Proposal for Optimization of the Inventory Level Using the Appropriate Method for its Procurement

Prijedlog za optimizaciju razine inventara korištenjem prikladne metode za njihovu opskrbu

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Summary

This paper deals with the optimization of the inventory level through determining and applying the appropriate way for the procurement of the inventory. It is important to determine the optimization criteria which are proposed on the basis of defining the factors affecting the determination of the procurement method. The criteria are proposed in such way in order the costs are optimized, and at the same time, the risk of the inventory deficiency is reduced. The paper also contains the algorithm regarding the determination of the appropriate procurement method. This algorithm takes into account the particular set of criteria and the proposal of multi-criteria model of the inventory management. Subsequently, the specific cases of costs reduction and reduction of risk of the inventory deficiency when applying the proposed model in comparison with the application of existing models are presented.

KEY WORDS

optimization
inventory level
procurement
multi-criteria model
inventory management

Sažetak

Ovaj članak bavi se optimizacijom razine inventara putem određivanja i primijenjivanja prikladnog načina opskrbe inventara. Važno je odrediti kriterije optimizacije koji se predlažu na temelju određivanja čimbenika koji utječu na određivanje metode opskrbe. Kriteriji se predlažu na takav način da se troškovi optimiziraju a istodobno se smanjuje rizik nedostatka inventara. Članak također sadrži algoritam koji se odnosi na određivanje prikladne metode opskrbe. Ovaj algoritam uzima u obzir poseban set kriterija i prijedlog višekriterijskih modela menađmenta inventara.Potom se prikazuju specifični slučajevi smanjivanja troškova i smanjivanja rizika manjka inventara kada se primijeni predloženi model u usporedbi s primjenom postojećih modela.

KLJUČNE RIJEČI

optimizacija
razina inventara
opskrba
višekriterijski model
menađment inventara

1. INTRODUCTION

Inventory management is an important field of company logistics from the several reasons. One of the main reasons is the fact that the inventory binds the substantial finances of the enterprise (10-25% of total assets) and also that its storage and maintenance requires to undertake the specific expenditures (10-20% of total costs), which may have a positive or negative impact on the economy of the enterprise [1-3].

Apart from the economic point of view, there is another important aspect that is taken into consideration when deciding about the inventory. This aspect is called the level of customer service which is an important factor within the competitiveness and position of the enterprise on the market. The customer service includes the observance of the delivery period, reliability, accuracy and flexibility, which represents the level of coverage of the random requirements. The level of inventory in the enterprise needs to be kept as low as possible in order not to exhaust the capital, however at the same time, as high as possible in order the company is able to cover the unexpected fluctuations, either in production or in the market. From the aforementioned, it is obvious that the enterprise needs to look for the optimal inventory level in order to ensure the continuity of production at reasonable costs and reasonable tying up of capital in the inventory. From that reason, it is important to take into account the various factors that affect the inventory level. The aim of this paper is to propose an algorithm that takes into consideration a set of criteria affecting the inventory level [1], [3-5].

2. ALGORITHM TO DETERMINE THE APPROPRIATE METHOD OF THE INVENTORY PROCUREMENT

Explicit and reliable identification of appropriate method of the material inputs procurement, on the basis of determined criteria, represents the objective of the proposed algorithm. The criteria determined on the basis of the factors affecting the identification of appropriate method of the material inputs procurement represent the foundation for the creation of the particular algorithm. They are shown in Table 1. The existing models of inventory management: 1. *ABC/XYZ* analysis and 2. the model of economic order quantity (the "*EOQ* model") are the background for the proposed algorithm [6-8].

