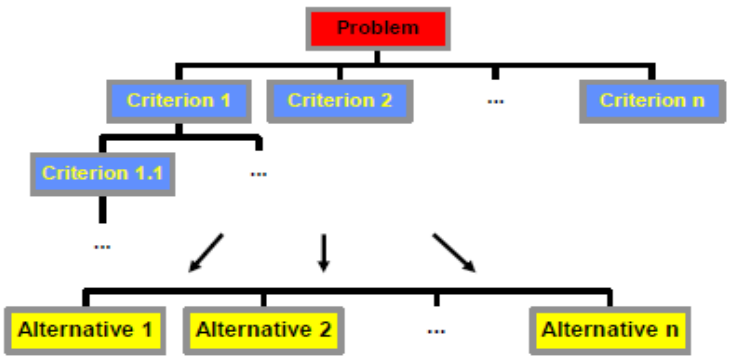

Figure 5-3 the Details of an AHP Hierarchy

The Expert Choice software was used to perform these pairwise comparisons in a structured way in real time with the respondents, which enabled them to follow the method more easily. It also provides a graphical user friendly interface, which made it easier to work with. The software also enabled us to perform different analyses of the responses. These will be discussed in detail in Chapter 8.

5.5.4.1 First Case: Aqua Company (Customer Side)

Aqua is an Italian public sector company, responsible for managing the water distribution system in an Italian city. We interviewed the maintenance manager who is responsible for restructuring Aqua's maintenance Dept. They are currently handling their maintenance functions by a mixture of in-house personnel, extended vendors and outsourcing it to third party companies. The pumps and water distribution systems are the parts of operations we have discussed with the respondent.

At the beginning of the interview, the interviewee was asked to review the hierarchy in order to inform us if there is any aspect of the outsourced maintenance services missing in the hierarchy before we start the interview. This would give us more feedback on the hierarchy on top of the feedback session as it gives the respondent a second chance to have a detailed individual review of the hierarchy. He was generally happy with how the hierarchy is structured and could comprehend it with no problem. Then the interviewee was asked to perform pairwise comparisons of the hierarchy. The details of the comparisons can be found in the matrices in Tables 5.1 to 5.6.

Table 5-1 Pairwise comparison matrix of the main criteria with respect to the Goal for Aqua- Note: row element is x (or 1/x) times important than column element

	Quality	Resources	Benefit/ Sacrifices	Solution expectations	Contractual Considerations	Local Priority
Quality	-	1/4	1/2	1/2	2	0.118
Resources		-	1/2	1/3	2	0.200
Benefit/Sacrifices			-	1/2	3	0.242
Solution expectations				-	3	0.358
Contractual Considerations					-	0.082

Inconsistency: 0.08

Table 5-2 Pairwise comparison matrix for the sub-criteria with respect to Quality

	Quality of service	Quality of repair	Quality of equipment	Local Priority
Quality of service	-	1/2	1/3	0.157
Quality of repair		-	1/3	0.249
Quality of equipment			-	0.594

Inconsistency: 0.05

Table 5-3 Pairwise comparison matrix for the sub-criteria with respect to Resources

	Human resources	Structural resources	Relational resources	Local Priority
Human resources	-	1/2	2	0.297
Structural resources		-	3	0.540
Relational resources			-	0.163

Inconsistency: 0.01

Table 5-4 Pairwise comparison matrix for the sub-criteria with respect to Benefit/Sacrifices

	Cost Savings	Control	Convenience	Local Priority
Cost Savings	-	3	2	0.634
Control		-	1/2	0.192
Convenience			-	0.174

Inconsistency: 0.01

Table 5-5 Pairwise comparison matrix for the sub-criteria with respect to Solution expectations

	Responsiveness	Range of product-services	Innovation	Local Priority
Responsiveness	-	6	4	0.701
Range of product-services		-	1/2	0.106
Innovation			-	0.193

Inconsistency: 0.01

Table 5-6 Pairwise comparison matrix for the sub-criteria with respect to Contractual considerations

	Pricing	Risk adverse	Nature of contract	Local Priority
Pricing	-	1/3	2	0.249
Risk adverse		-	3	0.594
Nature of contract			-	0.157

Inconsistency: 0.05

As per methodology described in Chapter 3, by using Expert Choice software, priorities for different outsourcing options are calculated as Table 5.7.

Table 5-7 Aqua- alternative priorities

alternative	Priority
In-house	0.397
Outsource	0.261
Extended vendor	0.342

As we can see in table 5.7, In-housing receives the highest priority (0.397) for the customer based on the values they receive from service providers. Also Extended Vendor's priority is 0.342. This means that based on the responses, the priority of In-housing and Extended Vendor are quite the same. In fact, it is recommended to analyse the criteria which led to these priorities for decision making rather than just focusing on the crisp numbers.

At the next stage the results have been discussed with the respondent in order to see if it fits with their viewpoint. The respondent has confirmed the results and explained the reason for in-housing as the most prior option as follows:

"The situation is that they have a lot of operators (similar to many public sector companies) but the plant is automated. So the ratio of operator to job is quite high. Therefore there is view that they need to use these extra resources for in-house maintenance jobs and there is reluctance towards outsourcing the whole maintenance operations."

Aqua's Maintenance Manager highlights this as:

"the problem is that we have a lot of operators and time that they can manage the situation but sometimes we use outsourcing...in any case we have a lot of time...public company performing a service, economical point is not so important..."

In fact they believe that they are performing a service, and their main obligation to people is the quality of water. So if they want to save money, they just have to provide good quality water in order to prevent claims. Even if they are in certain standard, a lower level of service means saving money, but this is not the idea of the company and the aim is to provide good water, even if it costs.

In order to gain better understanding of the values that lead to the selected alternative, a further analysis has been performed on the provided weightings of criteria and alternatives. This analysis will be presented in the following section.

5.5.4.1.1 Detailed Analysis

So far we have gained the priority of alternatives for Aqua, but we can now dig deeper into the reasoning behind these priorities. This analysis could be utilised either by the customer or their maintenance outsourcing service provider. Based on the weights for criteria and sub-criteria from respondents' pairwise comparisons we have developed following Tables 5.8 and 5.9, to compare outsourcing and in-housing. These tables combine the respondents' weightings for each criteria with relative performance of the suppliers (alternatives). This data presentation made it easier to compare the relative weighted performance of each supplier by criteria and sub-criteria which is a novel approach to presenting the AHP analysis.

It is to be considered that this type of analysis can be performed for any pair of alternatives based on its applicability in every case. As the discussion in this case is mostly on in-housing and outsourcing, we have chosen these alternatives for comparison analysis.

Table 5-8 Aqua, Comparing the criteria for In-house vs. Outsourcing (Customer Perspective) (Negative values means that In-house needs improving)

Criteria	Respondent weight(RW)	Outsourcing performance (OP)	In-house performance (IP)	Relative Weighted Performance Ratio RW*(IP-OP)
Quality	(0.118)	(0.314)	(0.129)	- 0.22
Resources	(0.200)	(0.373)	(0.201)	- 0.034
Benefit/Sacrifices	(0.242)	(0.198)	(0.623)	0.1
Solution expectations	(0.358)	(0.229)	(0.451)	0.08
Contractual considerations	(0.082)	(0.207)	(0.445)	0.02

Table 5-9 Aqua, Comparing the sub-criteria for In-house vs. Outsourcing (Customer Perspective)

Sub-criteria	Respondent Weight(RW)	Outsourcing Performance (OP)	In-house performance (IP)	Relative Weighted Performance Ratio RW*(IP-OP)
Quality of service	0.157	0.320	0.122	-0.03
Quality of equipment	0.594	0.333	0.140	-0.12
Quality of repair	0.249	0.258	0.105	-0.04
Human resources	0.297	0.540	0.163	-0.11
Structural resources	0.540	0.320	0.122	-0.11
Relational Resources	0.163	0.250	0.500	0.041
Cost Savings	0.540	0.230	0.648	0.23
Control	0.163	0.210	0.550	0.06
Convenience	0.297	0.137	0.625	0.15
Service interface performance	0.701	0.137	0.625	0.34
Range of product-services	0.106	0.297	0.163	-0.01
Innovation	0.193	0.429	0.143	-0.06
Nature of contract	0.157	0.200	0.600	0.06
Pricing	0.249	0.320	0.122	-0.05
Risk adverse	0.594	0.163	0.540	0.22

The first and second columns in these tables represents the criteria and their weights (in table 5.8) and sub-criteria (in table 5.9) based on the interviewee's response. It is important to mention that the Respondent Weights' column adds up to one as they are normalized. The third and fourth columns also represent the weight that the respondent has given to different alternatives based on different criteria and sub-criteria. The last column is a measurement developed by the author to identify the target for improving the provided services based on respondent's weighting of value dimensions and the outsourcing performance. In fact if we look at most of the literature on AHP, the results are just presented in the form of alternative priorities and are not analysed in this format. This measure could help suppliers to tailor their service offering for the targeted dimensions and also customers to understand how they can receive more value from suppliers and/or improve their in-housing value. In this respect, Relative Weighted Performance Ratio refers to outsourcing performance relative to in-house performance. In fact relative approach stems from the idea that respondents who have more diverse perceptions of different alternatives' performance, actually see that dimension of higher importance.

To target the improvement areas, we have to firstly identify the first level criteria which need improvement, as shown in Table 5.8 and then get more detailed sub-criteria for the selected criteria as shown in Table 5.9. For example, in this case we can see that Benefit/Sacrifices has the highest Relative Weighted Performance Ratio (0.1) which tells us this is the category where outsourcing is performing worst relative to in-house performance. At the next stage we have to go to Table 5.9 and the 3 rows belonging to this category. As we can see Cost Savings has the highest Relative Weighted Performance Ratio (0.23). Note that the sub-categories in Table 5.9 can only be analysed by comparing the sub-categories belonging to their own group.

This kind of analysis can be performed with different pairs of outsourcing, in-house and extended vendor, as needed. Also in the following figures 5.4 and 5.5, graphical representation of above tables can be found. In these figures, the smaller bars represent the groups and categories that need improvement more.

As in the table, positive values should be utilised for outsourcing improvement areas and negative values show that improvement needs to be done on the comparison basis (In-house in this case). In other words bigger positive values show the areas that the supplier needs to improve and bigger negative bars show the areas that in-house needs to consider for improvement.

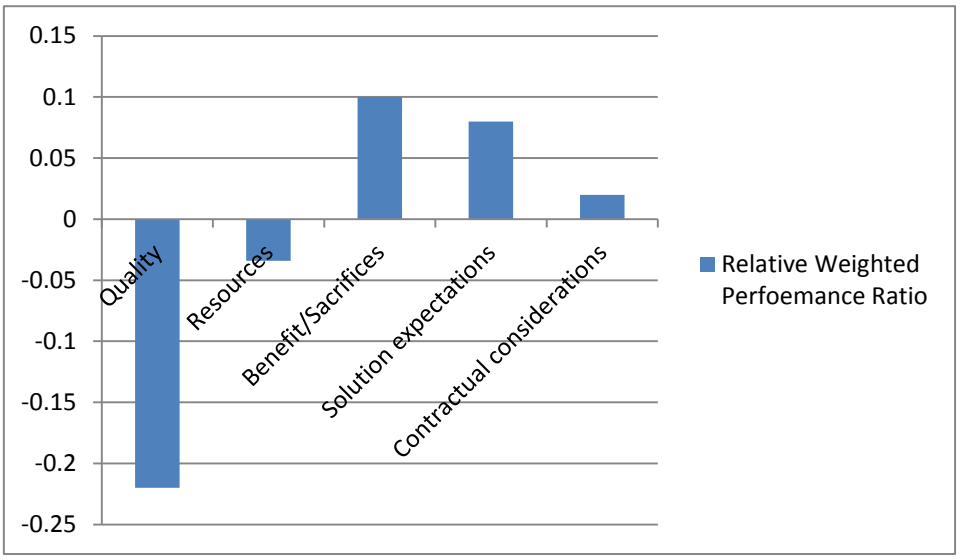

Figure 5-4 Aqua, comparing the criteria for In-house vs. Outsourcing

(Positive values indicate areas that outsourcing needs improvement, bigger bars more improvement/negative values indicate areas that in-house needs improvement, bigger negative bars need more improvement)

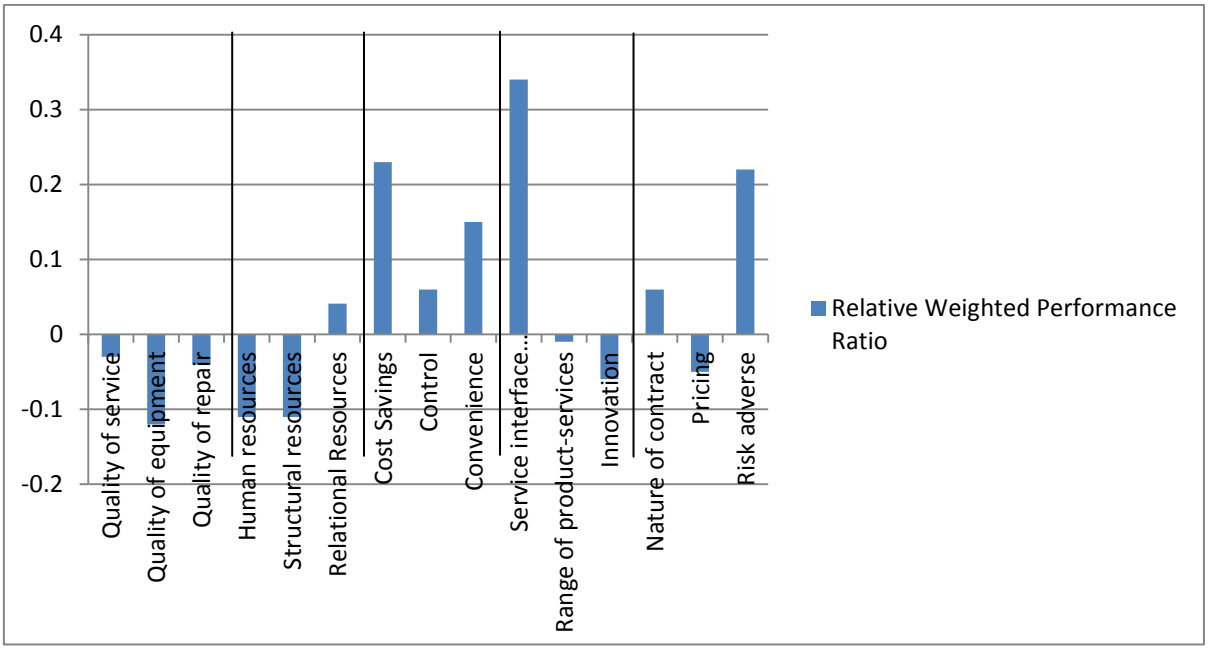

Figure 5-5 Aqua, comparing the sub-criteria for In-house vs. Outsourcing

Based on the above analysis, the following recommendations can be made to the supplier of maintenance services to increase the value-adding perception of these services to Aqua. The supplier needs to focus on the following areas to make sure that their service is adding value to the customer:

1- Cost Savings

2- Service Interface Performance

3-Being Risk Adverse

Also if Aqua wants to keep their in-house maintenance, they need to focus on the following areas in order to add value to their own business:

1- Quality of equipment

2- Structural resources

5.5.4.2 Second and Third Cases: Brake Company (Customer Side) versus Balance Company (Supplier side)

In order to compare the customer and supplier insight on the provided services, the developed hierarchy has been applied in both supplier and customer of a maintenance service. Balance Company is an Original Equipment Manufacturer (OEM) of balancing and machining products in Italy. They are suppliers of repair and maintenance services for their products as an Extended Vendor in our categorisation to Brake Company which is an Italian manufacturer of braking systems in automotive sector. One of the useful capabilities of this decision making framework in its ability to be used by both customer and supplier so in the case of Balance Company the respondent tried to put himself in customer's (Brake Company) shoes and respond as if they are the customers and he is assessing the service provider's (themselves) value adding abilities. By this approach, we can see how different or similar is the perception of service supplier to the customer on the value that is added through the provided services. In fact this method can also help the suppliers to capture this difference in perception and target the improvement areas effectively. This would ultimately add value to the customers and help the suppliers to remain in customer bases as a "value add" element of their businesses.

The maintenance managers of Brake and Balance companies have been the respondents for these cases and been interviewed separately.

As explained in the previous case, at the beginning of the interview, the interviewee is asked to review the hierarchy in order to inform us if there is any aspect of the outsourced maintenance services missing in the hierarchy before we start the interview. Interviewees were generally happy with the hierarchy's structure and could comprehend it without any problem. The comparisons have been performed which matrices have been shown in Appendix B for these two cases.

These comparison matrices have been analysed by using Expert Choice software. Calculated priorities of alternatives for Brake and Balance companies have been shown in the following Tables 5.10 and 5.11.

Table 5-10 Balance-alternative priorities

alternative	Priority
In-house	0.368
Outsource	0.122
Extended vendor	0.509

Table 5-11 Brake- alternative priorities

alternative	Priority
In-house	0.396
Outsource	0.268
Extended vendor	0.336

As we can see in Tables 5.10 and 5.11 for Brake (Customer), In-housing is the most preferred alternative (0.396) where for the Balance (supplier), Extended Vendor has the highest priority (0.509). Although these different perspectives have been expected, due to the different weights of the respondents, they need further analysis and investigation which will be presented in the following section. In fact from this difference there are lessons to be learnt for both supplier and customer in order to add value to their businesses.

5.5.4.2.1 Detailed Analysis

For the second and third cases, the same approach as in first case has been applied for detailed analysis of the data which you will find in the following tables 5.24 to 5.27 and figures 5.6 to 5.7.

