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POSSIBILITIES OF ENHANCING THE QUALITY OF RESOURCE MANAGEMENT IN THE LOGISTICS SYSTEM OF A MILITARY ORGANIZATION

Abstract: *Information about the state of available resources in the military system is of invaluable importance when making decisions in the process of providing logistical support to operations. The application of automatic identification technologies implies tag holders with high data quality and adequate description of resources, to ensure visibility throughout the supply chain. This way of marking resources has become an integral part of modern business information systems following the trends of Industry 4.0. Like companies in the civil sector, the military must adapt to needs, and monitor its performance to assess its position, strengths, and weaknesses. Through a comparative analysis of the experiences and practices of the application of smart technologies of selected military capacities, the informational basis for the justification of the application of automatic identification technologies has been provided. Matters related to decision-making and multi-criteria optimization were dealt with, the problem was set and the optimal solution was adopted using the TOPSIS method in the selection of the type of resource tags for adequate implementation in the military organization to increase the quality of resource monitoring and protection against cyber threats.*

Keywords: *Industry 4.0, Smart technologies, Resource management, Military organization, Quality improvement.*

1. Introduction

Modern trends of Industry 4.0 require radical changes in all spheres, including the military, primarily due to compatibility and cooperation with developing civil institutions. This transformation is difficult to implement without the adequate use of modern information technologies that provide accurate and timely information about the state of all available resources in the logistics support system. Considering the dynamics of changes and continuity of processes in the world, the use of flexible information systems is imposed as the only solution in the decision-making process following the basic principles of timeliness and efficiency in the execution of tasks. Automatic identification technologies (BARCODE, OCR - Optical Character Recognition, chip cards, biometric technologies, and RFID technology) have become an integral part of modern business information systems. The analysis of all aspects of the application of automatic

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identification technologies, and their contribution to the optimization of logistics services, with an emphasis on the two most prevalent and complementary technologies, BARCODE and RFID, is the subject of this research. The research is aimed at the scientific determination of all assumptions, possibilities, risks, and perspectives of implementing solutions based on automatic identification technologies with the aim of identifying and defining shortcomings by conducting a SWOT analysis and looking at possible ways to implement solutions based on smart technologies. The result and conclusions resulting from the development of this project should show the basis for the implementation of solutions based on automatic identification technologies in a military organization.

2. AutoID technologies

The need to mark resources for easy identification has always existed. With the development of more complex products, more complex names and more essential data for recognition are obtained. Globalization of business establishes a new product identification system on the international market and international exchange. With the general electronification of business, there was a need to create symbols that would be recognizable by machines. In this way, various symbols and modules appear that are classified as AutoID - Auto Identification technology (Fragapane et al., 2020). The best-known technologies for automatic identification of resources are BARCODE and RFID.

There are two groups of BARCODEs in use, one-dimensional and two-dimensional, and each group has several subtypes.

The first group, the one-dimensional BARCODE (1D) or linear code is a meaningful series of dark lines and light spaces that allow electronic equipment to read the logical business information about the resource contained in them. 1D BARCODE is a number converted into a meaningful string that the scanner, when reading, turns back into a number, and it is the key to the database with other information about the resource. 1D BARCODE as a symbol is directly printed on the packaging or the label and the identified resource goes to the distribution network, where it is scanned by optical reading of the code, which is based on the difference in the light reflection of the light and dark zones of the symbol. The reading provides entry into the computer database, where all the essential information about the resource is found (Heidi, 2023).

The second group consists of two-dimensional (2D) BARCODE, which allows for storing and transmitting a much larger amount of information about the resource (up to 4000 characters), its origin, production method, and similar data, with greater resistance to errors (Du & Wang, 2023). The most famous two-dimensional matrix code is the QR (quick response) code, which is composed of light and dark square modules. This 2D code was developed and protected by the Japanese company Toyota with a patent in 1994, to obtain a code that would be easily readable by readers (Du et al., 2023).

