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METHODS FOR ANALYZING THE EFFECTIVENESS OF INFORMATION SYSTEMS FOR INVENTORY MANAGEMENT

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ABSTRACT

Context. Information systems for inventory management are used to forecast, manage, coordinate, and monitor the resources needed to move goods smoothly, in a timely, cost-effective, and reliable manner. The more efficiently the system works, the better results a company can achieve. A common problem with existing performance measurement methods is the difficulty of interpreting the relationship between performance indicators and the factors that influence them.

Objective. The purpose of the study is to describe a method for evaluating the effectiveness of information systems, which allows to establish a link between performance indicators and factors that influenced these indicators.

Method. A set of indicators characterizing the effective operation of inventory management information systems is proposed. The rules for quantifying the factors that influence the performance indicators are proposed. The factors arise during events that affect the change in order, delivery, balance, target inventory level, parameters of the forecasting algorithm, etc. The proposed method performs an iterative distribution of the quantitative value of factors among performance indicators and thus establishes the relationship between performance indicators and factors.

Results. The implementation of the proposed method in the software was carried out and calculations were made on actual data.

Conclusions. The calculations carried out on the basis of the method have demonstrated the dependence of performance indicators on factors. The use of the method allows identifying the reasons for the decrease in efficiency and making the company's management more efficient. Prospect for further research may be to detail the factors, optimize software implementations, and use the method in inventory management information systems in various areas of activity.

KEYWORDS: inventory management efficiency, information system, management system, evaluation methods, factors, Big Data.

ABBREVIATIONS

COVID-19 is coronavirus disease 2019;

AI is artificial intelligence;

ISIM is information system for inventory management.

NOMENCLATURE

T_t is a target level of inventory;

f_t is a forecast demand;

d_t is a demand;

m_t is a forecast error;

q is a quantity of goods for visual representation on the shelf (or product display);

L_t is lost sales;

O_t is an overstock;

I_t is a balance in period t;

$\hat{I}_t$ is a balance in period t, taking into account the influence of factors;

l is a order fulfillment time;

c is a cyclical replenishment of goods;

Q_{t-l} is a quantity ordered at the beginning of period $t-l$ (which will arrive at the beginning of period t);

Q_t is a quantity ordered that arrived at the beginning of period t;

R_t is a set of factors in period t;

k is a number of factors that influenced the efficiency of the inventory management information system in period t;

n is a serial number of the factor occurrence;

id_i is a identifier of the factor characterizing the cause of its occurrence;

r_i is a quantitative value of the factor;

CR_t is a set of factors that influenced the performance indicator in period t;

cr_i is a quantitative value of the factor that influenced the performance indicator;

idL_i is a percentage of lost sales affected by the factor id_i;

idO_i is a percentage of overstock influenced by the factor id_i;

p is a purchase price;

s is a sale price;

$x^+ = \max(0; x)$.

INTRODUCTION

In a dynamic market, under the influence of external factors, or when scaling a business, effective inventory management is one of the key success factors [1]. Consumer demand can fluctuate at different stages of the supply chain for many reasons, such as inventory management strategy, forecasting methods, order processing time, and other factors. In addition, during the COVID-19 pandemic and the war, supply chains have faced a significant increase in unreliable order fulfilment. This leads to disruptions in the movement of information and material flows, violating the main goal of the work – to meet the needs of both their own and customers [5, 15].

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That's why more and more companies are implementing special information systems and specialized software to help them optimize and control stocks of goods, raw materials, supplies, and other resources.

Information systems and software for inventory management work with large amounts of data, collect data on sales, inventory, deliveries, and other indicators, automate forecasting and ordering processes, and offer data analytics. Mathematical methods of extrapolation and regression, as well as machine learning, are used for forecasting [10].

There are various methods for evaluating the effectiveness of an ISIM, which can be divided into two groups – quantitative and qualitative methods.

Quantitative methods:

– Inventory level analysis – whether the inventory level is optimal to minimize storage costs and the risk of spoilage, and to guarantee uninterrupted trading.

– Inventory turnover analysis – how many times in a certain period the inventory is renewed. High turnover indicates effective inventory management.

– Analysis of storage costs – what are the costs associated with storing inventory, such as warehouse rent, utilities, insurance, and others.

– Analysis of the level of lost sales – how many sales were lost because the demand for the product exceeded its availability. A low level of lost sales indicates effective demand forecasting.

– Analysis of the overstock level – what is the level of inventory that is not expected to be sold within a certain period of time.