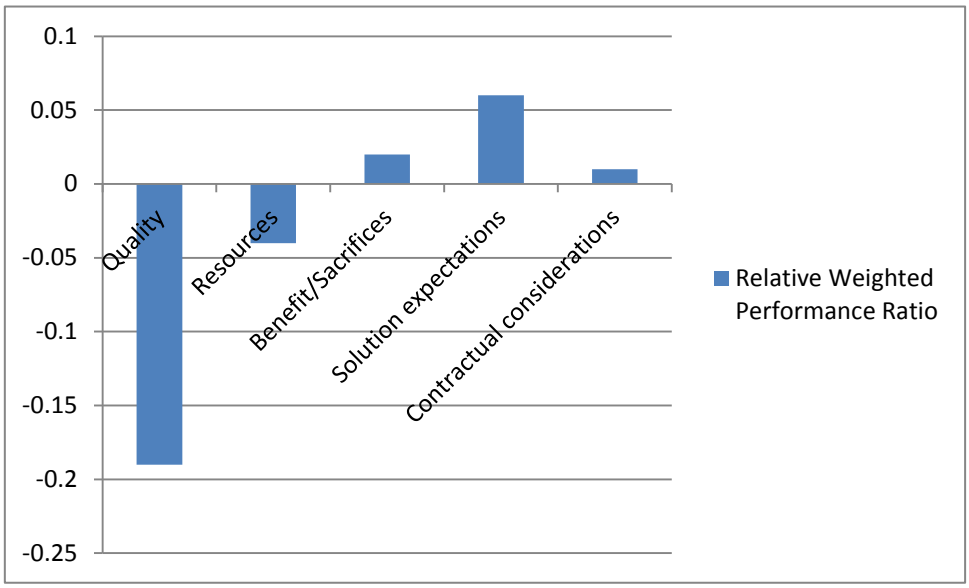

Figure 5-6 Balance, comparing the criteria for In-house vs. Extended Vendor

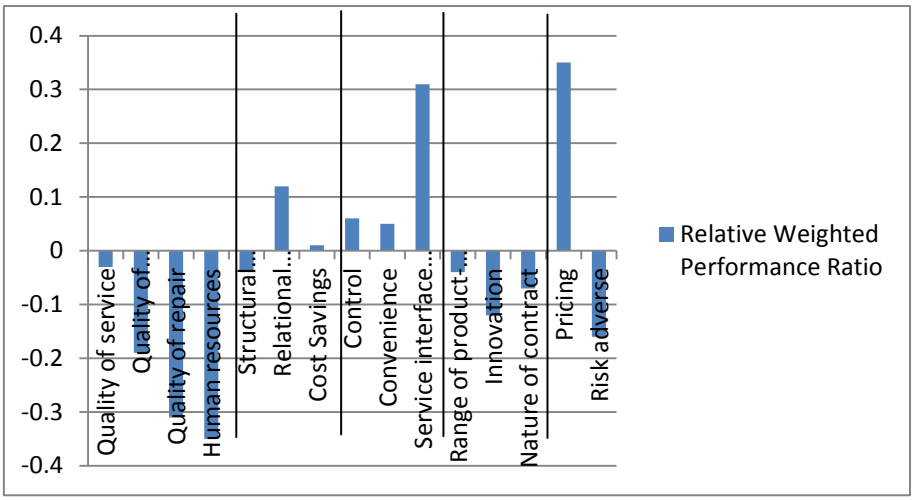

Figure 5-7 Balance, Comparing the sub-criteria for In-house vs. Extended Vendor

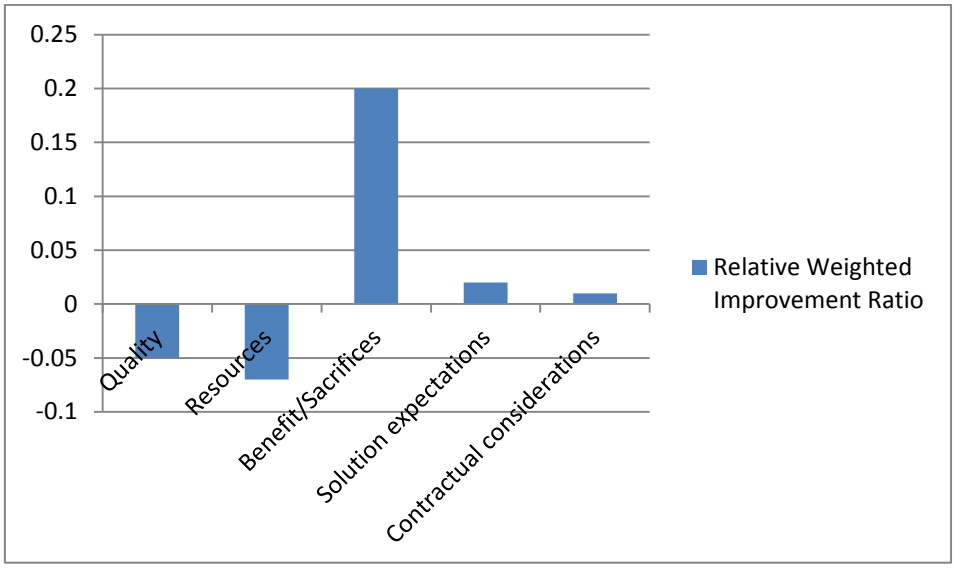

Figure 5-8 Brake, comparing the criteria for In-house vs. Extended Vendor

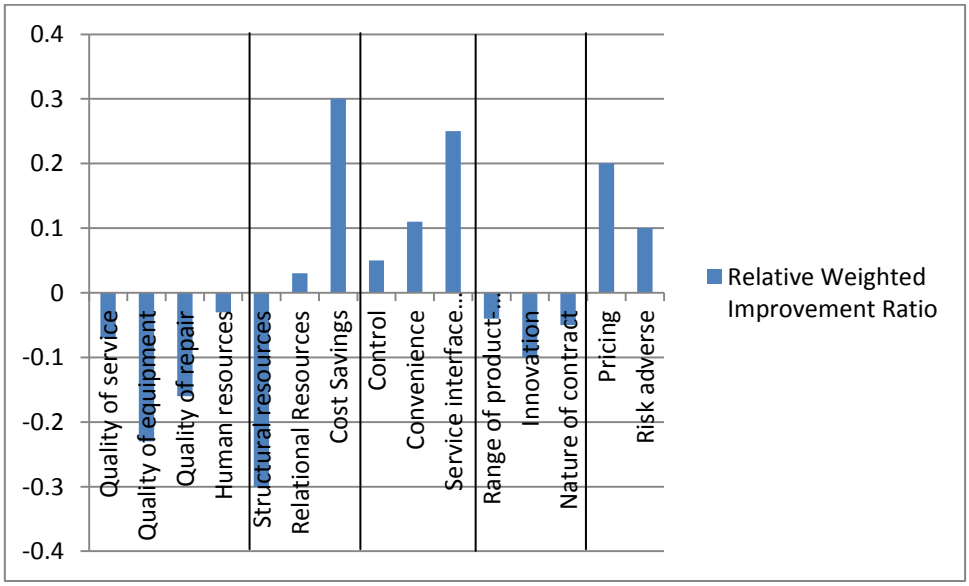

Figure 5-9 Brake, Comparing the sub-criteria for In-house vs. Extended Vendor

By looking at the detailed analysis, we can see that if the respondent from Balance Company considers himself as he is from Brake company and want to comment on Balance Company's adding value capabilities, he would consider the following as the area of improvement for Balance Company:

1- Service Interface Performance

2- Control

3- Pricing

Also if he wants to comment on Brake company's in-house abilities he would consider the following dimensions as the area of potential improvement:

1- Quality of Repair

2- Human Resources

But if we look at the actual responses from the Maintenance Manager of Brake company, he identifies following as the areas Balance System need to improve in order to add value to Brake Company's business:

1- Cost Savings

2- Service Interface Performance

3- Pricing

Also identifies the following dimensions as the area of potential improvement for their own in-house personnel if they want to add more value by keeping the maintenance functions in-house:

1- Structural Resources

2- Quality of equipment

As we can see, apart from the order of importance, both supplier and customer perceive Pricing and Service Interface Performance as two important dimensions which need to get improved by the service provider (Balance Company). Although the supplier thinks that the customer has issue with losing Control but actually the customer cares more about Cost Savings.

Also if the customer wants to keep the maintenance function in-house, both supplier and the customer think that Quality and Resources need to get improved, although the supplier (Balance Company) thinks that the customer (Brake Company) need to improve their Quality of repair and Human Resources

but the customer himself thinks that they need to improve their Structural Resources and their Quality if equipment.

As we can see in these last two cases and discussed earlier, applying the model with both customer and supplier sides provide us extra insights into the provided services and the areas which could get improved to add value to the businesses. In Chapter 7, as an industrial validation, the method will be applied in the project's industrial collaborator (Service World) and one of their major customers. For this case the AHP results are compared with the views expressed by the respondents. This will give us more confidence in applying this method in future cases.

5.6 Summary

In this chapter developing the AHP hierarchy based on value dimensions resulted from repertory grid technique has been presented. It has also been fed back on by a group of maintenance specialists to improve and validate its comprehension in maintenance management application. At the final stage of this phase of the study it has been tested and applied in three Italian cases and the results have been presented. The cases show that the developed hierarchy can be applied in industry and is easily understood by respondents. It has also been shown that applying the method in both supplier and customer side of a provided service will provide beneficial and value-adding results. This will be further discussed in the Chapters 7 and 8. In the next Chapter, the quantitative results from Repertory Grid Data will be inputted into the developed hierarchy and the result will be presented.

6 RESULTS OF PHASE 3: COMBINING REPERTORY GRID TECHNIQUE AND ANALYTIC HIERARCHY PROCESS

6.3 Introduction

At the second phase of the research, an AHP based multi-criteria decision making hierarchy was developed, based on the attributed value dimensions from the Phase 1 Repertory Grid interviews. The aim of the third phase of the research is to develop a novel value-centric decision making framework for maintenance outsourcing by combining Repertory Grid with AHP. Therefore quantitative results (frequency and variability) from Phase 1 of the research have been used as an input for weighting the criteria in the developed hierarchy. Figure 1.4 demonstrates how Phase 3 is embedded into the whole research project. In summary, Phase 3 had the following key characteristics:

- Combining the Repertory Grid interview technique with AHP and developing a combined decision making framework.
- Getting feedback on the developed framework and its results from the project's main industrial partner (Service World) to validate its applicability.

This chapter describes combining the repertory grid with AHP. The results from this combination will be presented and finally the industrial partner's feedback on the process will be discussed.

6.4 Combining AHP with Repertory Grid Technique

AHP's special feature is its flexibility to be combined with other methodologies (Vaidya and Kumar, 2006). As discussed earlier in chapter 5, this technique uses respondents' pairwise comparison of criteria in order to weight the criteria. Therefore despite the advantages of AHP, this technique is unable to deal with the uncertainty and imprecision of mapping the decision makers' perception into crisp numbers (Wang et al, 2007). In other words, comparing the criteria and assigning precise numbers for it might be difficult for the respondents. For example, in building up the comparison judgement matrices, it might be difficult

for respondents to exactly answer the questions such as “what is the relative importance of quality compared to resources, in respect to selecting the most valuable outsourcing option”. However, one might argue that, this is AHP’s strength, as the decision making does not require exact and precise numbers, which makes it easier. Therefore a fuzzy logic approach has been proposed for solving this problem (Al-Najjar and Alsyouf, 2003, Sharma et al, 2005, Mechefske and Wang, 2003) which uses fuzzy numbers for pairwise comparisons. But Ierace and Cavalieri (2008) argue that AHP is relatively a better technique in terms of reliability and easiness of construction of the model, in comparison with fuzzy logic in a maintenance context.

Therefore in this chapter we propose a more precise application of AHP by using quantitative values resulting from repertory grid analysis as the direct comparison of criteria instead of pairwise comparisons. As mentioned in Chapters 3 and 4, repertory grid technique uses frequency of mention and variability of ratings as two parameters representing the importance of value dimensions which have been used for criteria weightings. In this respect, the author proposes using the product of frequency and variability for criteria weightings as the basis for direct comparison of criteria and sub-criteria. This direct assessment solves pairwise comparison’s problem in giving crisp numbers and also reduces the inconsistency of the comparisons to zero, which in the case of performing pairwise comparisons it has to be less than 0.1(Saaty, 1980). It is important to mention that before choosing this product as the best weighting option, we have used frequency and variability separately for criteria weightings which did not give us a good weight contrast between the criteria and consequently the calculated alternative priorities were close together.

In order to calculate the product of frequency and variability, the average frequency and variability have been calculated separately for each criteria over the value dimensions that belong to that criteria. As presented earlier the frequency and variability of value dimensions can be found in Chapter 4.

6.4.3 Aggregating the Weights

The product of frequency and variability has been used as the basis for criteria weightings. From repertory grid analysis, frequency and variability have been calculated for each value dimension. For criteria and sub-criteria containing more than one value dimensions, product of frequency and variability have been averaged over the number of respondents who have mentioned a criteria or sub-criteria. As discussed in Chapter 4, the pattern of value dimensions for end-users and decision makers are different therefore we have calculated the alternative priorities separately in order to find out if the results are contrasted for respondents at different levels of an organisation.

For example: Quality criterion comprises of three sub-criteria, Service Orientation, Quality of Equipment and Quality of Repair. The frequencies of mention for these three sub-criteria in Metal company (End-User Group) are respectively 40, 20 and 80 percent. Also the Average Normalised Variability (ANV) are respectively; 13.2, 0 and 9.1. Therefore the average frequency 46.7%, the ANV 7.4 and their product is 1.98. These weightings for our four repertory grid case companies at decision maker and end-user levels are presented in Appendix B. The weightings have been normalised to 1.

Also, as for the alternative ratings, we have used Service World's data as the "Outsourcing" alternative and the most frequently mentioned supplier of products and added services by the respondents in each company as the Extended Vendor. In future applications of the framework, the suppliers need to be defined in a way that all the respondents rate the desired alternatives in repertory grid interviews. Due to the sequence of the data collection in this research this was not possible.

The global priorities of alternatives are calculated through the principal of hierarchic composition as discussed earlier in Chapters 3 and 5. These priorities are shown in tables 6.1 to 6.4 for each of four companies at decision maker and end user levels.

Table 6-1 Pharma, Alternative Priorities

alternative	Priority for DM*	Priority for EU**
In-house	0.393	0.331
Outsource	0.366	0.331
Extended vendor	0.242	0.337

Table 6-2 Metal, Alternative Priorities

alternative	Priority for DM	Priority for EU
In-house	0.307	0.331
Outsource	0.354	0.382
Extended vendor	0.339	0.309

Table 6-3 Medica, Alternative Priorities

alternative	Priority for DM	Priority for EU
In-house	0.323	0.298
Outsource	0.340	0.366
Extended vendor	0.337	0.336

Table 6-4 Insula, Alternative Priorities

alternative	Priority for DM	Priority for EU
In-house	0.417	0.300
Outsource	0.333	0.400
Extended vendor	0.250	0.300

*DM: Decision Maker

**EU: End User

6.5 Analysis of the Results

As we can see in the priority tables 6.1 to 6.4, for Medica and Metal (both End-User and Decision Maker groups) and for Insula (Decision Maker group) Outsourcing has the highest priority. In fact, although the case companies are outsourcing their maintenance function to Service World the resulting priority is not always in favour of outsourcing e.g. the priority of in-housing in Pharma Company is 0.393 in comparison with outsourcing which is 0.366. This means that although the customer company has outsourced its maintenance function as a valuable option, it does not mean that they perceive that they are still receiving the same value from it. This urges for a detailed analysis in order to understand why the method resulted in this priority and how the service can be improved by the supplier in order to sustain the value adding capacity of their provided services. This analysis will also help the customers to understand the reasoning behind the results and how they can improve their in-housing capacity if they ever want to keep their maintenance in-house.

We can also see that in Insula Company, the most prior alternative for the decision makers is In-house while it is Outsourcing for End-users which means that the perception of value varies at different levels of the organisation as the pattern of values are different (as discussed in Chapter 4).

Therefore we have conducted a detailed analysis similar to the previous chapter, in order to better understand the decision making situation in each case company at different organisational levels.

6.5.3 Detailed Analysis

Similar to section 5.3.2.1.1, a detailed analysis has been performed, based on the direct weightings for criteria and sub-criteria and we have developed following Tables 6-5a to 6-5d for the Pharma Company. The detailed analysis for the rest of the 3 companies can also be found presented in Appendix C. We have provided the analysis for comparing outsourcing and in-housing. As mentioned in the previous chapter, this is to be considered that this type of analysis can be performed for any pair of alternatives based on its applicability in every case.

Table 6-5a Pharma, Decision makers, comparing the criteria for In-house vs. Outsourcing

Criteria	Respondent weight(RW)	Outsourcing performance (OP)	In-house performance (IP)	Relative Weighted Performance Ratio RW*(IP-OP)
Quality	(0.303)	(0.363)	(0.424)	0.018
Resources	(0.133)	(0.347)	(0.500)	0.020
Benefit/Sacrifices	(0.212)	(0.296)	(0.222)	0.016
Solution expectations	(0.247)	(0.451)	(0.362)	-0.022
Contractual considerations	(0.104)	(0.333)	(0.556)	0.023

Table 6-5b Pharma, Decision makers, comparing the sub-criteria for In-house vs. Outsourcing

Sub-criteria	Respondent Weight(RW)	Outsourcing Performance (OP)	In-house performance (IP)	Relative Weighted Performance Ratio RW*(IP-OP)
Quality of service	1	0.364	0.424	0.06
Quality of equipment	-	-	-	-
Quality of repair	-	-	-	-
Human resources	0.467	0.400	0.500	0.05
Structural resources	0.346	0.300	0.500	0.07
Relational Resources	0.187	0.300	0.500	0.04
Cost Savings	0.734	0.277	0.120	-0.12
Control	0.266	0.333	0.417	0.02
Convenience	-	-	-	-
Service interface performance	0.121	0.223	0.485	0.03
Range of product-services	0.351	0.388	0.510	0.04
Innovation	0.528	0.556	0.222	-0.18
Nature of contract	-	-	-	-
Pricing	1	0.333	0.556	0.22
Risk adverse	-	-	-	-

Table 6-5c Pharma, End users, Comparing the criteria for In-house vs. Outsourcing

Criteria	Respondent weight(RW)	Outsourcing performance (OP)	In-house performance (IP)	Relative Weighted Performance Ratio RW*(IP-OP)
Quality	0.090	0.381	0.287	-0.01
Resources	0.386	0.338	0.311	-0.01
Benefit/Sacrifices	0.196	0.326	0.364	0.01
Solution expectations	0.172	0.326	0.312	0.002
Contractual considerations	0.156	0.298	0.382	0.01

Table 6-5d Pharma , End Users, comparing the sub-criteria for In-house vs. Outsourcing

Sub-criteria	Respondent Weight(RW)	Outsourcing Performance (OP)	In-house performance (IP)	Relative Weighted Performance Ratio RW*(IP-OP)
Quality of service	0.260	0.400	0.400	0
Quality of equipment	-	-	-	-
Quality of repair	0.740	0.375	0.250	-0.1
Human resources	0.374	0.272	0.243	-0.01
Structural resources	0.240	0.500	0.222	-0.1
Relational Resources	0.386	0.309	0.414	0.04
Cost Savings	0.134	0.364	.455	0.012
Control	0.373	0.269	0.346	0.03
Convenience	0.493	0.357	0.357	0
Service interface performance	0.449	0.366	0.375	0.01
Range of product-services	0.430	0.263	0.211	-0.02
Innovation	0.121	0.333	0.333	0
Nature of contract	-	-	-	-
Pricing	0.603	0.280	0.320	0.02
Risk adverse	0.397	0.333	0.500	0.07

We have also created the graphs similar to Chapter 5 as following figures 6.1a to 6.1d.

