A Simulation Based Continuous Improvement Approach for Manufacturing Based Field Repair Service Contracting

Abstract:

This paper develops and tests a novel extension to traditional supplier selection practice, with a particular focus on the concluding stages of a manufacturing based field service. Action based research was used to design and develop a discrete event simulation (DES) decision support for a large multinational manufacturing organisation with a significant after sales service supply chain. The framework has been designed to identify and validate the value attributable to collaborative supplier contracting with built in costed performance improvement targets. Use of the framework in the case organization was found to produce greater cost savings over traditional practice, facilitating extended supply chain contracts. The results provide evidence of the high level of savings achievable whilst also improving customer delivery through targeted service improvements over the contracts life cycle. This framework advances beyond the prevalent practice of cost focused short term adversarial supply contracting and is innovative in terms of its continuous improvement simulation based framework design.

Keywords: supplier selection; product service systems; continuous improvement; discrete event simulation;
1. Introduction

In recent times, manufacturing based services have continued to grow in terms of influencing customer choice in product selections, while also proving attractive for organisational profit growth. The traditional boundary between manufacturing and services is becoming increasingly blurred (Datta and Roy 2010; Hypko, Tilebein, and Gleich 2010) with increasing interest in adapted supply chains such as Product Service Systems (PSS) (Lockett et al. 2011). For these reasons service based programmes are continuing to evolve and grow in terms of importance in the manufacturing sector (Ahn and Sohn 2009). In addition, it is also well recognised that the provision of excellent supply chain service is noted as a potential foundation for assuring customer retention and loyalty (Wilson, Bostrom, and Lundin 1999; Ahn and Sohn 2009), which in turn leads to increased product sales and potential continued profit expansion. Equally, however poor service provision for manufacturing based services can erode customer retention and negatively impact continued profit growth.

Outsourcing as a trend is likely to continue into the future (Liston et al. 2008). In manufacturing, service purchasing is often referred to as supply chain “component services” (Wynstra, Axelsson, and Valk 2006), and involves outsourcing to specialized service providers so as to allow the manufacturing firm to continue to focus on their core manufacturing processes. When suppliers provide part of the total service to the customer, the supply chain transforms to a triad (Li and Choi 2009), with integrated service solutions leading to high dependency on the specialized skills and capabilities of service suppliers (Finne and Holmström 2013). A large share of the outsourced service operations becomes part of the buying organization’s value proposition to its customers where they are purchased (Wynstra, Spring, and Schoenherr 2014). However, many organizations experience difficulties in effectively organizing the transactions and relations involved in buying and managing services (Ellram, Tate, and Billington 2007; Valk and Rozemeijer 2009), although opportunities for increasing profits through more effective purchasing for service buying is large (Valk and Rozemeijer 2009). (Li and Choi 2009) suggest that there is a lack of understanding of the dynamic nature of such triadic relationships among service buyers, service suppliers, and the buyer's customer which leads to many failures in outsourcing services in supply chains, thus suggesting a need to incorporate more advanced techniques into the ongoing management and improvement of such relationships. In a similar
way (Chalal, Boucher, and Marques 2015) suggest that while the transition towards the integration of services in manufacturing organisations provides for strong opportunities of new business model development and implementation, the industrial transformation to such business models means decision-makers are confronted with high decisional complexity. They conclude that this presents a concrete need for developing servitization decision support systems (DSS), with a particular focus on DES.

According to (Saccani, Johansson, and Perona 2007; Amini, Retzlaff-Roberts, and Bienstock 2005; Wilson, Bostrom, and Lundin 1999), after sales service have been categorized into three main activities; 1) field technical assistance, encompassing, installations, training, product upgrade, software services, check-up, routine maintenance, repairs (warranty work and out of warranty repairs), and product disposal, 2) spare parts distribution, spare part inventory management, delivery of spare parts, direct and reverse flows, and customer order management, 3) customer care, providing technical and commercial information and services such as product registration, warranty extension, and complaint management to end users. Examples of manufacturing based services include payment plan services, installation, maintenance, repair, spare parts supply, basic and extended warranties, training, online, phone, consulting, upgrade… etc. (Saccani, Songini, and Gaiardelli 2006). The integrated product-service offerings are distinctive, long-lived, and easier to defend from competition based in lower cost economies (Baines et al. 2009).

The shift towards service operations requires manufacturers to focus on their relationship capabilities (Brax 2005). A PSS changes the relationship between the manufacturer and the customer from a single point transaction (e.g. product purchase from manufacturer) to an ongoing relationship where the manufacturer continues to provide services to the customer throughout the life of the PSS (Lockett et al. 2011). As manufacturing firms make the transition towards increased service offerings, provided by external third parties, they do so steeped in the tradition of manufacturing based principles and associated supplier selection strategies. (Luo et al. 2009) based on an earlier classification by (de Boer, Labro, and Morlacchi 2001) broadly categorise supplier evaluation and selection methods into three main stages: 1) Criteria formulation; 2) Qualification, in which suitable suppliers are identified; and 3) Choice, in which a selection is made. In an extension of this categorisation (Luo et al. 2009) suggested the addition
of a new fourth stage ‘Application feedback’, as future research directions, which incorporates an element of continuous improvement to identify the strengths and weaknesses of the recently completed selection process with a view to improving subsequent supplier selection applications. (C. Wu and Barnes 2011) propose that this phase has not been adopted by other researchers and that such a stage is important and necessary in today’s competitive environment.

