**A simulation based supply partner selection decision support tool for service provision in Dell.**

Byrne, P.J., Blake, P., Heavey, C. & Liston, P.. 2013. A Simulation Based Supply Partner Selection Decision Support Tool for Service Provision in Dell. COMPUTERS & INDUSTRIAL ENGINEERING, 64, 4, pp1033-1044.

## Abstract

*Partner selection is an important aspect of all outsourcing processes. Traditional partner selection, typically involves steps to determine the criteria for outsourcing, followed by a qualification of potential suppliers and concluding with a final selection of partner(s). Reverse auctions (RAs) have widely been used for partner selection in recent times. However, RAs, although proven successful in initial price reduction strategies for product and service provision, can suffer from reduced effectiveness as the number of executions increases.*

*This paper illustrates Dell's experience of such diminishing returns for its outsourced after sales product repair service and presents the development, of a new partner selection methodology which incorporates a new process improvement stage to be executed in combination with the final selection phase. This new methodology is underpinned by the development of a computer based simulation supply partner selection decision support tool for service provision. The paper highlights the significant additional cost saving benefits achievable and improvement in service through the use of advanced simulation based decision supports.*

**Keywords:** Supplier selection; reverse auctions; contract negotiation; after-sales services; computer based simulation;

# 1 Introduction

Research on supplier selection can be traced back to the early 1960s when it was termed vendor selection (Huang and Keskar, 2007). Supplier (partner) selection plays a crucial role in successful supply chain operation, enhancement and redevelopment. As outsourcing as a technique has become mainstream and continued to grow (Liston et al., 2008), the number and frequency of partner selection decisions has also grown. Over these years a variety of modelling approaches have been proposed to support supplier evaluation and selection. Detailed reviews of the literature on this topic are provided by de Boer et al. (2001), de Boer and van der Wegen (2003), Aissaoui et al. (2007), Luo et al. (2009), Ho et al. (2010), Wu and Barnes (2011) and (2012). In a comprehensive literature review of decision-making models and approaches in supplier selection Wu and Barnes (2011), suggest that construction of an effective and efficient partner selection model is one of the most important issues before such partnerships can be built.

de Boer et al. (2001) provide a classification of methods found in the literature grouping them into four categories according to their use in supplier evaluation and selection. The first two groups are concerned with the early stages of the outsourcing decision process and typically employ qualitative analysis tools. The latter two stages are primarily concerned with supplier approval, quotation analysis (price determination) and order allocation, employing quantitative analysis tools. In an extension of this work, Luo et al. (2009) re-categorised the de Boer et al. (2001), framework as comprising of three main stages: ‘criteria formulation’ and ‘qualification’ stages in which suitable suppliers are identified, followed by the ‘choice’ stage in which a selection is made. In this paper they extended the de Boer et al. framework to include a new fourth phase, which they termed ‘application feedback’, which incorporates an element of continuous improvement into the model. In a further evaluation of the concept of ‘application feedback’, 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. The paper presented here addresses this gap, but also extends this concept by developing a computer based simulation decision support tool for contract costing with a focus on phases 3 (final selection) and 4 (application feedback) of the Luo et al. (2009) framework simultaneously. In addition this paper also addresses a number of related gaps identified by Wu and Barnes (2011) in that it presents a descriptive empirical study, which is focused on a service operation in the area of manufacturing support, that prior to review, was extensively involved in electronic reverse auctions.

The remainder of the paper is organised as follows. Section 2 reviews the literature focusing in particular on the phase of the sourcing process called ‘price determination’ which involves establishing offers from one or more suppliers (Gattiker, Huang et al., 2007). Section 3 presents the problem formulation for the current supplier selection strategy in the case organisation – Dell, and in addition describes the service offering under review in this paper. Section 4 describes the case based research study under the following three headings: *(1) Improving the understanding of service delivery and performance, (2) Service cost analysis, and (3) Implementing the developed supplier selection and improvement strategy.* Section 5 presents the main research findings and opportunities for future work.

## 2 Literature review

Supplier selection is typically facilitated by either F2F negotiations or RAs; however, other tools in use include telephone negotiation, e-mail negotiation, paper sealed bidding, electronic sealed bidding, and electronic marketplaces (Gattiker, Huang et al., 2007). During the last decade RAs have grown in popularity in many cases replacing F2F negotiations as electronics and communications technologies have improved.

### *2.1 Reverse auctions*

Jap (2007) puts forward the argument that the use of online RAs is becoming a permanent fixture in industrial sourcing and in more recent times Hawkins et al. (2010) suggests that the RAs are maintaining this popularity. The popularity of RAs can be attributed to a number of factors, but in particular its ability to provide buyers with increased savings on price (Emiliani and Stec, 2002; Smeltzer and Carr, 2003; Arnold, Kärner et al., 2005; Hur, Hartley et al., 2006). Studies have shown that the greatest opportunity for savings occurs during the first use of RAs (Mabert and Skeels, 2002; Hur, Hartley et al., 2006) with documented savings in the region of 5 to 20 percent (Smeltzer and Carr, 2003). Beyond its first use, it has been documented that RAs provide diminishing savings in successive bidding events (Mabert and Skeels, 2002; Hur, Hartley et al., 2006; Schoenherr and Mabert, 2007), with Mabert and Skeels (2002) suggesting that the pattern of diminishing savings over time is exponential in nature.

There are several well documented benefits of using RAs from both the buyers and suppliers perspective (Emiliani and Stec, 2002; Smeltzer and Carr, 2002; Smart and Harrison, 2003; Smeltzer and Carr, 2003; Wagner and Schwab, 2004). From a buyer perspective the main benefits include cost savings (Emiliani and Stec, 2002; Smeltzer and Carr, 2003; Joo and Kim, 2004; Hur, Hartley et al., 2006), better market transparency (Emiliani and Stec, 2002; Smeltzer and Carr, 2003) and reduced cost in the outsourcing process due to standardisation and automation (Emiliani and Stec, 2002; Arnold, Kärner et al., 2005). From the suppliers perspective the main benefits include increased transparency on the target price and the possibility of capturing new business. In the case where products or services are purchased for the first time, the market may be subject to inefficiencies which can be minimised by online bidding events, as such RAs are a useful strategy for identifying the true competitive market price for a bid package (Schoenherr and Mabert, 2007).

Although RAs can provide many benefits for both buyers and suppliers, numerous risks exist which must be considered. On the suppliers side there are a number of risks associated with: (i) a reduction in the ability to build long term relationships (Smeltzer and Carr, 2003; Emiliani, 2004); (ii) pressures on incumbent suppliers to reduce their price with no guarantee of gaining new business (Van Tulder and Mol, 2002; Smeltzer and Carr, 2003; Emiliani, 2004; Caniëls and van Raaij, 2009); (iii) perceptions of opportunism and coercion that the use of RAs can create among participating suppliers (Jap, 2001; Smeltzer and Carr, 2002; Jap, 2003; Carter, Kaufmann et al., 2004; Carter and Stevens, 2007; Giampietro and Emiliami, 2007); (iv) unsustainable below cost selling by suppliers to gain business (Smart and Harrison, 2003; Smeltzer and Carr, 2003).

On the buyers side the main risks include; (i) deterioration in trust between the buyer and supplier where a good relationship existed previously (Smeltzer and Carr, 2003; Carter, Kaufmann et al., 2004; Emiliani, 2004; Tassabehji, Taylor et al., 2006; Carter and Stevens, 2007); (ii) the lack or perceived lack of buyer's commitment may lead to a supplier not investing in tooling, employee training or other capital investments (Smeltzer and Carr, 2003; Emiliani, 2004); (iii) lack of supplier participation (Emiliani and Stec, 2005); (iv) too few suppliers could result in a non-competitive RA environment (Smeltzer and Carr, 2003).

### *2.2 Alternative supplier selection methodologies*

Critics of RAs suggest that savings boasted by advocators of the strategy fail to consider all the costs that are incurred across the supply chain (Chen, Roundy et al., 2005); thus implying that the savings may be exaggerated (Emiliani and Stec, 2002; Emiliani, 2004; Emiliani, 2005). Furthermore, a study by Tassabehji et al. (2006) reported that most buyers and suppliers do not possess adequate costing systems to qualify the full transaction costs of RAs.