Table 1 Determining the criteria of proposed model of the inventory management

Factors affecting the inventory	Criteria of the model
tying up of capital in the inventory	inventory value
the risk that the acquired material will not be used	nature of the consumption
the risk of the inventory deficiency	
material consumption	annual consumption (Q)
inventory storage and maintenance costs	storage costs (C_{ST})
acquisition (procurement) costs	acquisition costs (C_A)
short delivery time	delivery times (DT)
deliveries in the exact time sequence	delivery reliability (DR)
deliveries of the exact amount of material	delivery precision (DP)
deliveries in the required quality	delivery quality (DQ)

Source: authors

On the basis of the *ABC/XYZ* analysis, all items of the inventory are divided into two groups. The first group consists of the inventory types that are suitable for the synchronous procurement (acquisition) or for procurement into the inventory (*AX, AY, BX, BY, CX, CY*). The second group consists of the inventory types that are, on the basis of the two above mentioned models, suitable for the procurement into the inventory or for the random procurement (*AZ, BZ, CZ*). The proposed algorithm continues by the calculation of the order period (t_d) for each inventory item. The period of the delivery cycle, corresponding to the optimal delivery (by the Harris - Wilson's formula), is calculated according to the formula (1) [1], [3], [7-10]:

$$t_d = \frac{T\sqrt{\frac{2*C_A*Q}{T*C_{ST}}}}{Q} \text{[days]} \quad (1)$$

where: C_A - cost per one order of the specific material item (acquisition costs = delivery costs) (€); Q - annual need of the material item (pcs/other units), or planned consumption (acquisition costs); T - the planning period during which the planned consumption Q is considered (days); C_{ST} - storage and maintenance costs of the inventory unit per time unit (one day).

Based on this data, the inventory items of the first group (synchronous method of procurement/procurement into the inventory), created in the previous section of the algorithm (*ABC/XYZ* analysis), are divided into two groups [7], [9-12]:

- inventory items group suitable for the synchronous method of procurement - short-time order period (within 1 week),
- inventory items group suitable for the procurement into the inventory - other inventory items that do not meet the conditions of synchronous method of procurement.

The inventory items of the second group, created in the previous section of the algorithm (*ABC/XYZ* analysis), are divided into two groups as well (procurement into the inventory/ random method of inventory procurement):

- inventory items group suitable for the random method of inventory procurement - long-time order period (over 90 days),
- inventory items group suitable for the procurement into the inventory - acquisition costs (cost per one order of the specific material item = delivery costs) are higher than the inventory storage and maintenance costs.

And thus, three inventory groups were established similarly to the *ABC/XYZ* analysis. The consideration of the criteria value and character of consumption as well as the criterion of acquisition costs, inventory storage and maintenance costs and annual consumption represent the difference compared to the *ABC/XYZ* analysis. In the next step, the groups suitable for synchronous and random methods of procurement are more detailed analyzed.

Within the proposed algorithm, in its next section, the inventory items of the group intended (suitable) for the random procurement method, created in the previous section of the algorithm (calculations based on the model *EOQ*) on the basis of assessment of the particular suppliers delivery times appropriateness, are divided into two groups [1], [7], [12-14]:

- inventory items group suitable for random method of inventory procurement - satisfactory delivery time of the specific inventory item particular supplier for the random method of procurement (since, the random method of procurement is carried out after the generating the material need, shorter delivery times are more appropriate),
- inventory items group suitable for procurement into the inventory - unsatisfactory delivery time of the specific inventory item particular supplier for the random method of procurement.

Within the section of the algorithm, where calculations are performed based on the *EOQ* model, when using the continuous analysis of the items supplier of such inventory group which is intended for the synchronous procurement method, the inventory items are divided into two groups [1], [7], [12-14]:

- inventory items group suitable for synchronous procurement method.
- inventory items group suitable for procurement into the inventory.

