APPLICATION OF CHURCHMAN-ACKOFF WEIGHTING METHOD FOR PROCUREMENT OF CONSIGNMENT SELLER DIETARY SUPPLEMENTS MANUFACTURING COMPANIES

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***ABSTRACT**: Today, the development of competent supply chains plays an important role in preserving the competitiveness of enterprises. The professional international literature examines supply chain design and operations extensively, but there are some types that supply chains which analysis of the development potential has not yet been in focus. One of the biggest problems in supply chains for consignment seller dietary supplements manufacturing companies is the selection of suppliers, as it is important to take into account a number of different aspects of the decision, which is the solution of the Churchman-Ackoff weighting method. The paper presents this problem and the solution method we have developed.*

***KEYWORDS**: Supplier selection, decision-making methods, dietary supplement*

1 INTRODUCTION

Today, the expansion of the number of product categories claimed by buyers has implications for the procurement logistics activities of companies selling confidentially. It can be said that this also increases the number of types of raw materials to be purchased and the volume of products to be stored, which can be explained by the fact that due to the expansion of the product structure, a minimum set of products should be stored in several products [1] to meet customer needs.

Raw materials are purchased by most of the dietary supplement manufacturing companies from China or America [2], which can lead to significant lead times of up to several months. Suppliers in the region can source raw materials at a higher cost but shorter lead time.

Experience shows that the quality of the raw material also differs considerably, as the quality of raw materials from neighboring countries can be better than for example from China [3].

It can be stated that in the case of food supplements companies the choice of a supplier of a particular base material type should be selected by taking a number of factors [4] into account, that is, the use of a decision-making method. The literature does not deal with this area or just in limited depth, as it focuses only on the acquisitions of large companies [5], so we have set the objective to discuss this topic, as selecting a suitable supplier can reduce operating costs and / or improve product quality [6].

In the rest of paper, the typical supply chain of the food supplement companies [3] will be presented, highlighting its procurement logistics system and determining the supplier selection method. Within the decision-making method, the set of logistics indicators required for the selection of suppliers, the normalization and the weighting method, will be presented. Basically, we define the weighted amount of normalized target function components by collating product types with suppliers.

2 PROCUREMENT LOGISTICS SYSTEM OPERATION OF CONSIGNMENT SELLER DIETARY SUPPLEMENTS MANUFACTURING COMPANIES

The typical operation and supply process of the consignment seller dietary supplements manufacturing companies are shown in Figure 1.

Presentation of Objects:

- Suppliers: Companies supplying raw materials.
- Central raw material warehouse: A warehouse for storing raw materials arriving from suppliers.
- Manufacturing plant: Capsule production is carried out at this location.

- Finished goods warehouse: The finished products from the capsule manufacturing plant are stored in this warehouse.
- Picking area: Picking and packaging the products to be transported as a replacement.
- Customer: The customer receives the product. Making stock reduction analysis to the central company about the quantities sold at certain time intervals.