Several papers provide guidelines on the best use of RAs, with particular focus on the potential pitfalls (Schoenherr and Mabert, 2007; Schoenherr, 2008; Hawkins, Gravier et al., 2010). To address the appropriateness of using RAs, Hawkins et al. (2010) suggest that sourcing managers consider the strategic factors (e.g. competition and expected savings) influencing its suitability for a particular sourcing situation as well as the internal and social factors (e.g. prior eRA satisfaction). It is recommended that RAs are best suited to commodity purchasing (Parente et al. (2004), Tassabehji et al. (2006)), or where the purchase price constitutes the largest value component (Jap 2002).

For buyers that find themselves in the position where they have exhausted the benefits of RAs what are the alternatives? Emiliani (2004) suggests that buyers should move away from power based bargaining (i.e. RAs) in favour of collaborative knowledge sharing networks once the benefits of RAs have been exhausted. Emiliani (2004) further states that the collaborative approach should embrace the use of collaborative problem solving routines and furthermore, these processes should be continually improved over time. They also suggest that this should include the development of disciplined inter-organisational cost management capabilities with continuous improvement which will have a much greater value, leading to lower costs, higher quality, enables faster response time to changing market conditions. Emberson and Storey (2006) also advocates the move away from the traditional approach of adversarial relationships with multiple suppliers to one of developing longer-term relationships with a select few.

Much of the recent literature published on the subject of F2F negotiations focuses on providing a comparison to RAs (Galin, Gross et al., 2007; Gattiker, Huang et al., 2007; Graham and Requejo, 2009). According to Galin et al. (2007) F2F negotiations offer a better flow of information between the negotiating parties enabling better decision making than either RAs or other supplier selection strategies. Research results have also shown lowered judgement accuracy, poorer outcomes, and less equal distribution of resources for computer-mediated interactions than for F2F interactions (Arunachalam and Dilla, 1995). It has also been found that F2F negotiations in mixed-motive conflicts facilitate better understanding of negotiators non-verbal cues and thus fostered the development of rapport, strengthened the basis of trust which helps negotiators coordinate a mutually beneficial settlement (Drolet and Morris, 2000).

## 2.3 *Supplier selection modelling techniques*

The majority of decision models discussed in the literature apply to the final selection phase (de Boer, Labro et al., 2001). The main approaches reported in the literature are: (i) Linear weighted models; (ii) Mathematical programming; (iii) Data Envelopment Analysis (DEA); (iv) Total Cost of Ownership (TCO); (v) Stochastic models with several papers integrating a number of these approaches.

Linear weighting models are one approach proposed for supplier selection (de Boer, Labro et al., 2001). Adaptations of the basic linear weighting model have been developed, such as the outranking approach proposed by de Boer, van der Wegen and Telgen (1998) which allows the buyer to apply limits to the compensation on bad scores. Akarte et al. (2001), Chan (2003), Chan and Kumar (2007), Hou and Su (2007) and van de Water and van Peet (2006) all propose the use of the Analytic Hierarchy Process (AHP) to deal with imprecision in supplier choice. According to de Boer et al. (2001) AHP overcomes the difficulty of having to provide point estimates for criteria as well as performance scores in basic linear weighting models.

There are many papers that propose the use of mathematical models to support supplier selection. For example, Talluri and Narasimhan (2003) use linear programming to evaluate the performance of suppliers employing two models to examine the maximum and minimum performance levels of each supplier. Other examples of linear programming models are provided by Talluri and Narasimhan (2005) and Ng (2008). Talluri (2002) developed a binary integer linear programming model to evaluate alternative supplier bids based on ideal targets for bid attributes defined by the buyer, and to select an optimal set of bids by matching demand and capacity constraints. Ghodsypour and O'Brien (2001) formulated a mixed integer non-linear programming model to determine the optimal allocation of products to suppliers so that the total annual purchasing cost could be minimised. Karpak et al. (2001) developed a Goal Programming (GP) model to evaluate and select suppliers. Narasimhan et al. (2006) developed a multi-objective programming model to determine the optimal suppliers and order quantities and Wadhwa and Ravindran (2007) developed a multi-objective programming model which included three objective functions to minimise price, lead time and rejects.

Data Envelopment Analysis (DEA) is another approach that has been proposed to aid supplier selection. DEA is used to evaluate decision alternatives by comparing the benefit criteria (output) against cost criteria (input) providing a ratio value, the higher the value the greater the efficiency of the alternative (de Boer, Labro et al., 2001). Liu et al. (2000) propose a DEA model to evaluate the overall performance of suppliers aimed at selecting a supplier with high supply variety. Examples of the use of DEA as a decision aid for supplier selection can be found in Forker and Mendez (2001), Narasimhan et al. (2001), Talluri and Baker (2002), Garfamy (2006), Ross et al. (2006).

Total Cost of Ownership (TCO) models are designed to quantify all possible costs that are incurred throughout a purchased items life cycle (Aissaoui, Haouari et al., 2007). Ellram (1995) discusses how the TCO approach can be applied to purchasing, providing comparisons against other purchasing frameworks and examples of TCO models used to support supplier evaluation and selection. Degraeve and Roodhooft (1999) and Degraeve and Roodhooft (2000) present mathematical programming models that minimise TCO, using an Activity Based Costing (ABC) system. Using these models the authors developed formulations to select suppliers and calculate order quantities over a multi-period time horizon for single (Degraeve and Roodhooft, 1999), and multiple (Degraeve and Roodhooft, 2000) items. Degraeve et al. (2004) propose a TCO model that selects suppliers of a multiple item service and determines the market share for each supplier.

Stochastic models can be used to account for uncertainty and fuzziness associated with a vendor selection problem. In real life vender selection problems are stochastic; however, most supplier selection approaches reported in the literature assume parameters to be deterministic and known (Aissaoui, Haouari et al., 2007). Only a limited number of studies consider the stochastic and uncertain nature associated with supplier selection decisions. Dasgupta and Spulber (1989) study both single and multiple sourcing scenarios. Using an auction model they identify settings which maximise the buyers expected gain, provided that the mechanism is perceived to be fair by the suppliers. Kasilingam and Lee (1996) developed a chance constrained integer programming formulation to address supplier selection and order allocation by minimising costs due to receiving poor quality, purchasing and transportation, and the fixed cost of establishing vendors. Feng et al. (2001) used stochastic integer programming to model the relationship between manufacturing cost, quality loss cost, assembly yield, and discrete tolerances. A number of authors suggest the use of Fuzzy Sets Theory (FST) to model uncertainty and imprecision in supplier choice situations (Chen, Lin et al., 2006; Sarkar and Mohapatra, 2006; Florez-Lorez, 2007).

### 2.4 Supplier selection – Integrated approaches

There are also a number of integrated approaches which have been proposed in the literature. Chen and Huang (2007) propose the integration of AHP and a multi-attribute negotiation mechanism. Ramanathan (2007) and Saen (2007) propose an integrated AHP-DEA approach in the first case to evaluate suppliers using both qualitative and quantitative data and in the second case to evaluate and select non-homogeneous suppliers. Other integrated approaches include (1) Integrated AHP and GP (Cebi and Bayraktar, 2003; Wang, Huang et al., 2005; Kull and Talluri, 2008; Mendoza, Santiago et al., 2008), (2) Integrated AHP and mixed integer non-linear programming (Mendoza, Santiago et al., 2008; Mendoza and Ventura, 2008), (3) Integrated AHP and multi-objective programming (Xia and Wu, 2007), (4) Integrated fuzzy approaches (Jain, Tiwari et al., 2004; Amid, Ghodsypour et al., 2006; Chan and Kumar, 2007; Bottani and Rizzi, 2008). A more exhaustive list of integrated approaches is provided by Ho et al. (2010).

## 3 Problem statement

The services side of Dell's business is one that has continued to experience significant growth in the last number of years. As is the case right across the computer manufacturing sector, Dell's service offerings, and their quality play an important role as a differentiator in the market. These services play a major role in the Dell business model where the product repair services constitute the largest proportion in terms of spend. . The services spend in 2008 for the EMEA (Europe, Middle East, and Africa) regions exceeded $190 million with theglobal spend on product repair services exceeding $2 billion. Based on these findings, the product repair services, and specifically the on-site element, which is the greatest proportion of this was selected for the research presented in this paper.

On-site repair refers to a service where the defective product is repaired at the location of the defective unit (i.e. the customer site). In total on-site repairs is further sub-divided into twelve different service categories or more commonly referred to as Service Level Agreements (SLAs). Each SLA is defined based on a combination of product categorisation and response time. There are four product categories (A, B, C, D) each with three different response times (next business day – NBD, 4hr and 2hr). For Example, Product A NBD, Product A 4Hr, etc.

