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Determining Sourcing Strategies : a Decision Model Based on Activity and Cost Driver Information

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Abstract

Determining sourcing strategies for different material groups provides a major challenge to most companies. There has been little research on the choice of the optimal number of different suppliers for a given product group and the determination of their market shares. In this paper we propose a mathematical programming model using activity based costing information to determine optimal order splitting among suppliers on the basis of the different costs associated with the purchasing decision. We argue that sourcing strategies should be based on the minimization of the total cost of ownership resulting from external purchases. The model is applied to the case of ball bearings at Cockerill Sambre S.A., a Belgian multinational company in the steel industry.

Keywords : Accounting/operations, Purchasing

1 Introduction

Since material costs represent an important percentage of the cost of goods sold for most companies, increasing the efficiency and effectiveness of the purchasing function can have a major impact on realized profits and return on equity. An important problem facing a purchasing department is the determination of sourcing strategies or the choice of an optimal number of vendors and the allocation of market shares to these suppliers to satisfy the demand for the different product groups. It is generally agreed that in addition to price, several elements should be considered in this process. Quality, delivery, production capacity, geographic location, financial position, performance history and warranties and claims seem to be the most important criteria studied in the existing literature (Weber and Current 1991).

The determination of optimal sourcing strategies offers important possibilities for cost savings. In recent years there has been a tendency to use fewer sources of supply. It is argued that a reduction in the supplier base results in better long term working relationships between vendors and the purchasing company (Mehra and Inman 1992). Furthermore, it would also aid in lowering the total cost of procurement (Hahn e.a. 1986, Trevelen 1987). The increased importance of vendors' performances in production strategies such as just-in-time and design-for-manufacturing makes it necessary to spend more time on training and development of a limited number of suppliers (Kekre e.a. 1995). As Lau and Lau (1994) note, many authors have advocated the use of single sourcing. In a single sourcing environment the total demand for a given item is purchased from one vendor. A shift to single sourcing has been observed in several industries (Kekre e.a. 1995). It would lead to a reduction in administrative costs, an improved communication between supplier and purchasing company, improved logistics operations, reduced inventory and increased process and product innovations (Quayle 1995). However, the use of a limited number of suppliers also has important disadvantages. Treleven and Schweikhart (1988) develop a taxonomy of the benefits and risks that correspond to single and multiple sourcing. They identify disruption of supply, price escalation due to more power of the vendor, inventory shortages and less access to new technologies in the market as the major risks in a single sourcing environment. An analysis of the advantages and disadvantages of reducing the supplier base seems to indicate that sourcing strategies can be different for different product groups dependent on their specific characteristics.

Notwithstanding the importance of using an optimal number of suppliers, there has been little research on the determination of sourcing strategies. The development of decision rules for the selection of an optimal number of vendors, the allocation of order quantities among suppliers and the determination of inventory policies where multiple sourcing is used are therefore highly ranked on the research agenda (Pan e.a. 1991). As far as we know there has been no work on the integration of these decisions that takes into account the different relevant criteria to the purchasing process in an objective way.

In this paper we introduce a multi period decision model based on activity and cost driver information to evaluate sourcing strategies. This approach simultaneously determines an optimal number of suppliers to be selected, optimal market shares for the selected vendors and an optimal order and inventory policy. It takes into account all costs associated with the purchasing process throughout the value chain of the purchasing company in the periods considered. It deals in an objective way with the criteria that are relevant in the process and can result in different sourcing strategies for different product groups depending on the specific characteristics of the items and suppliers involved. The ideas presented in this paper are motivated and illustrated by the real life procurement problem of ball bearings at Cockerill Sambre S.A., a multinational Belgian steel company.

The remainder of this paper is organized as follows. A second section discusses our approach and describes how new developments in management accounting can be used for the determination of sourcing strategies. The third section describes the case study of ball bearings at Cockerill Sambre S.A.. The fourth section gives conclusions and suggestions for future research.