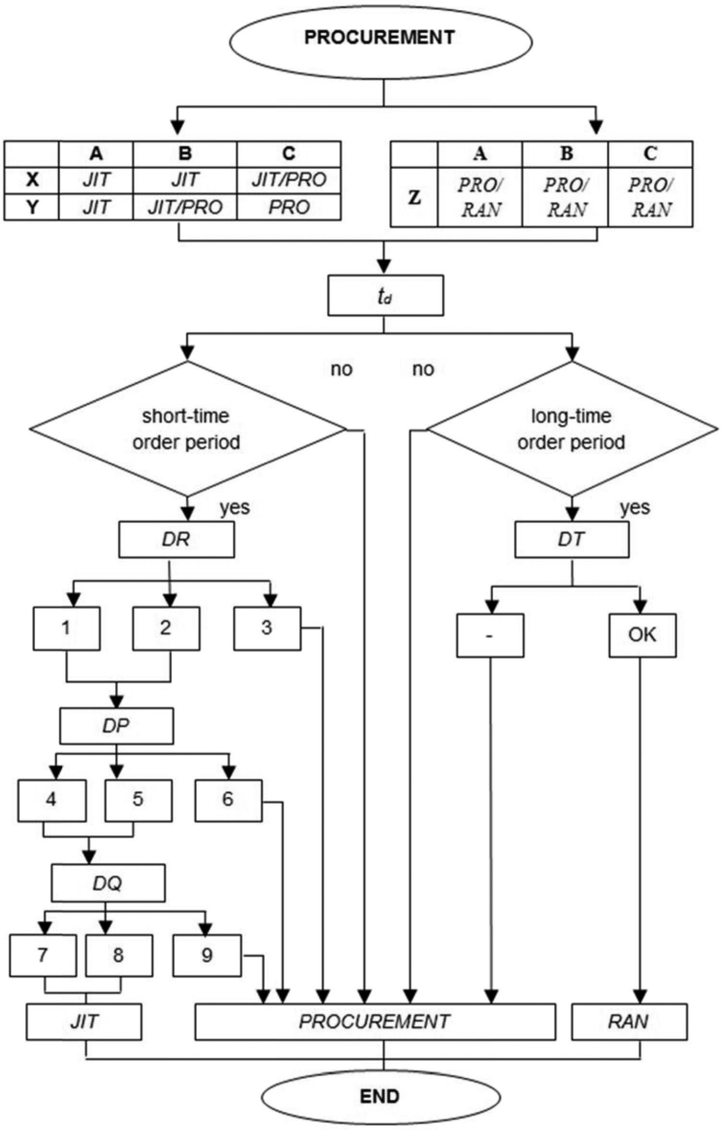
This distribution is realized based on the analysis of delivery reliability (DR), delivery precision (DP) and delivery quality (DQ) using the following formulas (2-4) [1], [8], [9]:

$$DR = \frac{\text{value of the material delivered on time}}{\text{total value of the delivered material}} [\%] \quad (2)$$

$$DP = \frac{\text{value of the delivered material}}{\text{value of the ordered material}} [\%] \quad (3)$$

$$DQ = \frac{\text{value of the received material}}{\text{value of the delivered material}} [\%] \quad (4)$$

On the basis of the calculations results, the inventory items, within each analysis, are divided into three groups. It is shown in Table 2 below. Inventory items included into the third group, even in a single analysis, are considered to be a part of an inventory group suitable for procurement into the inventory [7], [9], [15].



Source: authors

Figure 1 Algorithm of the inventory management

Table 2 The inclusion of inventory into group on the basis of supplier evaluation

	1. group	2. group	3. group
Fulfillment of the criterion	90-100%	80-90%	0-80%
Group (*DR/DP/DQ*)	1/4/7	2/5/8	3/6/9

Source: authors

Procedure of the individual inventory items assignment for each procurement method is illustrated using the following flow chart (Figure 1 - *PRO = procurement, RAN = random*):

Multi-criteria model of the inventory management is shown in the following figure (Figure 2):

3. BENEFIT-RISK ASSESSMENT OF THE PROPOSED MULTI-CRITERIA MODEL OF THE INVENTORY MANAGEMENT

The consideration of a large number of criteria represents the substantial difference of the proposed "multi-criteria model of the inventory management" compared to the existing models. This fact results in a more reliable determination of the procurement method. In addition, compared to the existing models, the clear procurement method is established on the basis of the proposed multi-criteria model of the inventory management [1], [2], [7].