### *3.1 Service provider selection:*

Dell like many of their closest competitors outsource the delivery of their repair services to service providers. Initially, Dell primarily executed partner selection through F2F communications, with Dell being regarded as an early adopter of RAs in its sector. Typical of many other companies experience of RAs, Dell in the early use of RAs obtained savings in line with those reported in the literature (Tully, 2000; Smeltzer and Carr, 2002). In line with the literature, Dell also experienced an exponential deceleration in savings as the number of RAs grew. This was further emphasised by supplier feedback with one supplier stating that future savings would not be possible as their profits had already reached a critical level and another stating that this may have a negative effect on service performance, as resources dedicated to these services may be reduced to maintain sufficient profits.

*Therefore, the research goal was the development of a new computer based supplier selection methodology, which could provide increased cost savings beyond what was being achieved using RAs, while also encapsulating a process improvement component that could adapt to change.*

### *3.2 Research design*

Based on the findings of Emiliani (2004), which identified the need to move away from power based bargaining (i.e. RAs) in favour of collaborative knowledge sharing networks, a research framework with the following three cycles was developed:. (i) greater internal transparency of service provision by Dell (which historically due to the competitive nature of the RA process was essentially completed by auction bidders); (ii) development of computer based decision supports that would allow better understanding of changes to the process of service provision and (iii) increased direct participation of suppliers in the final stage of the supplier selection programs.

To successfully research the development of such a framework, it was felt by Dell personnel that intensive field work and strong interaction between company personnel and researchers would be required. From a review of available research methodologies within supply chain (Kotzab et al. (2005)), action based research was selected as the most appropriate method. Action based research is an approach in which the researcher and client collaborate in the diagnosis of a problem and in the development of a solution based on this diagnosis (Mejía, López et al., 2007; Chakravorty and Hales, 2008). Action research is typically viewed through an interpretive lens (DeLuca and Kock, 2007) and in contrast to other qualitative research techniques, action research attempts to execute organizational change, while simultaneously studying the process (Baskerville and Myers, 2004). Action research is generally characterised by the following four steps: 1) diagnosing, 2) planning action, 3) taking action, and 4) evaluating action (Coughlan and Fergus, 2009). Each of the three cycles, described above embodied each of these four steps.

The three cycles were carried out over twelve months, with strong interaction between researchers and Dell personnel. One researcher spent 50% of their time in Dell and a Dell employee spent half a day a week in the research centre over the duration of the project.

## 4 Research study

### *4.1 Outsourced service delivery and performance for partner selection*

From early discussions with Dell, it was clear that there were limitations with respect to Dells own understanding of the full scope of service delivery activities and service performance issues. From Dell's experience this had occurred due to the continued use of RAs for these services. A series of meetings were conducted by the project team with partner selection personnel in Dell to identify and expand upon these current limitations in Dells knowledge of service delivery and performance by outsourced partners. The findings revealed scope for improvement with service delivery documentation with significant data collection in existence but with little conversion to useful information. One such outcome from this exercise was the translation of long verbal descriptors to process maps, which included data gap filling. An example of one such simplified process flow diagram is presented in Figure 1. For clarity of presentation, one European region and one representative service provider (Supplier A) in this region will be portrayed for illustration throughout the remainder of this section and indeed the rest of the paper. The general findings represented here for 'Supplier A' is representative of the general findings for all suppliers in the EMEA region. After initial data collection and analysis of existing service process documentation, it was found, and as confirmed by Dell, that the documentation was incomplete and was not in a form that allowed a detailed understanding of the service provision process.

In addition to process flow mapping, an extraction and analysis of historical service data from previous contracts was executed. These historical reports contained detailed information on each call for all SLAs; such as call types, products, failures, the supplier that the call is assigned to and the qualification of technician used to carry out the repair. To support this analysis a database was developed to query historical records and provide informative statistical information for all service suppliers over a defined period or volume of calls. Detailed statistics were obtained on, amongst others:

- Service call demand and duration by region;
- Profiling of SLA by provider and region;
- Profile and breakdown of products;
- Profile and breakdown of products by failures;
- Number of parts used in a repair
- Technician allocation call volumes
- Exception and repeat visit rates
- Multi Tag rates – where more than one service call is requested by the same customer.

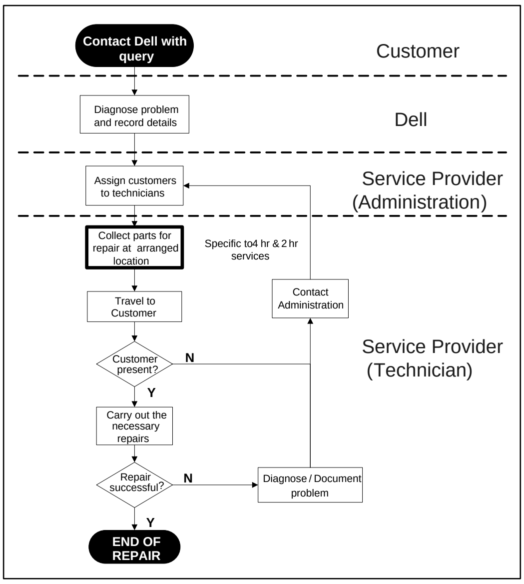



**Figure 1 Generic SLA process flow chart**

A sample of one of these output statistics is shown in Figure 2. Figure 2 provides a breakdown of multi tag rates based on the number of calls a technician has been assigned. The figures show that the chances of a multi tag occurring are generally low, especially at lesser call assignment levels. In general, when the number of calls assigned to a technician increases the possibility of a multi tag occurring and the number of calls in that multi tag also increase. Such information provides for better understanding and can be used to model the stochastic nature of the process in later cycles.

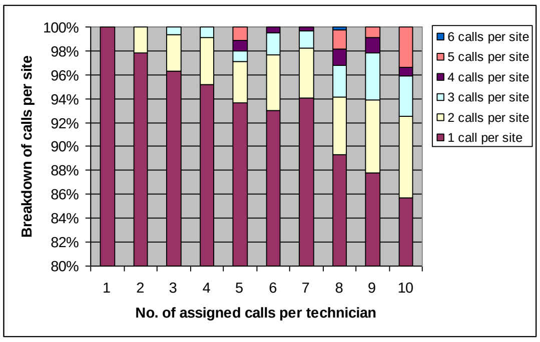



**Figure 2 Multi tag rates**

This cycle collated and simplified the SLA process descriptions. Prior to this, SLA descriptions were descriptive and difficult to comprehend. This cycle resulted in categorised and structured information for all individual SLAs but also provided a generic process flow diagram for ease of understanding. In addition, the process flow diagrams were identified as an important tool for process improvement initiation (already described in the literature review).

### *4.2 Service cost analysis*

The process and data analysis completed in cycle one demonstrated to Dell the feasibility and potential of developing a partner selection decision support tool that would give them greater transparency of the cost of product repair service provision and the effect on cost and service quality of process changes. After consultation with service managers, partner selection, financial and accounting personnel in Dell, Activity Based Costing (ABC) was chosen as a framework for cost analysis. As there are multiple interactions and shared resources in process delivery an ABC framework consisting of two cost models was proposed.

The first cost model captures indirect cost and is spreadsheet based. The indirect cost model contains an extensive list of the indirect cost elements and equations necessary to calculate an estimate for the indirect cost associated with a service call. The second cost model calculates the 'direct' cost associated with activities performed during the service delivery process. As this is a highly stochastic set of activities with numerous interactions, Discrete Event Simulation (DES) has been chosen for the modelling. DES is used to model the service activities performed by the provider, thus enabling correct attribution of costs to specific services and to facilitate future process improvements in future cycles.