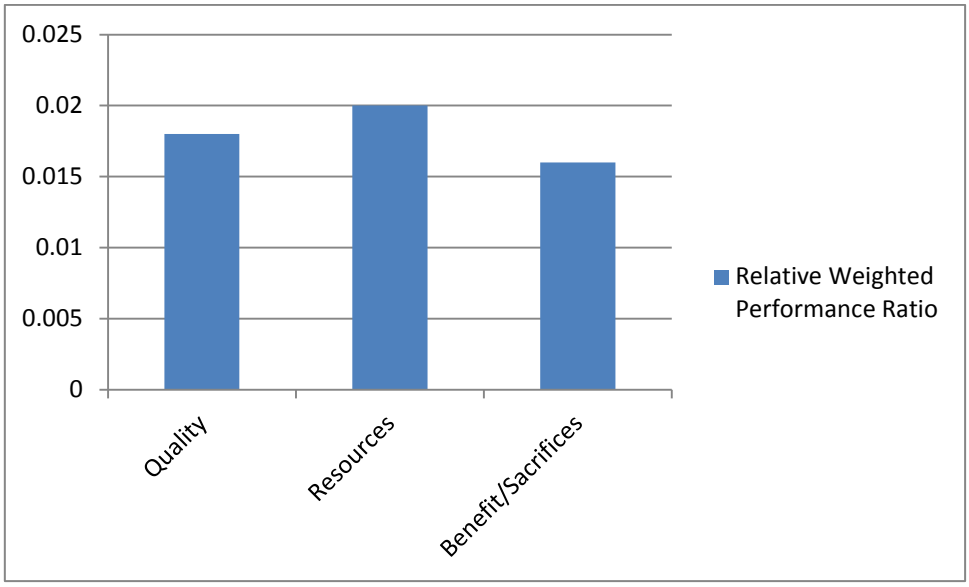

Figure 6a Pharma, Decision Makers, comparing the criteria for In-house vs. Outsourcing

(Positive values indicate areas that outsourcing needs improvement, bigger bars more improvement/negative values indicate areas that in-house needs improvement, bigger negative bars need more improvement)

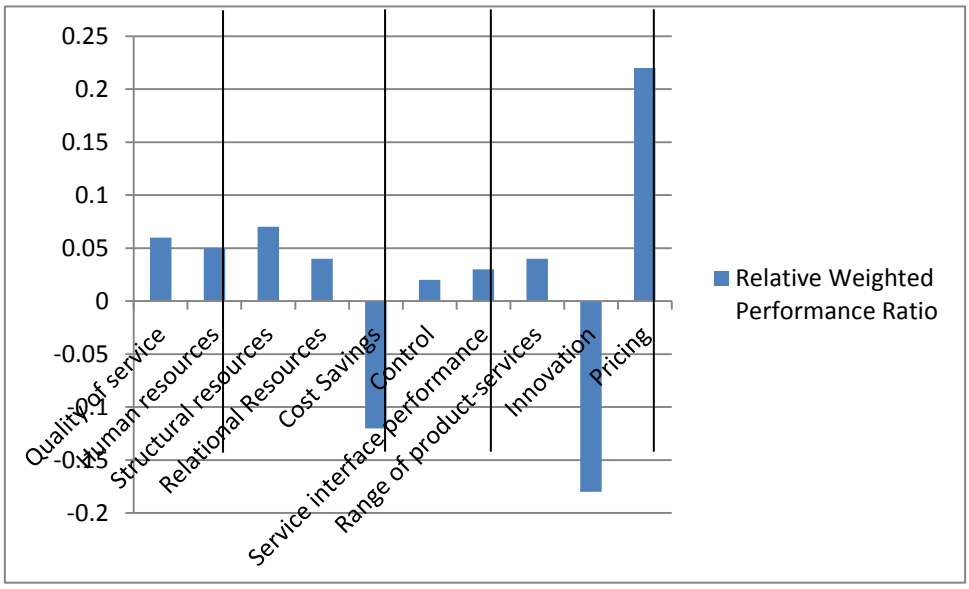

Figure 6b Pharma, Decision Makers, Relative improvement targets for outsourcing (sub-criteria level)

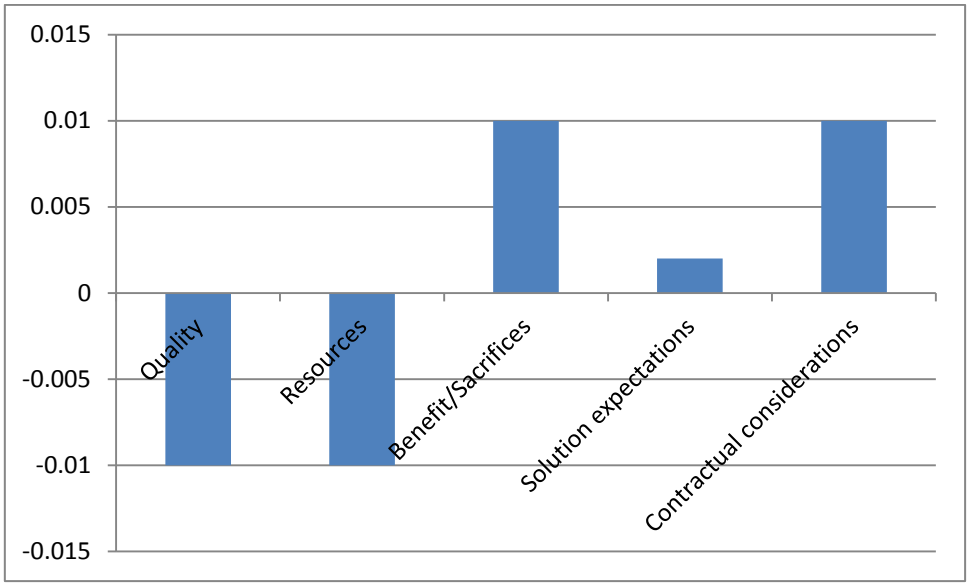

Figure 6c Pharma, End Users, comparing the criteria for In-house vs. Outsourcing

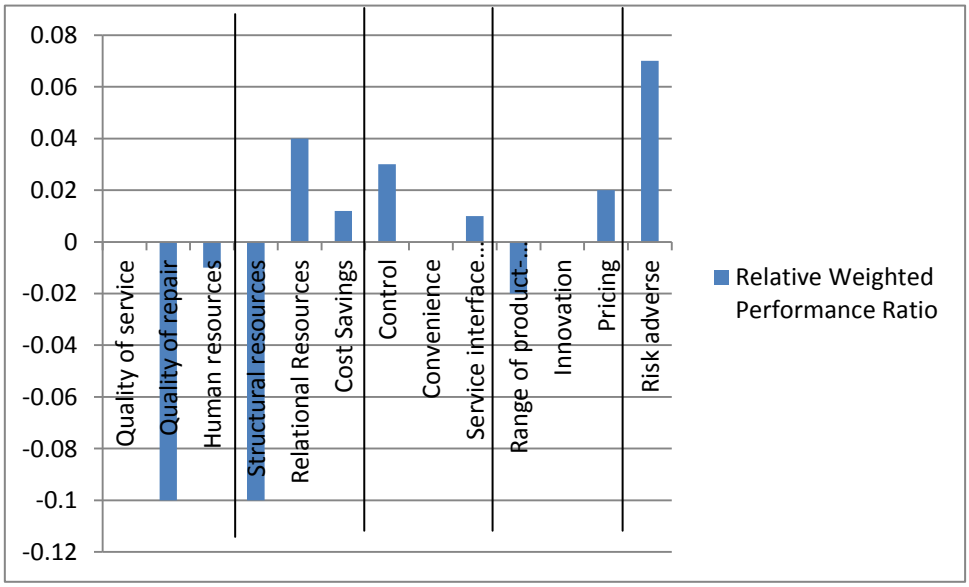

Figure 6d Pharma, End Users, Relative improvement targets for outsourcing (sub-criteria level)

Based on the above analysis, the following can be suggested to the supplier of maintenance services (Service World) in order to increase the value-adding perception for Pharma Company. In fact the supplier (at Decision Maker and

End-User levels) needs to focus on the following areas to make sure that their service is adding value to the customer:

Decision Makers

1- Pricing

2- Structural Resources

3- Quality of Service

4- Control

End Users

1- Control

2- Service Interface Performance

Also if Pharma Company wants to keep the maintenance in-house, they need to improve the following in order to add value to their own business:

Decision Makers

1- Innovation

End-Users

1- Quality of Repair

2- Structural Resources

As we can see, there are some commonalities between End-Users' and Decision Makers' improvement areas like issue of losing Control, which needs to be improved by the service provider in this setting, but they have different patterns in general. It can also be seen that Pricing is more important for the Decision Makers to be improved than for the End-users it is Control. Also Pharma Company's Decision Makers see their own shortcoming as Innovation as the End-Users see themselves weaker in Quality of Repairs in comparison to a third party company to which they outsource their maintenance to. The detailed analysis for the rest of the 3 cases are provided in Appendix C. We can

also see the same trend in the analysis of Appendix C which has to be considered for individual cases to improve the value that is perceived through the provided services.

6.6 Summary

In this chapter the novel approach of combining two methodologies, repertory grid and AHP has been presented. The quantitative results from the first stage of research (Repertory Grid Technique) has been input to the AHP hierarchy, which has been developed based on attributed value dimensions itself. The results of this stage have been analysed in detail and presented. This has provided customers with a means to conduct value-centric decision making for maintenance outsourcing. It can also help suppliers of outsourced maintenance services to continuously improve the value adding capacity of their provided services in order to remain in customer bases.

The use of rep grid's quantitative results in AHP provides more quantitative and unbiased basis for comparing the criteria and creates minimum inconsistency of the comparisons. But it also has shortcomings like the lengthy process of rep grid prior to running the AHP which might not be desirable for respondents in industry. The strengths and weaknesses of the methodology will be further discussed in Chapter 8.

In the next chapter, the numerical and industrial validation of the decision making model will be presented.

7 FIELD TEST AND VALIDATION

7.3 Introduction

As the last phase of the research, the validity of the developed decision making framework was tested. As we have seen in the test cases of Chapter 5, the decision makers who applied the model in three Italian cases and the group of maintenance specialists had no problem understanding the hierarchy and were satisfied by the model as a comprehensive and applicable way to conduct the decision making. Also the results reflected their perception of how they perceive value and as they claimed, it helped their decision making process.

In addition to the above test cases, the AHP model was applied in the main industrial partner company and one of their major customers. This helped to validate the model in the same company in which it was developed, based on the responses from their customers. In fact we can see if the developed model fits how they perform their decision making and how it can improve it.

This chapter first describes the general feedback session from the sponsoring company (Service World). It will follow with testing the AHP model with one of the major customers of Service World and finally a sensitivity analysis has been performed for the numerical validation of the model.

7.4 Feedback Session and Field Test

In order to assess the applicability of the developed AHP hierarchy and to get feedback, the results of the research were presented to four customer support and maintenance managers from Service World who are the main people responsible for managing the relationship with the customers for maintenance and support contracts. The session lasted nearly three hours around the both value dimensions resulted from the initial phases of the research and AHP results. Service World's feedback is summarised in the following:

- They suggested that in the future, studying the value dimensions at the pre-bid stage of supplier-customer would be interesting to investigate.

- Service World agreed with the tangible maintenance values and felt that they measure “all of these” both internally and externally. They agreed that intangible maintenance values were mostly difficult to measure, but still very important (particularly relational dynamics – they commented that if their onsite representative does not “fit in” in a particular company they will be removed).
- “Control” was identified as an area of concern for customers at the start of a contract but settles down as they gain trust.
- The importance of differentiating the Cost Savings and Pricing was highlighted. As we have seen, this has been considered in the research.
- “Relational Dynamic” – one of the managers commented that recently the contracts people had changed from just sending renewal paperwork at the end of the contract, to regularly visiting their customers throughout the contract. This has increased retention. They also commented that contract renewals are related to the number of “touch points” with the customer.
- Service World responded well to the hierarchy.
- Service World suggested that the AHP approach could be applied with a new customer to help make bid/ no-bid decisions earlier & to decide whether it is worthwhile for them to bid.
- They suggested that they could use the hierarchy to “self rate” their own customers.

They were keen to conduct it both in their own organisation and their customers. Therefore they suggested for us to conduct the AHP model with one of their major customers, which will be explained in the following section.

7.4.3 Field Test of the Decision Making Framework for Service World

As discussed earlier in Chapter 5, it is proposed to investigate in both customer and supplier perspectives when using the decision making model. Therefore we first applied the AHP model with one of the Service World’s managers who is responsible for the contract with the customer company (Engine Company), in which we will conduct AHP later on. Engine Company is one of the major

customers of Service World. They manufacture heavy duty vehicle engines. They have had a maintenance outsourcing contract with Service World since 2005. They also procure automation and control systems from Service World as an Original Equipment Manufacturer (OEM).

This approach would give us better understanding of how suppliers assess the value they believe they provide to their customer which would give us a comparison basis to identify the areas which customer and supplier have different perceptions. Similar to Chapter 5 test cases, the respondent from Service World Company tried to put himself as if he is the customer judging the quality of Service World's services in comparison to the customer. As it has been suggested by Service World, we have excluded Extended Vendor from alternatives in order to focus on Service World's outsourcing and in-house. The pairwise comparison matrixes can be found in Tables 7.1a to 7.1g.

Table 7-1a Pairwise comparison matrix of the main criteria with respect to the Goal for Service World- Note: row element is x (or 1/x) times important than column element

	Quality	Resources	Benefit/Sacrifices	Solution expectations	Contractual Considerations	Standards	Local Priority
Quality	-	1	1	1/7	1/2	7	0.239
Resources		-	5	1/5	3	5	0.151
Benefit/Sacrifices			-	1/5	1/5	1	0.051
Solution expectations				-	1	1/5	0.268
Contractual Considerations					-	1/5	0.103
Standards						-	0.188

Inconsistency: 0.88

Table 7-1b Pairwise comparison matrix for the sub-criteria with respect to Quality

	Quality of service	Quality of repair	Quality of equipment	Local Priority
Quality of service	-	1	1/5	0.143
Quality of repair		-	1/5	0.143
Quality of equipment			-	0.714

Inconsistency: 0.00

Table 7-1c Pairwise comparison matrix for the sub-criteria with respect to Resources

	Human resources	Structural resources	Relational resources	Local Priority
Human resources	-	1/5	1/7	0.063
Structural resources		-	1/7	0.184
Relational resources			-	0.753

Inconsistency: 0.28

Table 7-1d Pairwise comparison matrix for the sub-criteria with respect to Benefit/Sacrifices

	Cost Savings	Control	Convenience	Local Priority
Cost Savings	-	1/3	5	0.297
Control		-	5	0.618
Convenience			-	0.086

Inconsistency: 0.13

Table 7-1e Pairwise comparison matrix for the sub-criteria with respect to Solution expectations

	Responsiveness	Range of product-services	Innovation	Local Priority
Service Interface Performance	-	5	5	0.685
Range of product-services		-	1/5	0.080
Innovation			-	0.234

Inconsistency: 0.28

Table 7-1f Pairwise comparison matrix for the sub-criteria with respect to Contractual considerations

	Pricing	Risk adverse	Nature of contract	Local Priority
Pricing	-	5	5	0.685
Risk adverse		-	1/5	0.080
Nature of contract			-	0.234

Inconsistency: 0.28

Table 7-1g Pairwise comparison matrix for the sub-criteria with respect to Standards

	Operation Security	Environmental	Regulations	Local Priority
Operation Security	-	1	1	0.333
Environmental		-	1	0.333
Regulations			-	0.333

Inconsistency: 0.00

After performing the pairwise comparisons we have entered them into Expert Choice software and generated the alternative priorities as Table 7.2.

Table 7-2 Service World alternative priorities

Alternative	Priority
In-house	0.318
Outsource	0.682

The supplier perception will be presented in the next section, followed by detailed analysis and discussion will be presented in the following sections to compare supplier and customer perceptions.

7.4.4 Application of the Model for Engine Company

As previously mentioned, Service World invited us to conduct the AHP model in a feedback session with Engine Company. In this session 9 maintenance and operation managers and team leaders from Engine Company and 4 Service

World managers including their on-site representative participated. After a general presentation of the project and the developed model, respondents from Engine Company were encouraged to participate in the discussions and weight the criteria. The comparisons draw very good discussion, which will be presented later and resulted in the following pairwise comparison matrices as Tables 7.3a to 7.3g.

Table 7-3a Pairwise comparison matrix of the main criteria with respect to the Goal for Engine Company- Note: row element is x (or 1/x) times important than column element

	Quality	Resources	Benefit/Sacrifices	Solution expectations	Contractual Considerations	Standards	Local Priority
Quality	-	7	5	1	3	1/3	0.298
Resources		-	5	1	9	1	0.174
Benefit/Sacrifices			-	1	5	1/5	0.072
Solution expectations				-	5	1	0.152
Contractual Considerations					-	1/5	0.034
Standards						-	0.270

Inconsistency: 0.24

Table 7-3b Pairwise comparison matrix for the sub-criteria with respect to Quality

	Quality of service	Quality of repair	Quality of equipment	Local Priority
Quality of service	-	1/7	1/7	0.067
Quality of repair		-	1	0.467
Quality of equipment			-	0.467

Inconsistency: 0.00

Table 7-3c Pairwise comparison matrix for the sub-criteria with respect to Resources

	Human resources	Structural resources	Relational resources	Local Priority
Human resources	-	1	5	0.455

Structural resources	-	5	0.455
Relational resources		-	0.091

Inconsistency: 0.00

Table 7-3d Pairwise comparison matrix for the sub-criteria with respect to Benefit/Sacrifices

	Cost Savings	Control	Convenience	Local Priority
Cost Savings	-	1/3	1/4	0.114
Control		-	5	0.644
Convenience			-	0.242

Inconsistency: 0.39

Table 7-3e Pairwise comparison matrix for the sub-criteria with respect to Solution expectations

	Responsiveness	Range of product-services	Innovation	Local Priority
Service Interface Performance	-	3	1	0.405
Range of product-services		-	1/5	0.114
Innovation			-	0.481

Inconsistency: 0.03

Table 7-3f Pairwise comparison matrix for the sub-criteria with respect to Contractual considerations

	Pricing	Risk adverse	Nature of contract	Local Priority
Pricing	-	1	1	0.319
Risk adverse		-	1/3	0.221
Nature of contract			-	0.460

Inconsistency: 0.13

Table 7-3g Pairwise comparison matrix for the sub-criteria with respect to Standards

	Operation Security	Environmental	Regulations	Local Priority
Operation Security	-	1	1	0.333
Environmental		-	1	0.333
Regulations			-	0.333

Inconsistency: 0.00

The generated priorities can also be found in Table 7.4 by using Expert choice software. In the following section the detailed analysis and the discussion around it will be presented.

Table 7.4 Engine- alternative priorities

Alternative	Priority
In-house	0.446
Outsource	0.554

7.4.5 Detailed Analysis

The results give us a very good opportunity to perform detailed analysis. Therefore the detailed analysis has been performed which results can be found in Tables 7.5a to 7.5b and 7.6a to 7.6b. The results have also been presented graphically in Figures 7.1a to 7.1b and 7.2a to 7.2b. As can be seen, we have compared the outsourcing against in-house which is reverse to the way we presented the detailed analysis in the previous chapters. The reason for this is that as we fed back the results to Service World, we tried to present the data as the positive values represent the areas they perform better.