This paper addresses a number of identified research gaps in the traditional supplier selection practice literature. Traditional partner selection involves determining criteria for outsourcing, followed by a qualification of potential suppliers then concluding with a final selection of partner(s), with this final step in recent years typically being carried out using reverse auctions. The paper extends the work of (Byrne et al. 2013) through the presentation of a performance based contracting framework for use in the final stage of a supplier selection process for manufacturing based service contracting. At the centre of this framework is a DES based continuous improvement approach, which is encapsulated in a collaborative negotiation process between manufacturer and an individual service provider. Based on this premise, this paper proposes an innovative decision support framework which builds on the concept of cross party participation (i.e. across the manufacturer and service provider in the later stages of a strategic supplier selection exercise), with built in performance improvement targets detailed within the contract, which have been verified, costed and agreed upon for the duration of the contract life cycle. More specifically this framework has been designed to support: 1) collaborative continuous improvement by the manufacturer and service provider to support: 2) finalisation of an agreed service offering, including specific pricing points and contractual time horizons, 3) identification, evaluation and agreement on process improvement initiatives to be conducted over the life cycle of the contract, and 4) agreement on the sharing of identified cost savings and/or profit increases across both organisations achieved from actions taken in step 3 over the contract life cycle.

The remainder of the paper is organized as follows. Section 2 reviews the literature focusing on the manufacturing after sales services, supplier selection problem, and in particular the manufacturing field service performance based contracting and modelling. Section 3 presents the proposed performance based conceptual framework showing how the extended supplier selection works and also showing services analysis and a costing architecture. Section 4 describes the DES
model formulation and development illustrating a real case analysis example and showing the DES model validation. Section 5 presents the DES based negotiations between both the buyer and supplier with continuous improvement initiatives proposals and evaluations. Section 6 presents the main research findings and discusses the opportunities for future work.

2. Literature Review

This section first highlights after sales services demonstrating its importance in evolving manufacturing. We then overview the main approaches used in supplier selection and the role of performance based contracting in services highlighting the role of DES as a collaborative based tool.

2.1 After sales services

It is well acknowledged that service provision in addition to product sales is a common competitive practice (Kurata and Nam 2010; Neely 2008; Lockett et al. 2011). The offering of product-service solutions in the form of after sales services, warranties and extended warranties in addition to products offerings for customers, can be an important source of revenue, profit, and competitive advantage in most manufacturing industries (Cohen, Agrawal, and Agrawal 2006; Cohen and Kunreuther 2007; Gaiardelli, Saccani, and Songini 2007; Saccani, Johansson, and Perona 2007). After sales service is considered a key revenue generator in certain industries (Cohen and Seungjin Whang 1997; Cohen, Agrawal, and Agrawal 2006), where the margins from after sales service is much larger than that from a product (Kurata & Nam, 2010). In some industries it has been reported that manufacturers can achieve revenues equivalent to four times their product price from after sales service (Bundschuh and Dezvane 2003; Alexander et al. 2002). In addition, after sales services can contribute towards new customer attainment (Chien, SHEU, and CHEN 2005) in markets with severe brand competition and towards customer retention and new product development (Choudhary et al. 2011; Kurata and Nam 2013; Saccani, Johansson, and Perona 2007; Gaiardelli, Saccani, and Songini 2007; Cohen and Seungjin Whang 1997). Maintenance support involves cost-sharing arrangements, which include fixed-price and cost-plus contracts (Kim, Cohen, and Netessine 2007).

In order to compete in a manufacturing-service environment, it is imperative that companies carry out detailed assessment of such service offerings from a cost perspective in order to stay
competitive (Datta and Roy 2010), with (Ellram, Tate, and Billington 2007) suggesting that there is very limited understanding of the cost and quality drivers and structures associated with procured services. In supply management, buying services is not a replica of the process associated with purchasing industrial goods (Wynstra, Axelsson, and Valk 2006; Valk and Rozemeijer 2009). The process of creating and defining value across the service supply chain is not as straightforward as the manufacturing supply chain, since multiple actors, including the customer, are involved in service design, production, and delivery and the value cannot be transformed, transported, or inventoried in the same way as industrial goods (Giannakis 2011; Selviaridis and Norrman 2014).

2.2 Supplier selection

The criticality of supplier selection to overall supply chain performance is well documented in the literature (González, Quesada, and Monge 2004; Dursun and Karsak 2013; Chai, Liu, and Ngai 2013; Byrne et al. 2013). However, choosing the right supplier involves much more than scanning a series of price lists (Ho, Xu, and Dey 2010). The supplier selection problem is by its nature multi-dimensional and can include many different variables, such as quality, price, payment terms, lead time and reliability.

(Najla Aissaoui, Haouari, and Hassini 2007) suggest that most of the literature has been focused on the buyer’s perspective, with a clear need to move towards the inclusion of the buyer and seller in the negotiation process. Furthermore, the majority of published articles on supplier selection methods have tended to focus on product based systems (e.g. Degraeve, Labro, & Roodhooft, 2004; Dursun & Karsak, 2013; Kuo & Lin, 2012). However, in recent times a small number of articles have begun to focus on supplier selection methods for service based systems (B. Feng, Fan, and Li 2011; Huber and Spinler 2012; Amini, Retzlaff-Roberts, and Bienstock 2005; Byrne et al. 2013). Services by their nature are hard to evaluate in advance of their purchase, thereby complicating supplier selection (Valk and Rozemeijer 2009). Due to the complex nature of service provision there is a clear need for dedicated DSSs (Chalal, Boucher, and Marques 2015).

A wide array of solution approaches to the supplier selection problem can be seen in the literature. These papers can be broadly categorised into those that use a single modelling

In addition, (Wadhwa and Ravindran 2007) present and compare three multi-objective optimization methods which are weighted objective, goal programming and compromise programming.

