Comparison of the TMAL and the TOPSIS methods in selection of locations in order-picking

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Summary

There are two methods of storing products in a warehouse. First, there is a *dedicated storage*, for which each product can be stored in only one location and one location is dedicated for just one product. There is also a *shared storage*, in which each location can store any number of various products and each product can be stored in many, sometimes very distant locations. The advantage of the dedicated storage is that it is very simple to manage and the pickers can quite easily remember, where each product is stored. The disadvantage of such system is that the storing space is used much less efficiently. The shared storage uses the storage space much better, but causes that remembering, where each product is stored is impossible. Therefore, if a company utilises the shared storage system, it must use a specialised system of warehouse management. Such system must manage, where to place replenishment orders and from where products should be taken in order to complete the customers' orders. The article compares the two multi-dimensional techniques that will be used in order to select locations: the Taxonomical Measure of Location's Attractiveness (*TMAL*), based on the Synthetic Measure of Development and the *TOPSIS* method.

Keywords: warehouse management, order-picking, multi-dimensional techniques, Synthetic Measure of Development, TOPSIS

1. Introduction

Although there are many modern, automated *parts-to-picker* systems of warehouse management, such as carousels, A-frames or AS/RS (Automated Storage-and-Retrieval Systems) (Bartholdi & Hackman 2014), still vast majority of companies utilise classical, *picker-to-parts* approach, where the picker walks through the warehouse and collects the orders. There are many routing methods that can be used (optimal, *S-shape*, *midpoint*, *return*, *largest gap*, *combined*) (Tarczyński 2012), but it is a secondary problem. There are two general methods of storing goods in a warehouse:

- dedicated storage,
- shared storage.

In *dedicated storage*, one location is dedicated to one product only and one product can be stored only in one location. In *shared storage*, certain location can store many various products and one product can be stored in many, often very distant locations. Both methods have their advantages and disadvantages. Main advantage of *dedicated storage* is its simplicity and main disadvantage – poor space utilisation. Main disadvantage of the shared storage is the dispersion of products in the warehouse and main advantage of this method – much better space utilisation. Amongst shared storage methods there are such methods as: *chaotic storage*, *closest* *open location storage*, *full-turnover storage, class-based storage* or *family-grouping* (De Koster *et al* 2007). Whatever storing method is used, when completing the order, the question arises – if a product is stored in several locations, which one should be selected for picking the product for the order. The criteria of locations selection can be various (distance from the start, quantity of product in the given location, number of other products in close neighbourhood, or storage time). The decision maker may use one, some or all of them by creating the synthetic variable, in which particular criteria will have appropriate weights. In the research the author used the two methods of locations selection. Both of them rank locations in which every completed product is located and select these locations, which have the highest position in the ranking. The first method, named *TMAL* (after the Polish abbreviation of the Taxonomic Measure of Location's Attractiveness), is based on the classical Synthetic Measure of Development, created by Hellwig (1968), The second method is the *TOPSIS* method, created by Hwang and Yoon (1981). In both methods, each location was characterised by means of three variables:

- the distance from the start,
- the degree of demand satisfaction,
- the number of other picked products in the neighbourhood of the analysed location.

The goal of the article is comparison of selection of locations by means of two above-mentioned methods and its impact on the picker's route.

2. Assumptions, notations and methods

The selection of locations is performed for each product separately. When they are selected, the route for the picker is designated.

The two applied methods are the multi-criteria decision analysis methods. They involve calculation of one, synthetic measure out of the set of arbitrarily selected criterions. In both methods the criteria must be strictly quantitative, measured on the ratio scale. The used criteria (variables) are:

- the distance from the start (x_1),
- the degree of demand satisfaction (x_2),
- the number of other picked products in the neighbourhood of the analysed location (x_3).

The first variable, the distance from the start is the shortest distance from the start. It is worth noting that it is measured not in such units as metres, but one unit is a shelf width. The Manhattan distance was used. This variable has a negative impact (the lowest possible value is most desirable) – if we have a choice, we would select closer to the start point location in order to minimise the distance.