The general advantage of all BARCODEs compared to other product identification technologies is the low cost of production (Heidi, 2023). Radio Frequency Identification (RFID), or identification using radio waves, is a modern wireless technology that uses radio waves to transmit data from products to a database. A common use of this technology is to identify and track objects. The principle of operation is based on radio frequency communication between the tag, the controller, and the reader. The RFID device (reader) uses radio transmission to send energy to the transponder (RFID tag) which then transmits feedback to the controller (computer): a unique identification code and/or a series of data previously stored in the RFID tag itself. The data thus collected can be further processed by the

controller (Kubáňová et al., 2022). According to the type of power supply, RFID systems are designed with passive (it does not have its power supply, it receives energy exclusively through radio-wave emission from the reader), active (it has its power supply - a battery with a limited life) and semi-passive (it has a battery that powers the chip, but for communication uses the reader's energy) tags. Regardless of the type of tag used, they can take different forms: stickers, pendants, registration devices, cards, etc., and can be read at distances from 30 cm to several hundred meters (Kubáňová et al., 2022).

3. Comparative analysis

Since the first merchants, the quantity of goods has been counted and shipments have been tracked. Written labels and various symbols were useful for identifying a few products, but identifying hundreds of packages per hour still required some form of automation. Today, there are many ways to track and identify items, and the most widely used are RFID and BARCODE technology (Du et al., 2023). The question is, what is the advantage?

- The BARCODE requires a direct line of sight and nothing must be in the way between the laser and the BARCODE. Unlike it, RFID tags can be read even if the tag is facing the opposite side.
- Information on the BARCODE cannot be added after it is printed, while some types of RFID tags allow data to be written or changed multiple times.
- RFID identification can be applied in wet, dusty, and dirty environments, and enables long-term and repeated use of tags.
- Disadvantages of RFID implementation are the high price (up to several hundred euros) as well as its use on metal packaging.
- RFID technology has a greater possibility of reading from a greater distance and the capacity of RFID tags is significantly greater. Also, BARCODEs are more sensitive, and sometimes they cannot be read due to damage.
- The RFID system can be subject to abuse, with numerous significant data stored in tags that can be more easily tracked, tapped, and analyzed (Simić et al., 2020).

This comparative analysis confirms that these two technologies will coexist for many years to come. One of the examples of the simultaneous use of both technologies is the so-called "smart" stickers that contain an RFID tag with an antenna inside, but have a BARCODE label printed on the back (Paul et al., 2023).

4. SWOT analysis

Every organization should improve its benchmarking, i.e. "improve business according to the solutions of the best and become better than the best" in accordance with the modern trends of Industry 4.0, including the military organization (Milenkov et al., 2020). For the purpose of comparing and selecting the type of automatic identification technologies in a military organization, the most appropriate would be the Israel Defense Forces, on the one hand, due to the crisis risks in its territory and environment, and on the other hand due to the variety of application of technologies in its supply chains. The future state of the modern system in terms of identification should be recognizable by the following (Jovanović, 2016):

- a modern warehouse business system, unique and precise records,
- accurate inventory status in real-time through an efficient inventory,
- monitoring and management of resource status from one place, and procurement planning in

accordance with the actual inventory level,

- one resource, one name, and a unique identification number,
- computer monitoring of stock status and recognition is done by a reader.

dispensing. Also, RFID in combination with BARCODE technology, with the application of appropriate devices for identification, capture, and data transmission, gives the possibility of maximum efficient management of all types of resources.

STRENGTHS - S	WEAKNESSES - W
Available highly educated staff of the logistics and IT profession.	Insufficient presence and knowledge of automatic identification technologies in the defense system.
The necessary infrastructure is available.	Necessary training of system administrators.
Possession of the necessary knowledge on designing information systems.	Necessary operator training for use.
The state's determination to modernize the defense system.	Necessary acquisition of equipment.
The manual on material bookkeeping includes devices for automatic data collection and marking with barcodes	Site legacy and outdated infrastructure.
There is a desire of the final executors to modernize the system of marking assets and collecting data.	Despite the developed IT network, no form of automatic product identification is used.
The instruction foresees the use of bar codes and technical equipment for inventory.	
OPPORTUNITIES - O	**THREATS - T**
A member of the Partnership for Peace program, NATO or EU.	Cyber attacks are an essential threat in the 21st century.
The trend of development of the domestic IT market.	The trend of reducing public spending and the economic crisis.
Willingness of system integrators to participate in pilot projects in the defense system.	Insufficient financial resources for equipment in the military budget.
Adequate supply of necessary equipment on the domestic market.	Insufficiently stable political situation in the world.
Authorization to independently codify their products.	The emergence of artificial intelligence.
The existence of the organization GS1, which is responsible for EPC Global standards.	