Moreover, integrated approaches represent a significant proportion of the modelling techniques presented for the supplier selection problem in the literature. In particular AHP is a commonly used technique in this integrated approach. A selection of papers using AHP in an integrated approach for supplier selection include: (Wang, Huang, and Dismukes 2005) - pre-emptive goal programming; (Kull and Talluri 2008) - goal programming in the presence of risk measures and product life cycle considerations; (Mendoza, Santiago, and Ravindran 2008) - a three-phase methodology using ideal solution approach and goal programming; (Çebi and Bayraktar 2003) - using lexicographic goal programming; (Ghodsypour and O’Brien 1998) - linear programming; (Xia and Wu 2007) - multi-objective mixed integer programming; (Scott, Ho, and Dey 2013) - quality function deployment; (Felix T.S. Chan and Kumar 2007) - fuzzy extended analytical hierarchy process (FEAHP) including risk factors; (Ramanathan 2007) - TCO and DEA; (Bottani
and Rizzi 2008) - cluster analysis and Fuzzy logic; (F. T. S Chan 2003) - Expert Choice software; and (Y.-M. Chen and Huang 2007) - bi-negotiation agents. Other integrated approaches (not including AHP) are also used such as (Singh 2014) - an algorithm based on TOPSIS and MILP approaches, (Garfamy 2006) - DEA and TCO, (Omurca 2013) - fuzzy c-means and rough set theory, (Kannan et al. 2013) - fuzzy multi attribute utility theory and multi-objective programming, (Jolai et al. 2011) – fuzzy TOPSIS and multi-period goal programming, (Dursun and Karsak 2013) - fuzzy multi-criteria group decision making and QFD (quality function deployment).

A number of papers have applied simulation to the supplier selection problem. The studies of (Ding, Benyoucef, and Xie 2003; Ding, Benyoucef, and Xie 2005) propose a DES optimization approach for supplier selection for the supply of boots by a distribution company. In these papers the optimisation model utilise genetic algorithms (GAs) to configure the supply network and the DES model takes the GA inputs and evaluates relevant key performance indicators (KPI). In addition two papers present an analysis of a range of mathematical techniques using monte carlo simulation using the same general input data set (D. Wu and Olson 2008) and (Azadeh and Alem 2010). In these instances (D. Wu and Olson 2008) used monte carlo simulation: in combination with chance constrained programming (CCP), data envelopment analysis (DEA), and multi-objective programming (MOP) and (Azadeh and Alem 2010) in combination with Data Envelopment Analysis (DEA), Fuzzy Data Envelopment Analysis (FDEA), and Chance Constraint Data Envelopment Analysis (CCDEA). However, these papers have been applied to the product supplier problem and not to product services and none of these papers have used DES modeling for collaborative negotiations as proposed in this paper.

2.3 Performance based contracting and modelling

As organisations become more dependent on suppliers the direct and indirect consequences of poor decision making become more severe (de Boer, Labro, and Morlacchi 2001). As this dependency grows there has been a move away from shorter term adversarial contracts towards longer term relationships with suppliers for strategic and crucial items (Byrne et al. 2013; Ho, Xu, and Dey 2010) and there is currently a change of focus in contracting from traditional contracts toward performance-based contracts (Hypko, Tilebein, and Gleich 2010; Kim, Cohen, and Netessine 2007). Contracting and incentive systems may be useful in specifying and
managing customers’ and subcontractors’ inputs into service production and delivery (Selviaridis and Norrman 2014). Performance based contracting is shown to be particularly useful for aligning incentives and risk sharing across the service supply chain, since payment is tied to end customer performance (Selviaridis and Norrman 2014) and using performance based contracting along the after sales service supply chain can lead to improved services and reduced costs (Kim, Cohen, and Netessine 2007). In the presence of uncertainty associated with performance, cost sharing is still an effective tool (Kim, Cohen, and Netessine 2007).

2.4 Research Gap

From an examination of the literature it is obvious that there is a growing interest in and need for advancement in supplier selection methodologies for service provision. To date research in this domain has focused almost exclusively on product based systems. This in combination with the increasing prominence of product based service offerings highlights the need for more research to be carried out in this domain. In recognising this opportunity it is also important to take cognisance of the well documented characteristics which differentiate product and service offerings. The framework presented in this paper attempts to address this gap and extend the existing literature base by focusing on supplier selection for manufacturing based service offerings. In doing so the paper extends the supplier selection literature beyond its current predominantly product focused boundary. The framework also builds on the growing body of research which advocates the movement towards longer term contracts (Prajogo and Olhager 2012) and collaborative supply chain agreements and partnership (Aissaoui, Haouari, and Hassini 2007) in contrast to more traditional adversarial practices. Such longer term partnerships are developed around the key cornerstone of planned continuous improvement over the contract life cycle, especially in the area of service provision (Selviaridis and Norrman 2014). From a review of the modelling approaches presented in the literature it is clear that simulation in general and more specifically DES has to date been under utilised in the field. The development of a DES modelling approach presents the opportunity on which cross party negotiations can be developed and facilitates the movement towards longer term collaborative supply chain agreements and partnership.

3. Conceptual Framework Design
The conceptual framework presented hereafter was developed using an action based research approach with a large multinational computer manufacturing organisation with a significant after sales service supply chain. The framework, which has been designed, validated and successfully implemented in the case organisation, is presented in this paper in such a way so as to allow for replication across varying industrial scenarios and to maintain data anonymity for the case organisation. The framework was designed and tested over a 12 month period with strong interaction between researchers and the case organisation. First this section presents the extended supplier selection framework and then describes the architecture for its implementation.

3.1 Extended supplier selection framework

The proposed supplier selection framework (Figure 1) extends traditional supplier selection strategies (Luo et al. 2009) to include a collective roundtable negotiation stage introduced for the purpose of developing longer term contracts with suppliers which are underpinned by continuous improvement over the life cycle of the contract. For this, it is assumed that traditional supplier selection strategies are used by the buyer to reduce the potential supply market base to a single (or small number of) candidate supplier(s) for deeper shared engagement and collective negotiation between the buyer and each potential supplier – e.g. each individual service provider from the potential shortlisted suppliers (Figure 1). This paper proposes the use of a DES model to facilitate the roundtable negotiations between buyer and supplier representatives. The DES based roundtable negotiations method, emerged from the action based research to facilitate better supplier integration into the process with an overall goal of facilitating extended contracting while simultaneously achieving ongoing cost reductions and improved service quality over the contract life cycle, which is not to the detriment of either party. This directly enables a move away from the common practice of traditional or typically adversarial cost orientated short term contracting directed almost solely by the buying organisation parties.