The second variable – the degree of demand satisfaction measures, in what degree the demand in specific order is satisfied from the stock quantity in given location. It is calculated by means of the following formula:

$$x_2 = \begin{cases} \frac{l}{z} & \text{for} \quad z > l \\ 1 & \text{for} \quad l \geq z \end{cases}, \qquad (1)$$

where:

l – number of units of picked product in given location,

z – demand for completed product.

If the amount of the product in the order in given location (l) exceeds the demand for this product (z), then the demand is fully satisfied in this location. And it does not matter, how much l is larger than z. It means that the demand is satisfied in 100%. Variable x_2 takes values from the range $(0; 1\rangle$. This variable has a positive impact (the highest possible value – in this case 1 – is desired) – we would rather pick the whole demand from one location than go to more than one.

The third variable – the number of other picked products in the neighbourhood of the analysed location measures, how many other products (other than this, for which the locations' ranking is made) is in the neighbourhood of analysed location. First of all, the neighbourhood can be understood differently. In the case of the article, the neighbourhood consists of locations that are placed on the aisle, on which analysed location is placed. Variable x_3 takes integer values greater or equal 0. As in the case of x_2, it also has a positive impact (the highest possible value is desired) – if we pick the product from the location that is placed near locations, where the other completed products are, we can pick them without the need of going to other aisles or even further parts of the warehouse.

Calculation of the *TMAL*

Before further calculations, in the first step the variables having negative impact must be changed into the ones having positive impact. One of the possibility is to calculate their inverse values. In our case, it was done with the variable x_1.

The Taxonomic Measure of Location's Attractiveness (*TMAL*) as a whole is based on the Synthetic Measure of Development. The stages of its calculation are as follows (Nowak 1990):

- Variables were normalised.
- Maximum values of normalised variables were found, creating so-called "perfect object".
- Euclidean distances[1] between normalised variables in a given location and the corresponding values from the "perfect object" were calculated.
- Variables were weighted.
- Weighted distance between each location and the "perfect object" were calculated.
- The *TMAL* values were calculated and ranked in the descending order.
- The highest-ranked location(s) were selected. If the demand was satisfied in the highest-ranked location, then only one was selected. If not, the next highest-ranked was also selected and so on, until full demand satisfaction.

Stages of the *TOPSIS* method

- Variables were normalised and weighed.
- Normalised variables were multiplied by their weights.
- The worst and the best alternatives were determined.

[1] It's worth noting that the distance calculated in the *TMAL* has nothing in common with the distance of a location from the start.

- Euclidean distances between variables in each location and the worst and the best alternatives were calculated.
- For each location, the similarities to the worst condition were calculated and ranked in the descending order.
- The highest-ranked location(s) were selected. If the demand was satisfied in the highest-ranked location, then only one was selected. If not, the next highest-ranked was also selected and so on, until full demand satisfaction.

For both methods the variables were normalised by using the same method – unitisation with zero minimum:

$$u_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}. \tag{2}$$

After unitisation, obtained normalised variable always has the minimum value equal 0 and maximum – 1. Of course, there are many other methods of normalisation. Each of them has its advantages and disadvantages. Other normalisation methods will be analysed in further research within this area.

During calculations it can happen that a variable (it can happen with variables x_2 and x_3) has the same values in every location (for example in all locations, where a certain product is placed, the demand for it in analysed order is satisfied in 100%). In such case, values of normalised variable are equal 0 (although formally they cannot be calculated).

At certain stages of both *TMAL* and *TOPSIS* calculations, there is a need of weighting variables. System of weights is purely subjective, but weights must satisfy one condition – their sum must equal one. In the article, seven combinations of weights were assumed. They are presented in table 1.