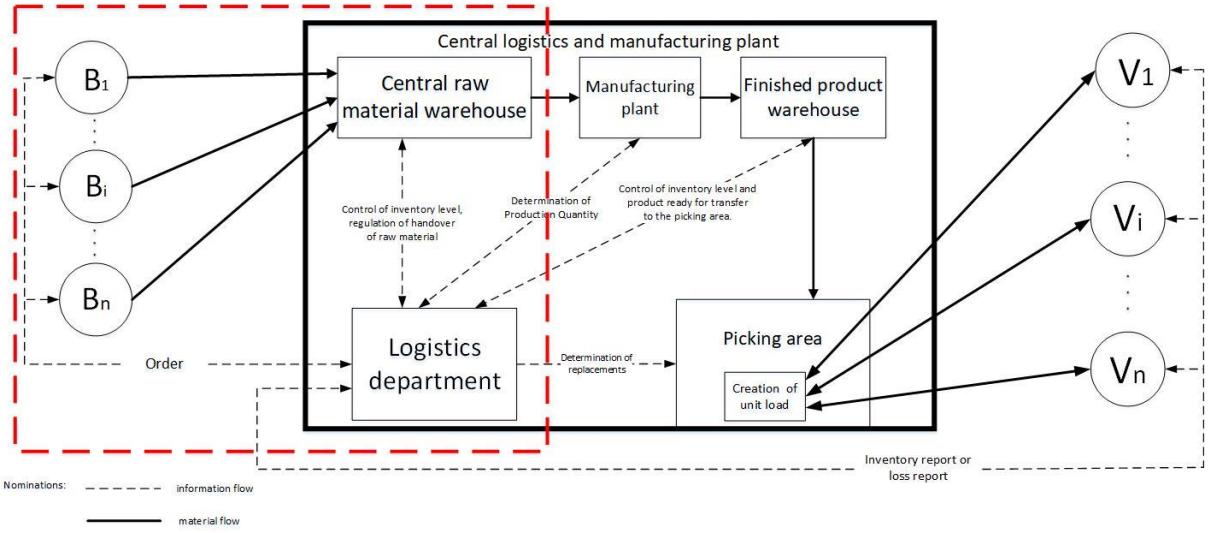

Figure 1 Material and information flow in consignment selling dietary supplements manufacturing companies [edited by the author]

The suppliers are delivering raw material in a predetermined regularity to produce the finished product, which the manufacturing system replaces the inventory decrease with. Implementation of production in most cases is done based on pressure principle. The implementation of the flow of information between the customer and production management, as well as between production management and suppliers is electronical; between production management and production process operations are done on paper.

The pre-ordered raw materials required for production from the suppliers are received to the central materials warehouse, where they will be stored until it is transferred to the capsule manufacturing division. This is where – using FIFO method – storage and release of the raw material for production plant is done. The manufacturing plant produces finished products with homogenized compositions prepared with different recipes and pack into boxes and label them.

As the total amount of homogenized is packaged and labelled, they will be handed over to the finished product warehouse. The finished product warehouse also uses the FIFO method. The picking department must maintain a certain level of product numbers. They replace the products towards consignment agents from here. After the calculation of the number of pieces to be replaced for each consignment customers, products are picked, packed and transported. The number of products to be replaced is determined based on the consumption data.

The subsequent procurement process can be based on the calculations of the central logistic and production plant. Taking the delivery lead time, the company's specialists determine their order date, order quantity and product concentration. As the influencing factors of procurement are highly complex [8], the choice of supplier in practice [9] is highly important. The order is made in electronic form, and the supplier will tell you what time the quantity is to be delivered.

3 SELECTION AFFECTING LOGISTICS INDICATORS

The selection of suppliers for companies producing dietary supplements depends on many factors, but their number is significantly reduced. Three indicators were defined for evaluation, i.e. the price of the product, the purchase cost and the product quality. Prior to the definition of logistical indicators, the suppliers involved in the investigation go through a pre-screening, so only those are involved in which all suppliers' expectations are met in terms of price and order lead time.

3.1 Order lead time

The lead time can be interpreted between two points of the logistics chain. One of the basic

principles of its calculation is that it is the longest to consider in parallel events.

Factors influencing the order lead time for dietary supplementary substances:

Supplier's distance from the central production plant,

Supplier's production equipment, flexibility of production programming,

mode of transport, characteristics of the means of transport,

raw material procurement, flexibility in purchasing packaging materials,

the possibility to dispose of the warehouse, the amount of inventory available,

customs procedure.

The order lead time is a process from order to product arrival, which can be calculated as i-th raw material j-th supplier:

$$t_{ij}^{R} = t_{ij}^{RE} + t_{ij}^{RS} + t_{ij}^{RW} \quad [\text{min}] \quad (1)$$

The values of the described logistic indicator should be recorded as a matrix:

$$T^{R} = \left[t_{ij}^{R} \right] \quad (i = 1...n) \quad (j = 1...m) \quad [\text{min}] \quad (2)$$

3.2 Total acquisition cost

The purchase price of raw materials will significantly affect the future sales price of the dietary supplement product, so it is important to consider when choosing the suppliers.