The simulation model presented in this paper is used as the prediction base for how the service supply chain will perform based on the collective input parameters provided by both buyer and supplier during final roundtable negotiations. The simulation model is a representation of the service supply chain under review and is an additional step to the normal supplier selection process, allowing for the evaluation and testing of process improvement initiatives as part of the negotiation process. This process is an innovative and novel alternative for existing more
adversarial techniques, such as electronic reverse auctions leading to enhanced performance and reduced costs over longer contract horizons.

The purpose of this collaborative activity is to together identify the expected performance targets for the service supply chain, define process improvement initiatives for the life time of the contract and negotiate final costings and benefit sharing where applicable. In many instances this exercise, will be used when the potential supply pool has been reduced to one or only a small number of potential suppliers.

3.2 Framework architecture

At the core of the proposed extended strategic supplier framework is an ability to experiment with a DES model, which is configured for the required after sales service supply chain during the later stages of the supplier selection process. The DES model is, 1) driven by factual data from a process and cost perspective, and 2) has the ability to be redefined (experienced with) as part of the final negotiation process. The architectural design for the software for the strategic supplier framework is presented in Figure 2. The extended component of the strategic supplier...
framework consists of two primary modules – The “Live Service” component and the “Services Costing” component.

The “Live Service” component represents the real world service provision scenario where real world data associated with enacting the pre-existing service is recorded and stored in the organisational “Service Operations Database”. As an example some of the following types of data are stored and updated in this database on a regular basis including: the number of units sold per product type, the number of customer calls per product type, the geographic region per call type, the number of failures for each fail category for each product type, the spare part requirements per fail type, the actual times taken to complete each customer call including repair and transit times.

The “Services Costing” module is at the core of the proposed extension and is used to evaluate the cost and quality of service associated with service provision into the future and to evaluate the impact of a proposed process improvement prior to implementation. The “Service Operations Database” module in combination with manual or semi-automated inputs (as part of the supplier
selection exercise and/or the roundtable negotiation process) is used to populate this module for the services under review. This module consists of three sub components – a GIS (Geographic Information Systems) tool, a service model database and a DES model. The GIS tool is used to geographically locate customers and assists in technician allocation and travel time determination. The service model database is used to locally store transformed model relevant data. This database provides the inputs to and receives the results from the DES model. The simulation model has been developed to represent the service scenario. The model operates on a given set of logic and translates real service data (where it exists) into statistical distributions representing the performance of pre-existing suppliers thus enabling future stochastic evaluation of service scenarios and; hence, continually improving future negotiations and contracting with service suppliers. A more detailed illustrative example of the simulation model and its experimental basis is presented in Section 4. The roundtable negotiations process, facilitates alternative scenario evaluation to take place, through a GUI (Graphical User Interface) of the service model database. The model can then be run and the results presented back to the participants through the database GUI without the need to experiment with the simulation model. This exercise can be repeated a number of times and is completed as part of a negotiation activity with one or a small number of potential service providers in the final stage of a supplier selection process (Figure 1).

4. Simulation Model Formulation

To illustrate the approach, the remainder of the paper presents a generalised version of a manufacturing after sales field repair service scenario based on the case organisation under review. This representation is equally applicable across a broad array of after sales service types such as installation, maintenance/repairs, upgrades, etc. and across a broad array of organisational types.

4.1 Case Analysis: Manufacturing after sales field repair services

As is evidenced in the literature and supported by case analysis in this paper, the manufacturing after sales field repair service consists of a number of common key actors and processes. In many instances the after sales field repair service is outsourced thus evoking the need for supplier selection. To execute the service, potential supply chain partners must typically be able to deliver a team of individuals with the requisite skills and expertise (usually administrative and technical) to address consumer enquiries, engage resource teams and spare parts logistically and
execute successful repair. To complete this, service supply chain networks must be designed, which include geographic region definition; personnel hub location(s); inventory hub location(s); resource pool categories – e.g. technician levels and numbers; transportation network selection; routing logic for technicians; routing logic for spare parts; break fix repair times; and associated costing models. A standardised after sales field service, dictated by the manufacturer (see Figure 3), consists of the following key actors:

- **Customer**: refers to the person who has bought a product or system with an associated after sales field repair service and in this instance has suffered from a product or system failure.

- **Technical Support Team**: this refers to the technical support party who receive customer calls, identify and diagnose problems, follow-up customer complaints, coordinate between all departments working in the after sales field repair service, and forward customer calls to the service provider (if a separate entity). This can be resourced and managed by either the manufacturing organisation or the outsourcing provider.

- **Field Repair Service Provider**: this refers to the party who manages and controls the technician resource pools. They have overall responsibility for assigning suitable technicians to each customer call, constructing and optimising each technician schedule, scheduling spare part inventory transport to customer (by technician or third party), and ensuring a successful repair for each customer.

- **Logistics Provider**: this refers to the party (usually a third party) who manages the storage (both centrally and in regional hubs) and distribution of these spare parts through the field repair service supply chain and to the final customer.
Figure 3: Generic manufacturing after sales field repair service

To illustrate the general interactions between these four actors a standardised Business Process Model and Notation (BPMN) model for the case organisation is presented in Figure 3. In this instance the process is triggered when a consumer, who has already purchased (or received) an after sales service (e.g. a warranty) with a physical product has a product failure and the customer contacts the manufacturers technical support line to request a field repair service. In
many instances as depicted here by swim lanes, the after sales field repair service is completed by a third party to the manufacturer.