2 Decision model based on activity and cost driver information

In today's competitive environment, purchasing managers build relationships with suppliers on the basis of net prices and different other criteria related to the sourcing decision. The selection of the right suppliers for a given product group and the determination of their market shares is the most fundamental decision a purchasing department makes. A major problem related to this decision is the analysis and quantification of the different elements that should be considered in the decision making process.

The choice of an optimal sourcing strategy is a relatively unexplored area in the purchasing literature. Gregory (1986) uses a weighted point plan that compare vendors on the basis of different relevant criteria. It generates a score for each supplier and derives an order split between different suppliers on the basis of the relationship between the different scores. He suggests that significant score differences between vendors should result in single sourcing, but provides no specific decision rules regarding sourcing strategies. Treleven and Schweikhart (1988) develop a risk/benefit assessment model to examine sourcing strategies. They distinguish five risk/benefit categories and use an additive rating model where the impact of the categories is subjectively determined by management. Pan e.a. (1991) concentrate on lead time distributions in a multiple sourcing environment. They conclude that the advantage of splitting orders among vendors increases as the variability in the lead times increases, but do not consider other criteria relevant to the sourcing decision. Weber and Current (1993) use a multi objective goal programming approach for supplier selection. A fixed number of vendors is introduced as a constraint in their problem formulation. The market shares of the suppliers result from the model. Akinc (1993) proposes a decision support system that minimizes net prices and the number of suppliers while maximizing suppliers' delivery and quality performances. Key elements in his analysis are the limitation of the size of the supplier base and the short term sacrifice in net price, quality and delivery performance caused by a reduction in the supplier base. Lau and Lau (1994) discuss the sourcing decision in the context of minimizing prices and costs related to delivery unreliability when two suppliers with different lead times and price performances can be used. Their analysis shows that the coordination of two suppliers has advantages in a wide variety of situations. Other authors working in this area concentrate on the price dimension and introduce different discount schemes in mathematical programming model (see Benton and Park 1996 for an overview) with the objective of achieving the least invoice cost without considering other criteria relevant to vendor selection or by introducing quality and delivery reliability as a constraint (Chaudry, Forst and Zydiac 1993; Rosenthal 1995; Zydiac and Chaudry 1995).

It should be clear from this literature review that there has been little systematic research on the choice of the number of suppliers and the determination of order quantities to be delivered by the different suppliers and that most papers concentrate on one or a limited number of relevant criteria. The few approaches that incorporate elements beyond price introduce subjectivity in the decision process. Our methodology takes into account all elements that are relevant to the decision process and simultaneously decides on the number of suppliers to be selected and the vendors' market shares. We propose a mathematical programming model based on activity and cost driver information to determine optimal sourcing strategies. This methodology allows us to make a trade off between different sourcing strategies considering all criteria relevant to the decision. The aim is to determine optimal market shares for different suppliers so that the total costs for a given number of externally procured items is minimized. These costs include net price plus all supplementary costs caused by the suppliers in the purchasing company's value chain and are associated with the different criteria in the purchasing process. Since activity based costing assigns resources to the different activities on a full cost basis, this approach is very interesting from a strategic point of view.

The determination of the total costs related to different sourcing strategies is an important challenge for most companies. Traditional management accounting systems were designed for manufacturing environments where direct costs accounted for a large percentage of total costs. They use volume driven allocation bases to assign overhead costs to cost objects such as products and customers and provide little or no helpful information for the determination of sourcing strategies. Contrary to these traditional systems, well designed activity based costing systems provide the users with a better understanding of the different activities performed in a company, the costs related to these activities and the activities consumed by the cost objects as reflected by cost drivers. In the context of sourcing strategy determination this information can be very useful. The analysis of the consumption of resources by the different activities caused by the external procurement in the value chain of the purchasing company enables us to quantify the full cost related to different sourcing strategies. From an activity based costing perspective, the optimal sourcing strategy is defined as the strategy that minimizes the total procurement costs for a given product group. Roodhooft and Konings (1997) use information on activities and cost drivers to select one supplier for a given number of orders. They do not consider the problem of splitting orders among suppliers. Degraeve and Roodhooft (1996) provide a methodological background for the use of activity based costing information in the vendor selection process. They recognize a hierarchical structure in activities and cost drivers with respect to the purchasing decision, an important concept for model formulation purposes.