Table 7-5a Service World, Comparing the criteria for Outsourcing vs. In-house (Supplier Perspective)

Criteria	Respondent weight(RW)	Outsourcing performance (OP)	In-house performance (IP)	Relative Weighted Performance Ratio RW*(OP-IP)
Quality	0.239	0.833	0.167	0.16
Resources	0.151	0.833	0.167	0.10
Benefit/Sacrifices	0.051	0.422	0.578	-0.01
Solution expectations	0.268	0.833	0.167	0.18
Contractual considerations	0.103	0.780	0.220	0.06
Standards	0.188	0.167	0.833	-0.13

Table 7-5b Service World, Comparing the sub-criteria for Outsourcing vs. In-house (Supplier Perspective)

Sub-criteria	Respondent Weight(RW)	Outsourcing Performance (OP)	In-house performance (IP)	Relative Weighted Performance Ratio RW*(OP-IP)
Quality of service	0.143	0.833	0.167	0.10
Quality of equipment	0.714	0.833	0.167	0.48
Quality of repair	0.143	0.833	0.167	0.10
Human resources	0.063	0.833	0.167	0.04
Structural resources	0.184	0.833	0.167	0.12
Relational Resources	0.753	0.833	0.167	0.50
Cost Savings	0.297	0.833	0.167	0.20
Control	0.618	0.167	0.833	-0.41
Convenience	0.086	0.833	0.167	0.06
Service interface performance	0.685	0.833	0.167	0.46
Range of product-services	0.080	0.833	0.167	0.05
Innovation	0.234	0.833	0.167	0.16
Nature of contract	0.234	0.833	0.167	0.17
Pricing	0.685	0.833	0.167	0.17
Risk adverse	0.080	0.167	0.833	-0.05
Operations Security	0.333	0.167	0.833	-0.22
Environmental	0.333	0.167	0.833	-0.22
Regulations	0.333	0.167	0.833	-0.22

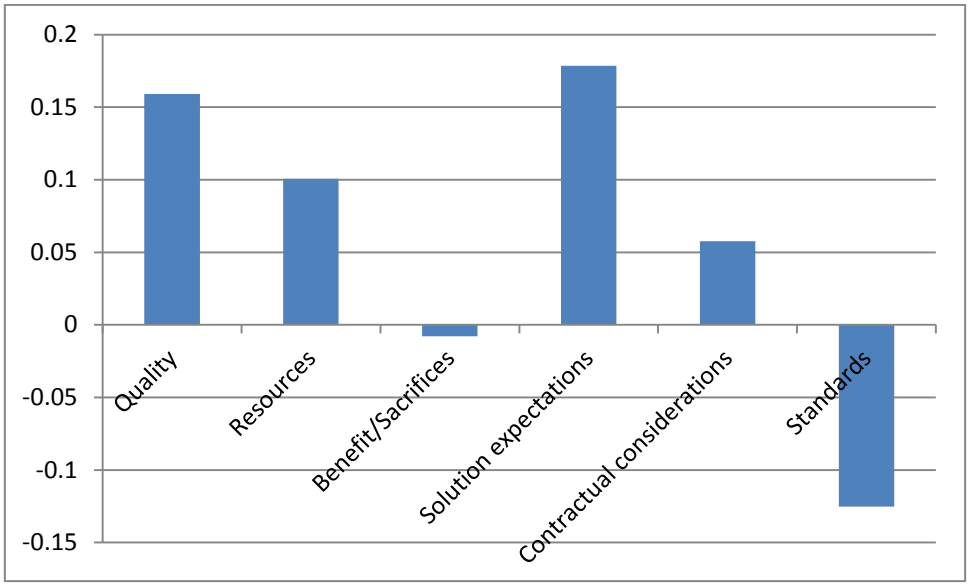

Figure 7-1a Service World, comparing the criteria for Outsourcing vs. In-house

(Positive values indicate areas that outsourcing is performing better, negative value indicates areas that in-housing performs better. Bigger positive values indicate areas that outsourcing is better and more negative areas are in-housing's stronger abilities.)

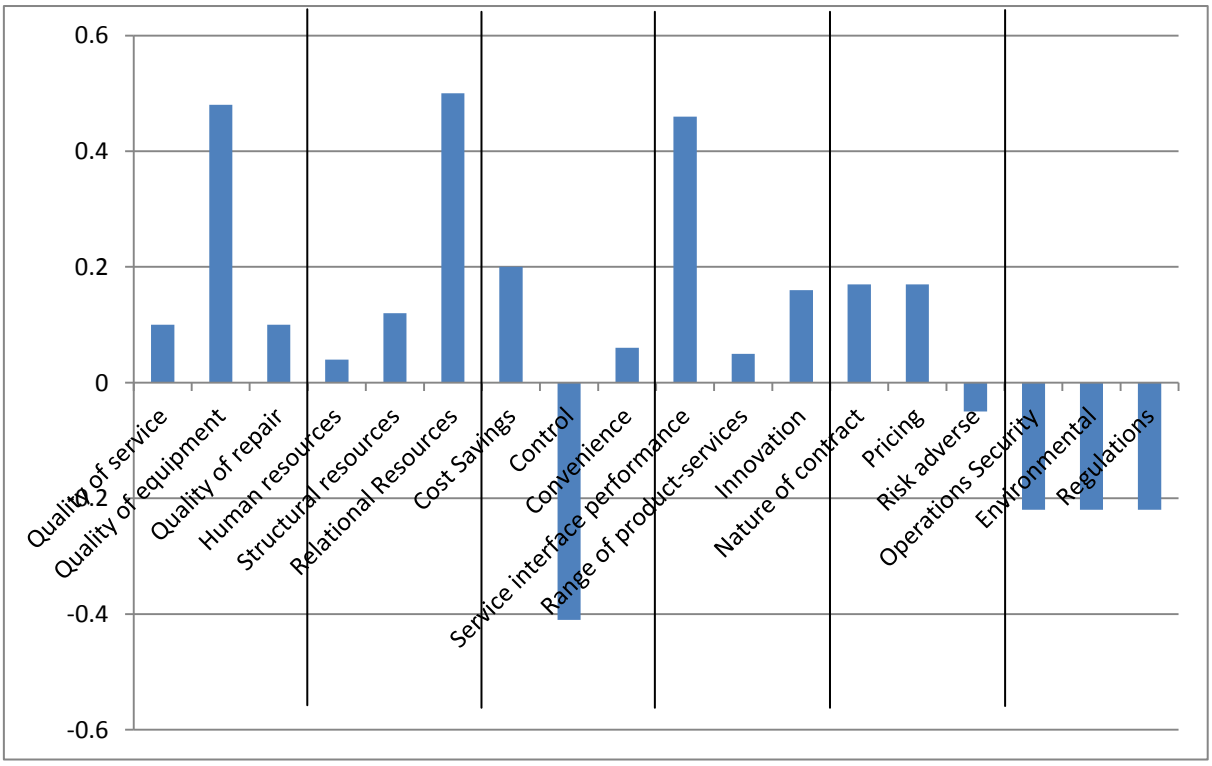

Figure 7.1b Service World, comparing the criteria for Outsourcing vs. In-house

Table 7-6a Engine, Comparing the criteria for Outsourcing vs. In-house

(Customer Perspective)

Criteria	Respondent weight(RW)	Outsourcing performance (OP)	In-house performance (IP)	Relative Weighted Performance Ratio RW*(OP-IP)
Quality	0.298	0.489	0.511	-0.01
Resources	0.174	0.825	0.175	0.11
Benefit/Sacrifices	0.72	0.419	0.581	-0.12
Solution expectations	0.152	0.823	0.177	0.1
Contractual considerations	0.034	0.647	0.353	0.01
Standards	0.270	0.423	0.577	-0.04

Table 7-6b Engine, Comparing the sub-criteria for Outsourcing vs. In-house

(Customer Perspective)

Sub-criteria	Respondent Weight(RW)	Outsourcing Performance (OP)	In-house performance (IP)	Relative Weighted Performance Ratio RW*(OP-IP)
Quality of service	0.067	0.250	0.750	-0.03
Quality of equipment	0.467	0.500	0.500	0
Quality of repair	0.467	0.500	0.500	0
Human resources	0.455	0.833	0.167	0.3
Structural resources	0.455	0.833	0.167	0.3
Relational Resources	0.091	0.750	0.250	0.05
Cost Savings	0.114	0.750	0.250	0.06
Control	0.644	0.200	0.800	-0.39
Convenience	0.242	0.875	0.125	0.18
Service interface performance	0.405	0.833	0.167	0.167
Range of product-services	0.114	0.750	0.250	0.06
Innovation	0.481	0.833	0.167	0.32
Nature of contract	0.460	0.750	0.250	0.23
Pricing	0.319	0.500	0.500	0
Risk adverse	0.221	0.750	0.250	0.11
Operations Security	0.333	0.167	0.833	-0.22
Environmental	0.333	0.500	0.500	0
Regulations	0.333	0.500	0.500	0

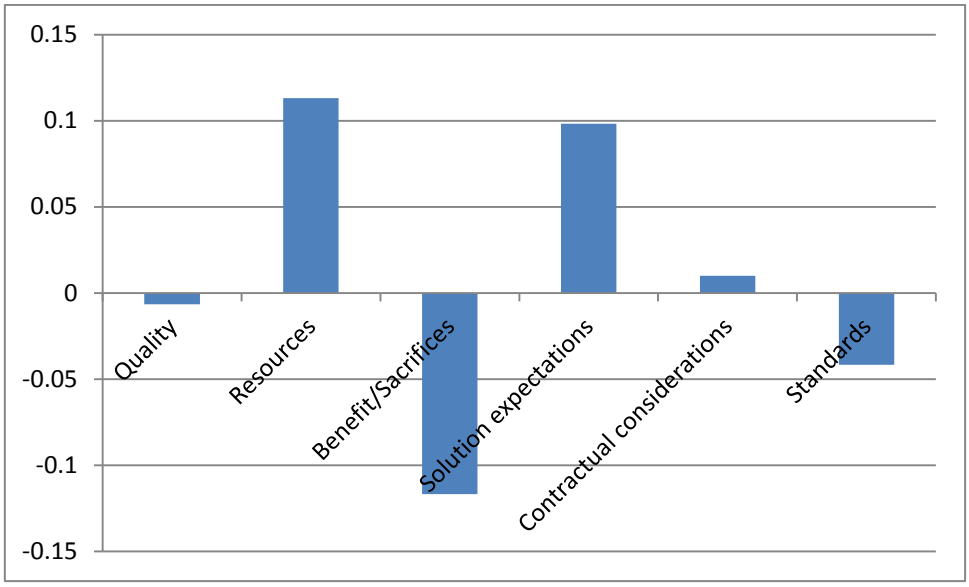

Figure 7-2a Engine, comparing the criteria for Outsourcing vs. In-house

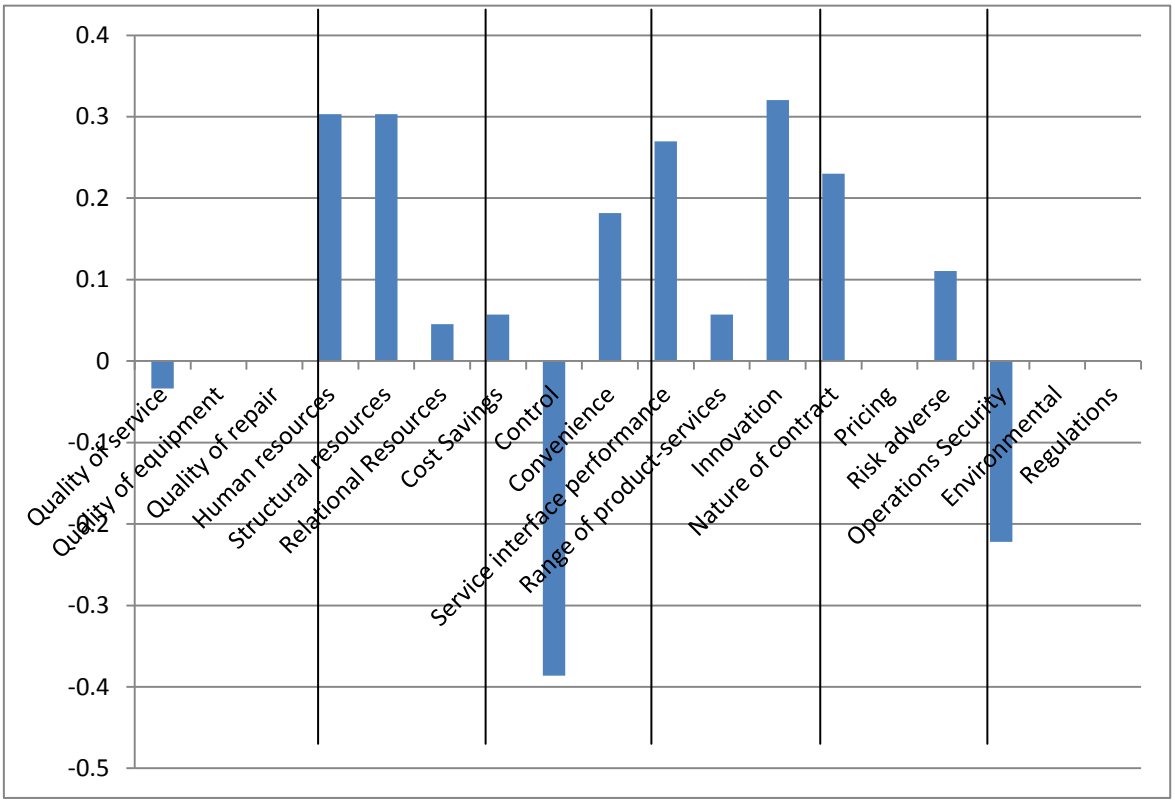

Figure 7-2b Engine, comparing the sub-criteria for Outsourcing vs. In-house

Based on the above analysis, in the supplier's (Service World) perception the following areas should be improved by the supplier. Although as the supplier's respondent mentioned, we have to be cautious in this kind of analysis that when a supplier thinks that the customer is better in a certain area might just mean that they do not wish to compete in this area.

- Standards (all three sub-criteria)
- Control

And the areas that supplier is already better than in-house but can improve are:

- Risk Adverse
- Human Resources

On the other hand, in customer's perception the areas that need to get improved by the supplier are:

- Control
- Standards(Operation Security)
- Quality of Service

And the area that supplier is already better than in-house but still can improve is

- Risk Adverse

As we can see, the supplier assumes that they have to improve their Human Resources as the supplier's respondent mentioned that the customer would have a bias towards their own human resources. Whereas the customer thinks that the supplier is performing better than in-house for Human Resources but they should improve their Quality of Service.

It is also evident from the sub-criteria comparisons where Service World thinks they are performing better which is the opposite in customer's perception. This is confirmed by the customer at the feedback event where one of the team leader's of Engine Company mentioned:

“When I get the repair back, it doesn’t matter what resources you (supplier) put in...”

In general if we look at both side’s perception it is evident that they have almost the same understanding of the situation. As it is seen, issue of losing control is both sides’ concern as a team leader in Engine Company mentions:

“We can still ask (Service World) to send failed stuff to the companies we prefer...we still want a bit of control.”

As we can see in the detailed analysis, the Relative weighted Performance Ratio for Control in customer and supplier’s perception are respectively -0.39 and -0.41 which confirms this similarity. Also another maintenance team leader adds to it:

“Sometimes we lose in translation because of the middle man (Service World). We don’t know what’s going on. If we knew the failure reason, we’d put preventative measures not to happen next time. You lose that level of control. There are advantages though...”

In fact this is as would be expected given that by outsourcing the issue of losing control is inevitable. Although the supplier should somehow manage it to create value for the customer.

Also referring to the importance of in-tangible value dimensions, we can see in this case that customer perceives Convenience as a more important dimension than Cost Savings as they have weighted the Convenience 0.242 comparing to 0.114 for Cost Savings. Although considering the weightings of outsourcing versus in-housing for them (Cost saving :0.06 vs. Convenience 0.18), the Cost Saving is more prior for the customer to get improved by the aupplier. A maintenance team leader emphasises this as:

“Ideally we want convenience but still cost is important...we got a business to run.”

Also as we can see, both sides have an issue with Standards and compliance to them as one of the operations team leader in Engine Company mentions:

"If you (supplier) get something wrong in the standards, they (authorities) can just close it down, no matter how much you put in your resources..."

In general, application of the model as discussed above, gave us very good confidence in applicability of the model in the real world. Not only did it provide useful results for both customers and suppliers, but also provided a very good discussion basis for them to gain better insights into their businesses. The final results have also been presented to Service World in order for them to get better output from the research. It is important to note that even if the results are different, the process helps to identify issues and areas to focus on.

Also application of the model as a pure AHP and joint with Rep Grid has both pros and cons that will be discussed in the following chapter.

In the following section we have described how sensitivity analysis validates the results of AHP numerically.

7.5 Validating by Sensitivity Analysis

As we have seen, AHP analysis gives the decision maker the priorities for outsourcing alternatives based on criteria weightings. Therefore changing the respondents criteria weightings can change the alternative priorities. In order to assess the AHP process's robustness to potential changes in the priority of outsourcing alternatives, we can perform sensitivity analyses of criteria weightings by changing each criterion's weight and assess its effect on decision alternative priorities. In fact we have to check whether a few changes to criteria weighting can result in significant changes in alternative priorities (Bertolini et al, 2004). In this way we can investigate the robustness of the alternatives' to change.

In this section we will present the sensitivity analysis on the first level criteria of our four AHP/ repertory grid cases and also this chapter's test cases by using the Expert Choice software. It is clear that "as the priority of one criterion increases the priorities of the remaining criteria must decrease proportionately and the global priority of the alternatives must be recalculated" (Bertolini et al, 2004). After performing the sensitivity analysis we have found out that most

results are not sensitive to the changes and only the following are considerably sensitive;

- In Insula Company for End-user group, by increasing the importance of “contractual considerations” criterion from 0.13 to 0.32 the most prior alternative switches from In-house to Outsourcing which makes it the most sensitive case.
- In Coin Company, for Decision Maker group, by increasing the importance of “Intangible resources” criterion from 0.12 to 0.83 the most prior alternative switches from Outsource to In-house.
- In Medica Company, for End-User group, by increasing the importance of “Contractual Considerations” criterion from 0.14 to 0.55 the most prior alternative switches from Outsource to In-house.
- In Pharma Company, for Decision maker group, by increasing the importance of “Solution Expectations” criterion from 0.25 to 0.57 the most prior alternative switches from In-house to Outsource.
- In Engine Company, by increasing the importance of Quality criterion from 0.30 to 0.90 or Benefits/Sacrifices from 0.08 to 0.55 or Standards from 0.30 to 0.60 the most prior alternative switches from Outsource to In-house.

The above sensitivity analysis is a sample of the results from a larger analysis which show the same pattern. As it is seen, only by applying large changes of the first level criteria weightings, it is possible to change the position of alternative priorities. This shows the robustness of the performed decision making by using this AHP hierarchy. It is to be added that as mentioned by Bertolini et al (2004) and Bevilacqua and Braglia (2000) the sensitivity analysis has been simplified by ignoring the “interaction effects” of the changes made to two or more weights.

7.6 Summary

In this chapter the applicability of the developed model has been tested in the project’s industrial partner and a group of respondents in one of its major customers. The supplier’s and customer’s different perspective on the provided

products and service have been analysed. We have also seen that the inconsistencies of the pairwise comparisons are higher than expected in these cases which will be further discussed in the following chapter. Also as a numerical validation, sensitivity analysis has been performed on the test cases. In the following chapter, we will further discuss the developed model and the results of the research.

8 DISCUSSION AND CONCLUSIONS

8.3 Introduction

In this final chapter, the results from four stages of the research are individually and generally discussed. Also the rationale for the whole study and the contribution to the knowledge is presented. At the beginning, the nature of customer value is discussed which is followed by the decision making model that is developed based on these attributed value dimensions. The novel combination of repertory grid technique and AHP will be evaluated and finally the suggestions for future research will be discussed.