The technical support team identifies the origin of the call and in the case of new calls attempts to resolve the issue remotely. In the event of a call out requirement the details of the issue are recorded and passed on to the field repair service provider, along with any potential spare part requirements (which are also communicated to the logistics provider). The field repair service provider manages the technician resource pool for each regional area and develops a routing schedule based on the field repair requirements on any given day. Therefore, after receiving the request, the service provider schedules the technician visit to the customer based on the problem and spare parts requirements. This schedule has to be completed taking the service level agreement that is in place between the manufacturer and each individual customer. In the case of expedited field repair service requirements the technicians are routed directly to customers with spare parts separately transported by the logistics provider. In the case of less urgent field repair (e.g. normal service) the technician collects all required spare parts at an allocated inventory hub and carries these directly to the customers location. In the case of unsuccessful repairs, a subsequent call is scheduled with spare parts determined by the technician while onsite during the unsuccessful repair.

After receiving a spare part request, the logistics provider checks on the spare part availability. If the spare part is available, the logistics provider allocates the spare part and arranges spare part transportation to the assigned inventory location point for the assigned technician (for normal services) or to the customer location directly (for expedited services). If it is a case that the spare part is not available in stock, the logistics provider places an order with the vendor (or manufacturer). In the case of an expedited service the logistics provider informs the field repair service provider of the expected spare part delivery time at the customer location to reduce unnecessary technician waiting time.

Within the case study company it was found that the process presented in Figure 3 was standard across all service providers, with each individual service provider modelled by populating this DES model with instance data for that service provider.
4.2 Simulation model development

Based on the scenario description presented in Figure 3, a DES based service supply chain has been developed, with a particular focus on the after sales field repair service. To ensure generalisation and broad application the model has been derived from a combination of case analysis and scenario definitions presented in the literature. The purpose of the model is to represent the real world scenario associated with the execution of an after sales service (in this case the field repair service). The model is required to capture the consumption and interacting logic of resources in the model (e.g. personnel, inventory, transport, etc.) and to represent proposed decision making. The DES models a single Pick-Up and Drop-Off (PUDO) where repair requests are stochastically generated based on real repair demand and location with technicians assigned by the service provider according to Figure 3. The model is stochastically driven and can be run using evaluated distributions based on historical real data or can be substituted by potential future state scenarios provided through expert opinion. In addition to the model structure and logic there is a costing module which is based on activity based costing for all actions in the model. The model has been designed using a hierarchical structure and an object oriented simulation modelling package (Plant Simulation). The database tables in the DES model are populated with input data which is taken directly from the live system, from the “Service Operations Database” and then transformed if required through the “Database GUI” in the local “Service Model Database”. In many instances this data is transformed to allow for experimentation with future state scenarios. For example, increasing or decreasing the demand quantities for this service type by a percentage (e.g. 20%, 50%, etc.), while still maintaining its existing data characteristics (e.g. standard deviation). In a similar fashion its data characteristics can be altered while maintaining its existing demand quantities or indeed both could be altered. Table 1 presents the main model inputs. A description of the inputs and an illustrative scenario is presented in Section 5 based on a scenario from the case organisation, with the structural representation remaining representative.
### Table 1: Simulation model inputs

<table>
<thead>
<tr>
<th>Main Model Inputs</th>
<th>Input Description and Case Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufactured Products</td>
<td>The manufacturer sells 9 different product types for which repair services are required.</td>
</tr>
<tr>
<td>Number of calls per day</td>
<td>Customer calls per day, categorised by product and repair type. This is based on a 5 day working week.</td>
</tr>
<tr>
<td>Field repair service technicians</td>
<td>The number of different repair service technician categories. The more complex repairs can only be assigned to the highest level of repair service technicians. 3 different levels (L1, L2 and L3) based on their skills with the following breakdown (50%-30%-20%).</td>
</tr>
<tr>
<td>Technician level capacity</td>
<td>Upper limit in relation to the number of calls a technician can serve in any working day. This is based on repair types and associated repair times.</td>
</tr>
<tr>
<td>Multiple tag rates</td>
<td>A requirement to repair more than one unit at the same location at the same time.</td>
</tr>
<tr>
<td>Service level agreements (SLAs)</td>
<td>The number of different individual repair service agreements based on number of product types and their repair categories.</td>
</tr>
<tr>
<td>SLA per technician level</td>
<td>Service technicians scheduled on specific SLAs with defined frequencies based on expertise level. Highest repair service technician levels (technician L3) can be scheduled to all repair types, but their time is limited to only a small proportion of lower levels repairs.</td>
</tr>
<tr>
<td>Exception rates and repeat visits</td>
<td>Repairs not resolved by technicians on their first customer visit. Possible causes - additional faults and original misdiagnosis. Each SLA has a defined proportion of exceptions and repeat visits based on historical experience.</td>
</tr>
<tr>
<td>Failures</td>
<td>Defined failures for each SLAs.</td>
</tr>
<tr>
<td>Repair time</td>
<td>Defined repair times for each SLAs.</td>
</tr>
<tr>
<td>Transport time</td>
<td>Defined transport times based on technician movements for different customer types and locations.</td>
</tr>
<tr>
<td>Administration time</td>
<td>Defined administrative times categorised based on call type, multiple tags, and exception rates.</td>
</tr>
<tr>
<td>Spare parts</td>
<td>Times and costs associated with dropping-off defective spare parts and picking-up new spare parts at different defined inventory location points.</td>
</tr>
</tbody>
</table>

Following full configuration the model is run for the required number of replications (in this paper 30 replications) for the contract duration specified (e.g. 1 year, 2 years, 5 years etc.). As the model is running it is collecting and recording costs using an activity based costing methodology and analysing service performance. Specifically the total costs per Service Level Agreements (SLA) are calculated from the summation of the following four individual cost categories:

- Administration costs – the cost of personnel administration time
- Transportation costs – the cost of transport and personnel transit time
- Inventory location costs – the cost of inventory pick up time
• Repair costs – the cost of personnel repair time

The simulation model is developed and configured separately to each individual supplier with the previous inputs and outputs in order to facilitate the roundtable negotiations process of exploring cost reduction opportunities through continuous improvement where the participating parties (i.e. buyer and single or individual supplier representative) can use the developed simulation model through the database GUI to model process improvement initiatives and to evaluate the cost savings which can be achieved. These savings can also be broken down into a number of costed performance measures that would help in evaluating the effectiveness of each proposed improvement to service provision. Implementation of the improvement opportunities will take place after the savings have been agreed and negotiations finalised.