**Table 1 Summarised indirect cost model data and sources**

| Resource | Data Requirements | Source |
|---|---|---|
| Administrative staff | Number of call dispatchers | Dell (response to RFQ) |
| | Non productive time of call dispatcher | Dell (calculation) |
| | Percentage of dispatcher dedicated to Dell | Local business unit, service provider |
| Technicians | Training costs per technician level | Local business unit, OECD, local papers, service provider |
| | Recruitment expenses | Local business unit, OECD, local papers, service provider |
| | Number of technicians at each level | Dell (response to RFQ) |
| | Wage information | Local business unit, OECD, local papers, service provider |
| | Number of trainers | Dell (response to RFQ) |
| | Percentage of trainers dedicated to Dell | Local business unit, service provider |
| Resource supervisor | Supervisor salary | Local business unit, OECD, local papers, service provider |
| | Number of supervisors | Dell (response to RFQ) |
| | Percentage of supervisors work dedicated to Dell | Local business unit, service provider |
| Technician team leaders | Salary | Local business unit, OECD, local papers, service provider |
| | Number of personnel | Dell (response to RFQ) |
| | Percentage of personnel work dedicated to Dell | Local business unit, service provider |
| Service escalation managers | Salary | Local business unit, OECD, local papers, service provider |
| | Number of personnel | Dell (response to RFQ) |
| | Percentage of personnel work dedicated to Dell | Local business unit, service provider |
| Service account manager/director | Salary | Local business unit, OECD, local papers, service provider |
| | Number of personnel | Dell (response to RFQ) |
| | Percentage of personnel work dedicated to Dell | Local business unit, service provider |
| Facilities | Rent per square meter per month/year | Local business unit, local papers, internet |
| | Square meters occupied by an employee | Local business unit, local papers, internet |
| Technician equipment | Yearly cost of communications equipment | Local business unit, local papers, internet |
| | Yearly cost of repair equipment | Local business unit, local papers, internet |
| | Percentage of equipment used by Dell | Local business unit, service provider |
| Information technology | Cost of computer equipment | Local business unit |
| | Working life of computer before replaced (yrs) | Local business unit, service provider |
| | Number of computers | Local business unit, service provider |
| Telecommunications | The duration of communication (mins) | Dell (calculation) |
| | Cost of communication per minute | Local business unit |
| Transportation vehicles | Vehicle leasing cost per year | Local business unit, local papers, internet |
| | Vehicle maintenance | Local business unit, local papers, internet |
| | Fuel | Local business unit, local papers, internet |
| | Insurance | Local business unit, local papers, internet |
| | Tax | Local business unit, local papers, internet |
| | Number of vehicles required | Local business unit, service provider |
| | Percentage of vehicle use dedicated to Dell | Local business unit, service provider |

In summary the total cost for a service will be the summation of the relevant indirect (model 1) and direct (model 2) costs.

*Indirect Cost Model:* The indirect cost modelling is dependent on the establishment of a service provider's organisational structure (ascertained during initial phases of partner selection), in particular the organisational resources assigned to service operations and management structures. To address this issue in a general fashion a range of service providers were analysed, to establish an exhaustive list of indirect cost requirements, which can then be used in all circumstances for all different types of suppliers. Suitable sources of information were then required to populate this list followed by actual data gathering and finally data validation. A summary of the resources that contain an indirect cost, the specific requirements and the sources for this information are shown in Table 1.

**Table 2 Direct cost DES data inputs**

| Data Group | Data | Data Source | | | |
|---|---|---|---|---|---|
| | | + + | + | Accuracy - | - - |
| | | Real Data (Data Analysis) | Service Provider | Other Source(s) | Assumptions/ calculations |
| Demand / Operational | Call volumes/day | X | | | |
| | Profile and breakdown of SLA's | X | | | |
| | Profile and breakdown of products | X | | | |
| | Profile and breakdown of faliures by product | X | | | |
| | Breakdown of the number of parts used in repair | X | | | |
| | Exception rate per SLA | X | | | |
| | Multiple visit rate per SLA | X | | | |
| | MultiTag rates | X | | | |
| | Mix of technicians (level of qualification) | | | X (Dell services) | |
| | % of technicians dedicated to Dell | | X | X (Dell services) | |
| Activity Times | Dispatching time per call | | X | | X |
| | Call screening time per call | | X | | X |
| | Exception management time | | X | | X |
| | Technician re-diagnosis time | | X | | X |
| | Travel time from PUDO to customer(s) | | X | X (Microsoft map point) | |
| | Travel time from customer to customer | | X | X (Microsoft map point) | |
| | ETA call time to each customer | | X | X (Microsoft map point) | X |
| | Time spent at the PUDO | | X | | X |
| | Time on-site per failure type per product | | X | X (Dell quality dept.) | |
| | Lunch time/day | | X | X (Local business unit) | |
| Personnel Wages | Technician salary | | X | X (Dell finance, papers, internet) | |
| | Call dispatcher salary | | X | X (Dell finance, papers, internet) | |
| | Call screening agent salary | | X | X (Dell finance, papers, internet) | |
| | Call coordinators salary | | X | X (Dell finance, papers, internet) | |

*Direct Cost Model:* The direct cost modelling approach uses DES to capture the inherent complexity and stochastic nature of the service delivery process. In particular the DES model has been developed using as a base, the flow process chart developed in cycle one (Section 4.1). Additional layers of complexity were built into the model as required, to model elements of the service delivery such as service provider crossover (where a service provider works on other non Dell activities). The objective of the DES model is to replicate realistic service operations over a defined period of time for each PUDO (Pick-Up and Drop-Off) region. The direct cost DES model data input can be collated into the following three groups:

- Demand / operational data.
- Activity times.
- Personnel wages (i.e. administration staff and technicians).

A summary of the data requirements for the direct cost DES model, for each of these groups, data source(s) and data accuracy is shown in Table 2.Before DES modelling commenced, a conceptual model was developed (see Figure 3). This conceptual model is of the service management and delivery process used by service providers.

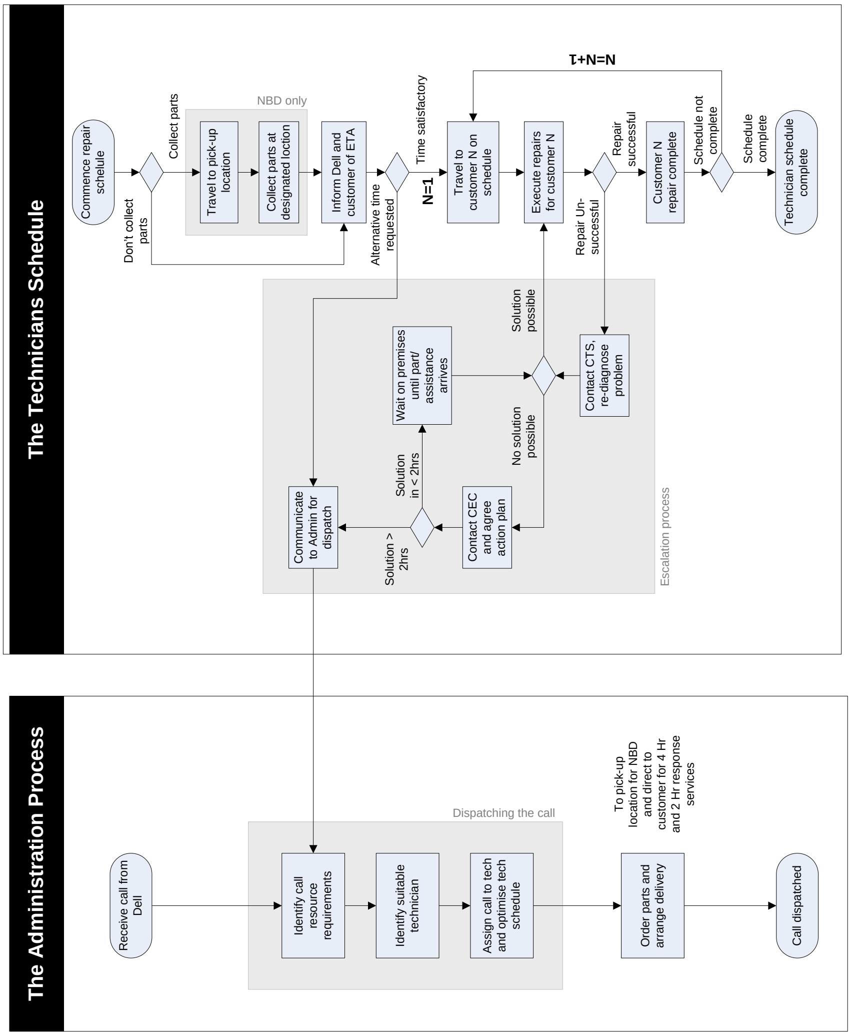



**Figure 3 Conceptual model of service management and delivery process**

There are three main sequences in the DES model: *initialisation, simulation execution and output.* At *initialisation* the DES model links to an Access database using an ODBC link. Following retrieval data is configured and the simulation sequence is started. The *simulation* *sequence* executes the main events that can be categorised into an Administration Process, a Technician Scheduling Process and a Service Costing Process. Table 3 describes the main elements that constitute the Administration Process and likewise Table 4 for the Technician Scheduling Process. Both the administration and the technician scheduling process are developed on a wide variety of stochastic components, hence the requirement for DES.