Figure 1. SWOT analysis

To perform an overall assessment of the assumptions and possibilities for the implementation of automatic identification technologies, we can apply a SWOT analysis (Strengths, Weaknesses, Opportunities, Threats Analysis), which includes an analysis of the internal environment through strengths and weaknesses, as well as an analysis of the external environment through opportunities and threats (Mirani et al., 2022). Based on the presented SWOT analysis (Figure 1), it can be concluded that the possibility of applying automatic identification technologies is extremely large. Starting with the identification of personnel and vehicles for access control and attendance records, through the identification of equipment, tools, and special vehicles and devices, all the way to the control of fuel

5. Mathematical model

After the theoretical foundations of possible ways of automatic identification, comparative analysis, and presentation of advantages and disadvantages, the question arises, what is more profitable for the system, BARCODE or RFID technology? In this chapter, the TOPSIS method will be used to determine the optimal solution for the automatic identification of resources in a military organization. The TOPSIS method (Technique for Order Preference by Similarity to an Ideal Solution) is used to determine the order of a number of alternatives that are evaluated based on several criteria and its development rests on the idea of distance. The steps of analysis are

explained below (Chanpuypetch et al., 2024).

Step 1 - Formation of the starting matrix:

$$X = \left\|x_{ij}\right\|_{mxn}$$

$$X = \begin{array}{c} \\ A_1 \\ A_2 \\ \dots \\ A_i \\ \dots \\ A_m \end{array} \begin{vmatrix} K_1 & K_2 & \dots & K_j & \dots & K_n \\ x_{11} & x_{12} & \dots & x_{1j} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2j} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ x_{i1} & x_{i2} & \dots & x_{ij} & \dots & x_{in} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mj} & \dots & x_{mn} \end{vmatrix}$$

Step 2 - Normalization of the starting matrix:

$$\|X\| \rightarrow \|R\|, R = \left\|r_{ij}\right\|_{mxn},$$

Where: $r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$

Step 3 - Weighting of the normalized matrix:

$$\|R\| \rightarrow \|V\|, V = \left\|v_{ij}\right\| = \left\|W_j^* \times r_{ij}\right\|,$$

Where: $W_j^* = \frac{w_j}{\sum_{j=1}^{n} w_j}$, $v_{ij} = W_j^* \times r_{ij}$,

Step 4 - Formation of ideal and non-ideal solutions:

A^*- the ideal solution, which has all the best features according to all criteria:

$$A^* = \{(max\, v_{ij} | j \in K')\ i\ (min\, v_{ij} | j \in K'')\} = \{v_1^*, v_2^*, \dots, v_i^*, \dots, v_n^*\}, i = 1,2, \dots, m$$

$K' \subseteq K \rightarrow K'$ - is a subset of the set K consisting of criteria of the type max.
$K'' \subseteq K \rightarrow K''$ - is a subset of the set K consisting of criteria of the type min.

A^-- a non-ideal solution, which has all the worst characteristics according to all criteria:

$$A^- = \{(min\, v_{ij} | j \in K')\ i\ (max\, v_{ij} | j \in K'')\} = \{v_1^-, v_2^-, \dots, v_i^-, \dots, v_n^-\}, i = 1,2, \dots, m$$

Step 5 - Calculating the distance of each alternative from the ideal and non-ideal solution:

- distance of the alternative from the ideal solution,

$$S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}$$

- the distance of the alternative from the non-ideal solution,

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}$$

Step 6 - Calculating the relative closeness of the alternative to the ideal solution:

$$C_i = \frac{S_j^-}{S_i^- + S_i^*}, 0 \leq C_j \leq 1$$

Step 7 - Rank of alternatives.

The rank of the C_i values arranged in descending order (from the largest to the smallest value) corresponds to the rank of the alternatives A_i (from the best to the worst).
It also applies:

$C_i = 0 \rightarrow$ the alternative is a non-ideal solution.

$C_i = 1 \rightarrow$ the alternative is the ideal solution.

An alternative is better if its preference coefficient is higher. Based on the above, table 1 was created, which defines the criteria and alternatives as well as their relationship.