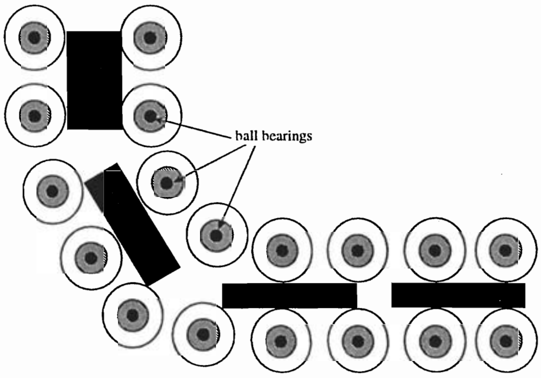
3 Case study

3.1 Description of the problem

We study the procurement of ball bearings at Cockerill Sambre S.A., a Belgian multinational company in the steel industry with external purchases approaching $2 billion annually or more than 70% of total costs. The company uses more than 4000 active suppliers. Management wants to improve the efficiency of the purchasing process and reconsiders the sourcing strategies for different product groups. Our case study refers to the ball bearings, a product selected for study by the purchasing managers of the firm, a business of about $1,000,000.- per year. There are 33 ball bearing types in the problem for which purchasing decisions must be made.

The ball bearings are mainly used for transportation of the hot steel slabs after steel has been produced in the blast furnaces and collected to form the slabs. The transportation lines consist of several rows of steel cylinders as depicted in Figure 1.

Figure 1 : Usage of the Ball Bearings.



The steel cylinders and the ball bearings are used in very rough conditions under extremely high temperatures. This causes the surface of the steel cylinders to deteriorate quickly such that they have to be replaced frequently and brought to a maintenance department for remodeling. At the time of replacement of the cylinders, the ball bearings are also replaced in anticipation of potential problems and thus before they have been used for their full useful live. There is a revenue associated with used ball bearings based on their weight and mounting to BF 6,000.- per ton. There are essentially 6 possible suppliers, two of which are currently used by the company. At the time of our study, quality engineers were also performing tests with the ball bearings of a third potential supplier. Important price differences exist at the individual ball bearing type level. No quantity discounts apply to this product group.

3.2 Formulation of the decision model

In this section, we present the mathematical programming decision model that was used for the determination of an optimal sourcing strategy for the ball bearing product group. The only assumption used is the fact that the company can place at most one order per time period with each supplier. This assumption is not restrictive, however, as the typical order frequency could determine the length of the time bucket to be a month, a week or even a day. Specifically for the case study, we consider a one year time horizon subdivided into six bi-monthly time buckets.

Before stating the model, we give a summary list of the notation for later reference. The following primitive sets, grouping the key elements of the model, are used :

N : set of ball bearing types, index i,
M : set of time periods, index t,
P : set of suppliers, index s.

The parameters indicate the data required. Following Degraeve and Roodhooft (1996), we distinguish three hierarchical levels of activities into which the parameters can be subdivided : (1) the supplier level, (2) the order level and (3) the unit level. The resources consumed by the activities at the different levels are determined on the basis of the activity based costing system installed by Cockerill Sambre S.A.. The first hierarchical level, the supplier level parameters, describe costs incurred and conditions imposed whenever the purchasing company actually uses the supplier over the decision horizon. For the ball bearings' problem specifically we consider :

mc_s : cost of a dedicated purchasing manager for supplier s, $\forall$ s $\in$ P,

se_s : discount resulting from service provided by the supplier, $\forall$ s $\in$ P,

slc : total supplier level costs,

mins : minimum number of suppliers to use,

maxs : maximum number of suppliers to use.