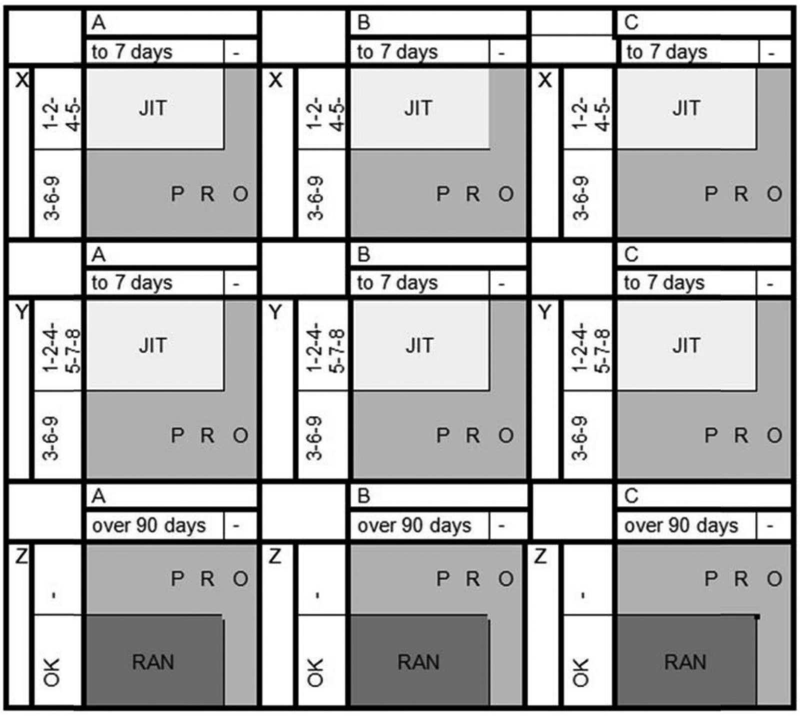
The benefits of the proposed model may be expressed in the following two fields:

- storage costs savings,
- reduction of risk of the inventory deficiency.

3.1. Storage costs savings

In the case of favorable conditions, the possibility of the inventory level reduction, compared to the inventory level after the application of the *ABC/XYZ* analysis that may occur after the taking into consideration the storage costs, delivery (acquisition) costs and annual consumption, represents the benefit of the proposed "multi-criteria model of the inventory management". Based on these criteria, synchronous procurement (frequent deliveries and relatively low quantities) or random procurement (long-time delivery period after the need arises) may be profitable for the enterprise. As long as these inventory items meet the criteria taking into account the suppliers, the release of finances and storage costs reduction will represent the acquired outcome [1], [7], [15].

Compared to the existing models, the higher storage costs savings and the lower tying up of capital in the inventory will be



Source: authors

Figure 2 Multi-criteria model of the inventory management

achieved in such case when the items *CY* have such costs and such annual consumption that, based on the model *EOQ*, it is more effective for the enterprise the inventory procurement at more frequent intervals (up to 1 week) and relatively low amounts. The similar example may also occur in the case of group items of *CX* and *BY* for which the *ABC/XYZ* analysis does not specify the unambiguous procurement method [7], [9], [15-17].

A similar situation may occur if there is such an inventory item of group *AZ*, *BZ* or *CZ*, of which the optimum order quantity and the order period, after the application of *EOQ* model, are suitable for the random procurement method [1], [7], [16].

The following table (Table 3) shows an example of a situation where a material input has such features that, using the "multi-criteria model of the inventory management" for the determination of the appropriate procurement method, may bring the storage costs savings for the enterprise.

$$t_d(CY) = \frac{365 * \sqrt{\frac{2*2*175\,200}{365*3}}}{175\,200} = 1.5 \text{ days} \qquad (5)$$

$$t_d(AZ) = \frac{365 * \sqrt{\frac{2*55*200}{365*8}}}{200} = 96 \text{ days} \qquad (6)$$

3.2. Reduction of risk of the inventory deficiency

Reduction of risk of the inventory deficiency, by taking into consideration the other three criteria - delivery precision, delivery quality and delivery times as well (besides the nature of the consumption and the delivery reliability, which the "Decision-cube" takes into account), represents another benefit of the proposed "multi-criteria model of the inventory management" [7], [8], [18].