**Table 3 The administration process**

| |
|---|
| **Daily Demand Generation:** requirements that must be met per day by the service provider, for the duration of the model run. |
| **Technician selection:** technicians are selected based on particular skill levels which are stipulated in the technician assignment constraints in the contract which is cross tabulated with product demand information provided by the data analysis. |
| **Generate technician call volume:** based on relevant constraints the number of calls assigned to each technician is defined and recorded. |
| **Generate MultiTag calls:** determines if the technician call assignments contain multitag calls. Multitag calls involve requests that originate from the same address, the implications of which are reduced transport activities where only one visit is required to the multiple call location. |
| **Generate and assign MultiTag transportation time and cost:** at this stage the transportation time is calculated for the multitag visit. |
| **Determine the SLA:** at this point the SLA of the call is randomly selected based on statistics provided from the data analysis performed earlier. |
| **Determine the product type:** this step involves defining the product type associated with the call. As in the SLA case, statistics from the data analysis step of the framework are used to define the product type. |
| **Determine the failure type:** here the nature of the product failure associated with the call is determined using statistics provided during the data analysis. |
| **Determine times and costs of first pass assignment activities:** this step of the simulation process involves simulating the timing of these activities and subsequent costing based on personnel applied to each task. Depending on the provider under review, personnel from outside the provider's organisation may be involved in the assignment process; such as call centre employees responsible for correspondence with the customer. |
| **Decision process for assigning repeat visit calls to technicians:** in addition to current demand received by the provider for a given day they must also manage all call escalations from the previous period that require a repeat visit in order to affect a successful fix. |
| **Administration times and costs for exception and repeat visit calls:** this includes the addition of other personnel which are involved in the management of exception and Repeat Visit (RV) calls. |
| **Set up the technician's route:** once all the demand, which includes both first time and RV calls, has been assigned the model plans the route for each technician, this route outlines the list of activities for that day and their sequence. |
| **Determine exception and RV calls:** after demand has been assigned and the characteristics of the call defined the simulation sequence determines the exception and RV status of each call using statistical information provided by the data analysis exercise. |

**Table 4 The technician scheduling process**

| |
|---|
| **Creating the technician entities:** to mimic the execution of the activities performed by the technicians the simulation model generates an entity for each technician's assigned calls in the given period. |

| |
|---|
| **Generate transportation times and associated costs:** although typically only required once per technicians planned route, the transportation activity can be required a number of times. This is based on statistical information. |
| **Allocating ancillary costs:** service provider allowed costs such as lunch need to be apportioned appropriately across the work schedule. |
| **PUDO (Pick-Up and Drop-Off location) simulation:** this involves simulating the activities that take place at the PUDO, these activities include confirmation of parts, dropping off defective parts from the previous days calls, and collection of good parts for the current days call allocations. |
| **Repair simulation:** this step may be required on a number of occasions during the completion of the technicians planned route, the number of occurrences will depend directly on the number of calls allocated. The repair time characteristic of an individual repair is affected by a number of factors which include the product type, the failure type and the number of parts required to perform the repair. |

All costs encountered during the execution of the model are allocated to one of four categories (Administration Costs, Transportation Costs, PUDO Costs and Repair Costs). The total activity based service cost for a call is the sum of the cost driver components expressed as follows.

$$TAC_i = AC_i + TC_i + PC_i + RC_i$$

where,

TACi = Total activity based service cost of call i.

ACi = Administration cost of call i.

TCi = Transportation cost of call i.

PCi = PUDO cost of call i.

RCi = Repair cost of call i.

The total activity based service cost is calculated in the model at the end of a simulation run. As the model is stochastic in nature, replications are required and this total activity based service cost is calculated at the end of each replication. The completed direct cost DES model was verified and validated using a series of structured walk-throughs with persons knowledgeable of the service delivery process and sensitivity analyses experiments were ran.

At the end of a simulation experiment run, statistical analysis is performed to determine the expected direct cost per service type, and the simulation model exports cost information into an Access database. The statistical analysis involves generating summary statistics per replication for each of the cost drivers and the expected total activity based service cost. Finally, these results (direct costs) are combined with the indirect model results to provide the total service cost per service provider for each service supplied. A sample of these results for the service cost for five repair types for Supplier A, adapted by a factor of X is shown in Figure 4.

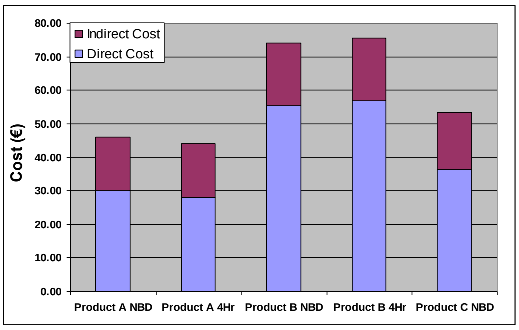



**Figure 4 Product service cost for Supplier A**

The indirect and direct models built significantly on the results from the first cycle, providing Dell with a means of obtaining greater insight into the service delivery process and a means to quantify the cost implications of process improvement changes. The two models developed using an ABC approach, enable detailed cost allocation to the correct sources when modelling a supplier's entire service portfolio (facilitating both partner selection and process improvement). These results and the detailed breakdown of cost drivers provide useful guidance which can be used to assist with the identification of opportunities with the greatest potential for cost reduction.

### *4.3 Supplier selection and improvement strategy*

The purpose of this cycle was to use the data and models of cycles one and two (Sections 4.1 and 4.2) to develop and test a new Dell supplier selection framework in a real collaborative negotiations supplier selection scenario for an existing supplier – Supplier A. Central to the success of this new supplier selection methodology is the need to engage the participation of the proposed service provider in the negotiation process (stage 3 – partner selection), promoting open discussions and information sharing. For the methodology to be successful it must ultimately provide benefits to both parties (the service provider and Dell). The implementation of the new supplier selection methodology involved three sequential actions:

1. Examining service costs - both parties explore the results from the cost modelling exercise and agree on an estimate of the service cost based on current state of the service(s) examined.

2. Exploring cost reduction initiatives – using the information support provided during cycle one and cycle two both parties identify cost reduction opportunities with the potential cost savings quantified with the modelling tools developed in cycle two.
3. Drafting the contract – Agree on the terms and conditions of the new contract, in particular defined process improvements and the allocation of savings and contract duration.

*Examining service costs:* At the outset of this cycle Dell presented the cost models and results of the analyses performed during cycle two to Supplier A. The objective of sharing this information was to encourage the service supplier to engage in the process and develop their confidence in the accuracy of the costing tools. Fundamental to such negotiations is the active engagement of both parties. During the evaluation of the cost results the supplier was given the opportunity to highlight any issues concerning; the approach used and the accuracy of the cost models. The collaborative environment and evaluation of costs encouraged information sharing and a level of transparency which in turn improved the accuracy of the cost models and results.

**Formatted:** Don't keep with next

On completion of the updated costing it was possible for Dell to measure the supplier's theoretical profit margins (for the top 5 service offerings – shown in Figure 5) by contrasting the models output and the prices charged by Supplier A. The results of this comparison which have been modified by a factor for confidentiality purposes are shown in Figure 5. These results indicate profits of ranging from 4.5% to 12.7%% across these five SLAs. In the case of 'A_NBD' profits are at 4.5% with this service accounting for approximately 77% of Supplier A's total call volume. This provides support for the supplier's claims of insufficient profits and the difficulty with reducing costs had another reverse auction been executed.

