DSS MODEL TO PURCHASING: FOCUSING IN SELECTION THE PAIR PRODUCT/SUPPLIER

Rogério Atem de Carvalho (CEFET-Campo)
ratem@cefetcampos.br

Helder Gomes Costa (UFF)
hgc@vm.uff.br

Selecting suppliers in a global economical environment is not an easy task, since supplier selection is a problem that includes both qualitative and quantitative factors. To address this problem, a purchasing methodology and supportive Decision Support System (DSS) are proposed. The DSS is able to maintain data regarding quality for each pair supplier/product, collect proposals, and build and solve an Integer Linear Programming problem with the help of a solver.

Keywords: Decision, Business-to-Business, Supply, Procurement, Data Marts, Supplier Classification
1. Introduction

Industrial purchasing research started in the 1960s, but it was after Kraljic (1983) that practitioners and researchers started to give more attention to this area. Nowadays business are concentrating on core activities and outsourcing other functions to external suppliers. As reported in Min e Zhou (2000), this focus on core competencies. On the other hand, the growing of Business to Business (B2B) electronic commerce gave buyers access to a larger chain of suppliers through a low cost fashion (McIvor et al. (2000)). This article aims to show a purchasing methodology and supportive DSS originally proposed by Carvalho e Costa (1999). We provide a description of the methodology and its methods, and then show the supportive DSS architecture, followed by the conclusions.

2. Proposed Methodology

The proposed methodology deals with the situation where a single buyer organization faces a supplier pool of various suppliers who can be segmented into class according to their quality level. This is a more controlled environment, in opposition to the totally open and more final consumer driven environment as described by Azoulay-Schwartz et al. (2004). Moreover, we take into account two practices:

(i) implementing supplier segmentation based on quality performance, and
(ii) establishing long-term supplying contracts based on costs.

These practices create a multicriteria problem of making a trade off between conflicting tangible and intangible factors to find the best suppliers. Therefore, the proposed methodology aims to create a strategic sourcing environment, where the buyer seeks to establish value-oriented relationships with its suppliers. This methodology can be classified as a supplier portfolio model, which concept was originally developed by Markowitz (1952), who used it as an instrument for managing equity investments. Since then, many others authors proposed the application of the portfolio model to purchasing (Gelderman e Van Weele (2000)), as a means of optimizing the capabilities of different suppliers. This proposal differs from the others, since it focuses in analyzing each pair formed by a certain product (or even a service) with a certain supplier. In a first step each pair is classified according to a set of specific, clear defined criteria related to the quality of services of the supplier. A second step comprises collecting bids from previously selected suppliers and submitting the whole set of bids to a mathematical model that determines the best combination of medium or long term supply contracts, under the light of the lowest feasible cost.

Therefore, the concerns of unknown supplier quality and cost of switching from one supplier to another constantly Azoulay-Schwartz et al. (2004), are overcome by the proposed methodology through long-term contracts with high quality suppliers, which simultaneously reduces the number of biddings and give time to the buyer to evaluate their actual and candidate suppliers. Thus the DSS is going to support decisions in trade-off problems through the separation of the questions of quality and price in two levels. In that way, with some limitations, it is believed that a simpler solution was accomplished, in opposition to more sophisticated solutions like the ones based on Gittins Allocation Indices (Gittins (1989)) and Nash Equilibrium (Azoulay-Schwartz et al. (2004)). In situations of incomplete information, the methodology suggests that the buyer should seek for non-structured information about the supplier in the market, establish contractual warranties, or demand standardized quality
certifications like ISO and others, in search for risk reduction. As said before, the methodology can be summarized into two steps:

- Classify into three tiers each pair supplier/product according to the historical quality of service that the supplier offers in relation to the product. This classification relies on the aggregation of multiple criteria to fit each pair into the classes, and is accomplished by the Supplier Classification Model. This step is related to quality.

- Implement a reverse auction with the selected suppliers. This auction will determine the combination of proposals that minimizes costs. To accomplish this, a multi-period, multi-product, multi-supplier mathematical model, named the Contract Selection Model, is build. This step is related to reduce costs.