8.4 Dynamic Nature of Value from Outsourced Maintenance Services

In this research the importance of assessing the value of services in the product-service setting has been highlighted. In other words, the nature of customer-supplier relationships and added value through the maintenance services included has been studied as an essential step in understanding the product-service settings which is in contrast with product procurement studies, which are based on one-off customer-supplier interactions.

The first phase of the research investigated the value dimensions customers use to evaluate outsourced maintenance services. Most of the previous research into maintenance value has focused on financial considerations and maintenance as a profit contributor. Although we have seen that maintenance is conventionally considered as a cost-centre and recently efforts have been put into demonstrating the value that maintenance adds to the businesses. Moreover, it is clear from our results that the intangible values can be as important as tangible values. In fact, eleven out of twenty nine value dimensions identified in our research across four customers relate to intangible value.

The research has also highlighted how end-users and decision-makers assess value differently. The PSS-Value project at Cranfield University has captured the articulated value dimensions from the first phase of the study, at different

phases of relationship and for end-user and decision maker groups in Figure 8.1.

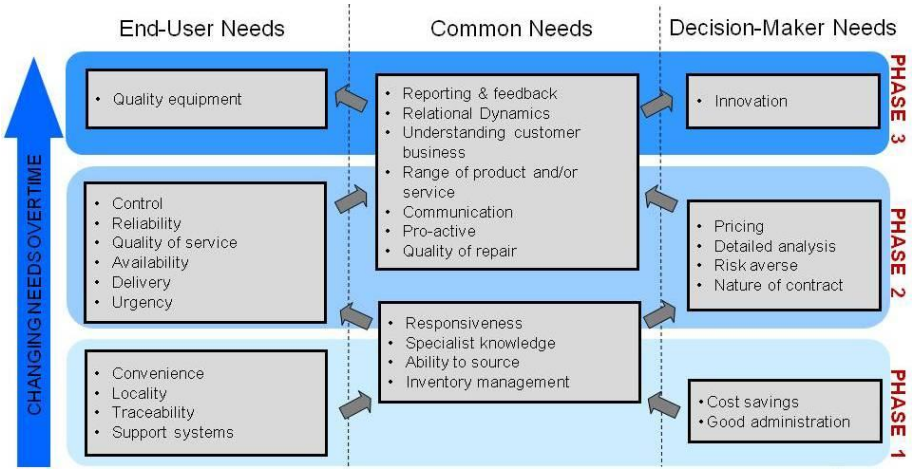

Figure 8-1 A Model of End-User and Decision-Maker Needs (Toossi et al, 2010)

As it is evident, maintenance stakeholders at different organizational levels, i.e. end-users and decision makers, realize value dimensions differently. Also this changes over time in different stages of customer-supplier relationship. For example, for decision makers, cost savings and financial values are more important in initial phases (Phase 1) which evolves over time and changes to soft needs like innovation in more mature phases (Phase2- 3). In contrast, end-users value the convenience that is delivered by outsourced maintenance suppliers at the beginning of the relationship which turns into measures like quality of equipment supplied in next phases.

The findings also show that customer values are diverse between different customers and that suppliers need to consider the particular needs of each customer when designing and delivering services. Customers of outsourced maintenance services need to ensure that they take into account the full range of value contributors when procuring maintenance services and maintenance service providers need to ensure that they address the full range of value dimensions when packaging services for their customers. In fact, the results whilst from a relatively small sample indicate that suppliers of outsourced services need to consider the breadth of customer needs, rather than just focussing on cost related factors.

Moreover, maintenance outsourcing companies should consider the somewhat contradictory fact that it is easier to show the benefits of outsourced maintenance activities when failures occur, especially before and at the beginning of conducting outsourced maintenance services, than it is when the production line is running smoothly in more mature phases (Al-Najjar,2007). For example as you can see in Figure 8.1, the decision makers attribute Cost Savings at the initial phases of the relationship, which evolves to dimensions like innovation in the later phases. In other words, although the service provider might still be providing cost savings through maintenance services for the customer, these are now taken for granted and now other dimensions are important to add value for the customers. However, this does not necessarily mean that they are not valuing Cost Savings which might be considered as an obvious dimension in more mature phases.

Important implications are drawn from this study for suppliers to consider how customers assess servitised offerings. Importantly, a value-centric approach that incorporates the value-creating capacity of maintenance services needs to account for longer-term relational issues. As discussed earlier, satisfying customers by showing cost savings in early stages of maintenance contracts is likely to prove easy. However, as the relationship progresses across the next two phases, the supplier is likely to find considerable challenges in delivering continuous cost savings as the use value metrics used by customers evolve overtime. We concur with the findings of Stremersch et al (2001), in that end-users will influence the decision-making process, but that it is the decision-making unit which in actual fact is responsible for outsourcing contracts. In fact, our research has also emphasised that people in different organizational levels, are active participants in decision making process and a well-informed decision making requires a better understanding of the different maintenance stakeholders' evaluation criteria and the extent to which they have influence on decision making process.

The needs of end-users and decision-makers are clearly shown to change over time. Such a perspective needs to be accounted for, in order to understand that

use value categories are not static dimensions. Hence, it is fair to conclude that no such thing as a steady state exists, rather that customer organisations are found to be in a constant state of flux as advocated by Chia and Tsoukas (2003).

8.5 Value-Centric Decision Making and Continuous Improvement

Most of the previous efforts in maintenance management research have been put into planning the maintenance function. In fact very little research has been done on the stage before planning maintenance strategies. At this initial stage the feasibility of outsourcing maintenance function in terms of value added through this outsourcing process needs to be assessed. Also, companies that have outsourced their maintenance functions suffer from a lack of understanding about whether outsourcing is still adding value to their business or not and what is the best alternative option. This is in line with the dynamic nature of value-in-use, as it changes over time through different phases of customer-supplier relationship and contrasts at different levels of the organisation. In fact there needs to be a process for continually improving the value created for customers. This would create a win-win situation where customer continually receives value and the supplier can remain in customer bases.

Therefore, based on the dynamic nature of value, AHP which is a multi-criteria decision making model has been chosen for this respect. Value dimensions attributed through repertory grid interviews have been used as a basis for developing a novel AHP hierarchy.

8.6 Discussion of Methodology

An AHP process has been conducted, both by using repertory grid's quantitative data (frequency and variability) and as its usual application by respondents conducting pairwise comparisons. Repertory grid and AHP methodologies individually and as in combined approach have strengths and weaknesses which need to be discussed as follows:

Pros for Repertory Grid Technique:

- Repertory grid interviewing technique is a useful method to uncover the respondents' hidden constructs by comparing the elements (suppliers in our case) in triads. In other words, it is more effective than asking the respondents direct questions.
- Repertory grid reduces the bias by comparing the elements.

Cons for Repertory Grid Technique:

- In some cases, respondents either found repertory grid confusing or refused to do it as they perceived technique as a psychological assessment tool.
- It is very unlikely that the individual respondents in a group come up with the same set of elements for comparison. Therefore this limits the validity of some analysis done on the data, especially the variability importance parameter. In fact, the variability is calculated across the respondents which might not necessarily come up with the same set of elements (suppliers). Also respondents sometimes rate the elements similarly, as they perceive their performance the same which results in low variability. Therefore one could argue that the resulted variability measure does not reflect the importance of the value dimensions.

Pros for AHP combined with Repertory Grid:

- As the repertory grid results are based on responses from a group of respondents, conducting group decision making is easier than conducting original AHP with individual respondents and later on aggregating composite priorities of individuals by its conventional methods like geometrical mean (HajShirmohammadi and Wedley, 2004).
- Combining AHP and repertory grid technique reduces the inconsistency of comparisons to zero as they are based on direct weightings rather than pairwise comparisons.

- As the repertory grid technique tries to reduce respondents' bias by comparing the suppliers to elicit the value dimensions, therefore it allows for more unbiased results than conducting AHP on its own.

Cons for AHP combined with Repertory Grid:

- Combining repertory grid results with AHP limits its application to group decision making. This is due to the fact that repertory grid's qualitative and quantitative results are based on responses from a group of people rather than individuals. However repertory grid interviews and elicited categories are a rigorous basis for developing the AHP hierarchy.
- Conducting repertory grid combined with AHP is more time consuming than the AHP as its original format.
- As discussed in cons for repertory grid technique, based on limitation and uncertainty of variability measure, the results from combining the quantitative rep grid data with AHP might not provide good results.

Pros for AHP Technique:

- As it was evident in the original AHP interviews and further confirmed by industrial feedback, conducting the AHP on its own provides an opportunity for everyone to get involved in the discussions around the pairwise comparisons especially when it is conducted in a group. Performing AHP combined with repertory grid does not provide this forum type discussions as the repertory grid in conducted with individuals.
- Conducting AHP is relatively quick to do.

Cons for AHP Technique:

- Conducting the original AHP creates inconsistency for comparison matrixes and if we want to deal with the inconsistencies, we have to ask the respondents to redo the comparisons, which will be very difficult and confusing for both interviewee and interviewer. However it has been discussed in the literature that consistent responses result in better

decisions but it's not necessarily true the other way around. In fact real life decisions, specially where intangibles are involved, are not based totally based on consistent responses (Forman, 1993).

As discussed above, combining AHP with repertory grid has strengths and weaknesses which need be considered before applying them. In fact the decision to combine them is subject to the situation. For instance, if the value dimensions are not known the decision maker may need to create an AHP hierarchy from scratch, he/she might want to start from conducting repertory grid interviews to define hierarchy which quantitative results can be used for direct weighting of the criteria. But for shorter decision making session, one might want to run it as the original AHP as long as the hierarchy is developed correctly. In other words, two different ways of applying the method depend on the situation and the most important part is using a hierarchy that is comprehensive and easy to understand for the respondents. Based on the experience and feedback from the industrial applications, this is especially relevant in the situations where the model is both applied at decision maker and end-user levels and the risk of shop-floor respondents struggling with making sense of the hierarchy.

8.7 Potential Improvements

Based on our experience of running the decision process:

- Before applying the developed method with a group, the AHP hierarchy, the application process and software need to be introduced over a longer period of time to allow respondents to fully understand the process and the categories.

- Although higher consistency gives better results, we have to be careful that dealing with the inconsistencies during the sessions can be time consuming, confusing and even frustrating for the respondents if they have to repeat responses. Inconsistent comparison does not necessarily result in bad decisions, especially in real-world applications.

In the following section, the conclusions from the research have been presented.

8.8 Conclusions

Four different phases of the research and the results have been presented and discussed in detail. In this section, the conclusions from the conducted research are summarised:

- There is a need to understand the maintenance value dimensions in product and services settings. These value dimensions are both tangible and intangible and have a dynamic nature over time and at different levels of the organisations. The value dimensions are also specific to the industrial sector that we are assessing.
- In out study on maintenance services, eleven out of twenty nine attributed value dimensions were intangibles. Therefore the importance of intangibles in value assessment and the difficulty to measure them, led us to base the assessment on comparison rather than direct assessment, which in the case of our research resulted to Analytic Hierarchy Process.
- The repertory grid results provide a rigorous basis for developing the AHP hierarchy that can also be confidently applied in other contexts.
- The developed AHP hierarchy has been developed based on four industrial cases (repertory grid), applied and validated in five different cases. The successful results has also motivated Service World to apply the approach in their other customer companies in the future.
- Both applications of AHP (combined with repertory grid and in its original format) have strengths and weaknesses as discussed earlier that need to be considered.

In the following, the generalisability of findings and contribution to knowledge are presented.

8.9 Generalisability of Research Findings

The scope of this research has been generalised across industrial sectors that outsource their maintenance function, therefore the findings have the potential to be used in any industrial sector. This has also been confirmed by validating the decision making model in different sectors. The methodology can also be used in many other contexts such as procurement etc. For this purpose, the value dimensions can be defined by conducting rep grid interviews and an AHP hierarchy can be further developed.

The literature review showed that decision making for maintenance outsourcing is usually based on and limited to tangible values. Therefore it is believed that by identifying intangible and tangible value dimensions this research provides more a general and comprehensive basis for decision making.

8.10 Contribution to Knowledge

The contribution to knowledge presented in this research is to:

- Provide a comprehensive understanding of value-in-use for maintenance services.
- Provide an AHP hierarchy based on the repertory grid technique.
- Create of a decision making framework that helps suppliers and customers to add value through outsourced maintenance services.
- Combine the repertory grid results with AHP.

Most AHP applications in the literature are based on criteria which are normally resulted from literature reviews and not based on a structured interviewing methodology like repertory grid. In fact, repertory grid interviews and their extensive analysis created a rigorous basis for designing the AHP hierarchy. This is evident in responses from the industrial case companies where they found the hierarchy to be comprehensive, understandable and helpful, in order to follow the decision making process easily. The hierarchy has also been understandable for both decision maker and end-user levels. Therefore,

developing the hierarchy based on the repertory grid data and later on using the repertory grid's quantitative data in the hierarchy has created a novel approach into designing a decision making process which can be used in many decision situations e.g. procurement.

Also this research has helped to better understand the value co-creation in the setting of customer-supplier relationship. Comparing the customer versus supplier perspectives by using the AHP and the detailed analysis of the data have also been a novel approach into using AHP which provided useful insights for both supplier and customer in order to continuously improve the value they receive from the maintenance services.

8.11 Future Work

- The value dimensions have been investigated in companies at different phases of their relationships with Service World. Therefore in order to have more rigorous results, each customer company needs to be investigated at different stages of relationship. In this way, we are able to monitor how exactly the perception of value changes over time.

  Also the method is designed to continuously improve the added value for the customers. Therefore it will be very informative and useful if the supplier could apply the method in customer company at different phases of their relationship in order to monitor the value add through time.

- Comparing the responses from repertory grid combined with AHP and AHP as its original form, might provide new insights to the applicants. Although due to the time limitations of PhD, this was not possible.

- As we have conducted the research in the context of products and services provided by the industrial partner, it will be very useful to develop a hierarchy just on the basis of repertory grid responses from customers for purchasing the products and compare it to the present hierarchy, to observe how they are contrasting to each other. This would give very good insights to both customers and suppliers to understand the decision making process for acquiring products/services versus products.

- The research methodology has got very good potential for future applications in new contexts other than maintenance services. For example, it can be applied in a situation where the companies are in the process of designing their services and defining their relationships.

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APPENDIX

Appendix A

Product Service Systems - Value Theme
Repertory Grid Interview Protocol

Prepared by Dr.Emma Macdonald

1. Interview Checklist

	TAKE TO INTERVIEW	
1	Blank Grids	☐
2	Blank Cards	☐
3	Note paper	☐
4	Interview Protocol	☐
5	Pen to write on cards	☐
6	Pen to write on grid	☐
7	Voice recorder / spare batteries	☐
8	Post-it notes	☐
	PERMISSION	
9	To use voice recorder	☐

2. Introduction

INTERVIEWER: My name is <NAME> and I am a researcher at Cranfield University. We are conducting an investigation of customer perceptions of industrial suppliers. Thank you for agreeing to participate in this study. This interview will take approximately 40-50 minutes.

AGREEMENT TO RECORD: With your agreement, I would like to record our conversation. All of the information from this interview will be treated as confidential and we will not reveal your name or the name of your company in any subsequent publications. Is it OK to record this interview?

Record the following details:

- *interviewee name*
- *position, title and description (establish relationship to RAAMP, Rockwell)*
- *company*
- *date of interview*
- *location of interview*
- *interview start time*
- *interview finish time*

Repertory Grid Design

Choice of the Elements

Respondents are asked to elicit a set of 6-10 suppliers. These may occur across the following categories. Note that the two options highlighted must be included as part of the element set.

SEVEN ELEMENTS

In-house on-site repairs **<REQUIRED ELEMENT>**	
A third party repair house	For example: Dowding & Mills B.S.L. Lectronica
OEM repairs	For example Hella Siemens Omron Schnieder
Rockwell RAAMP **<REQUIRED ELEMENT>**	Reliability centred maintenance and asset management
Repairs by stores providers	Sometimes known as ISM or ISP* For example: Marks &Crane

	Erics (prev. Wyco) Buck & Hickman
Fixed price management contract	For example: Dowding & Mills Erics (prev. Wyco)
Pay for repair (fixed price repairs)	For example: Lectronica PLC Centre

* ISM (Integrated Stores Mgt) or ISP (Integrated Service Provider).

Presentation of the Elements

The name of each of the companies / type of business model (elements) will be written on a separate card and an individual number will be noted on the back of it.

Selection of the Triads

The selection of cards in each triad will be randomised and the order will be documented (please see matrix below; triads are noted in the side box).

Handling of the Constructs

The respondents will name their personal constructs which will be entered onto a blank repertory grid in matrix form (see above). A construct consists of two poles and both will need to be recorded. A rating scale from 1 to 5 will be used between these two poles.

STEP 1: ELEMENT ELICITATION

INTERVIEWER: Today I am interested in your views of suppliers of products and / or services for industrial maintenance repairs and operations.

ELEMENT ELICITATION

Can you think of some suppliers of industrial maintenance products and services that you are aware of?

IF RESPONDENT HAS TROUBLE ELICITING ENOUGH SUPPLIERS, ASK:

What about third party repair houses? What about original equipment repairs?

What about repairs by stores providers? How about providers of fixed price management contracts? Or pay for repair services?

(Write down respondent-elicited suppliers on blank sheet of paper. Establish which of the categories they belong to. We require a minimum of 6 suppliers (max. 10).. One of these must be Rockwell RAAMP. Another one must be In-house on-site repairs.).

ONCE YOU REACHED THE REQUIRED NUMBER (6-10) ASK:

I'd like you to include Rockwell RAAMP as one supplier and In-House On-Site Repairs as another.

Have you dealt with all of the suppliers you have named? Which ones? (Make a note). If not, would you consider yourself reasonably knowledgeable about each of them?

WRITE THE SUPPLIER NAMES ONTO THE BLANK CARDS AND ONTO THE BLANK GRID. WRITE A NUMBER ON THE CARD THAT CORRESPONDS TO THE NUMBER ON THE GRID.

STEP 2: CONSTRUCT ELICITATION

Select the first triad.

Please look at these 3 cards. Feel free to pick them up and move them around.

Can you think of any ways in which two of these suppliers are similar to each other and different from the third in terms of the outcomes you get?

ALTERNATIVE PHRASING

Can you put any two of them together and the third one is different in terms of the outcomes you get?'

Tell me something that any two of these have in common that makes them different from the third.

1. *Record both poles. Clarify if the poles are not clear.*

Please rate them on this scale from 1 to 5 where 1 is <POLE 1> and 5 is <POLE 2>.

Now please rate all of the suppliers.

2. *Multiple constructs might be identified from one triad.*
3. *Try to ladder / pyramid so that you identify the embedded value and the VIU elements.*
4. *Ask respondent to rate all the cards now. Record rating for each company.*
5. *Then probe for underlying meanings of poles. Record on data sheet.*

LADDERING QUESTIONS:

Laddering up:

Which ones do you prefer? Those at Pole 1 or at Pole 2? Why is that important to you? And why is that important to you? And why is that important to you?

You drew a distinction between Pole 1 and Pole 2. Is that an important distinction for you? Why?

Laddering down:

Can you tell me more about how elements that are (one pole) differ from elements that are (other pole)?

