

VENDOR SELECTION AND DETERMINING PROCUREMENT QUOTAS IN CONDITIONS WHEN DISCOUNTS ARE OFFERED ON THE TOTAL VALUE OF THE CONTRACTED PROCUREMENT OF MANY DIFFERENT PRODUCTS

Zoran Babić¹

Review paper

Tunjo Perić

Sead Rešić

Faculty of Economics Split

Bakeries Sunce, Rakitje

Faculty of Science, Univerzity of Tuzla

Received: 10.03.2012

UDC: 330.45:519.852:338.55

Accepted: 29.03.2012

ABSTRACT

Vendor selection is a very significant business problem for ensuring the competitiveness on the market. That is why companies pay great attention to this problem. To solve the vendor selection problems can be applied to a number of quantitative methods. Depending on the goals of the company the vendor selection can be a mono-criterion or multi-criterion programming problem. This paper deals with the problem of vendor selection and determining procurement quotas from selected vendors under conditions where vendors offer discounts to the total order value within a specified period where the buyer buys more products from the vendors. The total value of procurement costs in a given period is taken as an optimization criterion. In this paper the specific flour purchase problem is solved for a company that manufactures bakery products.

Keywords: *vendor selection, discounts to the total order value, mixed integer programming.*

INTRODUCTION

The problem with vendor selection and determining procurement quotas from selected vendor is the most important phase for a production company in the process of procurement of materials. If all the selected vendors can completely satisfy the customer's product needs then the process of vendor selection becomes easier, because in that case it is

based solely on the vendor selection according to the criteria of the total value of procurement costs, product quality and vendor's reliability. However, the practice shows that it is not good to rely on only one vendor during the procurement. For this reason, companies sign contracts and buy materials for production from different vendors.

1 Correspondence to:
Faculty of Economics Split
Matice Hrvatske 31, Split, Croatia
E-mail: babic@efst.hr

Apart from that, even if one vendor is the best according to all procurement criteria, the management of the company needs to procure materials for production from different vendors, which is justified by numerous strategic reasons (Beil, 2010). The number of vendors, with whom the business is handled when it comes to procuring the material for production, varies between two and five. Also, there are cases when none of the vendors can satisfy the consumer's demands or they do not want to in order to protect their business interests. In this work there is a defined situation when none of the vendors can satisfy the customer's demands because of its limitations in capacity, quality or similar. Vendor selection is an important problem which many researchers encounter. Great efforts have been put into developing suitable models for vendor selections and determining procurement quotas from selected vendors, as well as into the application of suitable methods for resolving those models. The problem with vendor selection and determining the procurement quotas from selected vendors becomes even more complex if we also take into consideration the discounts which vendors give on the total order value within a specific period. There are numerous works on that topic (Amid, Ghodsypour, and O'Brien, 2009, pp. 323–332; Chaudhry, Forst, and Zydiak, 1993, pp. 52–66; Jurun, Plazibat, and Babić, 1999, pp. 99–104; Kokangul & Susuz, 2009, pp. 1417–1429; Perić, & Babić, 2011, pp. 49–58; Wang & Yang, 2009, pp. 12179–12187). On the other hand, only a small number of researchers dealt with the problem of vendor selection and determining the procurement quotas in cases when vendors give discounts on the total order value of various products in a specific period (Dahel, 2003, pp. 335–342; Xia & Wu, 2007, pp. 494 – 504).

Vendor selection is according to its nature a multi-criterion problem. Many works deal with the multi-criterion problem of vendor selection. Also, many researchers use various methods to resolve this problem. The difference in the approaches can be seen in works: (Babić, Jurun, and Plazibat, 2001, pp. 103–110; Beil, 2010; Perić & Babić, 2007, pp. 191–196; Perić & Babić, 2009, pp. 1317–1342; Weber & Current, 1993, pp. 173–184). In this work the problem of vendor selection was considered as a one-criterion problem, where the accent was given to building the model for vendor selection where the discounts on the total order value in a specific period of time are given.

Firstly, the methodology of vendor selection and determining procurement quotas of selected vendors is presented. Secondly, a methodology tested on a concrete example of vendor selection for a company that deals with the industrial production of bakery products is suggested.