Table 1. Combinations of weights

Combinations	Variables		
	x_1	x_2	x_3
C1	0.333	0.333	0.333
C2	0.5	0.25	0.25
C3	0.25	0.5	0.25
C4	0.25	0.25	0.5
C5	0.4	0.4	0.2
C6	0.4	0.2	0.4
C7	0.2	0.4	0.4

Source: own elaboration.

In the first combination we assume that each variable has the same impact on the level of the *TMAL* coefficient and on the *TOPSIS* measure. Combinations C2, C3 and C4 assume that one variable has twice as big impact than other ones, and combinations C5, C6 and C7 assume that two variables have twice as big impact than the remaining one.

3. Numerical example

In order to present, how the *TMAL* and *TOPSIS* methods compare to each other, four real orders were analysed. The company, for which the orders were analysed, is a Polish division of large company that produces and sells tools and working clothes. The company orders and sells about 20 thousand products. They are stored in the large warehouse that consists of five sectors: A, B, C/K, D/E and R. There are also locations described as 0P-0X-0X-00. They are the “floor locations”, where loose boxes are. Sectors A, B and C/K are the low-level sectors, the D/E is the high-level sector and the sector R is the sector, where spare parts are stored. Products in the analysed orders were stored only in low-level sectors (A, B and C/K). Locations in the warehouse are described by eight symbols: 0X-XX-XX-X0. First two symbols describe the sector, third and fourth symbols are the row of storage blocks, fifth and sixth symbols describe the storage block number and the last two symbols – the shelf number (from bottom to top). For example, 0A-14-01-20, means that it is a location in the sector 0A, in the fourteenth row of storage blocks, in the first storage block in this row and on the second shelf (shelves are numbered from the bottom – shelves with the number 1 are the lowermost and with the number 6 – the uppermost). Rows of storage blocks are numbered as follows: odd rows are numbered in the ascending order from the left and even rows – in the descending order from the left. Warehouse layout is presented on the figure 1.

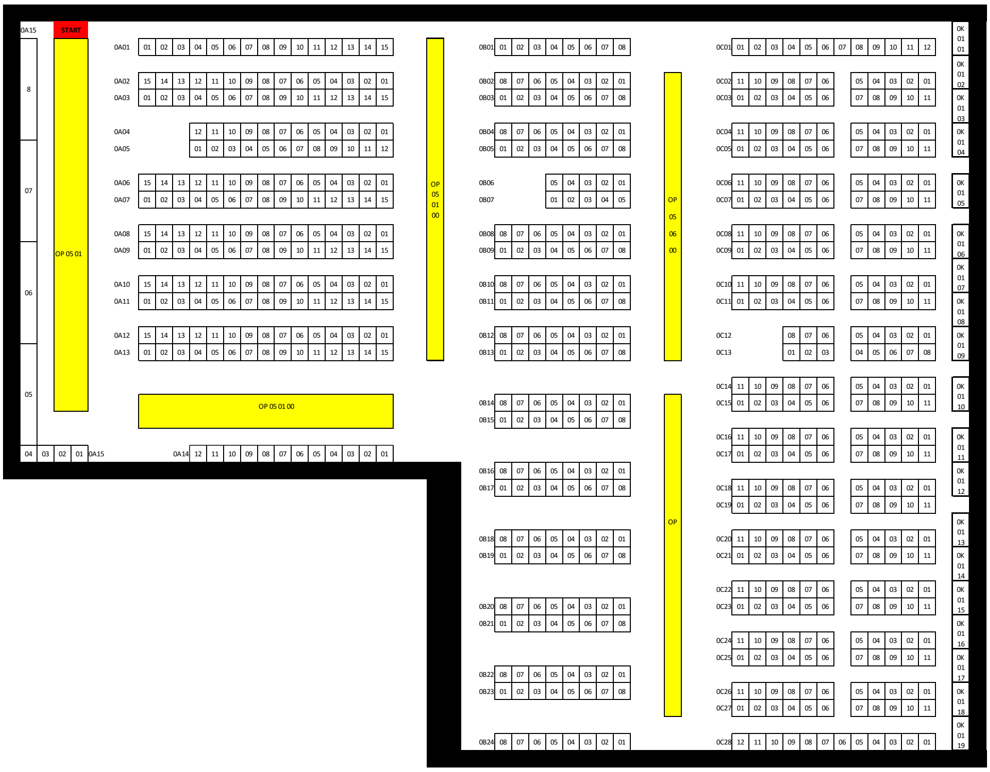

Fig. 1. Warehouse layout

Source: own elaboration.