The greatest risk of the inventory deficiency occurs during the synchronous procurement. For the enterprise, the inventory items of group *AX, AY* and *BX* are significant in terms of turnover share. Therefore, it is very important so that they are always available. These items are characterized by the high values as well. Due to the tying up the finances, their level should be minimized. Therefore, criteria of the suppliers - delivery reliability, delivery precision and delivery quality - are taken into account in the proposed "multi-criteria model of the inventory management". Delivery precision is also taken into account in the context of "Decision-cube", however, it ignores the other two criteria, which are also important for the synchronous acquisition [7], [19-21].

Table 3 Example of the costs savings

Criteria / Model	Value	Nature of the consumption	t_d			DR	*DP*	*DQ*	*DT*	Procurement method
			Q	C_{ST}/*day*	C_A/*1del*					
ABC/XYZ analysis	C	Y								into the inventory
Multi-criteria model of the inventory management	C	Y	1.5			1 (2)	4 (5)	7 (8)	-	synchronous
			175200 pcs	3mu	2mu					
ABC/XYZ analysis	A	Z								into the inventory/ random
Multi-criteria model of the inventory management	A	Z	96			-	-	-	OK	random
			200 pcs	8mu	55mu					

Explanatory notes: mu – del - delivery; monetary units; pcs – pieces

Source: authors

Table 4 Example of the reduction of risk of the inventory deficiency

<table>
<tr><th rowspan="2">Criteria
Model</th><th rowspan="2">Value</th><th rowspan="2">Nature of the consumption</th><th colspan="3">t_d</th><th rowspan="2">DR</th><th rowspan="2">DP</th><th rowspan="2">DQ</th><th rowspan="2">DT</th><th rowspan="2">Procurement method</th></tr>
<tr><th>Q</th><th>C_{ST}/day</th><th>C_A/1del</th></tr>
<tr><td>Decision-cube</td><td>A</td><td>Y</td><td colspan="3"></td><td>1.
group</td><td></td><td></td><td></td><td>partially suitable for synchronous method</td></tr>
<tr><td rowspan="2">Multi-criteria model of the inventory management</td><td rowspan="2">A</td><td rowspan="2">Y</td><td colspan="3">-</td><td rowspan="2">1
(2)</td><td rowspan="2">5
(6)</td><td rowspan="2">8
(9)</td><td rowspan="2">-</td><td rowspan="2">into the inventory</td></tr>
<tr><td>-</td><td>-</td><td>-</td></tr>
<tr><td>ABC/XYZ analysis</td><td>C</td><td>Z</td><td colspan="3"></td><td></td><td></td><td></td><td></td><td>into the inventory/ random</td></tr>
<tr><td rowspan="2">Multi-criteria model of the inventory management</td><td rowspan="2">C</td><td rowspan="2">Z</td><td colspan="3">96</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">OK</td><td rowspan="2">random</td></tr>
<tr><td>14600 pcs</td><td>0.2 mu</td><td>100 mu</td></tr>
</table>

Source: authors

One of the criteria relating to the suppliers is taken into account within the inventory items of group *AZ*, *BZ* and *CZ*. In the case that, even after the taking into consideration the storage costs, delivery (acquisition) costs and the annual consumption, these inventory items are potentially suitable for the random procurement, the delivery time of their supplier will be taken into account [6-8], [22], [23]. The following table (Table 4) shows an example of the reduction of risk of the inventory deficiency.

$$\mathrm{td(CZ)} = \frac{365 * \sqrt{\frac{2*100*14\,600}{365*0{,}2}}}{14\,600} = 96 \text{ days} \tag{7}$$

4. CONCLUSION

The number of criteria that results in a more reliable determination of the procurement method means a substantial difference of the proposed "multi-criteria model of the inventory management" compared to the existing models. Applying the proposed model to the inventory management method causes the optimization of costs while reducing the risk of the inventory deficiency. Model, considering its structure, eliminates the disadvantages of the existing models, when, given the limited criteria structure, there is an ambiguous determination of the inventory groups and thus the ambiguous determination of the procurement method [6-8], [24-27].

Moreover, previously used models do not take into consideration the reduction of risk of the inventory deficiency, or they take into consideration it only marginally. Multi-criteria model of the inventory management, with respect to the acceptance of the set of criteria, also takes into account the previous mentioned criterion and thus can clearly identify the inventory group, and subsequently, the appropriate procurement method.

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