THE MODEL OF VENDOR SELECTION WITH DISCOUNTS ON THE TOTAL PROCUREMENT VALUE OF VARIOUS PRODUCTS

Let us consider the situation in which a company orders m of product P_i , $i \in I = \{1, 2, \dots, m\}$ from n vendor V_j , $j \in J = \{1, 2, \dots, n\}$ who offer different levels of product prices and production capacity for each product that they sell. Also, depending on the buyer's total value of procurement over a specific period of time, vendor V_j offers a discount on the total value of procurement with the defined r of discount intervals, $r \in R_j = \{1, 2, \dots, m_j\}$. In order to form a model of vendor selection which includes discounts on the total procurement value of different products, we have inserted the following signs:

J_i = set of vendors who offer the product P_i , $J_i \subseteq J$,
 I_j = set of products offered by the vendor V_j , $I_j \subseteq I$,
 D_i = quantity of the product P_i sought by the buyer,
 c_{ij} = unit cost of product P_i which relates to vendor V_j ,
 q_i = maximum quantity of product P_i which can be bought from vendor V_j ,
 u_{jr} = upper limit in the interval of discount r for the vendor V_j ,
 u_{jr}^* = insignificantly less than u_{jr} ,
 d_{jr} = discount factor connected to the discount interval r function of expenses j vendor.

Variable decisions are:

x_{ij} = product quantity P_i which will be ordered from the vendor V_j ,
 v_{jr} = total procurement value by j vendor in the discount interval r . It should be mentioned that $v_{jr} > 0$ only if the procurement value from the vendor j falls inside the interval r and its function of expenses, in other cases it equals zero.
 y_{jr} = 0 or 1; 1 – if the value of procurement from the vendor V_j falls into the interval r and its function of expenses, 0 – in other cases.

Formulation of the model of mathematical programming is as follows:

$$\min Z = \sum_{j \in J} \sum_{r \in R_j} (1 - d_{jr}) \cdot v_{jr} \quad (1)$$

With the equation (1) the total expenses of the procurement are minimised, where the i represents the percentage of the discount.

Limitations:

$$\sum_{j \in J_i} x_{ij} = D_i, \quad i \in I \quad (2)$$

With the limitation (2) we ensure that the overall demand on all products is satisfied.

$$x_{ij} \leq Q_{ij}, \quad i \in I, j \in J_i \quad (3)$$

With the limitation (3) we ensure that the overall quantity of products which can be delivered by the vendor should be within the limits of their production capacities.

$$\sum_{i \in I_j} c_{ij} x_{ij} = \sum_{r \in R_j} v_{jr}, \quad j \in J \quad (4)$$

With the limitation (4) we define the amount of the discount of the j vendor.

$$v_{jr} \leq u_{jr}^* \cdot y_{jr}, \quad j \in J, r = 1, \dots, m_j - 1 \quad (5)$$

$$v_{jm_j} \leq u_{jm_j} \cdot y_{jm_j}, \quad j \in J \quad (6)$$

$$v_{j,r+1} \geq u_{jr} \cdot y_{j,r+1}, \quad j \in J, r = 1, \dots, R_j - 1 \quad (7)$$

With the limitations (5), (6) and (7) we connect the procurement of products to the discount of the total procurement value for each vendor.

$$\sum_{r \in R_j} y_{jr} = 1, \quad j \in J \quad (8)$$

With the limitation (8) we ensure that there is only one interval of discount for each of the vendors.

$$y_{jr} \in \{0, 1\}, \quad v_{jr} \geq 0, \quad j \in J, r \in R_j \quad (9)$$

$$x_{ij} \geq 0, \quad i \in I, j \in J_i \quad (10)$$

With the limitations (9) and (10) we ensure integrability and non negativity for the variables of decision making.