STEP 3: FINAL TWO QUESTIONS:

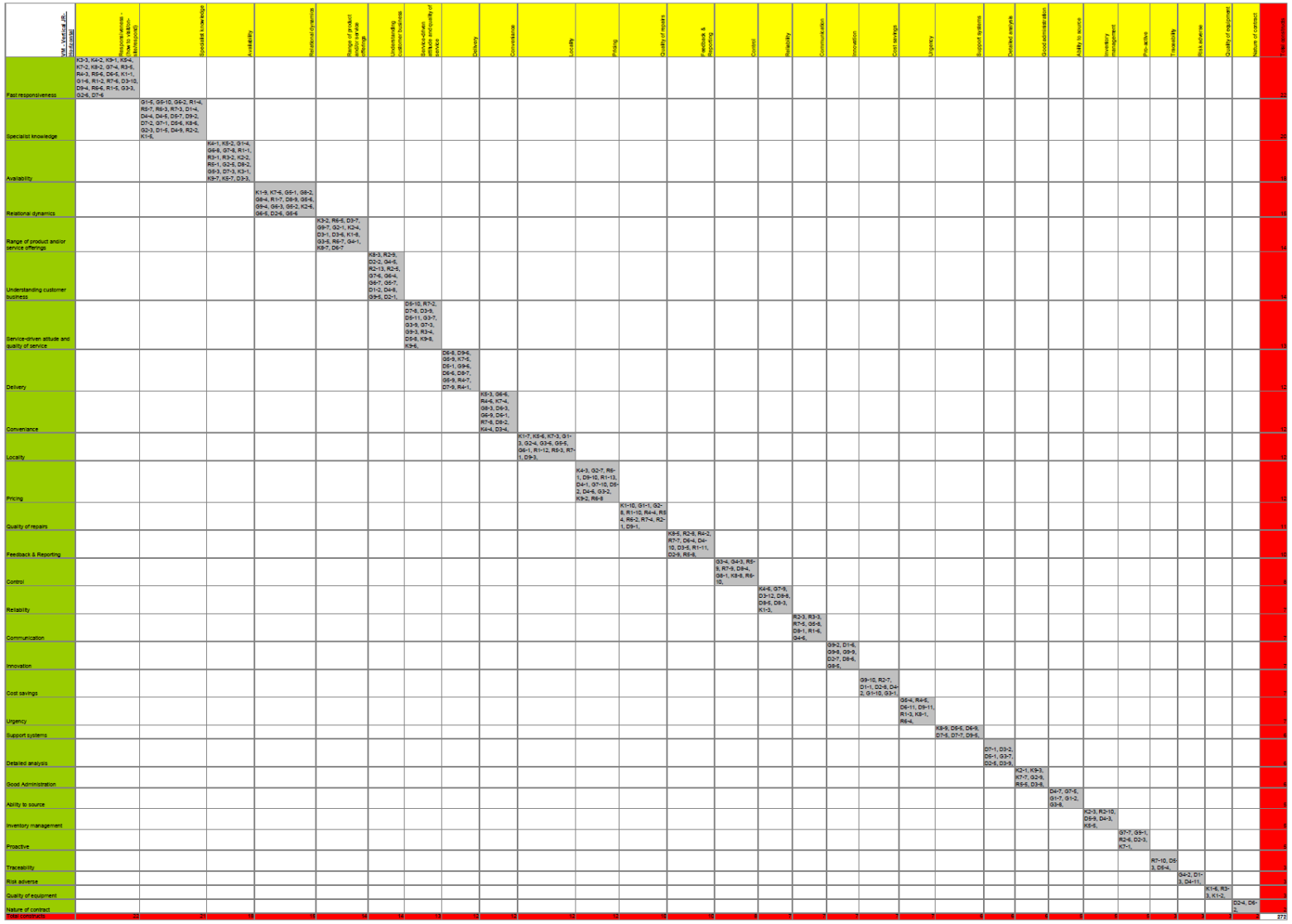
How would you rate your OVERALL SATISFACTION with these suppliers?

Overall I am very satisfied (1) to Overall I am very unsatisfied (5).

Now please rate these suppliers in terms of the VALUE they give you.

This supplier provides me with Maximum Value (1) or
provides me with Very Little Value (5).

Appendix B – Categorisation Table



Appendix C- Comparison Matrixes and Detailed Analysis of the AHP Results

Table B1.1. Pairwise comparison matrix of the main criteria with respect to the Goal for Balance- Note: row element is x (or 1/x) times important than column element

	Quality	Resources	Benefit/Sacrifices	Solution expectations	Contractual Considerations	Local Priority
Quality	-	3	7	1	8	0.365
Resources		-	5	1/3	7	0.179
Benefit/Sacrifices			-	1/7	5	0.066
Solution expectations				-	7	0.359
Contractual Considerations					-	0.031

Inconsistency: 0.09

Table B1.2. Pairwise comparison matrix for the sub-criteria with respect to **Quality**

	Quality of service	Quality of repair	Quality of equipment	Local Priority
Quality of service	-	1/8	1/8	0.057
Quality of repair		-	2	0.578
Quality of equipment			-	0.364

Inconsistency: 0.05

Table B1.3. Pairwise comparison matrix for the sub-criteria with respect to **Resources**

	Human resources	Structural resources	Relational resources	Local Priority
Human resources	-	4	2	0.558
Structural resources		-	1/3	0.122
Relational resources			-	0.320

Inconsistency: 0.02

Table B1.4. Pairwise comparison matrix for the sub-criteria with respect to **Benefit/Sacrifices**

	Cost Savings	Control	Convenience	Local Priority
Cost Savings	-	3	4	0.634
Control		-	1	0.192
Convenience			-	0.174

Inconsistency: 0.01

Table B1.5. Pairwise comparison matrix for the sub-criteria with respect to **Solution expectations**

	Responsiveness	Range of product-services	Innovation	Local Priority
Responsiveness	-	8	5	0.742
Range of product-services		-	1/3	0.075
Innovation			-	0.183

Inconsistency: 0.04

Table B1.6. Pairwise comparison matrix for the sub-criteria with respect to **Contractual considerations**

	Pricing	Risk adverse	Nature of contract	Local Priority
Pricing	-	3	5	0.648
Risk adverse		-	2	0.230
Nature of contract			-	0.122

Inconsistency: 0.00

Table B2.1. Pairwise comparison matrix of the main criteria with respect to the Goal for Brake- Note: row element is x (or 1/x) times important than column element

	Quality	Resources	Benefit/Sacrifices	Solution expectations	Contractual Considerations	Local Priority
Quality	-	1/3	1/4	1/2	2	0.106
Resources		-	1/2	2	2	0.250
Benefit/Sacrifices			-	2	3	0.371
Solution expectations				-	3	0.186
Contractual Considerations					-	0.087

Inconsistency: 0.04

Table B2.2. Pairwise comparison matrix for the sub-criteria with respect to **Quality**

	Quality of service	Quality of repair	Quality of equipment	Local Priority
Quality of service	-	1/2	1/3	0.157
Quality of repair		-	1/3	0.249
Quality of equipment			-	0.594

Inconsistency: 0.05

Table B2.3. Pairwise comparison matrix for the sub-criteria with respect to **Resources**

	Human resources	Structural resources	Relational resources	Local Priority
Human resources	-	1/3	3	0.258
Structural resources		-	5	0.637
Relational resources			-	0.105

Inconsistency: 0.04

Table B2.4. Pairwise comparison matrix for the sub-criteria with respect to **Benefit/Sacrifices**

	Cost Savings	Control	Convenience	Local Priority
Cost Savings	-	4	2	0.571
Control		-	1/2	0.143
Convenience			-	0.286

Inconsistency: 0

Table B2.5. Pairwise comparison matrix for the sub-criteria with respect to **Solution expectations**

	Responsiveness	Range of product-services	Innovation	Local Priority
Responsiveness	-	6	3	0.655
Range of product-services		-	1/3	0.095
Innovation			-	0.250

Inconsistency: 0

Table B2.6.. Pairwise comparison matrix for the sub-criteria with respect to **Contractual considerations**

	Pricing	Risk adverse	Nature of contract	Local Priority
Pricing	-	1/3	2	0.281
Risk adverse		-	1	0.464
Nature of contract			-	0.255

Inconsistency: 0.05

Table B3.1. Direct comparison matrix of the main criteria with respect to the Goal for **Metal. Decision makers**

Criteria	Priority weight
Quality	0.062
Resources	0.124
Benefit/Sacrifices	0.123
Solution expectations	0.448
Contractual Considerations	0.244

Table B3.2. Direct comparison matrix of the sub-criteria with respect to Quality for **Metal. Decision makers**

Quality	Priority weight
Quality of service	-*
Quality of repair	1
Quality of equipment	-

*respondents have not mentioned the category

Table B.3.3. Direct comparison matrix of the sub-criteria with respect to Resources for **Metal. Decision makers**

Resources	Priority weight
Human resources	0.218
Structural resources	0.569
Relational resources	0.213

Table B.3.4. Direct comparison matrix of the sub-criteria with respect to Benefit/Sacrifices for **Metal. Decision makers**

Benefit/Sacrifices	Priority weight
Cost Savings	1
Control	-
Convenience	-

Table B.3.5. Direct comparison matrix of the sub-criteria with respect to Solution Expectations for **Metal. Decision makers**

Solution expectations	Priority weight
Responsiveness	1
Range of product-services	-
Innovation	-

Table B.3.6. Direct comparison matrix of the sub-criteria with respect to Contractual considerations for **Metal. Decision makers**

Contractual considerations	Priority weight
Pricing	1
Risk adverse	-
Nature of contract	-

Table B.3.7. Direct comparison matrix of the main criteria with respect to the Goal for **Metal. End Users**

Criteria	Priority weight
Quality	0.144
Resources	0.223
Benefit/Sacrifices	0.119
Solution expectations	0.180
Contractual Considerations	0.333

Table B.3.8. Direct comparison matrix of the sub-criteria with respect to Quality for **Metal. End Users**

Quality	Priority weight
Quality of service	0.419
Quality of repair	0.581
Quality of equipment	-*

*respondents have not mentioned the category

Table B.3.9. Direct comparison matrix of the sub-criteria with respect to Resources for **Metal. End Users**

Resources	Priority weight
Human resources	0.452
Structural resources	0.273
Relational resources	0.275

Table B.3.10. Direct comparison matrix of the sub-criteria with respect to Benefit/Sacrifices for **Metal. End Users**

Benefit/Sacrifices	Priority weight
Cost Savings	0.434
Control	0.211
Convenience	0.356

Table B.3.11. Direct comparison matrix of the sub-criteria with respect to Solution Expectations for **Metal. End Users**

Solution expectations	Priority weight
Responsiveness	0.662
Range of product-services	0.338
Innovation	-

Table B.3.12. Direct comparison matrix of the sub-criteria with respect to Contractual considerations for **Metal. End Users**

Contractual considerations	Priority weight
Pricing	1
Risk adverse	-
Nature of contract	-

Table B.4.1. Direct comparison matrix of the main criteria with respect to the Goal for **Medica. Decision Makers**

Criteria	Priority weight
Quality	-
Resources	0.264
Benefit/Sacrifices	0.369
Solution expectations	0.187
Contractual Considerations	0.180

Table B.4.2. Direct comparison matrix of the sub-criteria with respect to Quality for **Medica. Decision Makers**

Quality	Priority weight
Quality of service	-*
Quality of repair	-
Quality of equipment	-

*respondents have not mentioned the category

Table B.4.3. Direct comparison matrix of the sub-criteria with respect to Resources for **Medica. Decision Makers**

Resources	Priority weight
Human resources	0.424
Structural resources	0.191
Relational resources	0.384

Table B.4.4. Direct comparison matrix of the sub-criteria with respect to Benefit/Sacrifices for **Medica. Decision Makers**

Benefit/Sacrifices	Priority weight
Cost Savings	1
Control	-
Convenience	-

Table B.4.5. Direct comparison matrix of the sub-criteria with respect to Solution expectations for **Medica. Decision Makers**

Solution expectations	Priority weight
Responsiveness	0.198
Range of product-services	-
Innovation	0.802

Table B.4.6. Direct comparison matrix of the sub-criteria with respect to Contractual considerations for **Medica. Decision Makers**

Contractual considerations	Priority weight

Pricing	0.160
Risk adverse	0.345
Nature of contract	0.495

Table B.4.7. Direct comparison matrix of the main criteria with respect to the Goal for **Medica. End Users**

Criteria	Priority weight
Quality	0.213
Resources	0.238
Benefit/Sacrifices	0.239
Solution expectations	0.169
Contractual Considerations	0.142

Table B.4.8. Direct comparison matrix of the sub-criteria with respect to Quality for **Medica. End Users**

Quality	Priority weight
Quality of service	0.856
Quality of repair	0.144
Quality of equipment	-*

*respondents have not mentioned the category

Table B.4.9. Direct comparison matrix of the sub-criteria with respect to Resources for **Medica. End Users**

Resources	Priority weight
Human resources	0.713
Structural resources	0.174
Relational resources	0.114

Table B.4.10. Direct comparison matrix of the sub-criteria with respect to Benefit/Sacrifices for **Medica. End Users**

Benefit/Sacrifices	Priority weight
Cost Savings	-
Control	0.549
Convenience	0.451

Table B.4.11. Direct comparison matrix of the sub-criteria with respect to Solution expectations for **Medica. End Users**

Solution expectations	Priority weight
Responsiveness	0.357
Range of product-services	0.594
Innovation	0.049

Table B.4.12. Direct comparison matrix of the sub-criteria with respect to Contractual considerations for **Medica. End Users**

Contractual	Priority

considerations	weight
Pricing	0.543
Risk adverse	-
Nature of contract	0.457

Table B.5.1. Direct comparison matrix of the main criteria with respect to the Goal for **Insula. Decision makers**

Criteria	Priority weight
Quality	0.245
Resources	0.294
Benefit/Sacrifices	-
Solution expectations	0.262
Contractual Considerations	0.200

Table B.5.2. Direct comparison matrix of the sub-criteria with respect to Quality for **Insula. Decision makers**

Quality	Priority weight
Quality of service	0.502
Quality of repair	0.382
Quality of equipment	0.116

*respondents have not mentioned the category

Table B.5.3. Direct comparison matrix of the sub-criteria with respect to Resources for **Insula. Decision makers**

Resources	Priority weight
Human resources	0.531
Structural resources	0.226
Relational resources	0.242

Table B.5.4. Direct comparison matrix of the sub-criteria with respect to Benefit/Sacrifices for **Insula. Decision makers**

Benefit/Sacrifices	Priority weight
Cost Savings	-
Control	-
Convenience	-

Table B.5.5. Direct comparison matrix of the sub-criteria with respect to Solution expectations for **Insula. Decision makers**

Solution expectations	Priority weight
Responsiveness	0.289
Range of product-services	0.711
Innovation	-

Table B.5.6. Direct comparison matrix of the sub-criteria with respect to Contractual considerations for **Insula. Decision makers**

Contractual considerations	Priority weight
Pricing	0.451
Risk adverse	-
Nature of contract	0.549

Table B.5.7. Direct comparison matrix of the main criteria with respect to the Goal for **Insula. End Users**

Criteria	Priority weight
Quality	-
Resources	0.307
Benefit/Sacrifices	0.240
Solution expectations	0.324
Contractual Considerations	0.129

Table B.5.8. Direct comparison matrix of the sub-criteria with respect to Quality for **Insula. End-users**

Quality	Priority weight
Quality of service	-
Quality of repair	-
Quality of equipment	-

*respondents have not mentioned the category

Table B.5.9. Direct comparison matrix of the sub-criteria with respect to Resources for **Insula. End-users**

Resources	Priority weight
Human resources	0.486
Structural resources	0.248
Relational resources	0.266

Table B.5.10. Direct comparison matrix of the sub-criteria with respect to Benefit/Sacrifices for **Insula. End-users**

Benefit/Sacrifices	Priority weight
Cost Savings	-
Control	0.288
Convenience	0.712

Table B.5.11. Direct comparison matrix of the sub-criteria with respect to Solution expectations for **Insula. End-users**

Solution expectations	Priority weight
Responsiveness	0.437
Range of product-	0.563

services	
Innovation	-

Table B.5.12. Direct comparison matrix of the sub-criteria with respect to Contractual considerations for **Insula. End-users**

Contractual considerations	Priority weight
Pricing	1
Risk adverse	-
Nature of contract	-

Table B.6.1. Direct comparison matrix of the main criteria with respect to the Goal for **Pharma. Decision Makers**

Criteria	Priority weight
Quality	0.303
Resources	0.133
Benefit/Sacrifices	0.212
Solution expectations	0.247
Contractual Considerations	0.103

Table B.6.2. Direct comparison matrix of the sub-criteria with respect to Quality for **Pharma. Decision Makers**

Quality	Priority weight
Quality of service	-*
Quality of repair	1
Quality of equipment	-

*respondents have not mentioned the category

Table B.6.3. Direct comparison matrix of the sub-criteria with respect to Resources for **Pharma. Decision Makers**

Resources	Priority weight
Human resources	0.467
Structural resources	0.346
Relational resources	0.187

Table B.6.4. Direct comparison matrix of the sub-criteria with respect to Benefit/Sacrifices for **Pharma. Decision Makers**

Benefit/Sacrifices	Priority weight
Cost Savings	0.734
Control	0.266
Convenience	-

Table B.6.5. Direct comparison matrix of the sub-criteria with respect to Solution expectations for **Pharma. Decision Makers**

Solution expectations	Priority

	weight
Responsiveness	0.121
Range of product-services	0.351
Innovation	0.528

Table B.6.6. Direct comparison matrix of the sub-criteria with respect to Contractual considerations for **Pharma. Decision Makers**

Contractual considerations	Priority weight
Pricing	1
Risk adverse	-
Nature of contract	-

Table B.6.7. Direct comparison matrix of the main criteria with respect to the Goal for **Pharma. End Users**

Criteria	Priority weight
Quality	0.090
Resources	0.386
Benefit/Sacrifices	0.196
Solution expectations	0.172
Contractual Considerations	0.156

Table B.6.8. Direct comparison matrix of the sub-criteria with respect to Quality for **Pharma. End Users**

Quality	Priority weight
Quality of service	0.260
Quality of repair	0.740
Quality of equipment	-

*respondents have not mentioned the category

Table B.6.9. Direct comparison matrix of the sub-criteria with respect to Resources for **Pharma. End Users**

Resources	Priority weight
Human resources	0.374
Structural resources	0.240
Relational resources	0.386

Table B.6.10. Direct comparison matrix of the sub-criteria with respect to Benefit/Sacrifices for **Pharma. End Users**

Benefit/Sacrifices	Priority weight
Cost Savings	0.134
Control	0.373
Convenience	0.493

Table B.6.11. Direct comparison matrix of the sub-criteria with respect to Solution Expectations for **Pharma. End Users**

Solution expectations	Priority weight
Responsiveness	0.449
Range of product-services	0.430

Innovation	0.121

Table B.6.12. Direct comparison matrix of the sub-criteria with respect to Contractual considerations for **Pharma. End Users**

Contractual considerations	Priority weight
Pricing	0.603
Risk adverse	0.397
Nature of contract	-

Table C.1.1- Balance, Comparing the criteria for Extended Vendor vs. In-house

Criteria	Priority for improving	Ex. vendor performance	In-house performance	Relative Weighted Performance Ratio PI*(IP-EV)
Quality	High 0.365	0.731	0.20	-0.19
Resources	Medium 0.179	0.565	0.329	-0.04
Benefit/Sacrifices	Low 0.066	0.299	0.531	0.02
Solution expectations	High 0.359	0.342	0.501	0.06
Contractual considerations	Low 0.031	0.292	0.446	0.01