The total purchasing cost (KB) of the i-th supplier can be calculated as follows:

$$k_{ij}^{B} = k_{ij}^{BF} + k_{ij}^{BR} + k_{ij}^{BB} + k_{ij}^{BV} \quad [\text{EUR}] \quad (3)$$

Values defined in relation (3) expressed in matrix form:

$$K^{B} = \left[k_{ij}^{B} \right] \quad (i = 1...n) \quad (j = 1...m) \quad [\text{EUR}] \quad (4)$$

3.3 Quality of raw materials

By increasing the quality of the ordered raw material, the concentration of the active ingredient is increased, increasing its purchase price, but decreasing the quantity of the required raw material since the quantity of active ingredient required in the formulation becomes less and the raw material quality can be related to the purchase of the ordered raw material cost and order lead time.

The concentration of the i-th raw material at the j-th supplier is contained in the matrix (5).

$$M = \left[m_{ij} \right] \quad (i = 1...n) \quad (j = 1...m) \quad [\%] \quad (5)$$

4 LOGISTICS INDICATORS

In order to have the characteristics presented above as a component of a single objective function, the values of the above-specified indicators should be normalized ((6) .. (12)). Basically, all costs, lead time, and quality factor will form the components of the target function.

Determination of target function components:

- Total order lead time:

$$t_i^{R(\max)} = \max_j \left\{ t_{ij}^{R(\max)} \right\} \quad (6)$$

$$\gamma_{ij}^{1} = t_{ij} / t_i^{R(\max)} \quad (7)$$

- Total acquisition cost :

$$k_i^{B(\max)} = \max_j \left\{ k_{ij}^{B} \right\} \quad (8)$$

$$\gamma_{ij}^{2} = k_{ij}^{B} / k_i^{B(\max)} \quad (9)$$

- Quality of raw materials (concentration):

$$m_i^{\max} = \max_j \left\{ m_{ij} \right\} \quad (10)$$

$$m_{ij} = m_{ij} / m_i^{\max} \quad (11)$$

$$\gamma_{ij}^{3} = 1 - m_{ij} \quad (12)$$

5 DETERMINATION OF WEIGHTING FACTORS OF SELECTION METHOD USING THE CHURCHMAN-ACKOFF WEIGHTING METHOD

An important element of the selection method to be described below is the determination of the weighting factors, the method of which is described in this chapter.

This procedure is a reliable estimation process both mathematically and psychologically. The order of the evaluation factors can be determined. By selecting any two of the evaluation factors, we will tell which one we prefer to the other, that is, which attribute and property is more important than the other [10].

Method steps:

- Step 1: Sort the logistic indicators by their importance (C1 most important, then C2, ..., Cp).
- Step 2: The weight of criterion C1 is taken as 1 and then the weight of the other criteria is compared to C1 (W1, W2, ..., Wp). In order to increase the reliability of the estimate, each aspect should be compared with the groups that can be formed by total points of view. For example: C1 {C2, ..., Cp), {C2, ..., Cn-1), ..., with {C2 ... C3}, If C1 is more important, but the inequality with the initial weights does not prove this you need to change the W1 value. so

- that inequality can be met. (if it is less if the same principle applies)
- Step 3: Compare C2 with C2 with {C3, C4, ..., Cp} as in Step 2.
- Step 4: Continue the comparisons until Cp-2 and {Cp-1, Cp} are obtained
- Step 5: Weight-Normalization: The weight of all aspects is divided by $\sum_{l=1}^{p} W_l$, so the total weights will be 1.