In the upper model we can insert some additional limitations. For example, if a customer wishes to reduce the number of vendors to let us say K , then it is necessary to include the following limitation instead of limitation (8):

$$\sum_{r \in R_j} y_{jr} \leq 1, \quad j \in J \quad (8a)$$

$$\sum_{j \in J} \sum_{r \in R_j} y_{jr} \leq K \tag{8b}$$

As an additional limitation there can occur the limitation of the total business value with j vendor to the maximum value amount U_j . This limitation is presented in the following way:

$$\sum_{r \in R_j} v_{jr} \leq U_j, \quad j \in J \tag{8c}$$

In the following chapter we will demonstrate how the model can be implemented when the problem is in the vendor selection and determining procurement quotas from selected vendors for different types of flour for a company whose business is the industrial production of bakery products.

ILLUSTRATIVE EXAMPLE

In this part of the work we will demonstrate how a suggested model can be used in determining procurement quotas from different vendors in a company whose business is the industrial production of bakery products. It should be pointed out that in the baking industry the contract for flour procurement lasts for the period of one year, from harvest to harvest. After the harvest, flour producers have the information about the available quantity of wheat, cost and quality, and that help them in defining the price, quality and quantity of the flour which they can offer in the following one-year period. That is how in the following one-year period the company plans to spend 4000 tons of flour type 550 (P_1), 1500 tons of flour type 850 (P_2), 500 tons of flour type 1100 (P_3) and 1000 tons of flour type 1150 (P_4), or $D_1 = 4000, D_2 = 1500, D_3 = 500$ and $D_4 = 1000$.

The company has contacted 4 potential flour vendors who, have all for themselves, defined the upper limit

of the delivered quantity of all available types of flour, and that is presented with the matrix Q :

$$Q = [Q_{ij}] = \begin{matrix} & V_1 & V_2 & V_3 & V_4 \\ P_1 & 2000 & 2000 & 2000 & 2000 \\ P_2 & 1000 & 1000 & 1000 & 1000 \\ P_3 & 500 & 500 & 500 & 500 \\ P_4 & 500 & / & 500 & 500 \end{matrix}$$

It is visible from the matrix Q that the vendor (V_2) doesn't offer flour P_4 , and that is why we have $J_4 = \{1,3,4\}$ and $J_1 = J_2 = J_3 = \{1,2,3,4\}$ set of vendors who offer the product P_i .

Similar, set of products offered by the vendor V_j are $I_1 = I_3 = I_4 = \{1,2,3,4\}$, while $I_2 = \{1,2,3\}$.

The suggested prices from each of the vendors for all types of flour are presented in the following matrix (C_{ij}):

$$C = [C_{ij}] = \begin{matrix} & V_1 & V_2 & V_3 & V_4 \\ P_1 & 220.10 & 207.60 & 207.10 & 230.80 \\ P_2 & 200.20 & 189.12 & 192.14 & 208.16 \\ P_3 & 190.11 & 182.14 & 185.20 & 190.40 \\ P_4 & 420.25 & / & 440.70 & 430.80 \end{matrix}$$

Depending on the customer's total procurement value within a period of one year, the vendors offer a discount expressed with r interval of discount, $r \in R_j = \{1,2,\dots,m_j\}$, and it is presented in the following table.

Table 1. The intervals of vendor's discounts

Vendor 1	Procurement value (000 Euros)	$M < 100$	$100 \leq M < 400$	$400 \leq M \leq 900$
	Discount (%)	5	8	10
Vendor 2	Procurement value (000 Euros)	$M < 100$	$100 \leq M < 400$	$400 \leq M \leq 650$
	Discount (%)	/	5	8
Vendor 3	Procurement value (000 Euros)	$M < 150$	$150 \leq M < 500$	$500 \leq M \leq 900$
	Discount (%)	/	4	6
Vendor 4	Procurement value (000 Euros)	$M < 100$	$100 \leq M < 300$	$300 \leq M \leq 900$
	Discount (%)	3	5	10