– Analysis of demand forecasting accuracy – assessment of forecasting accuracy using various metrics such as MAPE, MAE, ME, MSE, RMSE, and others.

Qualitative methods:

– Assessment of the level of customer service. This method assesses how satisfied customers are with the availability of goods.

– Assessment of warehouse logistics efficiency. This method assesses how well warehouse processes, such as receiving goods, storage, shipping, and inventory, are organized.

– Data quality assessment. This method assesses how accurately and completely the information system collects data on sales, inventory, deliveries, and other indicators.

– Ease of use assessment. This method assesses how easy it is to use the inventory management information system.

To assess the effectiveness of an ISIM, a comprehensive approach is used that takes into account both quantitative and qualitative methods, for example:

– ABC-XYZ analysis is a classification of goods by their importance and turnover to focus on the most important items.

– Benchmarking – comparing the company's performance with industry benchmarks.

– Audit – conducting inspections and inviting various consultants to analyze the results of the inventory management system.

– Customer surveys – collecting and analyzing customer feedback on the level of service.

The effectiveness of an ISIM is influenced by many factors, including the reliability of suppliers, logistical constraints and company policies, forecast accuracy, energy supply, data quality, and others..

The object of study is the process of evaluating the effectiveness of the ISIM. Information systems and software for inventory management work with large amounts of data, which makes the process of performance evaluation time-consuming. This is due to an extensive information storage system, different assessment rules in different departments, and employee interference with automated processes. Therefore, to increase the speed of analysis, unified rules for quantifying the factors that affect performance indicators are needed.

The subject of study is the methods for assessing the effectiveness of inventory management systems. A common problem of the known methods is the complex interpretation of the reasons that influenced the performance indicators.

The purpose of the work is to establish a link between the performance indicators of inventory management information systems and the factors that influence these indicators.

1 PROBLEM STATEMENT

Suppose that there is a set of factors R_t that affect the performance indicators of the ISIM in period t:

$$R_t = \begin{bmatrix} id_1 & id_2 & \ldots & id_k \\ n_1 & n_2 & \ldots & n_k \\ r_1 & r_2 & \ldots & r_k \end{bmatrix}. \quad (1)$$

For a performance indicator for a given set of factors R_t, it is necessary to build a correspondence matrix CR_t, which shows the relationship between the performance indicator and the factors that influenced it:

$$CR_t = \begin{bmatrix} id_1 & id_2 & \ldots & id_k \\ cr_1 & cr_2 & \ldots & cr_k \end{bmatrix} \quad (2)$$

2 REVIEW OF THE LITERATURE

In [1] is proved that the company's performance depends on the efficiency of inventory management. This conclusion is robust to the use of different evaluation methods. The level of inventories is a key factor in the effectiveness of the ISIM and depends on the chosen management methods, demand, and the impact of external and internal factors of the company.

In [2, 3] studied the impact of management methods on inventory levels. In particular, [2] investigates the impact of the ABC analysis method, the level of inventory controlled by the supplier and the periodic review approach on the level of inventory. In [3], a method of reducing inventory levels through the use of ABC-XYZ analysis is investigated, the process of assortment plan-

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ning, ordering and inventory management is analyzed. The importance of monitoring inventory movement to achieve optimal inventory levels, as well as the results and recommendations for future operations are presented.

Various forecasting methods are used to ensure that the level of stocks corresponds to consumer demand. In [4], the role of demand forecasting in a business intelligence system is considered. High forecast accuracy helps to formulate a sustainable market strategy, increase inventory turnover, reduce supply chain costs, and increase customer satisfaction. Demand for a particular product or service is usually associated with various uncertainty factors that can make it unstable and difficult to predict. Errors in demand forecasting and their dependence on various factors are discussed in [5]. Given the diversity of demand forecasting methods, it is unlikely that any single method of demand forecasting can provide the highest forecasting accuracy for all products. Approaches for automated model selection for retail demand forecasting based on economic profitability, taking into account lost sales and inventory costs, are presented in [6–8].

The use of artificial intelligence (AI) is gaining wide application in forecasting. The authors of [9] consider the role of AI in inventory management and identify challenges in implementing AI, such as data quality, interpretability, and model transparency.