Table 1. Relationship between criteria and alternatives (Hakola et al., 2023)

			Criteria					
			K1	K2	K3	K4	K5	K6
			Standardization	*Safety*	*Efficiency*	*Cost*	*Additional functions*	*Traceability*
Alternatives	A1	1D code	there are detailed regulations	high	low	low	no	low
	A2	2D code	partially there are regulations	high	medium	medium	medium number of additional functions	low
	A3	RFID Active	it is noted in the regulations	medium	high	very high	very large number of additional functions	high
	A4	RFID Passive	it is noted in the regulations	medium	very high	very high	very large number of additional functions	very high

After the formation of the initial matrix of initial data, coefficients are assigned, the values that we minimize and maximize are determined, as well as weighting values are assigned. Not all criteria are equally important, so their ″importance″ is represented by the weight of the criteria. In this part of solving multi-criteria analysis, subjectivism comes to the fore - individual or group.

6. Case study

The first step in the selection of resource identification technologies is the formation of the initial data matrix with the assignment of coefficients, the determination of the values that we minimize and maximize, as well as the assignment of weight values, which is shown in Table 2.

Table 2. Value assignment

Criterion	K1	K2	K3	K4	K5	K6
Altern.	0.1	0.25	0.15	0.3	0.1	0.1
A1	4	4	2	2	2	2
A2	3	4	3	3	3	2
A3	2	3	4	5	5	4
A4	2	3	5	5	5	5
Character	max	max	max	min	max	max

Then, ideal and non-ideal values are determined, which is shown in Table 3.

Table 3. Ideal and non-ideal values

Ideal values	4	4	5	2	5	5
Non-ideal values	2	3	2	5	2	2

After that, the values of the criteria are determined, where the values that are maximized are overwritten, and those that are minimized are converted to max, which is shown in Table 4.

Table 4. Normalized values

Criterion	K1	K2	K3	K4	K5	K6
Altern.	0.1	0.25	0.15	0.3	0.1	0.1
A1	5	4	1	4	1	1
A2	3	4	3	3	2	2
A3	2	3	5	1	5	3
A4	2	4	5	2	4	5
Character	max	max	max	max	max	max

In the next step, the norms are determined, the values of which are shown in Table 5.

Table 5. Norm values

norm values	
5.74456	Standardization
7.07107	Safety
7.34847	Efficiency
7.93725	Costs
7.93725	Additional functions
7.00000	Traceability

Then follows the determination of the weighted value, and the obtained data are shown in Table 6.

Table 6. Weighted values

Criterion	K1	K2	K3	K4	K5	K6
Altern	0.1	0.25	0.15	0.3	0.1	0.1
A1	0.070	0.141	0.041	0.076	0.025	0.029
A2	0.052	0.141	0.061	0.113	0.038	0.029
A3	0.035	0.106	0.082	0.189	0.063	0.057
A4	0.035	0.106	0.102	0.189	0.063	0.071
ideal	0.070	0.141	0.102	0.189	0.063	0.071
non-ideal	0.035	0.106	0.041	0.076	0.025	0.029

Then the ideal values are determined according to the data from Table 6, whereby the results shown in Table 7 are obtained.

Table 7. Ideal values

Criterion	K1	K2	K3	K4	K5	K6
Altern.	0.1	0.25	0.15	0.3	0.1	0.1
A1	0	0	0.061	0.113	0.038	0.043
A2	0.017	0	0.041	0.076	0.025	0.043
A3	0.035	0.035	0.020	0	0	0.014
A4	0.035	0.035	0	0	0	0

Non-ideal values are also determined according to the data from Table 6, whereby the results shown in Table 8 are obtained.

Table 8. Non-ideal values

Criterion	K1	K2	K3	K4	K5	K6
Altern.	0.1	0.25	0.15	0.3	0.1	0.1
A1	0.035	0.035	0	0	0	0
A2	0.017	0.035	0.020	0.038	0.013	0
A3	0	0	0.041	0.113	0.038	0.029
A4	0	0	0.061	0.113	0.038	0.043

Finally, the distance is calculated according to the values shown above, and the alternatives are ranked, which is shown in Table 9.

Table 9. Final ranking of alternatives

S+	S-	Gap to solution	Rank	smart technology
0.084	0.124	0.596	1	1D BARCODE
0.077	0.089	0.536	2	2D BARCODE
0.126	0.063	0.331	4	RFID Active
0.124	0.084	0.404	3	RFID Passive

The final result is a graphical representation of the choice of the range of alternatives shown in Figure 2.