The second hierarchical level, the order level parameters, indicate costs incurred and conditions imposed each time an order is placed with a particular supplier. At this level specifically we consider :

vc_s : invoice cost per order placed with supplier s, $\forall$ s $\in$ P,

oc_s : order cost per order when purchasing from supplier s, $\forall$ s $\in$ P,

rc_s : reception cost per order when purchasing from supplier s, $\forall$ s $\in$ P,

olc : order level costs.

The third hierarchical level, the unit level parameters, specify costs incurred and conditions imposed related to the individual units of the products for which a procurement decision has to be made. At this level we consider :

rev : salvage value of used ball bearings per kilogram,

wt_i : weight in kilogram of ball bearing type i, $\forall$ i $\in$ N,

p_{si} : price for ball bearing type i offered by supplier s, $\forall$ i $\in$ N, $\forall$ s $\in$ P,

dc_s : price discount as a percentage per time bucket due to payment delay given by supplier s, $\forall$ s $\in$ P,

b_s : beginning inventory of ball bearing type i, $\forall$ i $\in$ N,

SS_i : safety stock of ball bearing type i, $\forall$ i $\in$ N,

ap_i : average price of ball bearing type i, $\forall$ i $\in$ N,

d_{it} : demand for ball bearing type i in period t, $\forall$ t $\in$ M,

h : inventory holding cost per unit per period as a percentage of the product's price,

aulc : the additional unit level costs,

arev : revenue generated from selling off used ball bearings,

purc : purchase costs,

invc : the inventory holding cost,

ulc : total unit level costs.

As for the parameters, the decision variables can also be subdivided into the same three hierarchical levels. The supplier level decision variable models whether or not the supplier will be used by the purchasing company over the planning horizon and is as follows :

z_s = 1, if we buy from supplier s, 0, otherwise, $\forall$ s $\in$ P.

The order level decision variable models the characteristics of the individual orders placed with the suppliers used. For our problem, we only have two order level decision variables as follows :

u_{st} = 1, if we buy from supplier s in period t, 0, otherwise, $\forall$ s $\in$ P, $\forall$ t $\in$M,

xt_{st} = total amount bought from supplier s in period t, $\forall$ s $\in$ P, $\forall$ t $\in$ M.

The unit level decision variables pertain to the units of the products for which a procurement decision has to be made and are defined as follows :

sd_{sit} = consumption of ball bearings type i bought from supplier s in period t, $\forall$ s $\in$ P, $\forall$ i $\in$ N, $\forall$ t $\in$ M,

x_{sit} = amount of ball bearings type i bought from supplier s in period t, $\forall$ s $\in$ P, $\forall$ i $\in$ N, $\forall$ t $\in$ M,

y_{sit} = 1, if we buy ball bearing type i from supplier s in period t, $\forall$ s $\in$ P, $\forall$ i $\in$ N, $\forall$ t $\in$ M,

v_{sit} = inventory of ball bearing type i bought from supplier s period t, $\forall$ s $\in$ P, $\forall$ i $\in$ N, $\forall$ t $\in$ M,

sx_{it} = total amount of ball bearing type i bought in period t, $\forall$ i $\in$ N, $\forall$ t $\in$ M,

sy_{it} = 1, if we buy ball bearing type i in period t, , $\forall$ i $\in$ N, $\forall$ t $\in$ M,

sv_{it} = inventory of ball bearing type i in period t, , $\forall$ i $\in$ N, $\forall$ t $\in$ M.

With the notation given above, the mathematical decision model is described below.

Objective : minimize the total cost of ownership ;

$$Min \quad slc+olc+ulc \tag{1}$$

The objective function (1), which is used to evaluate alternative procurement policies, is a minimization of the total cost of ownership and reflects net prices and resources consumed by the activities in the three hierarchical levels distinguished.