*Negative values means that in-house needs to improve

Table C.1.2- Balance, Comparing the sub-criteria for Extended Vendor vs. In-house

Sub-criteria	Priority for improving	Ex. vendor performance	In-house performance	Relative Weighted Performance Ratio PI*(IP-EV)
Quality of service	0.057	0.763	0.176	-0.03
Quality of equipment	0.364	0.722	0.205	-0.19
Quality of repair	0.578	0.733	0.199	-0.31
Human resources	0.558	0.785	0.149	-0.35
Structural resources	0.122	0.550	0.210	-0.04
Relational Resources	0.320	0.258	0.637	0.12
Cost Savings	0.634	0.149	0.160	0.01
Control	0.192	0.114	0.405	0.06
Convenience	0.174	0.309	0.582	0.05
Service interface performance	0.742	0.230	0.648	0.31
Range of product-services	0.075	0.649	0.072	-0.04
Innovation	0.183	0.694	0.053	-0.12
Nature of contract	0.122	0.627	0.094	-0.07
Pricing	0.648	0.094	0.627	0.35
Risk adverse	0.230	0.743	0.063	-0.16

Table C2.1. Brake, Comparing the criteria for Extended Vendor vs. In-house

Criteria	Priority for improving	Ex. vendor performance	In-house performance	Relative Weighted Performance Ratio PI*(IP-EV)
Quality	0.106	0.556	0.129	-0.05
Resources	0.250	0.455	0.176	-0.07
Benefit/Sacrifices	0.371	0.175	0.626	0.2
Solution expectations	0.186	0.329	0.424	0.02
Contractual considerations	0.087	0.347	0.436	0.01

*Negative values means that in-house needs to improve

Table C.2.2 Brake, Comparing the sub-criteria for Extended Vendor vs. In-house

Sub-criteria	Priority for improving	Ex. vendor performance	In-house performance	Relative Weighted Performance Ratio PI*(IP-EV)
Quality of service	0.157	0.558	0.122	-0.07
Quality of equipment	0.594	0.528	0.140	-0.23
Quality of repair	0.294	0.637	0.105	-0.16
Human resources	0.258	0.297	0.163	-0.03
Structural resources	0.637	0.558	0.122	-0.3
Relational Resources	0.105	0.250	0.500	0.03
Cost Savings	0.571	0.122	0.648	0.3
Control	0.143	0.240	0.550	0.05
Convenience	0.286	0.238	0.625	0.11
Service interface performance	0.655	0.238	0.625	0.25
Range of product-services	0.095	0.540	0.163	-0.04
Innovation	0.250	0.429	0.143	-0.1
Nature of contract	0.122	0.558	0.122	-0.05
Pricing	0.648	0.297	0.540	0.2
Risk adverse	0.230	0.200	0.600	0.1

Table C3.1. Metal, Decision makers, Comparing the criteria for Outsourcing vs. In-house

Criteria	Respondent weight(RW)	Outsourcing performance (OP)	In-house performance (IP)	Relative Weighted Performance Ratio RW*(IP-OP)
Quality	Low (0.062)	Medium (0.308)	(0.346)	0.002
Resources	Low (0.124)	Medium (0.303)	(0.365)	0.01
Benefit/Sacrifices	Low (0.123)	High (0.600)	(0.200)	-0.05
Solution expectations	High (0.448)	Medium (0.312)	(0.354)	0.02
Contractual considerations	Medium (0.244)	Medium (0.400)	(0.200)	0.05

*Negative values means that in-house needs to improve

Table C3.2. Metal, Decision makers, Comparing the sub-criteria for Outsourcing vs. In-house

Sub-criteria	Respondent Weight(RW)	Outsourcing Performance (OP)	In-house performance (IP)	Relative Weighted Performance Ratio RW*(IP-OP)
Quality of service	-	-	-	-
Quality of equipment	-	-	-	-
Quality of repair	1	0.308	0.346	0.04
Human resources	0.218	0.321	0.357	0.01
Structural resources	0.569	0.304	0.370	0.04
Relational Resources	0.213	0.280	0.360	0.02
Cost Savings	-	-	-	-
Control	1	0.600	0.200	-0.4
Convenience	-	-	-	-
Service interface performance	1	0.312	0.354	0.042
Range of product-services	-	-	-	-
Innovation	-	-	-	-
Nature of contract	-	-	-	-
Pricing	1	0.400	0.200	-0.2
Risk adverse	-	-	-	-

Table C3.3. Metal, End-users, Comparing the criteria for Outsourcing vs. In-house

Criteria	Respondent weight(RW)	Outsourcing performance (OP)	In-house performance (IP)	Relative Weighted Performance Ratio RW*(IP-OP)
Quality	Low (0.144)	Medium (0.353)	0.364	0.002
Resources	Medium (0.223)	Medium (0.363)	0.309	-0.01
Benefit/Sacrifices	Low (0.119)	Medium (0.307)	0.330	0.003
Solution expectations	Low (0.180)	Medium (0.367)	0.266	-0.02
Contractual considerations	High (0.333)	High (0.450)	0.300	-0.05

*Negative values means that in-house needs to improve

Table C3.4. Metal, End-users, Comparing the sub-criteria for Outsourcing vs. In-house

Sub-criteria	Respondent Weight(RW)	Outsourcing Performance (OP)	In-house performance (IP)	Rel. Weighted P. Ratio RW*(IP-OP)
Quality of service	0.419	0.292	0.375	0.03
Quality of equipment	-	-	-	-
Quality of repair	0.581	0.400	0.356	-0.03
Human resources	0.452	0.357	0.286	-0.03
Structural resources	0.273	0.388	0.282	-0.03
Relational Resources	0.275	0.350	0.375	0.01
Cost Savings	0.434	0.231	0.385	0.1
Control	0.211	0.600	0.200	-0.1
Convenience	0.356	0.289	0.311	0.01
Service interface performance	0.662	0.326	0.296	-0.02
Range of product-services	0.338	0.466	0.194	-0.1
Innovation	-	-	-	-
Nature of contract	-	-	-	-
Pricing	1	0.450	0.300	-0.15
Risk adverse	-	-	-	-

Table C4.1. Medica, Decision makers, Comparing the criteria for Outsourcing vs. In-house

Criteria	Respondent weight(RW)	Outsourcing performance (OP)	In-house performance (IP)	Rel. Weighted P. Ratio RW*(IP-OP)
Quality	-	-	-	-
Resources	Medium (0.264)	Medium (0.304)	0.328	0.01
Benefit/Sacrifices	Low (0.369)	High (0.421)	0.316	-0.04
Solution expectations	Low (0.187)	Low (0.188)	0.441	0.05
Contractual considerations	Low (0.180)	Medium (0.376)	0.217	-0.03

*Negative values means that in-house needs to improve

Table C4.2. Medica, Decision makers, Comparing the sub-criteria for Outsourcing vs. In-house

Sub-criteria	Respondent Weight(RW)	Outsourcing Performance (OP)	In-house performance (IP)	Rel. Weighted P. Ratio RW*(IP-OP)
Quality of service	-	-	-	-
Quality of equipment	-	-	-	-
Quality of repair	-	-	-	-
Human resources	0.424	0.376	0.320	-0.02
Structural resources	0.191	0.223	0.298	0.01
Relational Resources	0.384	0.254	0.351	0.04
Cost Savings	1	0.421	0.316	-0.1
Control	-	-	-	-
Convenience	-	-	-	-
Service interface performance	0.198	0.286	0.333	0.01
Range of product-services	-	-	-	-
Innovation	0.802	0.158	0.474	0.3
Nature of contract	0.160	0.316	0.263	-0.01
Pricing	0.345	0.391	0.174	-0.1
Risk adverse	0.495	0.385	0.231	-0.1

Table C4.3. Medica, End users, comparing the criteria for Outsourcing vs. In-house

Criteria	Respondent weight(RW)	Outsourcing performance (OP)	In-house performance (IP)	Rel. Weighted P. Ratio RW*(IP-OP)
Quality	Medium (0.213)	High (0.304)	0.348	0.01
Resources	Medium (0.238)	Medium (0.372)	0.191	-0.04
Benefit/Sacrifices	Medium (0.239)	High (0.513)	0.244	-0.1
Solution expectations	Low (0.169)	Medium (0.355)	0.333	-0.003
Contractual considerations	Low (0.142)	Low (0.286)	0.393	0.02

*Negative values means that in-house needs to improve

Table C4.4.Medica, End users, comparing the sub-criteria for Outsourcing vs. In-house

Sub-criteria	Respondent Weight(RW)	Outsourcing Performance (OP)	In-house performance (IP)	Rel. Weighted P. Ratio RW*(IP-OP)
Quality of service	0.856	0.298	0.351	0.05
Quality of equipment	-	-	-	-
Quality of repair	0.144	0.333	0.333	0
Human resources	0.713	0.369	0.146	-0.2
Structural resources	0.174	0.324	0.288	-0.01
Relational Resources	0.114	0.476	0.286	-0.02
Cost Savings	-	-	-	-
Control	0.549	0.714	0.143	-0.3
Convenience	0.451	0.381	0.309	-0.03
Service interface performance	0.357	0.370	0.286	-0.03
Range of product-services	0.594	0.348	0.362	0.01
Innovation	0.049	0.345	0.310	-0.002
Nature of contract	0.457	0.333	0.417	0.04
Pricing	0.543	0.250	0.375	0.07
Risk adverse	-	-	-	-

Table C5.1. Insula, Decision makers, Comparing the criteria for Outsourcing vs. In-house

Criteria	Respondent weight(RW)	Outsourcing performance (OP)	In-house performance (IP)	Rel. Weighted P. Ratio RW*(IP-OP)
Quality	Medium (0.245)	High (0.403)	0.340	-0.02
Resources	Medium (0.294)	High (0.397)	0.368	-0.01
Benefit/Sacrifices	-	-	-	-
Solution expectations	Medium (0.262)	Medium (0.354)	0.520	0.04
Contractual considerations	Medium (0.200)	Medium (0.333)	0.417	0.02

*Negative values means that in-house needs to improve

Table C5.2. Insula, Decision makers, Comparing the criteria for Outsourcing vs. In-house

Sub-criteria	Respondent Weight(RW)	Outsourcing Performance (OP)	In-house performance (IP)	Rel. Weighted P. Ratio RW*(IP-OP)
Quality of service	0.502	0.435	0.348	-0.04
Quality of equipment	0.382	0.400	0.300	-0.04
Quality of repair	0.116	0.273	0.455	0.02
Human resources	0.531	0.398	0.361	-0.02
Structural resources	0.226	0.411	0.384	-0.01
Relational Resources	0.242	0.385	0.369	-0.004
Cost Savings	-	-	-	-
Control	-	-	-	-
Convenience	-	-	-	-
Service interface performance	0.289	0.396	0.450	0.02
Range of product-services	0.711	0.333	0.556	0.2
Innovation	-	-	-	-
Nature of contract	0.549	0.333	0.417	0.05
Pricing	0.451	0.333	0.417	0.04
Risk adverse	-	-	-	-

Table C5.3. Knuaf, End users, comparing the criteria for Outsourcing vs. In-house

Criteria	Respondent weight(RW)	Outsourcing performance (OP)	In-house performance (IP)	Absolute Improvement Ratio (RW/OP)	Rel. Weighted P. Ratio RW*(IP-OP)
Quality	-	-	-	-	-
Resources	High (0.307)	Medium (0.306)	0.328	1	0.01
Benefit/Sacrifices	Medium (0.204)	Medium (0.289)	0.350	0.7	0.02
Solution expectations	High (0.324)	Medium (0.335)	0.382	1	0.02
Contractual considerations	Low (0.129)	High (0.400)	0.300	0.3	-0.01

*Negative values means that in-house needs to improve

Table C5.4. Knuaf, End users, comparing the sub-criteria for Outsourcing vs. In-house

Sub-criteria	Respondent Weight(RW)	Outsourcing Performance (OP)	In-house performance (IP)	Absolute Improvement Ratio (RW/OP)	Rel. Weighted P. Ratio RW*(IP-OP)
Quality of service	-	-	-	-	-
Quality of equipment	-	-	-	-	-
Quality of repair	-	-	-	-	-
Human resources	0.486	0.361	0.277	1.3	-0.04
Structural resources	0.248	0.344	0.336	0.7	-0.002
Relational Resources	0.266	0.143	0.429	1.8	0.1
Cost Savings	-	-	-	-	-
Control	0.288	0.300	0.400	1	0.03
Convenience	0.712	0.285	0.331	2.5	0.03
Service interface performance	0.437	0.319	0.370	1.4	0.02
Range of product-services	0.563	0.348	0.391	1.6	0.02
Innovation	-	-	-	-	-
Nature of contract	-	-	-	-	-
Pricing	1	0.400	0.300	2.5	-0.1
Risk adverse	-	-	-	-	-

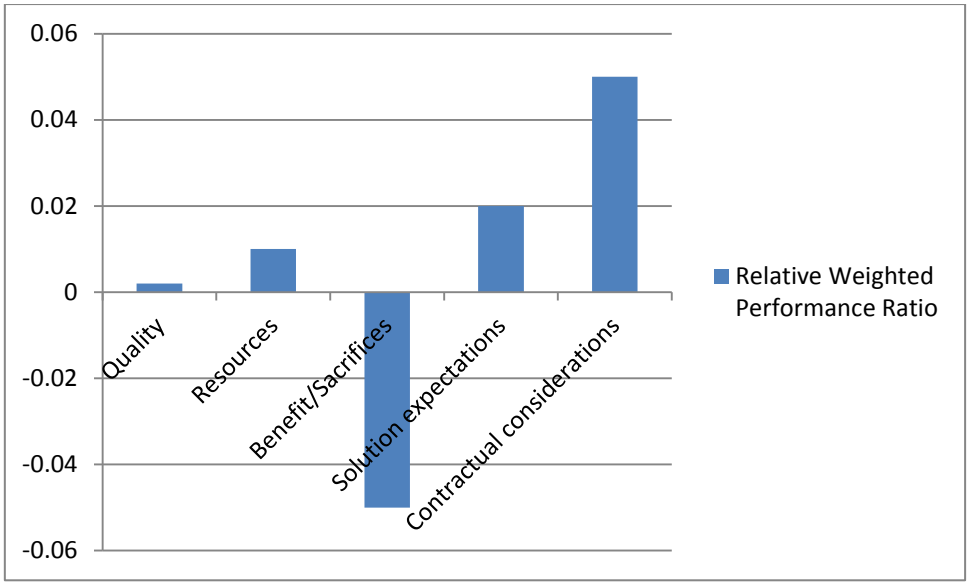


Figure 1a. Metal, Decision Makers, comparing the criteria for In-house vs. Outsourcing

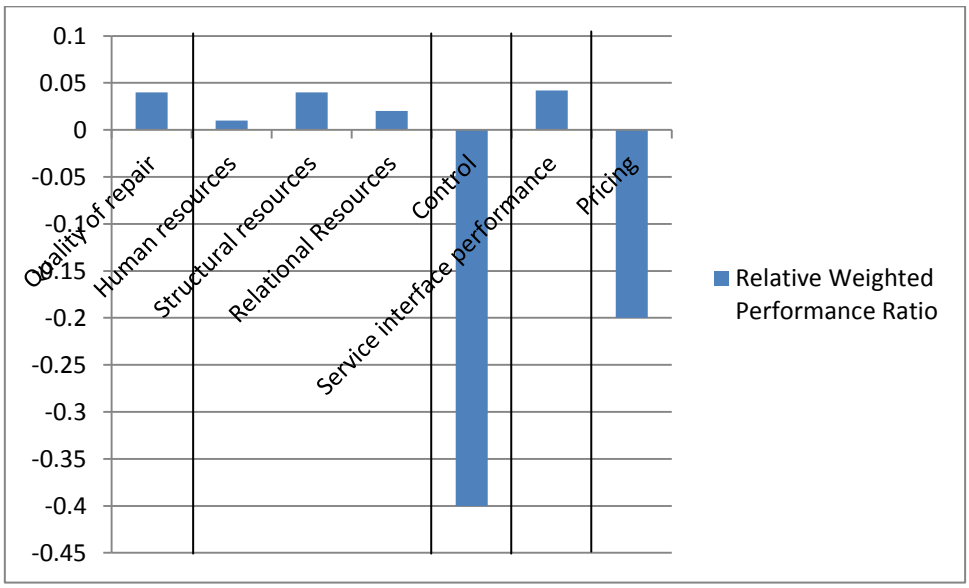


Figure 1b- Metal, Decision Makers, comparing the sub-criteria for In-house vs. Outsourcing

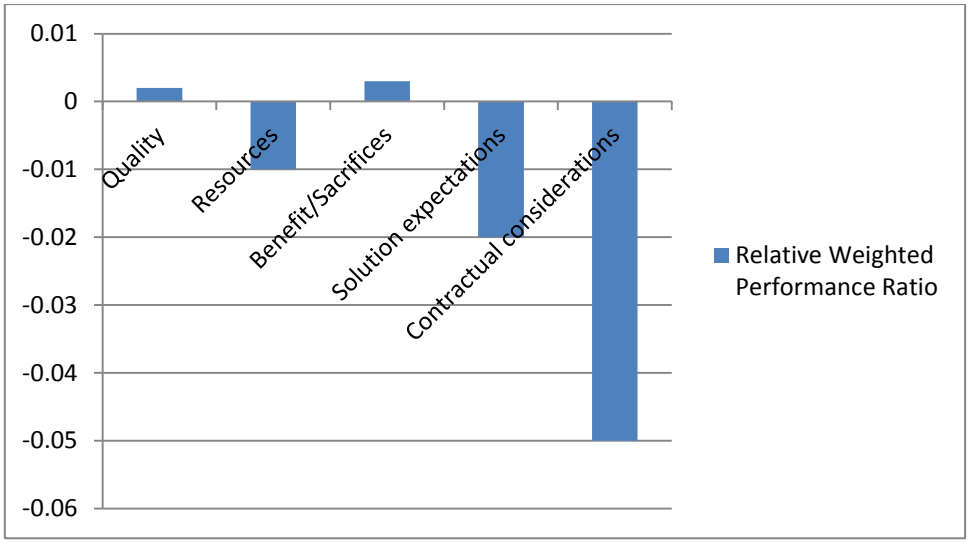


Figure 1c. Metal, End-Users, comparing the criteria for In-house vs. Outsourcing

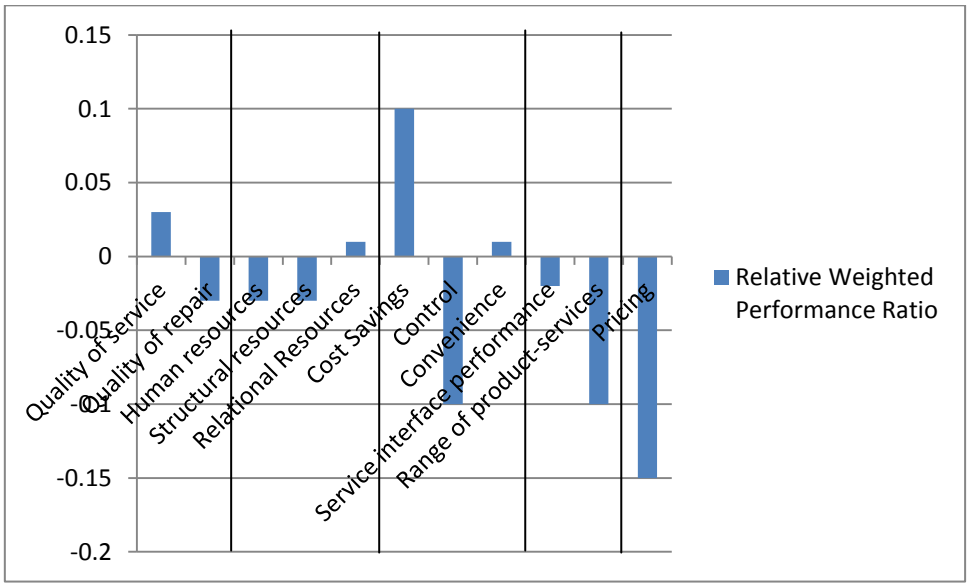


Figure 1d. Metal, End-Users, comparing the sub-criteria for In-house vs. Outsourcing

