Optimization of Warehouse Management in the Specific Assembly and Distribution Company: a Case Study

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Summary

This paper discusses the optimization of warehouse management in the assembly and distribution company. As part of complex logistics system, warehouse management plays a significant role in every company, connecting the areas of storage, material flow, production, record keeping and dispatch with the company´s economic objectives. It also has a significant impact on business operations and can be of an important competitive advantage. It may be argued that well-managed logistics, including a continuous material flow, cost minimization as well as overall streamlining of individual processes associated with manufacturing of products, are powerful strategic tools for companies and lead to their strong market position. It is almost an imperative for them to use modern knowledge in this area and strive for improvement. After the introducing chapters, paper includes an optimization proposal using particular methods of multi-criteria evaluation of variants which consists of determining the criteria for variants evaluation, developing the basic multi-criteria matrix and selecting as well as applying the specific method for final evaluation (in our case, the comparison with WSA and TOPSIS methods has been carried out). Final part of the paper outlines the most appropriate option regarding the introduction of an automatic identification system to optimize the warehouse management system.

KEY WORDS

warehouse management
assembly
distribution
material flow
RFID technology
automatic identification
cost minimization

1. INTRODUCTION

The selected company´s manufacturing program focuses on assembly and distribution of aerosol valves and their accessories, i.e. various aerosol dispensers, applicators and aerosol can lids. A part of the program also includes production of mechanical dispensers for non-pressurized packaging.

The Fig. 1 below presents a graphical illustration of the company site and the material flow of individual assembly and distribution inputs.

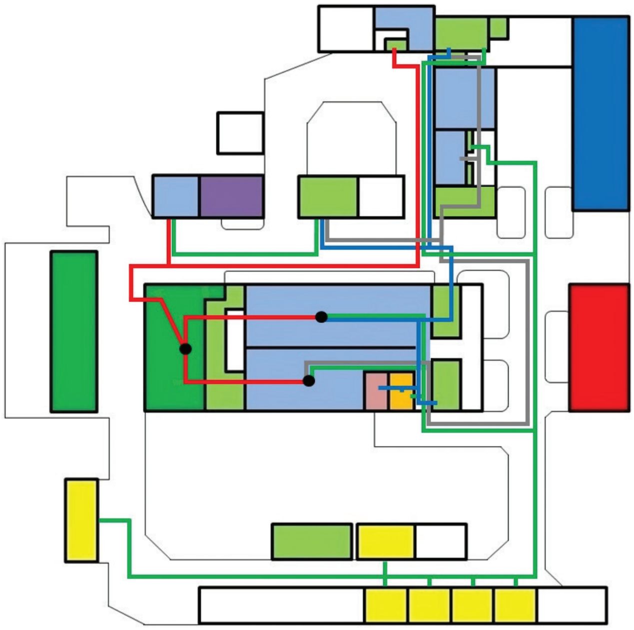
Based on a particular survey and analysis undergone at the company site, it was found that the greatest benefit of optimization would be to implement an automatic identification system. The implementation (and its wide scope) is able to streamline the whole warehouse management process not only within the selected company, but also within other companies dealing with similar warehousing issues. In addition, it can solve other emerging situations, and it is therefore necessary to consider an adequate selection of the aforementioned systems for automatic identification, i.e. a choice (a variant) between barcode identification system and RFID technology. Both of the systems will be further compared through specific methods of multi-criteria evaluation of variants, where certain criteria will be set on the basis of expected benefits for the company in the presented case study [1-3].

2. OPTIMIZATION PROPOSAL USING METHODS OF MULTI-CRITERIA EVALUATION OF VARIANTS

At present, there are a large number of multi-criteria evaluation methods based on different principles dealing with a particular evaluation of variants according to several criteria. A variant evaluated as advantageous under one criterion may not always be seen as the best evaluated variant under another criterion. Also, these methods solve conflicts between mutually contradictory criteria. For the given optimization proposal, the Weighted Sum Approach (WSA) method and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method were used, with the latter serving as a confirmation of results of the former [4-6].

3. DETERMINATION OF CRITERIA FOR EVALUATING VARIANTS AND DEVELOPMENT OF BASIC MULTI-CRITERIA MATRIX

Next, it was necessary to determine certain criteria and assign the corresponding weightings to them. The criteria were defined on the basis of the required benefits for the company. The following table shows an overview of the determined criteria and the assigned weightings (Metfessel allocation method) [4], [7], [8].



Explanatory notes:
Administrative Building; Warehouse of final products; Technical facilities; Tool works; Production and assembly; Other facilities;
Inbound warehouses; Granulate; Buffer stocks; Regranulate
Inbound raw materials into the production process; Flows into warehouse of final products; Production network; Covers.