Define the supplier level costs ;

$$slc=\sum_{s\in P} mc_s\, z_s - \sum_{s\in P} se_s \sum_{i\in N}\sum_{t\in M} p_{si}\, x_{sit} \qquad (2)$$

The supplier level costs are incurred whenever the purchasing company actually uses supplier s over the planning horizon, i.e. $z_s = 1$. A dedicated purchasing manager can be put to some alternative use if supplier s is not chosen, i.e. $z_s = 0$. In this case, the activities should not be considered in the purchasing decision. In addition, each supplier fulfills a service contract including such options as technical assistance with installation and removal, training in installation and removal procedures, providing help in an emergency situation. However, not all suppliers have all options included in the service contract and offer equal service on the options included. If an option is not included in the contract, it causes additional consumption of resources for these activities in the purchasing company. The difference among the suppliers' service intervention is quantified in terms of money saved as a percentage of the purchase price on the amounts bought. It reflects the cost savings in the value chain of Cockerill Sambre. This difference is taken into account in the second term of the supplier level costs (2). This means that perceived differences among suppliers with respect to service should not be considered in an arbitrary subjective way but have to be quantified in cost terms and included in the overall objective function of the decision model in order to objectively evaluate the various suppliers.

Define the order level costs ;

$$olc = \sum_{s \in P} \sum_{t \in M} \left(vc_s + oc_s + rc_s \right) u_{st} \tag{3}$$

The order level costs are incurred in those time periods t when an order is placed with a particular supplier, i.e. $u_{st} = 1$. They consist of the invoice cost and the ordering cost when purchasing from supplier s.

Define the unit level costs ;

$$ulc = purc + invc - arev \tag{4}$$

Specifically, the unit level costs consist of the purchase costs and the inventory holding cost. There is also an additional revenue due to sales of used ball bearings.

Define the purchase costs ;

$$purc = \sum_{s \in P} \sum_{i \in N} \sum_{t \in M} p_{si} \left(1 - dc_s \right) x_{sit} \tag{5}$$

Typically in this business, the suppliers allow for a payment delay of several months. We have chosen to model the payment delay by a price discount as a percentage on the purchase price per unit per period. As such, we can quantify the difference in payment delay given by different suppliers.

Define the inventory holding cost ;

$$invc = \sum_{s \in P} \sum_{i \in N} \sum_{t \in M} h\, p_{si}\, v_{sit} + \sum_{i \in N} 6h\, ap_i\, SS_i \tag{6}$$

The inventory holding cost applies to the total amount of ball bearings type i of supplier s held in inventory in each time period t, v_{sit}. A supplier selection model should consider inventories explicitly and thus be inherently dynamic, as there is the potential trade-off between ordering more and thus avoiding the order level costs and the cost of keeping the extra amounts in inventory. There is also a particular safety stock level required for each ball bearing type. Although not part of the decision problem, the second term is set by management based on experience and is included to compute the inventory holding costs.

Define the additional revenue ;

$$arev = \sum_{i \in N} \sum_{t \in M} rev\, wt_i\, d_{it} \qquad (7)$$

Additional revenue is generated by selling off used ball bearings which can partly be recycled. The salvage value which essentially includes the value of the steel is applied to the weight and the units consumed in time period t, d_{it}.

This concludes the derivation of the objective function. The constraints relevant to the procurement problem of the heating electrodes are as follows.

Satisfy the demand ;

$$\sum_{s \in P} \sum_{i \in N} sd_{sit} = d_t \qquad \forall t \in M \qquad (8a)$$

$$b_{si} + x_{si1} - v_{si1} = sd_{si1} \qquad \forall s \in P, \forall i \in N \qquad (8b)$$

$$v_{sit-1} + x_{sit} - v_{sit} = sd_{sit} \qquad \forall s \in P, \forall i \in N, \forall t \in M \setminus \{1\} \qquad (8c)$$

First, constraints (8a) will determine the consumption of ball bearings type i bought from each supplier in each time period of the planning horizon, sd_{sit}. The consumption of ball bearings type i from each supplier in the first time period, sd_{si1}, modeled by constraints (8b), can be satisfied either from beginning inventory, b_{si}, and/or from purchases from the potential suppliers, x_{s1}. The amount that remains is end-of-period inventory, v_{s1}. Constraints (8c) model the consumption of products from each supplier in later time periods, sd_{sit}. This consumption is satisfied either from begin-of-period inventory, which equals the ending inventory of the previous period, v_{st-1}, and/or from purchases, x_{sit}. Again, the amount that remains is end-of-period inventory, v_{sit}.