The main task of any forecasting algorithm is to obtain results with a minimum forecast error. The use of forecasting algorithms implies a linear development of events: calculation of the forecast, creation of an order based on the forecast, fulfilment of the order by the supplier on time and in full, timely placement of goods on the store shelf, no disruptions in the store itself, etc. However, there is some uncertainty in the development of events caused by the influence of external factors and internal rules and policies of the company, so it is difficult to find solutions to real-life problems in a precise form. This directly affects the result of calculating the forecast quality indicators [10].

An analysis of external and internal factors affecting the effectiveness of the ISIM is given in [11–14]. The factors include the economic situation, reliability of suppliers, delivery time, quality of internal production operations, level of process automation, logistics rules and policies, etc. However, the articles do not provide rules for calculating the quantitative impact of factors on the effectiveness of the ISIM. Thus, the available methods provide an indirect link between the result of the inventory management system and the factors that influenced it.

3 MATERIALS AND METHODS

In this article, the authors propose a method that will allow establishing a link between the results of the assessment of the effectiveness of the ISIM and the factors that influenced these results.

The ISIM automates the forecasting and ordering process, thus influencing the availability of goods. To forecast demand, raw sales data is first collected from the market, and then the future demand for the product is forecasted according to the data [4]. The efficient operation of the system is when there is neither too little nor too much of the product. An indicator of effective operation is the presence of a balance I_t that does not exceed the target inventory level T_t, i.e. the amount required for sales and visual representation of the product. The target inventory level T_t is proposed to be calculated by the formula:

$$T_t = \sum_{i=t}^{t+l+c} f_i + q. \qquad (3)$$

It is proposed to use lost sales L_t and overstock O_t as quantitative indicators of performance evaluation.

Lost sales are sales that did not take place because the product was unavailable, i.e., the stock I_t for the product is zero. Lost sales are equal to the demand d_t in period t minus the existing inventory level for the previous period I_{t-1} and the order quantity Q_t for the last period [16]:

$$L_t = (d_t - I_{t-1} - Q_t)^+. \qquad (4)$$

Overstock is inventory that exceeds the target inventory level T_t:

$$O_t = (I_t - T_t)^+. \qquad (5)$$

Lost sales and overstock can be expressed in both absolute and relative terms, i.e. as an amount or percentage of total sales and inventory, respectively.

The values of lost sales and overstock depend on the balance. Therefore, we will further consider what influences the inventory balance. The level of inventory in period t upon receipt of an order is proposed to be determined as follows:

$$I_t = (I_{t-1} + Q_{t-l} - d_t)^+ = (I_{t-l} + Q_{t-l} - \sum_{i=t-l}^{t} d_i)^+ \qquad (6)$$

Then, the order is determined by the formula:

$$Q_{t-l} = (\sum_{i=t-l}^{t+c} f_i + q - I_{t-l})^+. \qquad (7)$$

In this case, the forecast can be represented by the demand and the forecast error [5] as:

$$f_i = d_i + m_i \qquad (8)$$

The ideal model of the ordering and replenishment cycle can be described as follows: the ISIM makes a forecast and calculates the quantity for the order of goods, the order is fulfilled by the supplier on time and in full, it appears in the store on time and sales data is received by the information system on time and without distortion. Therefore, in this case, the level of inventory in the period between delivery and the next delivery is proposed to be defined as:

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$$I_t = \begin{cases} \left(\sum_{i=t}^{t+c} f_i + \sum_{i=t-l}^{t} m_i + q \right)^+ , if \sum_{i=t}^{t+c} f_i + q \geq I_{t-l} \\ \left(I_{t-l} - \sum_{i=t-l}^{t} (f_i + m_i) \right)^+ , else. \end{cases} \quad (9)$$

In an ideal order cycle model, the forecast f_i is a constant value, i.e., the variability of the stock I_t depends only on the forecast error m_i. With an absolutely accurate forecast, the stock balance will fluctuate between the quantity of goods for visual display on the shelf q and the target inventory level T_t. Lost sales L_t will be caused by an insufficient forecast, i.e., when m_i is negative, and overstock O_t will be caused by an over-forecast, i.e., when m_i is positive.

However, events during the ordering and replenishment cycle do not unfold linearly: the supplier may not have the goods or they may not be available in full quantity, the delivery may be late, the goods may be damaged, etc. In other words, the goods will not be available on the store shelf in the required quantity and at the required time not only because of the forecast error, but also due to certain external and internal factors. These factors can be grouped as follows:

– Logistics rules and policies of the company (order multiplicity, minimum delivery batch, financial restrictions, etc.)