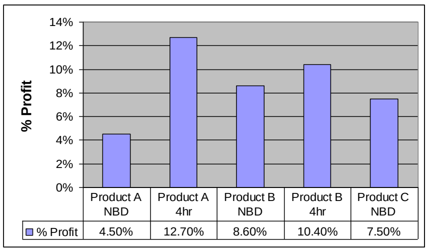



**Figure 5 Profit margins for each SLA**

*Exploring process improvement and cost reduction initiatives:* To execute this step a workshop where both parties (Service Provider and Dell) explored service improvement opportunities with a focus on reducing the service cost was scheduled. The objective of this workshop was to use the knowledge and tools developed during the previous two cycles. In the first instance, process flow diagrams and statistical data generated in cycle one was used to identify potential process and performance improvement opportunities. A sample of improvement opportunities identified in collaboration with Supplier A is shown in Table 5. In addition, service performance improvements were also investigated. Some examples of these enhancements included a reduction in the number of calls where more than one visit is required to complete a successful repair and an increase in the utilisation of technicians by improving the planning and scheduling of calls.

**Table 5 Service process opportunities**

| Improvement Opportunity | Problem Description | Solution Description |
|---|---|---|
| **Operating system loading** | Time taken to re-load operating system | Reduce the loading time by employing new technologies developed by the OS manufacturer, thus reducing manual activities performed by the technician |
| **Collection location improvements** | Time technician spends in queue at the parts collection location waiting to be served | A self service system where the technician can locate, pick and check out the parts themselves. |
| **Re-diagnosis improvements** | In the event of an incorrect first time diagnosis a re-diagnosis is required. Currently there is a delay in the system in the communication between the technician and technical support staff | A new communications framework which involves the formation of a central point of feedback where all technician queries are prioritised by technical support. |
| **Improve customer notification of Estimate Time of Arrival (ETA)** | Time technician spends informing customers of ETA. Currently, calls are performed using hand held technology | Multi tasking, where hands free technology is employed to enable the technician contact customers while performing other tasks |

The impact of these improvement opportunities on performance and cost was then analysed using the cost models developed in cycle two and were then compared with the results from the base line models. Results representative of the percentage savings on top of the existing profit margins are shown in Figure 6. The results show that the potential combined process and performance improvement initiatives provide for a minimum saving of 8% across all of the SLAs with a maximum saving of 21.48% on C_NBD. Taking into account existing profit levels highlights there is potential for considerable scope for cost reductions, subject to improvement implementation.

*Drafting the Contract:* The primary change to the final phase of the supplier selection for such new contracts is the determination of the duration of the contract and pricing conditions. Historically, contracts were only valid for a period of 1 year at which point the outsourcing process (e.g. reverse auction) was repeated. The result from this research has highlighted the worth of longer term contracts in conjunction with joint improvement initiatives (collaborative negotiations and process improvement in the supplier selection process). As this is a joint initiative both parties must have a win element. To achieve this, terms and conditions were applied, such as the responsibilities of each party, constraints under the new contract, agreed savings, and a time plan for implementing the improvement initiatives. It was agreed that the highlighted improvements would be carried out within the first 6 months of the contract with defined tasks for both parties.

Based on the results shown in Figure 6 a targeted saving of 10% is to be applied across each of the SLAs. The 10% saving will be applied in 3 steps over the duration of the contract, 3% saving at the beginning of the contract, a further 3% at the beginning of the second year and the final 4% at the beginning of the third year (see Figure 7 – cost figures adapted by a factor for confidentiality). Under the terms of the agreement the surplus savings will not be targeted by Dell. If for example, in the best case scenario, Supplier A can achieve the full predicted potential for C_NBD, which is 29% (21.5% savings + 7.5% previous profit level) then they will be able to retain at least an improved 19% profit margin on this offering over the duration of the contract.

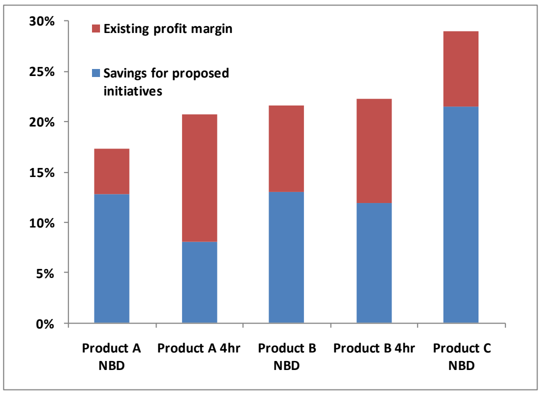
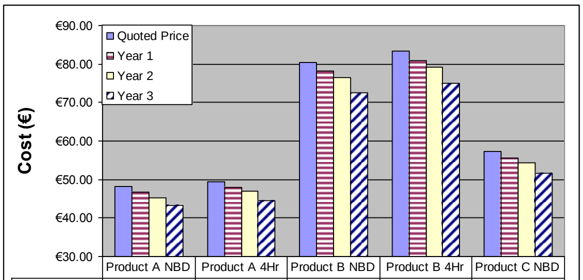



**Figure 6 Existing profit margins and estimated savings for proposed initiatives**




| | Product A NBD | Product A 4Hr | Product B NBD | Product B 4Hr | Product C NBD |
|---|---|---|---|---|---|
| Quoted Price | €48.21 | €49.53 | €80.49 | €83.43 | €57.32 |
| Year 1 | €46.76 | €48.04 | €78.08 | €80.93 | €55.60 |
| Year 2 | €45.32 | €47.05 | €76.47 | €79.26 | €54.45 |
| Year 3 | €43.39 | €44.58 | €72.44 | €75.09 | €51.59 |

**Figure 7 Yearly step cost reductions**

This cycle was heavily reliant on the previous two cycles with process mapping from cycle one being used to identify opportunities and cycle two models providing the means to gain an understanding of the cost drivers of on-site repair services provision. In cycle three a collaborative negotiation framework for supplier selection was successfully implemented in real contract negotiations. Cost savings were gained in the negotiations that in the opinion of Dell personnel would not have been obtained if a straightforward RA was used. Furthermore, the framework provided assurance to Dell that service quality would be maintained, and even in some cases improved by the implemented process improvements. This is because the framework, as well as providing transparency on cost, also provides transparency on implications on the implemented process changes on service quality measures (e.g. reducing exception cases and repeat visits). The collaborative framework also brings benefits to suppliers, with an extended contract period, increased profits if agreed process improvements are front loaded within the contract period and strengthened ties with the buyer. This new partner selection methodology can be used for the development of existing partnerships and new partner selection from phase 1 (supplier selection preparation) through to phase 4 (process improvement). However, in contrast to RAs, as can be seen in cycles one, two and three, there is an increase in administration costs to the buyer.

## 5 Research findings

Both manufacturing and service provision outsourcing are trends that are set to continue into the foreseeable future. In the execution of such outsourcing, RAs have been and will continue to be a highly utilised tool in price determination and partner selection. However, as has been shown in the literature and is confirmed in this study, RAs in certain circumstances have a limited useful shelf-life. Dell had found that the repeated use of such auctions had led to a continual falling off in price reductions over time and had begun to put service quality at risk in continued partner selections.

This paper, reviews price determination and partner selection for Dells after sales product repair services. The research presented has shown that the repeated use of RAs can lead to neglect with respect to service process knowledge and cost realisation. This is due to the fact that in reality it is the competitive nature of auction bidders that is stipulating the service process and ultimately ensuring value for money. The more times RAs are executed the further removed an organisation can become from this process.

The research presented outlines the steps associated with the development of a new computer based price determination and partner selection methodology. The culmination of the process was the replacement of RAs with a collaborative partner selection strategy, which is enabled by decision support costing models. Due to the complexities of the multiple interactions and shared resources two separate but related cost models were developed – one spreadsheet based model to capture the 'indirect' costs and a second DES based model to calculate the 'direct' costs associated with activities performed during service delivery. The cost models are used as the starting point for collaborative negotiations with a supplier with the models being used to understand profit margins and quantify the impact of proposed process improvements. Although the study was carried out on an existing supplier, it can also be used for new partner selections. For new supplier selection phase 1 (supplier selection preparation) and 2 (Pre-classification) would be completed using traditional methodologies.

The results of this study for the outsourcing instance presented clearly indicate the superior performance of the negotiations strategy over previously run complete RAs. It is clearly evident that both parties (buyer and seller) experience significant benefits in terms of cost savings and surety of business over a longer period of time. The cost savings achieved were well in excess, of what based on Dell experience, would have been achieved if a further RA had been used. Significant to this success is the promotion of information sharing and trust. This is in direct contrast to the adversarial aspects of RAs, which have been highlighted in the literature review. The collaborative negotiations strategy has been built on the premise of partnership strengthening between the outsourcing organisation and the supplier.