Impose the bound on the order quantity ;

$$x_{sit} \leq \sum_{l \in M, l \geq t} d_{il} \, y_{sit} \qquad \forall s \in P, \forall i \in N, \forall t \in M \qquad (9)$$

The conditions (9) essentially model the logical relationship between the ordering, y_{sit}, and the order quantity variables, x_{sit}. If an order is placed for ball bearing type i with supplier s in period t, i.e. $y_{sit} = 1$, then the given upper bound on the number of units to be bought applies. In case an order is not placed for ball bearing type i with supplier s in period t, $y_{sit} = 0$, then the amount bought from the supplier should indeed be zero.

Compute total amount bought ;

$$\sum_{i \in N} x_{sit} = xt_{st} \qquad \forall s \in P, \forall t \in M \qquad (10a)$$

$$xt_{st} \leq \sum_{i \in N} \left(\sum_{l \in M, l \geq t} d_{il} \right) u_{st} \qquad \forall s \in P, \forall t \in M \qquad (10b)$$

$$u_{st} \leq \sum_{i \in N} y_{sit} \qquad \forall s \in P, \forall t \in M \qquad (10c)$$

$$y_{sit} \leq u_{st} \qquad \forall s \in P, \forall i \in N, \forall t \in M \qquad (10d)$$

For information purposes, it is nice to know the total amount of ball bearings of any type that are bought from a vendor s in time period t, xt_{st} modeled by the constraints (10a). Constraints (10b) model the proper relationship between the ordering variables, u_{st} and the total amount ordered. The logical conditions (10c) and (10d) are required to correctly define the ordering variables u_{st} which are used in the objective function at the order level (3).

Enforce the bounds on number of suppliers used ;

$$\sum_{s \in P} z_s \geq mins \qquad (11a)$$

$$\sum_{s \in P} z_s \leq maxs \qquad (11b)$$

$$z_s \leq \sum_{t \in M} u_{st} \qquad \forall s \in P \qquad (11c)$$

$$u_{st} \leq z_s \qquad \forall s \in P, \forall t \in M \qquad (11d)$$

The conditions (11a) and (11b) force the purchasing plan to have at least the minimum number, mins, and at most the maximum number, maxs, of suppliers over the complete time horizon. Using constraint (11c), the decision variable z_s will be equal to 0, if the model suggests not to buy from the supplier s, while constraint (11d) forces z_s to be equal to 1, if during some time period t, an order has been placed with supplier s.

Integrality and nonnegativity ;

$$z_s \in \{0,1\} \qquad \forall s \in P \qquad (12a)$$

$$u_{st} \in \{0,1\},\ xt_{st} \geq 0 \qquad \forall s \in P, \forall t \in M \qquad (12b)$$

$$y_{sit} \in \{0,1\}, x_{sit} \geq 0, sd_{sit} \geq 0, v_{sit} \geq 0 \qquad \forall s \in P, \forall i \in N, \forall t \in M \qquad (12c)$$

To conclude the model specification, constraints (12a) - (12c), impose the proper integrality and nonnegativity conditions that apply to the decision variables. Model (1) - (12c) is a mixed integer linear program that can be solved with specialized optimization software such as LINGO (Cunningham and Schrage 1995) on any IBM compatible 486 or higher PC. The current dimensions of the problem are 33 ball bearing types that can be bought from 6 suppliers using a time horizon of 6 periods. In order to obtain an optimal solution in a reasonable amount of computation time, we have added the following constraints to the model :

$$\sum_{s \in P} x_{sit} = sx_{it} \qquad \forall i \in N, \forall t \in M \qquad (13a)$$

$$\sum_{s \in P} v_{sit} = sv_{it} \qquad \forall i \in N, \forall t \in M \qquad (13b)$$