Table 1 Criteria and Assigned Weightings for Multi-Criteria Evaluation of Variants

Criterion	Criterion Weighting
Cost of Realization	0.25
Cost of Labelling per 1 Piece	0.40
Handling in Case of Damage	0.15
Information Content	0.20
Σ	1

Source: authors

3.1. Criteria explanation

- *Cost of Realization* – it is the total cost of realization. This criterion will be given in thousands of CZK.
- *Cost of Labelling per 1 Piece* – as regards barcodes, it is CZK 0.40 per piece/code label, and as regards RFID technology, namely Smart label, it is CZK 3 each.
- *Handling in Case of Damage* – should the barcodes be damaged (e.g. by water, tearing off), and a given device reader (scanner) is unable to identify the code, there is still the option of manually registering and writing the barcode number. However, if one of the RFID tags is damaged, the information contained cannot be managed in any way. This criterion will be evaluated in the scale from one to ten (1 –10), where 1 denotes a certain possibility of additional handling in case of damage and 10 represents an impossibility of additional handling in case of damage.
- *Information Content* – the criterion states how large the information content of data about a product or goods may be contained in the given automatic identification element. This criterion will be evaluated in the scale from one to ten (1 – 10), where number 1 represents a small data entry option and number 10 stands for a large data entry option.

Table 2 Basic Matrix for Multi-Criteria Decision-Making

	Cost of Realization [in thousands of CZK]	Cost of Labelling per 1 Piece [in CZK]	Handling in Case of Damage [1 – 10]	Information Content [1 – 10]
Barcodes	1 105,970	0.40	2	4
RFID	1 504,670	3	9	9
Weightings	0.25	0.40	0.15	0.20
Character	minimization	minimization	minimization	maximization

Source: Own processing

4. WEIGHTED SUM APPROACH (WSA) METHOD

This method is based on constructing a linear utility function on the scale from 0 to 1, with the worst variant (according to the given criterion) benefiting zero, the best variant benefiting 1 and the other variants benefiting between both values. Additionally, the method requires major information, a criteria matrix, and a vector of criteria weightings. It allows an overall evaluation for each of the variants and may therefore be used to search for the most favorable variant as well as to organize the variants from best to worst.

Moreover, the above method is a special case of the utility function method. If an a_i variant (on the basis of a j criterion) reaches a certain y_{ij} value, it gives its user a particular benefit that may be expressed using the linear utility function. The total variant benefit is expressed by a weighted sum of values of partial utility functions, where u_j are the partial utility functions of individual criteria and v_j are the criteria weightings. The calculation (1) below applies [6], [9-11]:

$$u(a_i) = \sum_{i=1}^{m} v_j u_j (y_{ij}) \quad (1)$$

4.1. The WSA method procedure is specified by the following steps

1. Determine an ideal H variant with a certain valuation (h_1,…,h_n) and a basal D variant with a certain valuation (d_1,…, d_n).
2. Create a standardized criteria matrix (R), whose elements are obtained by using the formulas (2) and (3)

$$r_{ij} = \frac{y_{ij} - d_j}{h_j - d_j} \quad (2)$$

$$r_{ij} = \frac{h_j - y_{ij}}{h_j - d_j} \quad (3)$$

The R matrix is already a value matrix of the utility function of the i-th variant according to the j-th criterion, since the elements of this matrix are linearly transformed criterion values so that r_{ij}є<1;0>. Following from that, the basal variant corresponds to zero and the ideal variant corresponds to one.

3. For individual variants, calculate an aggregate utility function using the calculation (4) below [6], [12]:

$$u(a_i) = \sum_{j=1}^{n} v_j r_{ij} \quad (4)$$

4. Order the variants in a descending manner according to the value (a_i) and consider the necessary number of variants with the highest utility values as the problem solution.

4.2. Calculations based on the WSA method

Table 3 Standardized Criteria Matrix

	Cost of Realization	Cost of Labelling per 1 Piece	Handling in Case of Damage	Information Content
Barcodes	1	1	1	0
RFID	0	0	0	1
Weightings	0.25	0.40	0.15	0.20

Source: authors

4.3. Determining the order of individual variants

Variant 1 (Barcodes):

(0.25 x 1) + (0.40 x 1) + (0.15 x 1) + (0.20 x 0)=0.8

Variant 2 (RFID):

(0.25 x 0) + (0.40 x 0) + (0.15 x 0) + (0.20 x 1)= 0.2

Using the WSA method, it was found that Variant 1 (Barcodes) reached the highest utility value of 0.8. Thus, it is the most suitable option for introducing an automatic identification system and the related optimization of warehouse management in the given manufacturing company.

5. TOPSIS METHOD

This method is based on selecting a variant that is closest to the ideal variant and furthest from the basal variant. The maximization character of all criteria is assumed, but if all criteria are not in the maximization level, it is necessary to convert them to it.

5.1. The TOPSIS method procedure

1. Create a normalized criteria matrix $R = (r_{ij})$ based on the following formula (5):

$$r_{ij} = \frac{y_{ij}}{\sqrt{\sum_{i=1}^{m} y_{ij}^2}} \quad (5)$$

The R matrix columns are unit length vectors.