This paper proposes the use of a multi technique process for partner selection with phases 1 and 2 using traditional techniques and phases 3 and 4 using the new devised computer supported methodology proposed in this paper. More research is required to further test this theory in alternative organisations and sectors as the models developed in this paper are specific to the Dell case. Finally, the combined simulation and ABC tools can be further developed to provide an application that is robust, requires low maintenance, and requires a low level of expertise to use.

**Bibliography**


Aissaoui, N., Haouari, M., Hassini, E., 2007. Supplier selection and order lot sizing modeling: A review. Computers & Operations Research 34(12), 3516-3540.

Akarte, M.M., Surendra, N.V., Ravi, B., Rangaraj, N., 2001. Web based casting supplier evaluation using analytical hierarchy process. Journal of the Operational Research Society 52(5), 511-522.

Amid, A., Ghodsypour, S.H., O'Brien, C., 2006. Fuzzy multiobjective linear model for supplier selection in a supply chain. International Journal of Production Economics 104(2), 394-407.

Arnold, U., Kärner, H., Schnabel, M., 2005. Target-oriented use of strategic sourcing tools: A critical analysis creating process awareness for electronic reverse auctions. Journal of Purchasing and Supply Management 11(2-3), 116-128.

Arunachalam, V., Dilla, W.N., 1995. Judgment accuracy and outcomes in negotiation: A causal modeling analysis of decision-aiding effects. Organizational Behavior and Human Decision Processes 61(3), 289-304.

Bartholomew, D. 2002. The big squeeze. Retrieved 17th August 2010 from http://www.industryweek.com/articles/the_big_squeeze_1044.aspx.

Baskerville, R., Myers, M.D., 2004. Special issue on action research in information systems: making is research relevant to practice--foreword. MIS Quarterly 28(3), 329-335.

Bottani, E., Rizzi, A., 2008. An adapted multi-criteria approach to suppliers and products selection – An application oriented to lead-time reduction. International Journal of Production Economics 111(2), 763-781.

Caniëls, M.C.J., van Raaij, E.M., 2009. Do all suppliers dislike electronic reverse auctions? Journal of Purchasing and Supply Management 15(1), 12-23.

Carter, C.R., Kaufmann, L., Beall, S., Carter, P.L., Hendrick, T.E., Petersen, K.J., 2004. Reverse auctions-grounded theory from the buyer and supplier perspective. Transportation Research Part E: Logistics and Transportation Review 40(3), 229-254.

Carter, C.R., Stevens, C.K., 2007. Electronic reverse auction configuration and its impact on buyer price and supplier perceptions of opportunism: A laboratory experiment. Journal of Operations Management 25(5), 1035-1054.

Cebi, F., Bayraktar, D., 2003. An integrated approach for supplier selection. Logistics Information Management 16(6), 395-400.

Chakravorty, S.S., Hales, D.N., 2008. The evolution of manufacturing cells: An action research study. European Journal of Operational Research 188(1), 153-168.

Chan, F.T.S., 2003. Interactive selection model for supplier selection process: An analytical hierarchy process approach. International Journal Production Research 41(15), 3549-3579.

Chan, F.T.S., Kumar, N., 2007. Global supplier development considering risk factors using fuzzy extended AHP-based approach. OMEGA - International Journal of Management Science 35(4), 417-437.

Chen, C.-T., Lin, C.-T., Huang, S.-F., 2006. A fuzzy approach for supplier evaluation and selection in supply chain management. International Journal of Production Economics 102(2), 289-301.

Chen, R.R., Roundy, R.O., Zhang, R.Q., Janakiraman, G., 2005. Efficient auction mechanisms for supply chain procurement. Management Science 51(3), 467-482.

Chen, Y.M., Huang, P.N., 2007. Bi-negotiation integrated AHP in suppliers selection. Benchmarking: An International Journal 14(5), 575-593.

Coughlan, P., Coghlan, D., 2002. Action research for operations management. International Journal of Operations & Production Management 22(2), 220-240.

Coughlan, P., Fergus, M.A., 2009. Defining the path to value innovation. International Journal of Manufacturing Technology and Management 16(3), 234-249.

Dasgupta, S., Spulber, D., 1989. Managing procurement auctions. Information Economics and Policy 4(1), 5-29.

de Boer, L., Labro, E., Morlacchi, P., 2001. A review of methods supporting supplier selection. European Journal of Purchasing & Supply Management 7(2), 75-89.

de Boer, L., van der Wegen, L., Telgen, J., 1998. Outranking methods in support of supplier selection. European Journal of Purchasing & Supply Management 4(2-3), 109-118.

de Boer, L., van der Wegen, L.L.M., 2003. Practice and promise of formal supplier selection: a study of four empirical cases. Journal of Purchasing and Supply Management 9(3), 109-118.

Degraeve, Z., Labro, E., Roodhooft, F., 2004. Total cost of ownership purchasing of a service: the case of airline selection at Alcatel Bell. European Journal of Operational Research 156(1), 23-40.

Degraeve, Z., Roodhooft, F., 1999. Improving the efficiency of the purchasing process using total cost of ownership information: the case of heating electrodes at Cockerill Sambre S.A. European Journal of Operational Research 112(1), 42-53.

Degraeve, Z., Roodhooft, F., 2000. A mathematical programming approach for procurement using activity based costing. Journal of Business Finance & Accounting 27(1-2), 69-98.

Degraeve, Z., Roodhooft, F., 2000. A mathematical programming approach for procurement using activity based costing. Journal of Business Finance & Accounting 27(1/2), 69.

DeLuca, D., Kock, N., 2007. Publishing information systems action research for a positivist audience. Communications of the Association for Information Systems 19, 183-204.

Drolet, A.L., Morris, M.W., 2000. Rapport in conflict resolution: Accounting for how face-to-face contact fosters mutual cooperation in mixed-motive conflicts. Journal of Experimental Social Psychology 36(1), 26-50.

Ellram, L.M., 1995. Total cost of ownership, an analysis approach for purchasing. International Journal of Physical Distribution and Logistics Management 25(8), 4-23.

Emberson, C., Storey, J., 2006. Buyer-supplier collaborative relationships: Beyond the normative accounts. Journal of Purchasing and Supply Management 12(5), 236-245.

Emiliani, M.L., 2004. Sourcing in the global aerospace supply chain using online reverse auctions. Industrial Marketing Management 33(1), 65-72.

Emiliani, M.L., 2005. Regulating B2B online reverse auctions through voluntary codes of conduct. Industrial Marketing Management 34(5), 526-534.

Emiliani, M.L., Stec, D.J., 2002. Realizing savings from online reverse auctions. Supply Chain Management: An International Journal 7(1), 12-23.

Emiliani, M.L., Stec, D.J., 2005. Wood pallet suppliers reaction to online reverse auctions. Supply Chain Management: An International Journal 10(4), 278-288.

Feng, C.X., Wang, J.W., Wang, J.S., 2001. An optimization model for concurrent selection of tolerances and suppliers. Computers and Industrial Engineering 40(1-2), 15-33.

Florez-Lorez, R., 2007. Strategic supplier selection in the added-value perspective: A CI approach. Information Science 177(5), 1169-1179.

Forker, L.B., Mendez, D., 2001. An analytical method for benchmarking best peer suppliers. International Journal of Operations and Production Management 21(1-2), 195-209.

Galin, A., Gross, M., Gosalker, G., 2007. E-negotiation versus face-to-face negotiation what has changed - if anything? Computers in Human Behavior 23(1), 787-797.

Garfamy, R.M., 2006. A data envelopment analysis approach based on total cost of ownership for supplier selection. Journal of Enterprise Information Management 19(6), 662-678.

Gattiker, T.F., Huang, X., Schwarz, J.L., 2007. Negotiation, email, and Internet reverse auctions: How sourcing mechanisms deployed by buyers affect suppliers' trust. Journal of Operations Management 25(1), 184-202.

Ghodsypour, S.H., O'Brien, C., 2001. The total cost of logistics in supplier selection, under conditions of multiple sourcing, multiple criteria and capacity constraint. International Journal of Production Economics 73(1), 15-27.

Giampietro, C., Emiliani, M.L., 2007. Coercion and reverse auctions. Supply Chain Management: An International Journal 12(2), 75-84.

Graham, J.L., Requejo, W.H., 2009. Managing face-to-face international negotiations. Organizational Dynamics 38(2), 167-177.