It is supposed that the buyer organization has correct information about the quantities of products it demands and the money available for the periods considered in the mathematical model. Quantities can be previously determined by a Production Planning method, like MRP (Materials Requirements Planning). The solution used is more suitable to strategic materials, and is based on long term contract that specifies a quantity the firm guarantees to buy throughout the planning period and associated payments, with discrepancies between supply and demand resolved in the spot market. For achieving this, the buyer determines quantities, and price is discovered through a reverse auction process, where previously classified suppliers compete for the lowest bid. The problem here focused treats not only many suppliers, but also many products, and the goal of obtaining the lowest total cost in many periods – time dimension is important, since industrial purchases are often recurrent, and the planning horizon depends on products’ obsolescence. This means that a supplier with the lowest price on one product may not be chosen if its payment terms cause an increase on total cost, due to cash flow problems for instance.

2 Supplier Classification Model

The criteria selected are the ones proposed by Ferreira (1993), who estates that besides price, there are ten other determinants of cost; each represents a service level provided by the supplier:

- Product Quality: problems of quality, if not detected by the supplier, will incur an increase in costs related to inspection and rejection on the part of the producer.
- Order Fulfillment Lead Time: the smaller the lead-time, the greater the flexibility of the buyer in being able to respond to the fluctuations of demand.
- Fill Rates: the percentage of the order delivered on the exact date is an important factor in maintaining schedule. Partial deliveries can result in synchronization problems in the production program.
- On-Time Delivery Performance: the percentage of the order delivered on the exact date is an important factor in maintaining schedule. Partial deliveries can result in synchronization problems in the production program.
- Responsiveness to Demand: suppliers must be flexible enough to quickly respond to demand changes.
- Technical Support: a good supplier technical support adds expertise to the company's staff and assists the company to become aggressive in product design, ease of assembly, part commonality and cost control.
− Product Warranty: how readily can replacement components be sourced? If the supplier is fast enough for that, the company will not have synchronization problems.
− Freight Enhancements: good logistics lead to lower costs and shorter lead-times.
− Payment Terms: with what ease can better payment terms be negotiated which bring a return for both sides, allowing a reduction in costs?
− Ordering Practices: how far can the supplier facilitate the placing of orders so as to reduce administrative costs and speed up the whole process as, for example, in the use of Electronic Commerce.

Classification of each pair is accomplished through the use of aggregation of grades for each criterion. Specialists supported by a database with historical supplying data determine these grades. This method places the criteria above in three aggregation sets - Quality, Punctuality and Flexibility. These final criteria will originate a final level of service for each supplier/product pair. Table 1 shows this hierarchical aggregation of criteria. Besides the use of the overall level of service for strategic purposes, the three aggregation criteria or even the basic ones can be used to support specific necessities.

<table>
<thead>
<tr>
<th>Quality</th>
<th>Product Quality: Percentile of the product rejected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Technical Support: Support to the use of the product</td>
</tr>
<tr>
<td></td>
<td>Product Warranty: How fast and in which rates rejected products are replaced</td>
</tr>
<tr>
<td>Punctuality</td>
<td>Fill Rates: Percentile of the orders delivered in the right amount</td>
</tr>
<tr>
<td></td>
<td>On Time Delivery Performance: Frequency with which the orders are received in the right moment</td>
</tr>
<tr>
<td></td>
<td>Order Fulfillment Lead Time: Total time for delivery of an order</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Responsiveness to Demand: Capacity to answer to changes in orders</td>
</tr>
<tr>
<td></td>
<td>Ordering Practices: Use of practices that reduce order costs</td>
</tr>
<tr>
<td></td>
<td>Freight Enhancements: Capacity to transport small amounts</td>
</tr>
<tr>
<td></td>
<td>Payment Terms: Discounts and parceled out payment</td>
</tr>
</tbody>
</table>