The model of vendor selection and determining the procurement quotas for the given company looks like this:

$$\min Z = \sum_{j \in J} \sum_{r \in R_j} (1 - d_{jr}) \cdot v_{jr} = 0.95v_{11} + 0.92v_{12} + 0.90v_{13} + v_{21} + 0.95v_{22} + 0.92v_{23} + v_{31} + 0.96v_{32} + 0.94v_{33} + 0.97v_{41} + 0.95v_{42} + 0.90v_{43} \quad (1)$$

$$x_{11} + x_{12} + x_{13} + x_{14} = 4000$$

$$x_{21} + x_{22} + x_{23} + x_{24} = 1500$$

$$x_{31} + x_{32} + x_{33} + x_{34} = 500 \quad (2)$$

$$x_{41} + x_{43} + x_{44} = 1000$$

$$x_{ij} \leq Q_{ij}, \quad i \in I, \quad j \in J_i \quad (3)$$

Taking into consideration that we have fifteen variables x_{ij} in relation (3), there are also fifteen limitations that can be included in the model as the upper limits for those variables, for example $0 \leq x_{11} \leq 2000$, $0 \leq x_{21} \leq 1000$, etc.

Relation (4) $\sum_{i \in I_j} c_{ij} x_{ij} = \sum_{r \in R_j} v_{jr}$, $j \in J$ defines the j vendor's discount amount, hence we have the following four limitations:

$$\begin{aligned}
 220.10x_{11} + 200.20x_{21} + 190.11x_{31} + 420.25x_{41} &= v_{11} + v_{12} + v_{13} \\
 207.60x_{12} + 189.12x_{22} + 182.14x_{32} &= v_{21} + v_{22} + v_{23} \\
 207.10x_{13} + 192.14x_{23} + 185.20x_{33} + 440.70x_{43} &= v_{31} + v_{32} + v_{33} \\
 230.80x_{14} + 208.16x_{24} + 199.40x_{34} + 430.80x_{44} &= v_{41} + v_{42} + v_{43}
 \end{aligned}
 \tag{4}$$

Limitations (5), (6) and (7) connect the procurement of products to the corresponding discount segment form each of the vendors. According to that we have the following twenty equations:

$$\begin{aligned}
 v_{11} &\leq 99999 \cdot y_{11}, v_{12} \geq 100000 \cdot y_{12}, v_{12} \leq 399999 \cdot y_{12}, v_{13} \geq 400000 \cdot y_{13}, v_{13} \leq 900000 \cdot y_{13}, \\
 v_{21} &\leq 99999 \cdot y_{21}, v_{22} \geq 100000 \cdot y_{22}, v_{22} \leq 399999 \cdot y_{22}, v_{23} \geq 400000 \cdot y_{23}, v_{23} \leq 650000 \cdot y_{23}, \\
 v_{31} &\leq 149999 \cdot y_{31}, v_{32} \geq 150000 \cdot y_{32}, v_{32} \leq 499999 \cdot y_{32}, v_{33} \geq 500000 \cdot y_{33}, v_{33} \leq 900000 \cdot y_{33}, \\
 v_{41} &\leq 99999 \cdot y_{41}, v_{42} \geq 100000 \cdot y_{42}, v_{42} \leq 299999 \cdot y_{42}, v_{43} \geq 300000 \cdot y_{43}, v_{43} \leq 900000 \cdot y_{43}.
 \end{aligned}$$

Finally, we have limitation (8) which enables us to use only one discount interval for the total procurement value for each of the vendors.

Limitation (10) ensures us integrability, while limitation (11) ensures us non-negativity of the variable:

$$\begin{aligned}
 y_{11} + y_{12} + y_{13} &= 1 \\
 y_{21} + y_{22} + y_{23} &= 1 \\
 y_{31} + y_{32} + y_{33} &= 1
 \end{aligned}
 \tag{8}$$

$$\begin{aligned}
 y_{41} + y_{42} + y_{43} &= 1 \\
 y_{jr} &\in \{ 0, 1 \}, v_{jr} \geq 0, j \in J, r \in R_j
 \end{aligned}
 \tag{9}$$

$$x_{ij} \geq 0, i \in I, j \in J_i
 \tag{10}$$

Our model has 39 variables, (15 x_{ij} , 12 v_{jr} i 12 y_{jr}), and 32 limitations. The obtained model represents the model of mixed integer programming, and it has been solved with the usage of WINQSB software. The achieved results are presented in the following table.