– Reliability of the supplier (the supplier may be late, deliver the goods incompletely, not at all, or deliver more than ordered)

– Data in the system (errors in document data can be corrected “retroactively”, outdated data in the central database, communication, etc.)

– Receiving, processing and sending an order to a store may be delayed due to a shortage of warehouse workers

– Decrease in the balance not related to sales (write-offs, thefts, transfers to other divisions, inaccurate information about the balance when ordering, etc.)

– Manual order adjustment.

Factors have a certain order of occurrence and affect changes in the inventory balance, order, delivery, or target inventory level. That is, each factor can be quantified. The set of factors in period t can be represented as the matrix R_t (1).

Taking into account the influence of the factors, the inventory level in period t is proposed to be determined as follows:

$$\hat{I}_t = \begin{cases} \left(\sum_{i=t}^{t+c} f_i + \sum_{i=t-l}^{t} m_i + q + \sum_{i=t-l}^{t} r_i \right)^+ , if \sum_{i=t}^{t+c} f_i + q \geq I_{t-l} \\ \left(I_{t-l} - \sum_{i=t-l}^{t} (f_i + m_i + r_i) \right)^+ , else. \end{cases} \quad (10)$$

Thus, both an insufficient forecast and a negative value of r_i will lead to lost sales, and both an excessive forecast and a positive value of r_i will lead to overstock. The task of the method is to establish a link between the values of lost sales L_t, overstock O_t and the quantitative values of the factors r_i.

The link between the factors R_t and lost sales L_t or overstock O_t is represented in the form of the correspondence matrix CR_t (2).

To determine the factors that led to the appearance of lost sales L_t, is need to:

1. Determine the nearest order that was to be delivered before the date of the lost sale (Fig. 1)

2. Determine the events that led to a decrease in backlog, delivery, or balance from the date of the order that was to be delivered to the date of the lost sale.

3. For each of the events, determine the cause id_i, calculate the factors r_i and the order of their occurrence n_i. Examples of calculating factors are given in the section “Experiments”

4. Determine the factors that influenced L_t using algorithm 1. The influence of a factor on lost sales is limited in quantity. That is, if the factor r_i influenced the lost sales of L_t in the amount of cr_i, then the lost sales of L_{t+1} are influenced in an amount not exceeding $r_i - cr_i$

5. If the value of L_t is greater than the total value of the factors $\sum r_i$, then the reason for the difference $L_t - \sum r_i$ – forecast error.

Algorithm 1. Determine the factors that influenced the lost sales L_t

Input: Lost sale L_t, factor matrix R_t[id,n,r]
Output: correspondence matrix CR_t[id,cr]

```
L_value ← L_t
WHILE L_value>0 AND EXISTS r_i>0, i = 1,2,…,k
    #find index of first event with positive r_i
    min_i ← GET_INDEX(for r_i>0 MIN(n_i))
    r_value ← MIN(r_min_i;L_value)
    CR_t[id,cr] ← (id_min_i,r_value)
    R_t[r_min_i] ← r_min_i – r_value
    L_value ← L_value – r_value
END WHILE
IF L_value>0
    #forecast error
    CR_t[id,cr] ← (id_forecast_error, L_value)
END IF
RETURN CR_t
```

In order to determine the factors that led to the overstock O_t, it is necessary:

1. Determine whether the events led to an increase in the balance or a decrease in the target T_i level. Identification and calculation of events that led to an increase in the balance or a decrease in the target level should be carried out in descending order of dates from the overstock (Fig. 2).

2. Determine the cause id_i for each of the events, calculate the factors r_i and the order of their occurrence n_i. Examples of calculating factors are given in the section “Experiments”