Table 1: Criteria Hierarchy

To store historical data collected from orders and deliveries transactional databases a data mart model was developed. This database uses a star schema (Kimball (1996)), shown in Figure 1. This kind of schema is especially useful for analytical databases, in other words, databases that must be optimized for queries. It is supposed that a transactional system supplies data necessary to feed the data mart. Star schemas are based on a single Fact Table, a table that holds transactions’ data, and many Dimensions, or tables that hold data associated to the transactions, for instance, what supplier held a specific delivery. The Deliveries Fact Table holds data of each delivery transaction. The Time dimension places the facts in time, the dimensions Supplier and Product links the facts to the pairs, the Transportation and Agreement dimensions are related to each fact (order/delivery) deal characteristics, and finally the dimension Location simply places a fact in a geographical reference.
The classification process proceeds by evaluating the performance of each pair supplier/product according to each sub-criterion. The next step is to aggregate the grades towards Quality, Punctuality, and Flexibility and then towards the Overall Performance. As showed in Carvalho (2001), to aggregate criteria, many methods can be used: the use of Fuzzy Logic, Rough Sets Theory and Back Propagation Artificial Neural Networks. Yet other solutions like arithmetic mean and Multi-Criteria Decision Making techniques can also be used, depending on the levels of subjectivity involved in the process and the technical culture of purchasing experts.

The final step of this method is to segment pairs into three classes:

− First Class: the supplier is selected to compete for long and medium term contracts for the product. Also, it can enter ordinary bidding process for spot necessities, and joint product development programs.

− Second Class: the supplier can compete for spot necessities and may substitute a First Class supplier for the product if necessary.

− Third Class: the supplier must enter a quality development program to rejoin purchasing processes in the future.

### 3 Contract Selection Model

This model seeks to minimize the direct purchasing costs, since the classification process treats the indirect costs. Prices must be negotiated in terms of the total quantity, and each supplier adjusts its offer to its selling multiples and capacity, establishing a final price that considers its own price ranges and logistics costs. Each supplier bids in terms of periods, selling multiples, prices, and payment conditions. Based on the proposals, demand, financial conditions and storage capacity available, the buyer coordinates the creation of different purchasing scenarios through the DSS, according to different parameters like maximum indebtedness and inventory levels. These scenarios can be used to coordinate purchasing with planning, like in the case of earlier and latter MRP dates. Optionally, numerical values obtained in the classification process can be used to adjust price coefficients (Carvalho (2001)). The mathematical model, which is classified as a Deterministic Single Objective Model, can be described as follows.

**Objective Function:**

(0) Minimize the total direct cost of acquisition: (total of loans – total of invested surplus) + (total inventory cost) + (total spent directly in acquisition). This function aims to minimize the direct acquisition costs. When using classification coefficients, indirect costs are also
considered. Loans and invested surplus are updated according to interests paid or earned respectively.

**Supply Constraints:**

1. **Product Necessity:** (previous period inventory + amount acquired in the current period) ≥ (product necessity in the current period). This set of constraints aims to guarantee the acquisition of the minimum necessary amount.

2. **Inventory Formation:** (current period inventory) = (previous period inventory + amount acquired in the current period – consumed amount). Set of constraints that controls inventory formation.

3. **Supply Scheme:** (amount acquired in the current period) = (total amount acquired from one selected supplier). Binary variables are used to guarantee that one and only one supplier will be selected.

**Financial Aspects:**

4. **Financial Inventory Formation:** (money “inventory” at the end of the period) = (initial “inventory” available for the period + loans + previous period invested surplus – amount of money spent in the current period – parcel payments relative to loans taken in previous periods). This set of constraints establishes the relation between orders and the necessity of obtaining financial resources from the market, or, inversely, the formation of financial surplus in a given period. Again, loans and invested surplus are updated according to interests paid or earned respectively.

5. **Necessary Investment per Period:** (amount spent in the period) = (sum of the payments to be realized in the period). This set of equalities totalizes the amount of money to be invested directly in products acquisition.

**Storage Aspects:**

6. **Storage Limits:** (total room for products) ≤ (available room for products) or (maximum inventory allowed). Establishes the storage limits for each group of materials. Room is expressed in quantities of products, not in real physical volume.

**Tie-in-Sales:**

7. **Tie-in-sale:** For the cases where the order of a given product for a given condition is tied to the order of another material.

The algebraic representation of the model is as follows.