4.3 Model validation

The case simulation model developed as part of the described extension to traditional supplier selection was validated by conducting a, 1) structured walk-through, and 2) sensitivity analysis. The structured walk-through was conducted with members in the buyer company working directly with the service outsourcing process in addition to service managers with knowledge of the service provider’s business. A complication was the lack of knowledge within the buyer company to how the service provider actually provided the service. Thus personnel within the buyer company had to gain knowledge of this process through, for example, travelling with the repair person on a call, understanding how the PUDO worked and studying the detailed data generated by the buyer database documenting how this service is provided. This is an important outcome of this approach over the traditional or adversarial approaches which were used within the buyer company.

Over time personnel within the buyer company gained a complete understanding of the provider’s field repair service process. This was an iterative process, where if costs significantly exceed those quoted by the providers then the cost model or data assumptions used in the model were re-examined. Likewise, if costs are excessively low then the model may include anomalies thus requiring further verification and validation. Following this iterative process of validation, amendments were made to the model.
In addition, sensitivity analysis was conducted to examine the effect of changes to demand information and service performance metrics on service costs. When planning the sensitivity analysis on the final model, discussions were conducted with service managers to identify a range of experiments that would provide useful insight into the cost effects of possible changes to demand and service performance metrics (representing possible changes to the services in the future). The selected experimental factors included: i) the percentage of tasks dedicated to the case organisation by the service provider, ii) product breakdown mix and iii) technician wages. The costs associated with factor i) above (activities performed by the technician for all organisations) are apportioned based on the percentage of the technician’s daily tasks dedicated to the case company. The input values used to represent the percentage of a technician’s tasks dedicated to the case company are informed assumptions; therefore, experimentation is important to determine the cost impact of this factor. In all instances the variables were adjusted by ±20% to determine the impact on overall results. Figure 4 shows the experimental analysis results for a certain service class, where the service cost (activity based service cost) for each experimental case are compared against the cost results for the current scenario.

Figure 4: Example sensitivity analysis results

In the case of the current scenario the results show that the service cost is estimated using 30 replications. For factor i) above a slight and proportional change to the service cost resulting in an increase in costs of 2.44%, with a decrease in this factor giving a proportional decrease in
costs. Changing factor ii) had a minimal effect on costs, which would be expected as a particular product over another within a given SLA has a negligible effect on service cost, due to the similarity of the repair complexities. Experimentation on factor iii), technician wages, demonstrates the largest effect to service cost, which approximately corresponds to the magnitude of percentage changes to the wage (i.e. where the technician wage is increased by 20% results in a corresponding increase in service cost of almost 20%). It can be observed that technician wages have a major impact of cost of service.

Following the structured walkthrough and sensitivity analysis the model was declared valid by the case organisation for use in their partner selection negotiations.

5. Simulation Based Negotiations
To successfully implement the modelling framework presented above, it is necessary for the supplier selection team to obtain detailed data from potential suppliers through the Request for Quotation process. In the initial stages of a traditional supplier selection process the selection team will need to identify sources of data required. This will primarily involve data related to operational management of the service (such as resources, organisational dedication, geographical locations, etc.), proposed timings with the operational set-up (e.g. repair times, transit times, etc.) and associated costings. Following a reduction in the potential supply base using traditional supplier selection strategies to one (or possibly a small number) of shortlisted suppliers, the process of completing the final collaborative negotiations based on simulations started (see Figure 1). What is unique about this approach, as compared with traditional approaches is the intended purpose of collectively negotiating a longer term contract through an open and transparent process between buyer representative and each individual service provider.

The base line scenario represents the configuration of the buyer service supply chain design according to historical data of pre-existing suppliers with identified field repair service operations demand, requirements, timings, and costs. Each one of shortlisted suppliers proposes his service offering costs. Simulation based negotiations allow for rapid evaluation of the existing base line proposal of the shortlisted suppliers in an individual manner. In addition to identifying process improvement pathways the decision support platform allows for rapid evaluation of the modified service offering based on the proposed process improvements
initiatives through simulation experimentation and quantification of the overall impact on cost and performance (positive, negative or neutral), thus providing a basis for informed decision making. The incentive for both parties in identification of cost savings and/or profit increase is the implications of profit/cost sharing by both parties and longer term business satiability through extended contracting timeframes. DES lends itself well to such decision support as it provides a flexible platform which has the capacity to rapidly evaluate a wide range of potential improvement scenarios taking stochastic variation into account within the negotiation process itself.

5.1 Contract Negotiations – Continuous Improvement Evaluations

The results from the decision support simulation based model present all parties with an insight into the potential effects of process / organisational change on the cost of service, both positively and negatively. This process enables informed extended supplier contracting (e.g. longer contract timeframes) with built in performance improvement targets, which have been verified, costed and agreed upon for the duration of the contract life cycle period. The simulation based decision support system allows for rapid scenario evaluation across a broad spectrum within the confines of negotiations with limited timeframes available. The quoted cost scenario by the outsourcing company is the starting position towards the specification of an agreed service offering between the buyer and supplier organisation and will be developed prior to the negotiation process. This quoted scenario is then used to initiate negotiations, where process evolution, contractual timelines, and associated contract pricing points are evaluated and agreed upon. It is the flexibility of scenario evaluation power of DES which adds significantly to the traditional supplier selection strategies.