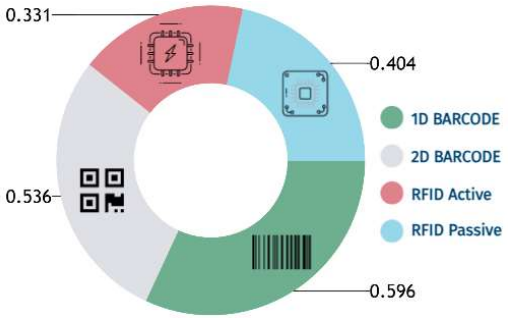

Figure 2. Graphic representation of the final result using the TOPSIS method

7. Results and Discussion

What emerges from this analysis is the importance of the applied criteria, where the cost criterion has the greatest value, but the benefits of the application of smart technologies do not have to be evaluated exclusively through money savings, but also through the completeness of information and regulations, timeliness of delivery, visibility in the system and availability of resources, security and overall efficiency. In any case, by looking at all the relevant data, it is possible to generally claim that the costs of introducing smart identification technologies are lower than the benefits realized by its application, providing a whole series of benefits that optimize resource management and enable optimal management decisions to be made.

Based on the mentioned comparative analysis, presented facts, and conducted research, it follows that 1D BARCODE, i.e. LINEAR BARCODE, represents the optimal solution in the process of identifying resources in the observed military organization.

8. Conclusion

The state of defense resources adequate to the requirements of the army is of vital importance and requires their constant development, maintenance, and improvement. Defense resources are built for the needs of defense and protection of defense interests, prevention of conflicts and crises, and preservation of peace and stability. The research was carried out mainly under the outlined methods and guidelines. To the maximum extent available, data from foreign and domestic literature were used, to more comprehensively approach the role, importance, and place of automatic identification technologies in the processes of asset management in the military organization. The advantages and disadvantages of BARCODE technology, one of the most common automatic identification technologies, and RFID, the most promising technology, were compared. Necessary lessons were drawn from the experiences of foreign military capacities and companies, and various phenomena related to the application of these technologies were discussed. Based on the knowledge gained during the work on the project and research on the method of identifying assets of foreign armies, certain contributions and conclusions that this work provides can be stated:

- High existing risks for the system of applying smart technologies.
- The real possibility of applying smart technologies.
- Adequate selection of smart technologies with the goal of minimum costs.
- Improving the functioning of the entire system.

It is concluded that there are certain problems. First, with the application of RFID technology, and the reading of assets by wireless method at certain distances, there would be a risk of asset detection via GPS, which would practically represent the absurdity of hiding army warehouses throughout the territory, primarily when talking about ammunition tagging. The next problem of introducing some of the smart technologies appears in the high cost, primarily due to the cost itself, but also the entire implementation process as well as the great variety of resources. By studying and analyzing the application of automatic identification technologies, using the multi-criteria decision-making method, the results of the selection of the type of automatic identification technology tags were obtained. Matters related to decision-making and multi-criteria optimization were processed, the problem statement was made and the concrete application of the TOPSIS method was shown in the selection of the type of tag for a specific organization. Based on the results of the research, the facts were confirmed that the decision-maker, through his direct work, defining the value of the weights of the criteria and his preference for a certain criterion, influences the final ranking of all observed alternatives and the choice of an alternative in the defined set of criteria. Due to safety criteria and minimum costs, the result of the analysis showed that 1D BARCODE is the optimal solution for introduction into the system. The scientific contribution of this project lies in a new theoretical approach, defining the place, role, and importance of automatic identification technologies in resource management processes in the military organization, where a comparative analysis of BARCODE and RFID technology was performed in one place and a multi-criteria optimization model was proposed, using the TOPSIS method for the selection of the type of markings of automatic identification technology, for the sake of adequate application in the military organization. In addition, the professional contribution of the project is reflected in the practical fields of application of automatic identification technologies, with increasing effectiveness and reducing losses, and it will have a special contribution in combat and

crises when the availability of information and the accuracy of information is of inestimable importance for decision-making. During the development of this project and progress in certain fields, new possibilities and perspectives of applying automatic identification technologies to various processes constantly appeared and opened up, which made the conducted research more interesting and challenging.

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