**MINIMIZE:**

\[(\forall t \in T) \land (\forall g \in G)\]

\[\Sigma_{g} \left[ ((1 + j_{g})J_{g} - d_{g}D_{g}) + \Sigma_{meM} (e_{tm}E_{tm}) \right] + C_{g rf_{m}}\]

**SUBJECT TO:**

1. **Product Necessities**

\[(\forall t \in T) \land (\forall m \in M)\]

\[E_{(t - 1)m} + Q_{tm} \geq N_{tm}\]
(2) Inventory Formation

\((\forall \, t \in T) \land (\forall \, m \in M)\)

\(E_{tm} = E_{(t-1)m} + Q_{tm} - N_{tm}\)

(3) Supply Scheme

\((\forall \, t \in T) \land (\forall \, m \in M) \land (\forall \, f \in F(m))\)

\(Q_{tm} = \Sigma_f Y_{mf} P_{tmf}\)

\((\forall \, m \in M) \land (\forall \, f \in F(m))\)

\(\Sigma_f Y_{mf} = 1\)

(4) Financial Inventory Formation

\((\forall \, t \in T) \land (\forall \, g \in G)\)

\(D_g = D_g^0 + J_g + d_{g-1}D_{g-1} - C_g - j_{g-1}J_{g-1}\)

(5) Necessary Investment per Period

\((\forall \, g \in G) \land (\forall \, m \in M) \land (\forall \, f \in F(m))\)

\(C_g = \Sigma_m \Sigma_f P_{gmf} Y_{mf}\)

(6) Storage Limits

\((\forall \, t \in T) \land (\forall \, a \in A) \land (\forall \, m \in M(a))\)

\(\Sigma_m S_{tm} E_{tm} \leq CA_{ta}\)

(7) Tie-in-sale

\(Y_{If} = Y_{Jf}\)

**Where:**

T: Set of supply periods

t: T index

M: Set of products

m: M index

F: Set of suppliers

f: F index

G: Set of payment periods

g: G index

F(m): Set of suppliers for a given product m

A: Set of warehouses

a: A index

M(a): Set of products that can be stored at the warehouse a \in A
r_{mf}: Classification coefficient for product m, supplier f  
J_g: Loan amount in period g  
j_g: Interest rates for loans in period g  
D_g: Money surplus at the end of period g  
d_g: Interest rates for invested surplus in period g  
D_0^g: Available money in the beginning of the period g  
C_g: Total money spent in period g  
E_{tm}: Inventory of m in period t  
e_{tm}: Unitary cost for E_{tm}  
P_{tmf}: Proposed amount of m in period t by supplier f  
p_{tmf}: Proposed price for P_{tmf}  
Q_{tm}: Amount ordered of product m in period t  
N_{tm}: Necessity of product m in period t  
S_m: Approximated space occupied by a unit of product m  
C_A_{ta}: Storage capacity available of warehouse a in period t  
i, j: Indexes for tie-in-sales  

To support the storage of data necessary for the mathematical model an object-oriented information system model was developed. This approach can provide a solid methodological and philosophical basis for both decision making and the development of DSS (Liu e Stewart (2000)).

5 DSS General Structure

The DSS must support classification and contract selection methods in a Web based environment. Therefore, it should allow users to: (i) keep a database that helps quality analysis for each pair supplier/product, (ii) builds and solves contract selection problems, (iii) access all its functionalities through the Web.

The platform chosen to build the DSS is the Z Object Publishing Environment (Zope). The high-level DSS architecture. The architecture relays on a web server that answers to HTTP requests from a browser. Integrated with the web server there is an application server that runs the algorithms related to data collecting and storage, and mathematical model building. A relational database is used to store analytical data and an OODB (ZODB - Zope Object Database) stores transactional data, in order to facilitate algorithm implementation, making persistence the more transparent possible. ZODB is also used to store procurement process documentation, since Zope is also an excellent platform for Content Management. A Solver is used to solve contract selection problems created by the system, which can hold the results obtained for future analysis. Finally, it is necessary to integrate a classification engine if techniques like Fuzzy Logic are used. According to Holsapple e Whinston (1996), this DSS is classified as a hybrid one. It is, at the same time; database based (classification data mart), solver based, and text based (general documentation storage and retrieval).
6 Conclusions

Although the DSS here described directly supports the specific methodology developed in Carvalho (2001), it was implemented to be flexible. All system models can be adapted for specific purposes, depending on the adopting organization. The work developed on top of it is now divided in two efforts: (i) creating a module for the open source ERP project ERP5 (http://www.erp5.org), so it can be freely adopted and customized by any organization that may get interested for it, and (ii) adapt the methodology and DSS implementation to a specific environment and technological platform used by a major Brazilian oil company, which aims to use the DSS to support decisions on contracts for offshore materials and services.

References