The general procedure for process change evaluation involves the following three steps:

1. Review service performance statistics resulting from the data analysis performed to date using the quoted cost scenario and process intelligence on the buyer and supplier side.
2. Identify areas for potential improvement.
3. Investigate the cost impact of implementing changes identified in the previous step using a DES model.
5.2 Process improvements

In this subsection we illustrate how the simulation model can be used to support collaborative negotiations, by describing four example experiments that followed a review of the service performance statistics for the case presented in this paper (see Table 2).

Table 2: Roundtable Negotiations – Process Improvement Simulation Evaluation

<table>
<thead>
<tr>
<th>Process</th>
<th>Items for Evaluation</th>
</tr>
</thead>
</table>
| Exp 1: Repeat visit rate | **Identified Issue:** The high percentage of SLA calls that result in a repeat visit.  
**Proposed Improvement:** To reduce through root cause evaluation causes of repeat visits  
**Method:** Build on service intelligence and reduce/eliminate – e.g. incorrect diagnosis, availability of the customer to provide access, incorrect address information. Minimal investment required – better processes.  
**Considerations:** Cost savings from reduced repeat visit rates, better quality experienced by customer. |
| Exp 2: Call allocations to technicians | **Identified Issue:** Maximum call allocations per technician per day – perceived as being low.  
**Proposed Improvement:** To evaluate the perception of low call allocations in light of above changes and increased availability of technicians.  
**Method:** Build on service intelligence and remove cap on allocations per day. Allocations based on evaluated routing and issues.  
**Considerations:** To explore the cost benefit of increasing the number of calls allocated to each of the technician levels. |
| Exp 3: Spare parts usage per repair | **Identified Issue:** Excessive number of parts being used during a repair. Past practice – to maintain high first time fix levels a policy of identification of ‘most likely’ faults is followed and replacement parts order accordingly. This has led to a practice where technicians are often replacing all collected parts during a repair even though only one part may be required.  
**Proposed Improvement:** The proposed initiative aims to improve the diagnosis process and technician awareness of actual issue when onsite so as to reduce the number of parts used in a repair while maintaining quality levels in terms of ‘first time fix’ success rates.  
**Method:** Better procedures for fault diagnosis. Technician training.  
**Considerations:** Cost savings due to reduction in spare part usage. Technician training and fault diagnostic costs. |
| Exp 4: Repair training for | **Identified Issue:** Overtraining of technicians as new products is brought to market. A number of new products may be introduced each month, however many of these products |
technicians may be similar with identical repair requirements as previous versions.

**Proposed Improvement:** To evaluate the training needs of technicians more closely. Develop a training matrix against which new products can be evaluated and need for additional training identified.

**Method:** Evaluation of training needs based on past training undertaken. Schedule new training on a needs determined basis.

**Considerations:** Cost savings due to increased availability of technician in field. Reduction in training costs.

The first of these service performance initiatives experiment 1 (Exp 1) focuses on the percentage of an SLA’s calls that result in a repeat visit, the objective of this initiative is to realise cost savings by reducing this statistic, which will involve tackling the main causes contributing to the need for a repeat visit. Some of the main causes for a repeat visit include; incorrect diagnosis, availability of the customer to provide access to the technician, incorrect address information. Each of the previous contributing factors can be reduced with minimal investment on the buyer’s part (i.e. the cost incurred by the buyer to affect the proposed improvements) which will result in improved quality for the customer (less disturbance and higher proportion of first time fixes) and reduced cost for the service provider (fewer repeat visits required). The simulation model is once again used to model and cost the proposed reductions to the repeat visit rates of each SLA, which are in the region of 50%.

The second experiment (Exp 2) focuses on the number of call allocations for each level of technician. An example allocation for a service provider is shown in Figure 5, which shows that 60% of the time level 2 and level 3 technicians are assigned only 1 call. The purpose of this experiment is to explore the cost benefit of increasing the number of calls allocated to each of the technician levels to an average of 5 calls for level 1 technicians and an average of 3 calls for both level 2 and level 3 technicians. This improvement initiative also utilises the simulation model to evaluate the cost impact of the proposed operational performance changes.
Experiment 3 (Exp 3) focuses on the number of parts used during a repair, to maintain a high level of first time fixes, an important goal of the buyer company. The buyer company staff technicians identify the ‘most likely’ faults and order parts accordingly, which the service provider technicians then install. This can often result in multiple parts being replaced during a repair even though only one part may be required. The proposed initiative aims to improve the diagnosis process and reduce the number of parts used in a repair while maintaining quality levels in terms of ‘first time fix’ success rates. Once again the activity based cost simulation model is used to examine the potential cost benefits of introducing this change. The goal in the experiments are that 70% of faults must be satisfactorily repaired with only 1 part and a further 25% with only 2 parts, the remaining 5% will be repaired with no more than 3 parts.

The final experiment focuses on technician training, in particular the procedures used to train technicians on the repair of product failures. To ensure a consistent and high level of quality, technicians must be highly trained to successfully carry out the necessary repairs. It is important to remember that the training requirements of technicians are determined based on the qualification level, technicians with a higher qualification tend to be assigned to more complex repairs in addition to a larger range of potential product failures, therefore, more training is required. A number of new products may be introduced each month which necessitates a high level of training by the technicians even though many of these products may be similar with identical repair requirements. This initiative will focus on reducing technician training costs by
optimising training procedures to reduce the training of technicians each time a new product is introduced with the same repair procedures.