2. Calculate a normalized weighted criteria matrix $W = (w_{ij})$ based on:

$$w_{ij} = v_j r_{ij}$$

3. Determine an ideal H variant with a certain valuation (h_1,...,h_m) and a basal D variant with a certain valuation (d_1,..., d_m) considering the W matrix values.
4. Calculate distances of individual variants:

a) from the ideal variant using the following formula (6):

$$d_i^+ = \sqrt{\sum_{j=1}^{k} (w_{ij} - h_j)^2} \quad (6)$$

b) from the basal variant using the following formula (7):

$$d_i^- = \sqrt{\sum_{j=1}^{k} (w_{ij} - d_j)^2} \quad (7)$$

3. Calculate relative parameters of the distances of individual variants from the basal variant according to the formula (8) below:

$$c_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad (8)$$

Particular values of these parameters range from 0 to 1, with the basal variant reaching 0 and the ideal variant reaching 1.

The variants are ordered in a descending manner according to the c_i values, with the necessary number of variants (with this parameter's highest values) being considered as the problem solution [7], [13].

5.2. Calculations based on the topsis method

Table 4 TOPSIS Method – R Matrix

	Cost of Realization [in thousands of CZK]	Cost of Labelling per 1 Piece [in CZK]	Handling in Case of Damage [1 – 10]	Information Content [1 – 10]
Barcodes	1	1	1	0.406
RFID	0	0	0	0.914

Source: authors

Table 5 TOPSIS Method – Z Matrix

	Cost of Realization [in thousands of CZK]	Cost of Labelling per 1 Piece [in CZK]	Handling in Case of Damage [1 – 10]	Information Content [1 – 10]
Barcodes	0.25	0.4	0.15	0.081
RFID	0	0	0	0.183

Source: authors

5.3. Determination of a set of basal variant and a set of ideal variant

H = { 0.25; 0.4; 0.15; 0.183}

D = { 0; 0; 0; 0.081}

5.4. Determination of distances from the ideal variant

$$\sqrt{(0.25-0.25)^2 + (0.4-0.4)^2 + (0.15-0.15)^2 + (0.081-0.183)^2} = 0.102$$

$$\sqrt{(0-0.25)^2 + (0-0.4)^2 + (0-0.15)^2 + (0.183-0.183)^2} = 0.494$$

5.5. Distance from the basal variant

$$\sqrt{(0.25-0)^2 + (0.4-0)^2 + (0.15-0)^2 + (0.081-0.081)^2} = 0.494$$

$$\sqrt{(0-0)^2 + (0-0)^2 + (0-0)^2 + (0.183-0.081)^2} = 0.102$$

5.6. Determination and order of results

$$\frac{d_i^-}{d_i^+ + d_i^-} = \frac{0{,}494}{0.494 + 0.102} = \mathbf{0.828}$$

$$\frac{d_i^-}{d_i^+ + d_i^-} = \frac{0.102}{0.102 + 0.494} = 0.171$$

Variant 1 (Barcodes): 0.828

Variant 2 (RFID): 0.171

Using the TOPSIS method, it was found again that Variant 1 (Barcodes) is the most advantageous option for introducing an automatic identification system. The TOPSIS method also confirmed the result of the WSA method. Therefore, Variant 1 will be selected for the automatic identification [13-15].

6. EVALUATION

The above analysis of the current state of the given manufacturing company pointed to the possibility of introducing an automatic identification system as the most advantageous variant proposing to optimize warehouse management. The main focus was predominantly on choosing between two systems, i.e. barcodes and RFID technology [1], [2], [16-18].

These systems were further subjected to multi-criteria evaluation of variants, where both of the used methods, based on a table of the set criteria, favor Variant 1 – introducing the considered automatic identification system through barcodes. By evaluating the proposals for effective implementation of warehouse management, the variant of introducing an automatic identification system by means of barcodes was eventually chosen.

In regard to the proposed implementation within the aforementioned company, the main benefits will include greater system clarity, saving time, eliminating paper documentation, eliminating errors and streamlining the material flow.

7. CONCLUSION

Both systems are used to collect the automatic data and can be used in a wide range of applications. Their implementation is entirely individual and depends on a number of other factors, such as the implementation environment, implementation costs or expected benefits.

Barcodes are the most widely used means of automatic data identification, and as opposed to the RFID tags, they represent a cheaper alternative. On the contrary, RFID technology does not require direct visibility when reading or writing data (and when reading more RFID tags at one time), yet it is a more costly solution.

Barcodes and RFID technology were further compared by particular methods of multi-criteria evaluation of variants, where the Weighted Sum Approach method and the TOPSIS method were used. The former evaluated Variant 1, i.e. the introduction of automatic identification using barcodes, as the most suitable option. Subsequently, this result was confirmed by the TOPSIS method.

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