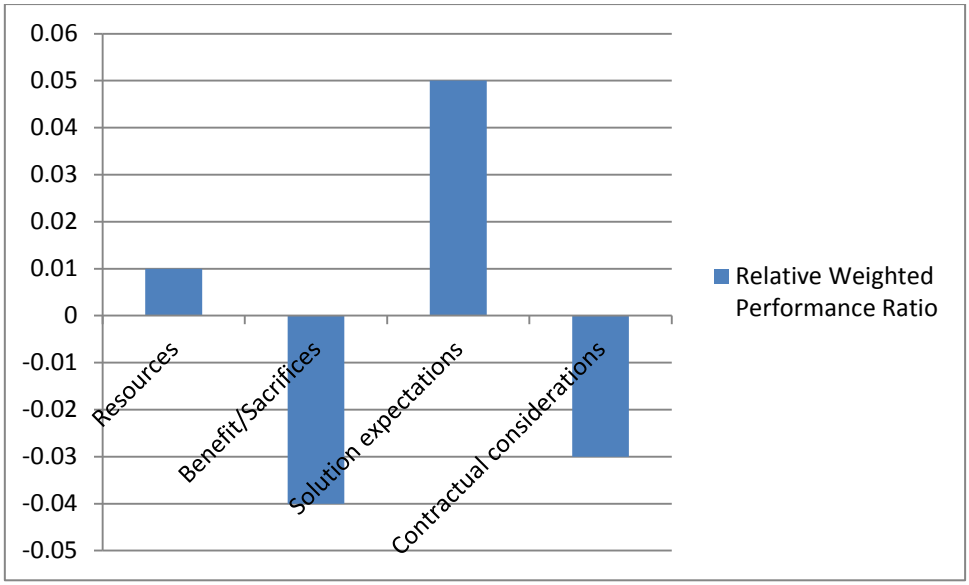


Figure 2a. Metal, Decision Makers, comparing the criteria for In-house vs. Outsourcing

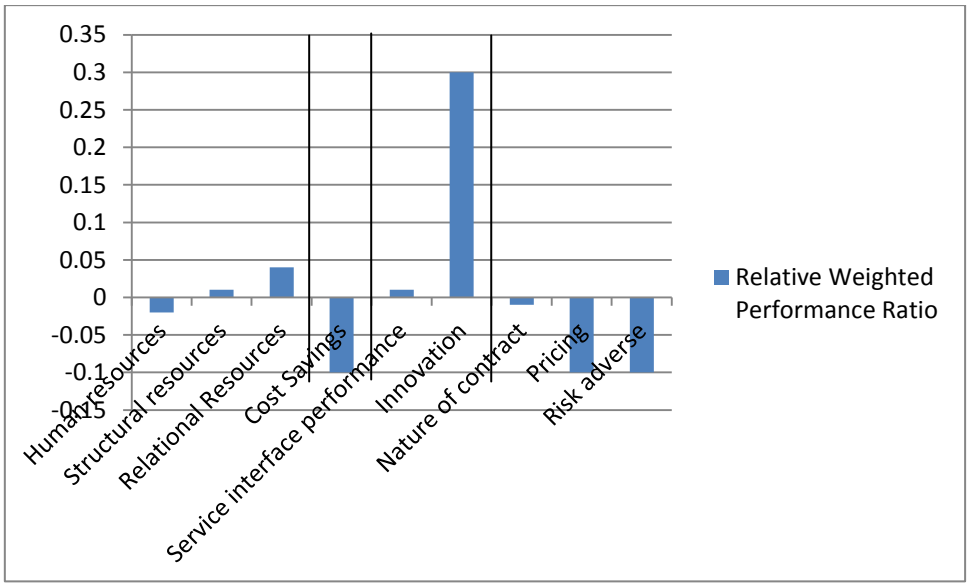


Figure 2b. Metal, Decision Makers, comparing the criteria for In-house vs. Outsourcing

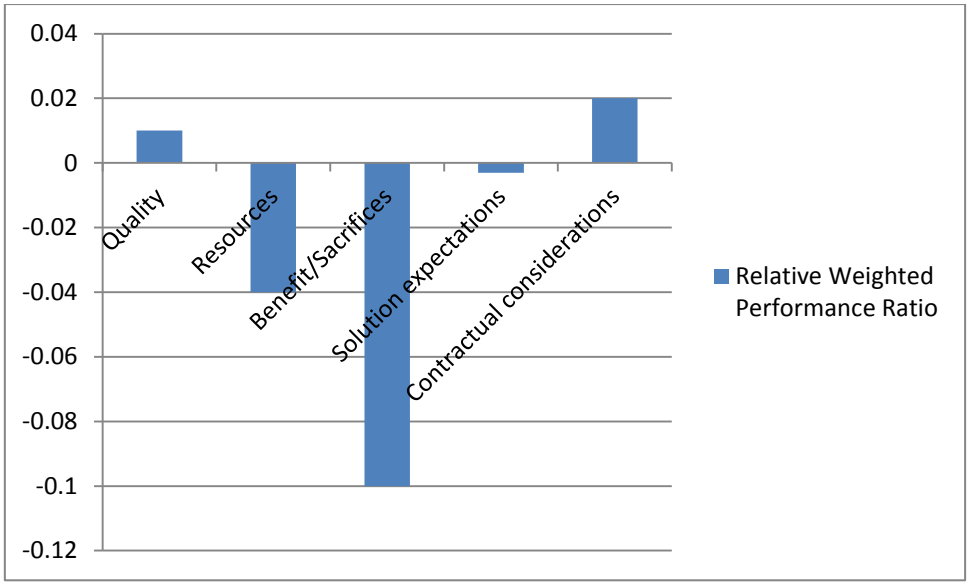


Figure 2c. Metal, End-Users, comparing the criteria for In-house vs. Outsourcing

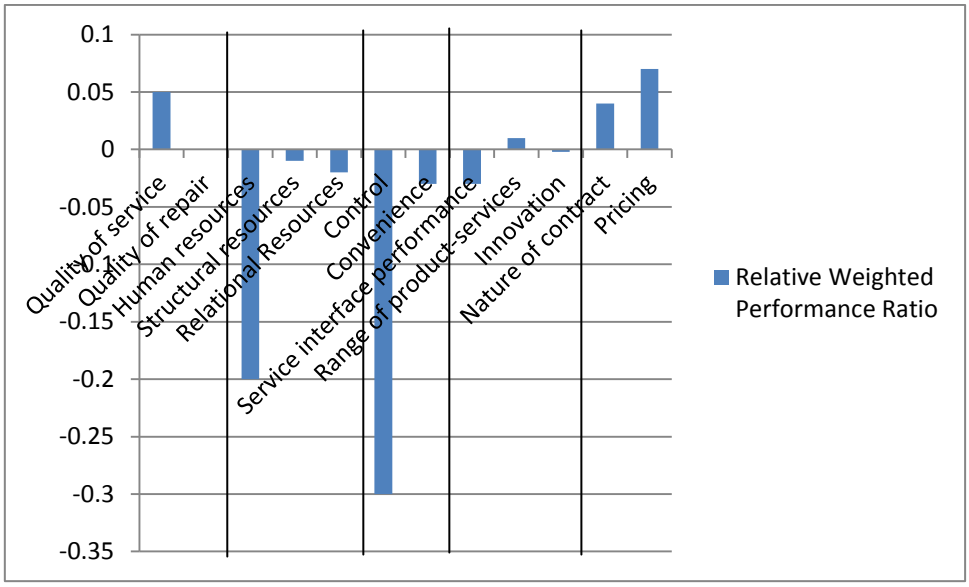


Figure 2d. Metal, End-Users, comparing the sub-criteria for In-house vs. Outsourcing

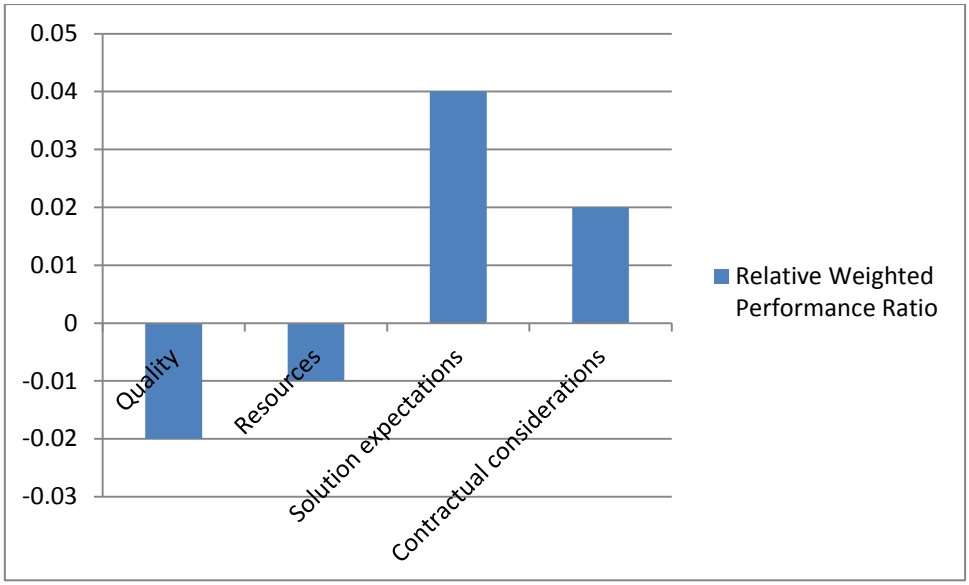


Figure 3a. Insula, Decision Makers, comparing the criteria for In-house vs. Outsourcing

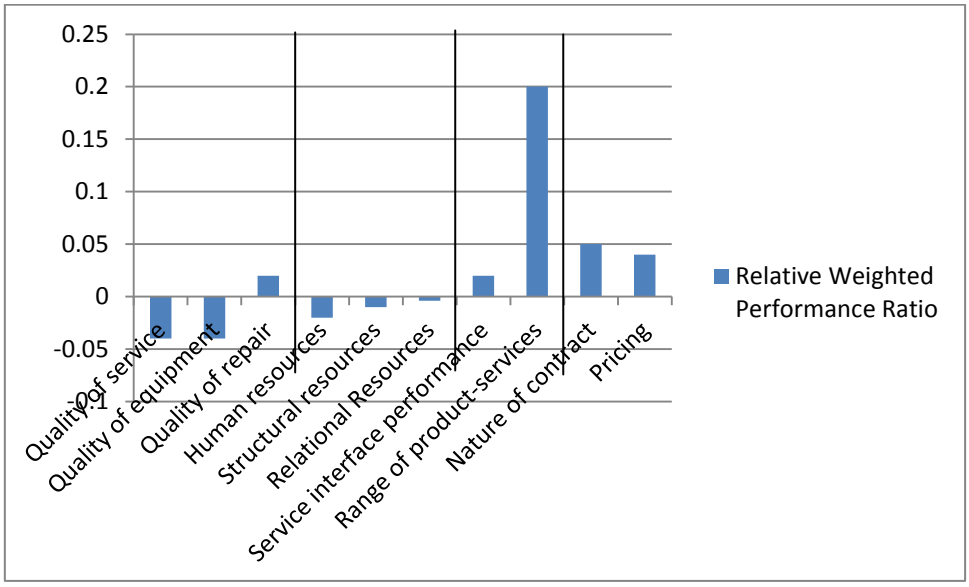


Figure 3b. Insula, Decision Makers, comparing the sub-criteria for In-house vs. Outsourcing

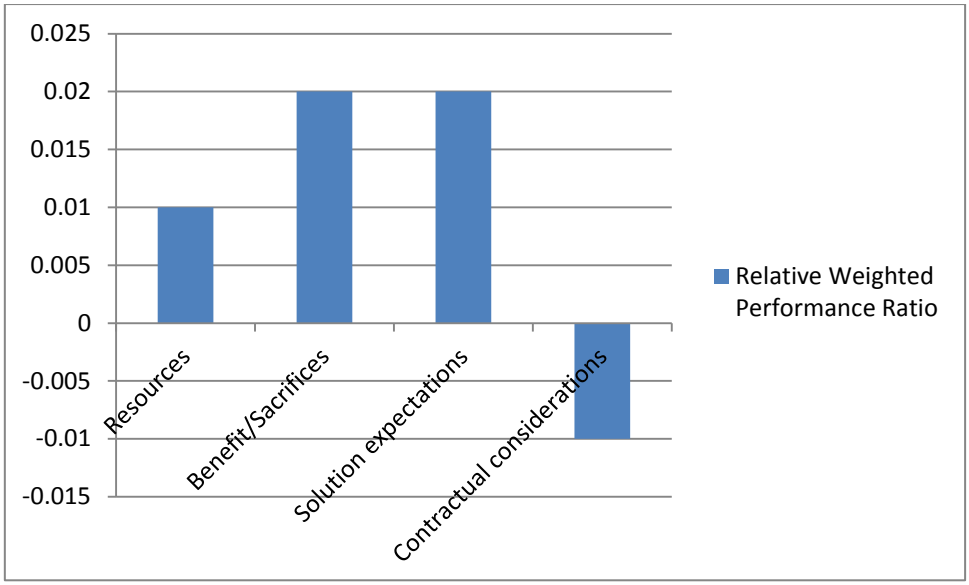


Figure 3c. Insula, End-users, comparing the criteria for In-house vs. Outsourcing

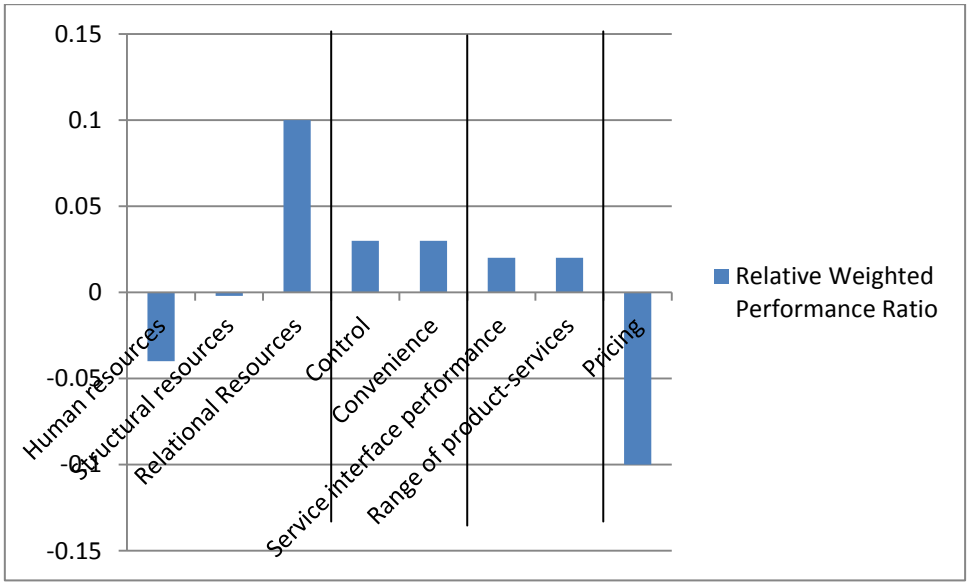


Figure 3d. Insula, End-users, comparing the sub-criteria for In-house vs. Outsourcing

Appendix D- Comparing Maintenance Design Methodologies

Maintenance Program Design Models		Inputs																Organizational Level			
		Failure Data			Repair Data	Process Data		KPIs												Cost-Centric	Value-Centric
		Failure Rate	Failure Cause	Failure Effect	MTTR	Plant Register	Plant Inventory	Quality	Availability	Cost: Mainten./ Asset replacement/Training	Production cost	Capital Cost	Profit	Insurance premiums	SHE	Work orders completed in time	Technical Productivity	Intangible values	Operational	Strategic		
	RCM	●	●	●		●	●	●	●	●					●				●		●	
	FMECA	●	●	●		●	●	●	●	●					●				●		●	
	T. Rosqvist et al.	●	●	●		●	●	●	●	●					●		●		●	●	●	●
	VDM						●		●	●					●	●	●		●	●		●
	Karen B.Marais	●								●			●						●			●
	Basim Al-Najjar's	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●		●	●	●	●
	AHP*	●			●			●		●	●	●		●	●			●**	●	●	●	●

* Bevilacqua M, Braglia M,"The analytic hierarchy process applied to maintenance strategy selection", Reliability Engineering and System Safety Journal, 2000

** Image damage, know-how

Marais K, Saleh J, "Beyond its cost, the value of maintenance: An analytical framework for capturing its net present value", Reliability Engineering and System Safety Journal, 2008

Rosqvist T, Laakso K, Reunanen, "Value-driven maintenance planning for a production plant", Reliability Engineering and System Safety Journal, 2007

Al-Najjar B," The lack of maintenance and not maintenance which costs: A model to describe and quantify the impact of vibration-based maintenance on company's business", Int. Journal of Production Economics, 2006

Appendix E- Publications List

Journals:

- Toossi A., Lockett H., Raja J., Martinez V., “Assessing the Value Dimensions of Outsourced Maintenance Services”, Submitted to the Journal of Quality in Maintenance Engineering
- Macdonald E. K, Wilson H, Martinez V, Toossi A, “Assessing Value-in-Use: A Conceptual Framework and Exploratory Study”, accepted for the Journal of Industrial Marketing Management special issue Service and Solution Innovation, Apr 2011
- Toossi A., Lockett H., Greenough R., Macdonald E.K. and Roozendaal E., “Maintenance outsourcing: A step towards Product-Service Systems”, Maintenance and Asset Management Journal, Vol. 25 No. 3, May/June 2010

Conferences:

- Toossi A., Lockett H., Raja J., Martinez V., “Understanding the use value dimensions of Outsourced maintenance services”, Advances in Production Management Services conference, Italy, Oct 10
- Macdonald E.K., Wilson H., Martinez V. and Toossi A. , “Assessing the Value-In-Use of Integrated Product-Service Offerings: A Repertory Grid Approach”, 18th Annual Frontiers in Service conference, USA, Oct 09
- Toossi A., Ghodrati B., “Monitoring the Condition of Rolling-element and Plain Bearings”, 4th International Conference on Maintenance, Tehran, Nov. 07