5.3 Evaluation of process improvements

The cost saving predictions for the four service performance improvement initiatives (experiments 1, 2, 3 and 4) are presented in Figure 6, which total service cost savings over the originally quoted cost. Considering the size of SLA2 (greater than 70% of total call volume) our attention is drawn to the predicted cost benefits on this service group. Referring to Figure 6 the results show that the proposed increases to technician call allocations (Exp 2 see Table 2) will provide the largest cost savings in the region of 5%. Predicted savings from a reduction to the repeat visit rate (Exp 1) are estimated at almost 3% while savings achieved from reducing the number of parts used in a repair (Exp 3) are estimated at less than 2%. Of all the service performance initiatives evaluated technician training presents the least savings potential estimated at less than 1%. Across all the SLA the greatest savings can be achieved by imaging SLA 5, where the predicted total service cost savings are much greater at approximately 10% in the case of a reduction to the repeat visit rate (Exp 1). This considerable saving can be attributed to greater volume of repeat visits in the case of SLA5 and a reduction to this statistic has a larger impact on savings.
Following individual evaluation of the four proposals as shown in Figure 6 there was acceptance across the negotiation team as to the positive value of each of these initiatives in their own right. Following a series of discussions it was decided by the negotiation teams to investigate the combined impact of implementing all four initiatives. To perform this analysis the simulation model was employed to model the combined effect of these initiatives and cost accordingly which helps in the identification of pathways for continuous improvement implementation over the life time of the contract where some of the initiatives will be implemented immediately at the beginning of the contract while others will be implemented incrementally over the period of the contract.

Figure 7 illustrates the total margin for further cost reductions, comparing between the service provider quote price and the total service cost estimate for the implemented initiatives. The SLA 2 category provides the least savings potential estimated at greater than 17%. In the case of SLA 5 the margin for savings is substantially greater at almost 29%. These figures outline the considerable scope for future reductions subject to the implementation of the proposed initiatives.
At the end of the collaborative negotiations and general outsourcing process both parties must come to an agreement on the terms of the contract, some of the common terms and conditions outlined in this contract include:

- Actors / parties involved.
- The responsibilities of each actor.
- The duration of the contract.
- Pricing conditions.

Each of these terms are standard in traditional contract agreements, however, alterations are required based on the motivations and results of this extended collaborative negotiations selection strategy.
6. Discussion

One of the primary amendments relates to the duration of the contract, in the past contracts in the case organisation were only valid for a period of 1 year at which point the outsourcing process was repeated. An exploration of adversarial supplier selection strategies (e.g. reverse auctions) has suggested that their repetitive nature have a number of negative findings relating to difficulties maintaining strong partnerships and the willingness of their partners to share information, (Gattiker, Huang, and Schwarz 2007). Under this innovative approach, new contract partnerships are formed for a number of years – e.g. 3, 4, 5 etc. In addition to longer term contracts, identified service improvements present scope for continued cost reductions within the services. To execute these cost reduction opportunities parties must agree the terms and conditions of implementation, such as; the responsibilities of each party, constraints under the new contract, agreed savings, and a time plan for implementing each of the agreed cost reduction initiatives. In the presented case, some of the improvements are quickly and easily implemented such as; increasing the number of customers allocated to a technician, optimising the training processes, and reducing the number of parts used for repair. A tool like simulation, which has flexibility in its modelling, can capture costs based on a process to support profit sharing distributed over the life time of the contract based again on collaborative negotiation, taking into consideration the risks and investments of both parties.

7. Conclusions

Manufacturing based field services are a key competitive priority for many modern manufacturing supply chains (Cohen, Agrawal, and Agrawal 2006; Cohen and Kunreuther 2007; Gaiardelli, Saccani, and Songini 2007; Saccani, Johansson, and Perona 2007). After sales service is seen by many as a major contributor to revenue generation (Cohen, Agrawal, and Agrawal 2006; Cohen and Seungjin Whang 1997), and in certain industries the revenues earned from after sales service is significantly greater than that achieved from the product sale in isolation. By their very nature after sales field repair services are of strategic importance to a manufacturing based organisation that wishes to retain and grow its customer base.

In many instances after sales field repair services are delivered through outsourced third party providers, thus requiring the execution of a suitable supplier selection process. The literature
shows that a significant body of work is presented on strategic supplier selection, however very little has been presented on service based support systems. Based on case analysis and a review of the literature, this paper suggests that although it is well recognised that long term partnerships are of benefit (Ho, Xu, and Dey 2010), and even more crucially for service based outsourcing, few buyer-supplier scenarios are built on a long term platform and even fewer tend towards combined collaborative evolvement and process improvement over the contract life cycle.

The decision support framework presented in this paper is an extension to the traditional supplier selection process and allows collective negotiations to: 1) specification of an agreed service offering, including pricing points and contractual time horizon, 2) identification, evaluation and agreement on process improvement initiatives to be conducted over the life cycle of the contract, and 3) agreement on the sharing of cost savings and/or profit increases across organisations achieved from actions taken in step 2 over the contract life cycle. Within this research a discrete event simulation model is used to capture the complexities of the after sales field repair service supply chain and evaluate its stochastically to support continuous improvements.

Unlike the majority of other decision support techniques presented in the literature, the simulation based platform allows for rapid evaluation of a wide array of alternative scenarios as is necessary in real time negotiations. Such a platform instils confidence in both parties as to the veracity of the decision making due to the combined process improvement initiatives and presents a strong foundation for cross party cooperation and collaboration into the future. This is in stark contrast to the use of more adversarial supplier selection techniques. In addition to providing for longer term partner stability the process has shown in the case organisation to provide benefits which far exceed anything that was possible using traditional methodologies. This was only made possible by the working together of both the buyer and supplier organisations. In the case reviewed additional total service cost savings of between 8% and 21% were identified as achievable across the 5 SLAs evaluated. What is also noteworthy is that these savings were on top of already factored in profit margins.

Although the framework has been used successfully in the case organisation, further testing is required on the sustainability to this approach to quantitative modelling within this company and to other PSS configurations found in other companies.
8. Bibliography


Ramanathan, Ramakrishnan. 2007. “Supplier Selection Problem: Integrating DEA with the Approaches of Total Cost of Ownership and AHP.” *Supply Chain Management: An*