3. Determine the factors that influenced O_t using algorithm 2.

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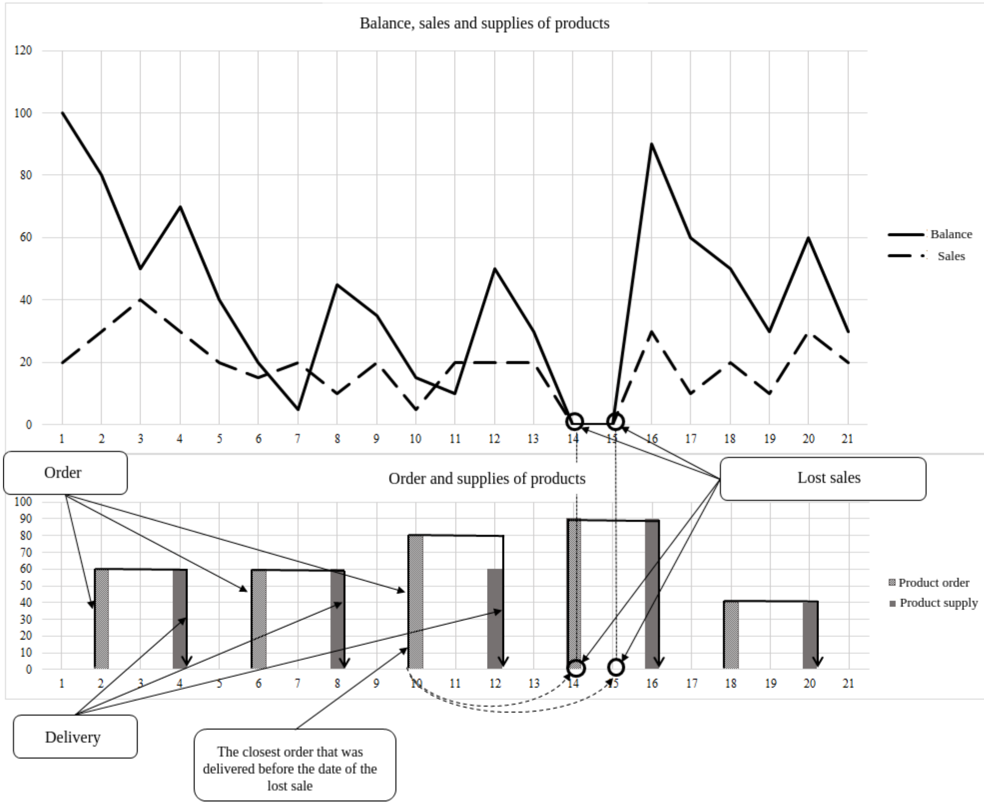

Figure 1 – The closest order that should have been delivered to the date of the lost sale

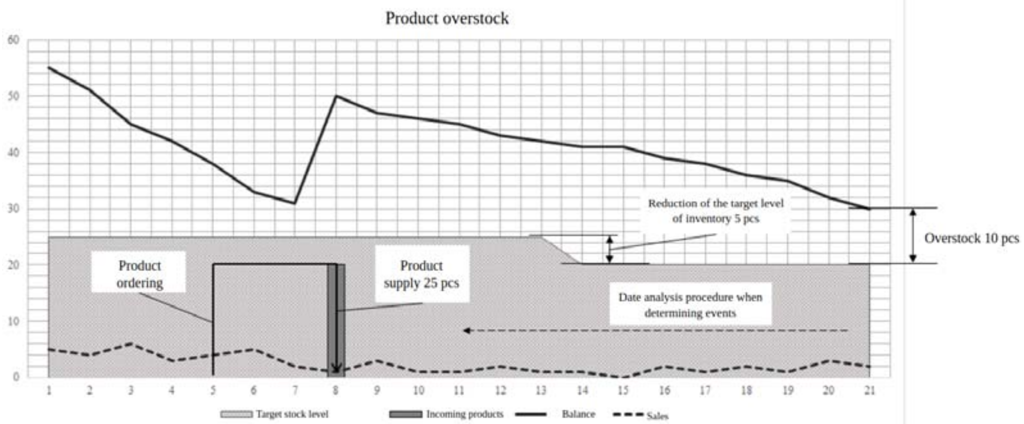

Figure 2 – Events that led to overstock

Algorithm 2. Determine the factors that influenced the overstock O_t
Input: overstock O_t, factor matrix R_t[id,n,r]
Output: correspondence matrix CR_t[id,cr]

1. O_value ← O_t
2. **WHILE** L_value>0 AND EXISTS r_i>0, i = 1,2,…,k
3. #find index of first event with positive r_i
   min_i ← GET_INDEX(for r_i>0 MIN(n_i))
4. r_value ← MIN(r_{min_i};O_value)
5. CR_t[id,cr] ← (id_{min_i},r_value)
6. O_value ← O_value – r_value
7. **END WHILE**
8. **RETURN** CR_t

4 EXPERIMENTS

Below are the factors that can cause lost sales or overstock and how they are calculated. The list of factors is provided to understand the principle of their calculation, it can be expanded or adjusted depending on the specifics of the organization of business processes in a particular company.