$$sx_{it} \leq \left(\sum_{l \in M, l \geq t} d_{il} \right) sy_{it} \qquad \forall i \in N, \forall t \in M \qquad (13c)$$

$$sy_{it} \leq \sum_{s \in P} y_{sit} \qquad \forall i \in N, \forall t \in M \qquad (13d)$$

$$y_{sit} \leq sy_{it} \qquad \forall s \in P, \forall i \in N, \forall t \in M \qquad (13e)$$

$$\sum_{t\in C} sx_{it} \leq \sum_{t\in C}\left(\sum_{r=t}^{l} d_{ir}\right) sy_{it} + sv_{il} \qquad 1\leq l\leq |M|, L=\{1,2,\ldots,l\}, and\, C\subseteq L \qquad (13f)$$

The purpose of the above constraints is to cut off part of the linear programming relaxation solution space without eliminating any feasible integer solutions. Equalities (13a) and (13b) define the total quantity bought and inventory of ball bearing type i in time period t. Inequalities (13c) model the relationship between the total amount ordered and the ordering decision while inequalities (13d) and (13e) enforce the logical relationships among the 0/1 decision variables involved. Cutting planes (13f) were developed by Barany et al. (1984) and represent facet defining inequalities for the lot size polytope (8a) - (8c). They provide for tighter linear programming relaxations which are used in the bounding procedure for the branch and bound solution process. Tighter bounds are obtained and shorter computation times result. For all computational experiments reported in the next section, the resulting gap between the linear programming relaxation objective and the integer optimum is typically less than 1%.

3.3 Results

This section gives an overview of our analysis. The computational results are given in Table 1. The first case of Table 1 describes the current sourcing strategy of Cockerill Sambre for the procurement of ball bearings. Supplier 2 is the main supplier with a market share of 82.5%. This supplier has the best service level as reflected by the savings at the supplier level. Furthermore, this suppler uses Electronic Data Interchange (EDI) for ordering and invoicing purposes and offers the lowest prices for some of the types. The market share of supplier 1 amounts to 15.1%. This supplier offers a good service level, works with EDI but has somewhat higher prices. Cockerill Sambre S.A. currently performs tests with supplier 6 resulting in a limited market share of 2.4%. Total sales equal 38,706,206 and represent 74% of the total cost of ownership. Costs beyond price that are related to activities caused by the selected suppliers in the value chain of the purchasing company amount to 26% of the total cost of ownership.

The second case of Table 1 gives the optimal sourcing strategy that results from our mathematical programming decision model. The use of four suppliers minimizes the total cost of ownership related to the procurement of ball bearings. Compared to the current strategy, the market share of supplier 2 decreases in favor of supplier 5 and supplier 6. The first supplier is removed from the solution and supplier 3 is used for the procurement of one item. Total savings amount to 11.5% when compared to the current strategy. Costs increases are incurred at the supplier level and the order level. Due to the introduction of more suppliers and the lower service levels offered by the suppliers in the optimal solution, there is an important decrease in savings realized at the supplier level. The increase in order level costs is due to the absence of EDI ordering and invoicing possibilities for suppliers 3,5 and 6. On the other hand, important sales savings are realized at the unit level. These savings amount to 18.7% due to lower prices offered by the new suppliers for some of the ball bearing types.

From the theoretical perspective of our paper, it is important to compare the optimal sourcing strategy with other strategies generated by our decision model. Case 3 of Table 1 gives the solution and the related cost of ownership if Cockerill Sambre S.A. would prefer single sourcing. In this case supplier 2 is selected for all items. This increases savings at the supplier level because of the decrease in the number of suppliers and the use of the supplier with the best service level. The reduction in the number of orders and the use of EDI for ordering and invoicing purposes with the second supplier results in cost reductions at the order level. When compared to the optimal strategy, single sourcing gives rise to an increase in total sales volume of 25.6%. Taken into account the difference at all levels considered in our analysis, this leads to an important total cost of ownership increase.