Hawkins, T.G., Gravier, M.J., Wittmann, C.M., 2010. Enhancing reverse auction use theory: an exploratory study. Supply Chain Management: An International Journal 15(1), 21-42.

Ho, W., Xu, X., Dey, P.K., 2010. Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. European Journal of Operational Research 202(1), 16-24.

Hou, J., Su, D., 2007. EJB–MVC oriented supplier selection system for mass customization. Journal of Manufacturing Technology Management 18(1), 54-71.

Hur, D., Hartley, J.L., Mabert, V.A., 2006. Implementing reverse e-auctions: A learning process. Business Horizons 49(1), 21-29.

Hur, D., Mabert, V.A., Hartley, J.L., 2007. Getting the most out of reverse e-auction investment. Omega 35(4), 403-416.

Huang, S.H., Keskar, H. 2007. Comprehensive and configurable metrics for supplier selection. International Journal of Production Economics 105(2), 510-523.

Jain, V., Tiwari, M.K., Chan, F.T.S., 2004. Evaluation of the supplier performance using an evolutionary fuzzy-based approach. Journal of Manufacturing Technology Management 15(8), 735-744.

Jap, S.D., 1999. Pie-expansion efforts: Collaboration processes in buyer-supplier relationships. Journal of Marketing Research (JMR) 36(4), 461-475.

Jap, S.D., 2001. Perspectives on joint competitive advantages in buyer-supplier relationships. International Journal of Research in Marketing 18(1-2), 19-35.

Jap, S.D., 2002. Online reverse auctions: Issues, themes, and prospects for the future. Journal of the Academy of Marketing Science 30(4), 506-525.

Jap, S.D., 2003. An exploratory study of the introduction of online reverse auctions. Journal of Marketing 67(3), 96-107.

Jap, S.D., 2007. The impact of online reverse auction design on buyer-supplier relationships. Journal of Marketing 71, 146-159.

Joo, Y.-B., Kim, Y.G.Y.-G., 2004. Determinants of corporate adoption of e-Marketplace: An innovation theory perspective. Journal of Purchasing and Supply Management 10(2), 89-101.

Karpak, B., Kumcu, E., Kasuganti, R.R., 2001. Purchasing materials in the supply chain: Managing a multi-objective task. European Journal of Purchasing & Supply Management 7(3), 209-216.

Kasilingam, R.G., Lee, C.P., 1996. Selection of vendors—a mixed-integer programming approach. Computers and Industrial Engineering 31(1-2), 347-350.

Kotzab, H., Seuring, S., Müller, M., Reiner, G., 2005. Research methodologies in supply chain management. Heidelberg, Physica-Verlag.

Kull, T.J., Talluri, S., 2008. A supply-risk reduction model using integrated multi-criteria decision making. IEEE Transactions on Engineering Management 55(3), 409-419.

Liu, J., Ding, F.Y., Lall, V., 2000. Using data envelopment analysis to compare suppliers for supplier selection and performance improvement. Supply Chain Management: An International Journal 5(3), 143-150.

Luo, X., Wu, C., Rosenberg, D., Barnes, D. 2009. Supplier selection in agile supply chains: An information-processing model and an illustration. Journal of Purchasing & Supply Management 15, 249-262.Mabert, V.A., Skeels, J.A., 2002. Internet reverse auctions: Valuable tool in experienced hands. Business Horizons 45(4), 70-76.

Mejía, R., López, A., Molina, A., 2007. Experiences in developing collaborative engineering environments: An action research approach. Computers in Industry 58(4), 329-346.

Mendoza, A., Santiago, E., Ravindran, A.R., 2008. A three-phase multicriteria method to the supplier selection problem. International Journal of Industrial Engineering 15(2), 195-210.

Mendoza, A., Ventura, J.A., 2008. An effective method to supplier selection and order quantity allocation. 2 1(1-15).

Narasimhan, R., Talluri, S., Mahapatra, S.K., 2006. Multiproduct, multicriteria model for supplier selection with product life-cycle considerations. Decision Sciences 37(4), 577-603.

Narasimhan, R., Talluri, S., Mendez, D., 2001. Supplier evaluation and rationalization via data envelopment analysis: An empirical examination. Journal of Supply Chain Management 37(3), 28-37.

Ng, W.L., 2008. An efficient and simple model for multiple criteria supplier selection problem. European Journal of Operational Research 186(3), 1059-1067.

Parente, D.H., Venkataraman, R., Fizel, J., Millet, I., 2004. A conceptual research framework for analyzing online auctions in a B2B environment. Supply Chain Management: An International Journal 9(4), 287-294.

Ramanathan, R., 2007. Supplier selection problem: Integrating DEA with the approaches of total cost of ownership and AHP. Supply Chain Management: An International Journal 12(4), 258-261.

Ross, A., Buffa, F.P., Dröge, C., Carrington, D., 2006. Supplier evaluation in a dyadic relationship: An action research approach. Journal of Business Logistics 27(2), 75-102.

Saen, R.F., 2007. A new mathematical approach for supplier selection: Accounting for non-homogeneity is important. Applied Mathematics and Computation 185(1), 84-95.

Sarkar, A., Mohapatra, P.K.J., 2006. Evaluation of supplier capability and performance: A method for supply based reduction. Journal of Purchasing and Supply Management 12(3), 148-163.

Schoenherr, T., 2008. Diffusion of online reverse auctions for B2B procurement: an exploratory study. International Journal of Operations & Production Management 28(3), 259-278.

Schoenherr, T., Mabert, V.A., 2007. Online reverse auctions: Common myths versus evolving reality. Business Horizons 50(5), 373-384.

Smart, A., Harrison, A., 2003. Online reverse auctions and their role in buyer-supplier relationships. Journal of Purchasing and Supply Management 9(5-6), 257-268.

Smeltzer, L.R., Carr, A., 2002. Reverse auctions in industrial marketing and buying. Business Horizons 45(2), 47-52.

Smeltzer, L.R., Carr, A.S., 2003. Electronic reverse auctions: Promises, risks and conditions for success. Industrial Marketing Management 32(6), 481-488.

Talluri, S., 2002. A buyer–seller game model for selection and negotiation of purchasing bids. European Journal of Operational Research 143(1), 171-180.

Talluri, S., Baker, R.C., 2002. A multi-phase mathematical programming approach for effective supply chain design. European Journal of Operational Research 141(3), 544-558.

Talluri, S., Narasimhan, R., 2003. Vendor evaluation with performance variability: A max-min approach. European Journal of Operational Research 146(3), 543-552.

Talluri, S., Narasimhan, R., 2005. A note on a methodology for supply base optimization. IEEE Transactions on Engineering Management 52(1), 130-139.

Tassabehji, R., Taylor, W.A., Beach, R., Wood, A., 2006. Reverse e-auctions and supplier–buyer relationships: An exploratory study. International Journal of Operations & Production Management 26(2), 166-184.

Tully, S., 2000. The B2B tool that really is changing the world. Fortune 141(6), 132-137.

van de Water, H., van Peet, H.P., 2006. A decision support model based on the Analytic Hierarchy Process for the Make or Buy decision in manufacturing. Journal of Purchasing and Supply Management 12(5), 258-271.

Liston, P., Byrne, J., Heavey, C., Byrne, P.J., (2008). Discrete-event simulation for evaluating virtual organizations. International Journal of Production Research 46 (5): 1335-1356

Van Tulder, R., Mol, M., 2002. Reverse Auctions or auctions reversed:: First experiments by Philips. European Management Journal 20(5), 447-456.

Wadhwa, V., Ravindran, A.R., 2007. Vendor selection in outsourcing. Computers and Operations Research 34(12), 3725-3737.

Wagner, S.M., Schwab, A.P., 2004. Setting the stage for successful electronic reverse auctions. Journal of Purchasing and Supply Management 10(1), 11-26.

Wang, G., Huang, S.H., Dismukes, J.P., 2005. Manufacturing supply chain design and evaluation. International Journal of Advanced Manufacturing Technology 25(1-2), 93-100.

Wu, C., Barnes, D., 2011. A literature review of decision-making models and approaches for partner selection in agile supply chains. Journal of Purchasing and Supply Management 17, 256-274.

Wu, C., Barnes, D., 2012. A dynamic feedback model for partner selection in agile supply chains. International Journal of Operations & Production Management 32(1), 79-103.

Xia, W., Wu, Z., 2007. Supplier selection with multiple criteria in volume discount environments. OMEGA - International Journal of Management Science 35(5), 494-504.