To quantify the factors that affect lost sales L_t, must be calculated:

1. Reducing the Q_t order at the stage of order formation and fulfilment.
2. Reduction of the I_t balance, which was not taken into account when ordering due to damage to the goods, theft, transfer to another unit or store.
3. Reduction of Q_t order due to forecast error f_i.

In order to quantify the factors on which the overstock O_t depends, it is necessary to identify:

1. What events led to the increase in the It balance. To do this, it is necessary to determine the increase in orders or deliveries relative to the initial order Q_t.
2. What events led to a decrease in the target level of T_t.

Examples of quantitative calculation of factors are given in Table 1.

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Table 1 – Examples of quantitative calculation of factors

Efficiency indicator	**Stage**	**ID**	**Factor description**	**Calculation example**
Lost Sales	Order formation	id_1	reducing the order to ensure multiplicity	the initial order was 120 units, while the order multiplicity is 100 units, so only 100 units were ordered, r_1= 20 units
		id_2	reducing the order to secure the logistics batch	the initial order was 50 units, the total weight of the order to the supplier was 23 tons, while the logistics batch is 20 tons, so only 40 units were ordered, in this case r_2= 10 units
		id_3	order reduction due to financial constraints	the initial order was 50 units, but due to lack of funds, the goods were not ordered, then r_3 = 50 units
		id_4	reduction or cancellation of the order manually by the manager	the initial order was 500 units, but the manager reduced the need and an order of 100 units was sent to the supplier, then r_4 = 400 units
	Order fulfilment	id_5	the supplier fulfilled the order in a smaller quantity than was ordered	100 units were ordered from the supplier, but only 70 units were delivered, then r_5 = 30 units
		id_6	delivery took place later than scheduled.	this case applies only to those days with lost sales that occurred between the scheduled delivery date and the date of actual receipt of the goods. In this case, r_6 is equal to the total amount of the delayed order. For example, 100 units were ordered on Friday and were to be delivered on Saturday. But the delivery took place only on Tuesday. Sales were lost on Sunday and Monday. Then for the lost sales on Sunday and Monday r_6 = 100 units
	Reducing the balance	id_7	reducing the balance of goods as a result of moving to other units or stores, if the possibility of such movements is not taken into account in the forecasting algorithm	the store has a bakery, for which flour is supplied separately. The finished products were quickly sold out and the bakery did not have enough flour available, so they took 100 kg of flour from the store shelf, then r_7 = 100 kg
		id_8	reduction of the balance of goods due to spoilage	5 units were written off due to the expiration date, then r_8 = 5 units
		id_9	reducing the balance of goods as a result of the inventory	during the inventory, it was found that the actual balance of the goods is 0 pcs. and there are 15 units in the system, then r_9 = 15 units
		id_{10}	reducing the balance of goods due to inaccurate information in the information system	the balance of the goods was 100 units, of which 20 units were sold, but due to the lack of communication, this information was not received by the information system, i.e. the order was made based on the amount of the balance of 100 units, although the actual balance was 80 units, then r_{10} = 20 units
	Forecast error	id_{11}	between the date of the order and the date of the lost sale, the parameters were changed, which resulted in a lower forecast at the time of the order	at the time of the order, the sales forecast was 100 units, but after the order, the price of the goods was reduced due to the start of pro-activity, and the updated sales forecast, taking into account the price reduction, was 300 units, then r_{11} = 200 units
		id_{12}	forecast inaccuracy, which is not related to the parameters of the forecast algorithm, i.e. an increase in demand that the algorithm cannot predict	the outbreak of the COVID-19 pandemic led to a sharp panic increase in demand, which resulted in empty store shelves. The number for this reason is equal to the difference between the lost sales and the sum of all other reasons related to a particular order. That is, the amount of lost sales that is not covered by other reasons should be attributed to r_{12}
Overstock	Order formation	id_{13}	increasing the order to ensure multiplicity	the initial order was 70 units, while the order multiplicity is 100 units, so 100 units were ordered, in this case r_{13} = 30 units
		id_{14}	increasing the order through a logistics batch	the initial order was 50 pieces, the total weight of the order to the supplier was 17 tons, while the logistics batch is 20 tons, so only 90 pieces were ordered, in this case r_{14} = 40 units
		id_{15}	increase the order manually by the manager	the inventory balance was sufficient, so the initial order was 0 units, but the manager decided to order the goods and the supplier was sent an order in the amount of 500 units, then r_{15} = 500 units
	Order fulfilment	id_{16}	the supplier fulfilled the order in a larger volume than was ordered	100 units were ordered and 150 units were delivered, then r_{16} = 50 units
	Balance increase	id_{17}	increase the balance of goods as a result of moving from another store or unit, if the possibility of such movements is not taken into account in the forecasting algorithm	the balance of a neighboring store were moved to the store as a result of its closure
		id_{18}	Increase in the balance of goods as a result of the inventory, for example, when a re-sort is detected	during the inventory, it was found that the actual balance of the goods is 50 pieces, and there are 10 pieces in the system, then r_{18} = 40 units
		id_{19}	data errors, increase in overstock due to inaccurate information in the information system	the delivery of goods in the amount of 200 units was not entered into the system in time, which resulted in the re-formulation of an order for 200 units, which was fulfilled, then r_{19} = 200 units
	Target level reduction	Id_{20}	reducing the quantity for visual representation of the product	at the end of the season, the number of items on the shelf decreases from 50 to 10, resulting in a target level of 40 units, then r_{20} = 40 units
		id_{21}	reduction of order multiplicity	the product was delivered to the store only in multiples of boxes of 40, but a decision was made to order by the piece, as a result of which the target level decreased from 40 to 25, then r_{21} = 15 units
		id_{22}	forecast error, reduction of the target level due to changes in the parameters of the forecasting algorithm	after the order was placed, the price of the product was increased, resulting in a decrease in demand for the product, which led to a decrease in the target level from 80 units to 30 units. In this case r_{22} = 50 units
		id_{23}	reduction of the target level due to a decrease in demand, which is not related to the parameters of the forecast algorithm	an unpredictable decline in demand for the product resulted in the target level being reduced from 150 units to 70 units, then r_{23} = 80 units