6 DESCRIPTION OF SELECTION METHOD

The η_1, η_2, η_3 indicates the importance of lead times, purchasing costs, and quality factors, which is determined by the Churchman-Ackoff method described in the previous chapter, where:

$$0 \le \eta_k \le 1 \tag{13}$$

and,

$$\sum_{k=1}^{n} \eta_k = 1 \tag{14}$$

The value of the target function is for the j-th supplier of i-th raw material:

$$C_{ij} = \sum_{k=1}^{n} \eta_k \gamma_{ij}^k \tag{15}$$

The formula (16) determines which of the i-th raw material should be assigned to j-th supplier.

$$C_i = \underset{j}{Min}\left\{C_{ij}\right\} \tag{16}$$

7 INTRODUCTION OF PROCESSED METHODS FROM A CASE STUDY

For reasons of confidentiality, do not name the names of the objects in the study.

Define Input Data:

The investigated company acquires A1, A2 ... A5 raw materials from suppliers B1, B2, ..., B5, whose order lead time, total purchasing costs and raw material quality are included in the following matrices (17) (19)

Ordering lead time:

$$T^R = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array} \begin{array}{c} \begin{array}{ccccc} B_1 & B_2 & B_3 & B_4 & B_5 \end{array} \\ \begin{bmatrix} 100 & 400 & 550 & 600 & 350 \\ 100 & 600 & 900 & 250 & 500 \\ 100 & 600 & 950 & 700 & 700 \\ 100 & 550 & 400 & 800 & 650 \\ 100 & 550 & 800 & 1000 & 600 \end{bmatrix} \end{array} \text{[h]} \tag{17}$$

Full Purchase cost:

$$K^B = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array} \begin{array}{c} \begin{array}{ccccc} B_1 & B_2 & B_3 & B_4 & B_5 \end{array} \\ \begin{bmatrix} 1200 & 120 & 110 & 110 & 170 \\ 650 & 290 & 120 & 220 & 300 \\ 500 & 280 & 250 & 200 & 180 \\ 900 & 620 & 700 & 450 & 750 \\ 750 & 420 & 320 & 250 & 390 \end{bmatrix} \end{array} \text{[Eur/kg]} \tag{18}$$

Raw material quality (concentration):

$$M = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array} \begin{array}{c} \begin{array}{ccccc} B_1 & B_2 & B_3 & B_4 & B_5 \end{array} \\ \begin{bmatrix} 75 & 75 & 65 & 60 & 80 \\ 80 & 75 & 70 & 85 & 80 \\ 90 & 95 & 90 & 85 & 70 \\ 60 & 62 & 70 & 75 & 60 \\ 85 & 90 & 87 & 78 & 90 \end{bmatrix} \end{array} \text{[\%]} \tag{19}$$

Normalization of logistical indicators:

Ordering lead times, total purchasing costs, and normalized values of raw material quality included in matrices ((20)..(22)):

$$T_{max}^R = \begin{array}{c} \begin{array}{ccccc} A_1 & A_2 & A_3 & A_4 & A_5 \end{array} \\ [600 \quad 900 \quad 950 \quad 800 \quad 1000] \end{array}$$

$$\gamma^1 = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array} \begin{array}{c} \begin{array}{ccccc} B_1 & B_2 & B_3 & B_4 & B_5 \end{array} \\ \begin{bmatrix} 0,16 & 0,6 & 0,91 & 1 & 0,58 \\ 0,12 & 0,66 & 1 & 0,27 & 0,55 \\ 0,18 & 0,63 & 1 & 0,74 & 0,74 \\ 0,13 & 0,69 & 0,5 & 1 & 0,81 \\ 0,1 & 0,55 & 0,8 & 1 & 0,6 \end{bmatrix} \end{array} \tag{20}$$

$$K_{max}^B = \begin{array}{c} \begin{array}{ccccc} A_1 & A_2 & A_3 & A_4 & A_5 \end{array} \\ [1200 \quad 650 \quad 500 \quad 900 \quad 750] \end{array}$$

$$\gamma^2 = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array} \begin{array}{c} \begin{array}{ccccc} B_1 & B_2 & B_3 & B_4 & B_5 \end{array} \\ \begin{bmatrix} 1 & 0,1 & 0,09 & 0,09 & 0,14 \\ 1 & 0,44 & 0,18 & 0,33 & 0,46 \\ 1 & 0,56 & 0,5 & 0,4 & 0,36 \\ 1 & 0,68 & 0,77 & 0,5 & 0,83 \\ 1 & 0,56 & 0,42 & 0,33 & 0,52 \end{bmatrix} \end{array} \tag{21}$$