04-20-2011 10:32:52	Decision Variable	Solution Value	Unit Cost or Profit C(j)	Total Contribution	Reduced Cost	Basis Status
1	x11	0	0	0	11,5000	at bound
2	x12	2,000,0000	0	0	0	basic
3	x13	2,000,0000	0	0	0	basic
4	x14	0	0	0	2,9643	at bound
5	x21	0	0	0	9,2536	at bound
6	x22	1,000,0000	0	0	0	basic
7	x23	446,5493	0	0	0	basic
8	x24	53,4507	0	0	0	basic
9	x31	0	0	0	7,3324	at bound
10	x32	131,5260	0	0	0	basic
11	x33	0	0	0	1,0432	at bound
12	x34	368,4740	0	0	0	basic
13	x41	500,0000	0	0	0	basic
14	x43	0	0	0	0	basic
15	x44	500,0000	0	0	0	basic
16	v11	0	0,9500	0	0,0300	at bound
17	v12	210,125,0000	0,9200	193,315,0000	0	basic
18	v13	0	0,9000	0	0	basic
19	v21	0	1,0000	0	0,0800	at bound
20	v22	0	0,9500	0	0	basic
21	v23	628,276,1000	0,9200	578,014,1000	0	basic
22	v31	0	1,0000	0	0,0896	at bound
23	v32	0	0,9600	0	0,0496	at bound
24	v33	500,000,0000	0,9400	470,000,0000	0	basic
25	v41	0	0,9700	0	0,1296	at bound
26	v42	0	0,9500	0	0,1096	at bound
27	v43	300,000,0000	0,9000	270,000,0000	0	basic
28	y11	0	0	0	6,574,1860	at bound
29	y12	1,0000	0	0	18,000,0300	at bound
30	y13	0	0	0	0	basic
31	y21	0	0	0	-18,400,0000	at bound
32	y22	0	0	0	2,999,9850	at bound
33	y23	1,0000	0	0	0	basic
34	y31	0	0	0	0	at bound
35	y32	0	0	0	0	at bound
36	y33	1,0000	0	0	0	basic
37	y41	0	0	0	-34,696,0100	at bound
38	y42	0	0	0	-34,696,0100	at bound
39	y43	1,0000	0	0	0	basic
	Objective Function	(Min.) =	1,511,329,0000			

From the upper table it is visible that vendor 1 delivers only the fourth type of flour in the quantity of 2000 tons ($x_{11} = x_{21} = x_{31} = 0, x_{41} = 2000$). Taking into consideration that the vendor's unit cost for that flour type is $c_{41} = 420.25$, it means that the customer's expense for the procurement of that flour type is $v_{12} = 210125$ Euros, and we are in the second discount interval with an 8% discount (see table 1). Of course, $v_{11} = v_{13} = 0$, while $y_{12} = 1$. For the second vendor we have $x_{12} = 2000, x_{22} =$

Table 2: Model solution

1000, $x_{32} = 131.526$, $x_{42} = 0$, and because the total procurement value of that vendor is 628276.1 (> 400000) we are in the third cost interval with the maximum discount of 8% .

The third vendor delivers 2000 t of the first flour type ($x_{13} = 2000$), 446.55 t of the second type ($x_{23} = 446.55$), but it doesn't deliver third and four type flour ($x_{33} = x_{43} = 0$). The procurement value of that vendor is 500000 Euros; hence we are once again in the third discount interval with the maximum discount of 6%.

For the fourth vendor we have $x_{14} = 0$, $x_{24} = 53.45$, $x_{34} = 368.47$ and $x_{44} = 500$ with that vendor's total procurement value which is $v_{43} = 300000$ Euros, and again we have the maximum discount of 10%. The optimum value of the aimed function which expresses the total procurement expenses is 1511329 Euros.

CONCLUSION

Taking into consideration that the procurement expenses for vendors, who deliver materials for production to many companies, significantly influence the selling price of the product, the selection of the vendors has an important influence on the level of competitiveness of the company.

In this work the model of mixed integer linear programming is presented, which solves the problems concerning vendor selection and determining the procurement quotas from selected vendors in cases when the buyer buys more products from the vendors who offer discounts on the total procurement value in a specific period through a permeable interval.

A developed model, which has been verified on a real example in this work, can be generalised, and in that way successfully used in solving similar practical problems.

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