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The following functionality has been implemented in the inventory management information system to collect data on the factors of influence:

– order and delivery schedules;

– link between the order and the delivery, i.e., which order was delivered, and whether the delivery was late;

– order parameters – initial order, fixing order changes when applying multiplicity, logistics batch, financial constraints, order adjustment by the manager;

– storing the history of changes in the parameters of the forecasting algorithm, the quantity for visual representation, and the order multiplicity;

– ability to recalculate the order and target inventory level with changed parameters.

5 RESULTS

The method was tested on actual data. The data for 2023 of one of the Ukrainian retail chain selling cosmetics, perfumes, care and health products were analyzed. The chain consists of 1072 stores and has an average of 8 thousand products in its assortment. The data is presented on the condition of company anonymity.

For each product at each storage point, the values of performance indicators were calculated: lost sales L_t and overstock O_t. The lost sales were calculated for each day, and overstock for the end of each week of the analysis period.

Software was developed to collect data on the id_i influence factors. Using the rules described in the "Experiments" section, the quantitative values of the r_i factors were calculated. According to the method described above, the relationship between the id_i factors in the amount of cr_i, lost sales L_t and overstocks O_t was established. The results obtained on the influence of factors on performance indicators were converted into percentages.

The percentage of lost sales influenced by the id_i factor is calculated by the formula:

$$idL_i = \sum cr_i \cdot s \Big/ \sum L_t \cdot s \cdot 100\%. \qquad (11)$$

The percentage of overstock influenced by the id_i factor is calculated by the formula

$$idO_i = \sum cr_i \cdot p \Big/ \sum O_t \cdot p \cdot 100\%. \qquad (12)$$

The values of lost sales L_t, overstock O_t, and the quantitative values of factors r_i and cr_i in monetary and quantitative terms are not given due to commercial secrecy. Table 2 shows the results of the calculation of the percentage of lost sales and overstock affected by each factor.

Table 2 – Influence of factors on the performance indicators of the inventory management information system

Indicator	Factors	Influence of the factor, %
Lost sales	The supplier fulfilled the order in a smaller volume	22.3%
	Reducing or cancelling an order manually by a manager	22.1%
	Forecast error	15.5%
	Adding a new product to the assortment	10.8%
	Sharp increase in demand (aftermath of shelling)	8.5%
	Reducing the order to ensure multiplicity	5.8%
	The delivery took place later than scheduled	5.6%
	Promotional activity	3.5%
	Order reduction for a logistics batch	2.4%
	Decrease in the balance due to inaccurate information in the information system	1.2%
	Other reasons	2.2%
Overstock	Manual order increase by the manager	31.6%
	Increasing the order for a logistics batch	20.8%
	Promotional activity	17.0%
	Data errors	11.5%
	Removing a product from the assortment	7.0%
	Reducing the quantity for visual representation of the producty	5.4%
	Forecast error	2.9%
	Increase the order to ensure multiplicity	2.1%
	The supplier fulfilled the order in a larger volume than was ordered	1.1%
	Other reasons	0.7%

6 DISCUSSION

According to the results obtained, only 15.5% of lost sales and 2.9% of overstocks depend on the accuracy of the forecast. That is, improving the forecasting algorithm will have a limited impact on the efficiency of the inventory management information system. A small percentage of the forecast's impact on the efficiency of inventory management is explained by external factors and internal company rules. Thus, to increase efficiency, it is necessary to control and measure all processes that affect the availability of goods in the right quantity and in the right place.