Case 4 of Table 1 describes the results of the optimal solution when the sourcing strategy consists of using two suppliers. Market shares for suppliers 2 and 5 equal respectively 62.3% and 37.7%. When compared to the optimal policy, supplementary savings are realized at the supplier and order levels resulting from a decrease in the number of suppliers and orders. Unit level costs increase because of higher net prices paid for some of the items. Case 5 of Table 1 gives our solution to the sourcing strategy that consists of using three suppliers. Only minor differences exist between the optimal sourcing strategy and the use of three suppliers. It seems to be clear that single sourcing and even using two suppliers is not a recommended course of action for the procurement of ball bearings at Cockerill Sambre S.A..

Table 1 : Computational Results.

Case 1 : Current Policy			Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6
Supplier Level	-1,818,160.-	Sales Volume 38,706,206.-	5,861,042	31,918,164	0.0	0.0	0.0	927,000.-
Order Level	438,504.-	Market Share	15.1%	82.5%	0.0%	0.0%	0.0%	2.4%
Unit Level	53,624,630.-							
Total	52,244,974.-	Total Savings	0.0%	Sales Savings	0.0%			
Case 2 : Optimal Policy			Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6
Supplier Level	-889,383.-	Sales Volume 31,451,322.-	0.-	16,178,339.-	563,496.-	0.-	11,039,618.-	3,669,869.-
Order Level	609,312.-	Market Share	0.0%	51.4%	1.8%	0.0%	35.1%	11.7%
Unit Level	46,489,100.-							
Total	46,209,029.-	Total Savings	11.5%	Sales Savings	18.7%			

Table 1 (continued) : Computational Results.

Case 3 : Single Sourcing			Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6
Supplier Level	-1,954,976.-	Sales Volume 39,499,519.-	0.-	39,499,519.-	0.-	0.-	0.-	0.-
Order Level	193,248.-	Market Share	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%
Unit Level	54,347,010.-							
Total	52,585,282.-	Total Savings	-0.7%	Sales Savings	-2.0%			
Case 4 : Using 2 Suppliers			Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6
Supplier Level	-1,007,515.-	Sales Volume 33,166,937.-	0.-	20,650,300.-	0.-	0.-	12,516,637.-	0.-
Order Level	505,296.-	Market Share	0.0%	62.3%	0.0%	0.0%	37.7%	0.0%
Unit Level	48,015,910.-							
Total	47,513,691.-	Total Savings	9.1%	Sales Savings	14.3%			

Table 1 (continued) : Computational Results.

Case 5 : Using 3 Suppliers			Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6
Supplier Level	-873,194.-	Sales Volume 31,608,332.-	0.-	15,984,962.-	0.-	0.-	12,128,518.-	3,494,852.-
Order Level	609,312.-	Market Share	0.0%	50.6%	0.0%	0.0%	38.4%	11.1%
Unit Level	46,546,110.-							
Total	46,282,228.-	Total Savings	11.4%	Sales Savings	18.3%			

4 Conclusion and suggestions for future research

In this paper we propose a mathematical programming model based on activity and cost driver information for determining sourcing strategies. Our model gives the opportunity to take into account all costs related to external purchases. These costs include net prices as well as costs beyond price incurred in the value chain of the purchasing company. The model allows us to make an objective trade off between different sourcing strategies. Optimal strategies are derived on the basis of the minimization of the total cost of ownership.

The case study of ball bearings at Cockerill Sambre S.A. illustrates the approach. For this product group it seems optimal to select four suppliers. Single sourcing would increase the total cost of ownership by almost 13%. The importance of price differences between possible suppliers for the ball bearing items explains this result. This does not mean that multiple sourcing is optimal for all product groups. The optimal sourcing strategy indeed depends on the specific characteristics of the items and suppliers involved.

Future research could include the following items: (1) the evaluation of other approaches determining sourcing strategies in our framework; (2) the choice between different contract forms in the relationship with suppliers; (3) the use of our approach for negotiations with suppliers; and (4) the introduction of uncertainty with respect to some elements included in the analysis.

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