$$M_{max} = \begin{array}{c} \begin{array}{ccccc} A_1 & A_2 & A_3 & A_4 & A_5 \end{array} \\ [80 \quad 85 \quad 95 \quad 75 \quad 90] \end{array}$$

$$\gamma^3 = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array} \begin{array}{c} \begin{array}{ccccc} B_1 & B_2 & B_3 & B_4 & B_5 \end{array} \\ \begin{bmatrix} 0,93 & 0,93 & 0,81 & 0,75 & 1 \\ 0,94 & 0,88 & 0,82 & 1 & 0,94 \\ 0,94 & 1 & 0,95 & 0,89 & 0,73 \\ 0,8 & 0,82 & 0,93 & 1 & 0,8 \\ 0,94 & 1 & 0,96 & 0,86 & 1 \end{bmatrix} \end{array} \tag{22}$$

Determination of Weighting Factors (Churchman-Ackoff Method) ((23)..(27)):

Step 1: Sort the logistic indicators by their importance (C1 most important, then C2, ..., Cp).

$$C_1 = K^B;\ C_2 = T^R;\ C_3 = M \tag{23}$$

$$C_3 < C_1;\ C_2 < C_1 \tag{24}$$

Step 2:

$$W_1 = 1;\ W_2 = 0,8;\ W_3 = 0,6 \tag{25}$$

$$C_2 + C_3 > C_1 \tag{26}$$

Step 3-4: Not applicable, since only 3 logistic metrics are tested.

Step 5: Weight-Normalization: The previously determined weights are divided by the sum of the weights, so the sum of the normalized values will be 1.

$$\eta_1 = 0,33\ \eta_2 = 0,41 \eta_3 = 0,25 \tag{27}$$

Use of a selection method (28),(29):

$$K = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array} \begin{array}{c} \begin{array}{ccccc} B_1 & B_2 & B_3 & B_4 & B_5 \end{array} \\ \begin{bmatrix} 0,695 & 0,471 & 0,539 & 0,554 & 0,498 \\ 0,684 & 0,618 & 0,608 & 0,474 & 0,605 \\ 0,704 & 0,687 & 0,772 & 0,630 & 0,574 \\ 0,652 & 0,711 & 0,713 & 0,785 & 0,807 \\ 0,678 & 0,661 & 0,676 & 0,683 & 0,661 \end{bmatrix} \end{array} \tag{28}$$

In each row, the lowest value is selected so that it is possible to determine which supplier of raw materials should be obtained:

$$\begin{aligned} A_1 &\rightarrow B_2 \\ A_2 &\rightarrow B_4 \\ A_3 &\rightarrow B_5 \\ A_4 &\rightarrow B_1 \\ A_5 &\rightarrow B_2 \end{aligned} \tag{29}$$

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10 NOTATION

The following symbols are used in this paper:

t_{ij}^{RE} = the availability lead time of the *i*-th raw material (if necessary, production lead time at supplier) for *j*-th supplier,

t_{ij}^{RS} = the *i*-th packing material lead-time and assembly time of loading unit for the *j*-th supplier

t_{ij}^{RCS} = the delivery time for the *i*-th raw material in the *j*-th supplier's case,

t_{ij}^{RW} = the waiting time (storage) of the *i*-th raw material for the *j*-th supplier

k_{ij}^{BF} = the total freight cost of the *i*-th raw material from the order to the arrival at the *j*-th supplier,

k_{ij}^{BR} = the total loading cost of the *i*-th raw material in the case of a *j*-th supplier,

k_{ij}^{BB} = the total purchase price of the *i*-th raw material for the *j*-th supplier,

k_{ij}^{BV} = the cost of customs clearance of the *i*-th raw material in the case of a *j*-th supplier