Due to the fact that all calculations in the method were made in the context of specific products and stores, further analysis can be carried out in different sections, for example, by suppliers, regions, supply routes, individual stores, product groups, product category managers, etc. For each breakdown, it is possible to identify the biggest causes and specific items that lead to losses and compare the losses with the cost of solving the problem.

It should also be noted that the automation of data collection on impact factors and computations make it possible to conduct analysis on a regular basis and take into account the dynamics of changes in the impact of factors. This allows for a quick assessment of the impact of decisions made on the effectiveness of the ISIM.

CONCLUSIONS

The study proposes a new method for evaluating the effectiveness of information systems, which allows estab-

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lishing a link between performance indicators and the factors that influenced these indicators.

Based on actual data, the study calculates the impact of factors on lost sales and surplus of one of the Ukrainian retail chains. The result of the company's work depends on the efficiency of the inventory management information system. Various factors affect the effectiveness of the system: company policies and rules, logistical and financial constraints, supplier reliability, and forecast accuracy. It is shown that improving the forecast algorithm has a limited impact on the efficiency of the inventory management information system.

The scientific novelty of obtained results is that for the first time a method for analyzing the effectiveness of inventory management information systems has been proposed, which allows establishing a link between lost sales, excess inventory and the factors that influenced these results. This makes it possible to automate the analysis and perform it for different data sections and reduce the time for making management decisions

The practical significance of obtained results lies in the fact that the rules for calculating the factors and the necessary functionality of the inventory management information system have been formed, software that implements the proposed method has been developed, and the method has been applied to real data. The results of the experiments allow us to recommend the use of the method for systematic identification of the causes of efficiency reduction in practice**.**

Prospects for further research is to study the results of the method for a wider range of practical tasks.

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МЕТОДИ ДЛЯ ПРОВЕДЕННЯ АНАЛІЗУ ЕФЕКТИВНОСТІ ІНФОРМАЦІЙНИХ СИСТЕМ ДЛЯ УПРАВЛІННЯ ЗАПАСАМИ

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АНОТАЦІЯ

Актуальність. Інформаційні системи управління запасами використовуються для прогнозування, керування, координації та моніторингу ресурсів, необхідних для плавного, своєчасного, економічно ефективного та надійного переміщення товарів. Чим ефективніше працює система, тим кращі результати може здобути компанія. Загальною проблемою наявних методів оцінки ефективності є складна інтерпретація зв'язку показників ефективності з факторами, які на ці показники вплинули.

Мета. Метою роботи є опис методу для оцінки ефективності інформаційних систем, що дозволяє встановити зв'язок між показниками ефективності та факторами, що вплинули на ці показники.

Метод. Запропоновано набір показників, що характеризують ефективну роботу інформаційних систем управління запасами. Запропоновано правила для кількісного обчислення факторів, що впливають на показники ефективності. Фактори виникають під час подій, що впливають на зміну замовлення, постачання, залишку, цільового рівня товарного запасу, параметрів алгоритму прогнозування, тощо. Запропонований метод виконує ітераційний розподіл кількісного значення факторів серед показників ефективності і встановлює таким чином зв'язок між показниками ефективності та факторами.

Результати. Виконано реалізацію запропонованого методу у програмному забезпеченні та проведено розрахунки на фактичних даних.

Висновки. Проведені на основі методу розрахунки продемонстрували залежність показників ефективності від факторів. Використання методу дозволяє виявляти причини зниження ефективності та робити управління компанією більш оперативним. Перспективою подальших досліджень може бути деталізація факторів, оптимізація програмних реалізацій та використання методу в інформаційних системах управління запасами різних напрямків діяльності.

КЛЮЧОВІ СЛОВА: ефективність управління запасами, інформаційна система, система управління, методи оцінки, фактори, великі дані (Big Data).

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