For every order, locations were selected by means of the *TMAL* and the *TOPSIS* methods for all seven combination of weights. Next, for every method and every combination of weights, the picker’s route was designated. In every case, the *s-shape* method was used. The reason for using this particular method was that it was the most commonly used one in practice and it was also used in the analysed company. The shortest route, the better for the picker and for the whole system. The results of calculations are presented in the table 2.

Table 2. Comparison of results generated by the *TMAL* and the *TOPSIS* methods

TMAL								
Combinations	Order 1		Order 2		Order 3		Order 4	
	Ranking	Route length	Ranking	Route length	Ranking	Route length	Ranking	Route length
C1	3	199	4	226	4	274	1	118
C2	5	202	6	248	7	324	1	118
C3	6	205	4	226	4	274	1	118
C4	**1**	**160**	**1**	**167**	**1**	**237**	1	118
C5	6	205	7	281	6	297	1	118
C6	3	199	3	223	3	269	1	118
C7	2	167	**1**	**167**	2	256	1	118
TOPSIS								
Combinations	Order 1		Order 2		Order 3		Order 4	
	Ranking	Route length	Ranking	Route length	Ranking	Route length	Ranking	Route length
C1	4	202	5	220	4	287	4	118
C2	6	204	6	224	7	339	7	140
C3	**1**	**178**	4	215	3	280	4	118
C4	**1**	**178**	**1**	**198**	**1**	**237**	**1**	**86**
C5	6	204	7	282	6	312	3	104
C6	4	202	2	209	5	291	6	134
C7	**1**	**178**	2	209	2	256	**1**	**86**

Source: own elaboration.

As seen in the table 2, in every order, for every combination and in both methods, the best results are obtained for combination C4 – where variable x_1, x_2 and x_3 have weights 0.25, 0.25 and 0.5, respectively. It means that the most important feature is the number of other picked products in the neighbourhood of the analysed location. It means that selected locations may not be the closest to the start, the degree of demand satisfaction may not be the highest, but after selection the picker would have to visit locations that are relatively close to each other, so the route can be shorter. Also, quite good results were also obtained with the combination C7 (with weights 0.2, 0.4 and 0.4).

When comparing both methods of locations' selection for four analysed orders, the results were ambiguous. For orders 1 and 2, better results were obtained for the *TMAL* method, for order 3 both methods generated the same the best solutions and for the order 4, the *TOPSIS* method was better. More orders should be analysed in order to check, which method would give in general better results.

4. Conclusions

The goal of the article was to present a comparison between selection of locations in the process of order-picking by means of the *TMAL* and the *TOPSIS* methods and its impact on the picker's route. The results showed that no method appeared to be better. However, in both methods the best combination of weights was the combination, in which the distance from the start had weight 0.25, the degree of demand satisfaction – 0.25, and the number of other picked products in the neighbourhood of the analysed location – 0.5. Quite good results were also obtained when the weights were 0.2; 0.4 and 0.4, respectively.

Future research in this area would be to check other normalisation and ranking methods and also greater number of orders should be analysed. Then it would give the answer to the question, which method is the best one in this particular warehouse.

Of course, this method can be applied in other warehouses, also for high-level ones. Both *TMAL* and *TOPSIS* methods are quite versatile and we can add new variables in order to adjust it to new conditions. It can also be included in packages that support warehouse management.

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