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Business information system for forecasting raw material stocks for the production of flexible packaging

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Abstract — **A specialized information system of the enterprise has been developed for forecasting and raw materials ordering, which allows for the optimization of warehouse stocks of raw materials and reduces the risks of under-fulfillment of orders for finished products. It is important to control warehouse stocks and orders for basic raw materials of pure film. The essence of control comes down to constant monitoring of raw material balances in warehouses, and forecasting orders for base films in advance, since the execution of raw material deliveries is also stretched from two weeks to several months. The developed program automatically takes into account the available balance of raw materials in warehouses, the ordered quantity, and the required quantity according to forecasts, which improves the raw materials turnover ratio in warehouses. As customer expectations and behavior change dynamically, having such demand forecasting software empowers companies and helps them respond quickly to changes. An analytical decision-making mechanism based on a weighting function that provides the degree of raw material relevance for an order has been proposed. Recommendations have been given for choosing weighting function coefficients. The research results have been implemented in a business process at an enterprise engaged in the production of flexible packaging. The advantage of this system is the user-friendly interface, in particular the advisory component regarding the need and number of orders.**

Keywords — information system, forecasting, demand, orders, raw materials, optimization, MS Excel, MS SQL Server, database, big data.

I. Introduction

Information technologies affect the activity of a specific enterprise, which allows implementation of the task of managing production processes, to improve the information support of the system of forecasting orders for raw materials and demand for goods.

By forecasting future demand for goods, you can calculate the optimal number of raw materials or goods in warehouses without creating a surplus or shortage. This will allow you to avoid overpayments for excess storage, or, conversely, help you prepare in advance for the rush during periods of increased sales.

Modern businesses can save a significant amount of money by using technology solutions. Business analytics and machine learning are important tools in the decision-making process as they solve many problems in the field of business decision-making.

II. State-of-the-Art

Different methods have been proposed in the scientific literature for forecasting demand and product orders for businesses.

The creation of separate departments for demand forecasting in enterprises appeared at the end of the last century. At first, forecasts were mostly based on simple statistical models and methods, such as average value, smoothing, or instinctive judgment. Later, with the development of technologies in the field of storage and processing of big data, the process of forecasting demand and orders of goods has undergone significant changes and has become an indispensable tool for running a business of different sizes and industries of enterprises.

Typically, most companies, due to data privacy policies, do not publicly disclose the methodologies they use to create their sales forecasts, making it difficult to learn and analyze these methods.

Let us review the literature on the use of mathematical models and modern information technologies to ensure optimization of both the business management process itself and the set of technical means for its implementation. Enterprises are beginning to implement information systems for management and decision-making [1] using business analytics [2]. Business analytics studies important factors of regional economic growth [3] and plays a key role in formulating enterprise strategies and creating decision support systems based on data analysis throughout the business process. First, data on sales from the market is collected, and then, based on the data, future demand for products is forecasted.

The demand forecasting method uses the collected sales data to analyze and create an estimate of the current customer

demand forecast. Competition in the market requires making necessary decisions and planning for future business events such as production, sales, ordering raw materials, etc.

The problem of determining demand for products and services is of interest to the international scientific community and enterprise management since it is an effective tool for increasing economic profits and competitiveness of enterprises.

Let us consider the main known methods of forecasting

Accurate forecasts of demand from products are crucial for the production, procurement, and sale of raw material stocks from warehouses. The relevance of this topic is disclosed in [4], which considers the use of various methods for forecasting the need for materials and calculating the safety stocks of raw materials.

Models for forecasting demand for perishable products in food trading companies are considered in articles [5,6].

The review article [7] presents different approaches to forecasting, including the entire demand for goods, analysis of the forecast in the supply chain, etc.

Accurate forecasting of product demand is a competitive advantage for businesses for all components of the supply chain, including retailers. Approaches such as moving average [8,9], weighted average, and exponential smoothing are commonly used for demand forecasting. However, such simple approaches may lead to increased inventory holdings and may not always cover distribution costs when demand trends are nonlinear. The proposed model can help retailers make informed inventory management decisions, leading to improved operational efficiency and profitability.

Forecasting product demand is important for manufacturing companies as it provides the basis for production planning. Forecasting product demand can be complex as customer requirements often depend on several factors. The nearest neighbor model can be considered as an alternative to forecasting product demand in an industrial context to ensure high forecast accuracy over a short calculation period. In this context, raw material inventory orders as well as enterprise software systems are largely based on product demand forecasts, and customer requests are met directly from finished goods inventory. Typically, forecasts are calculated weekly or monthly for approximately one year based on time series of past customer orders [10].

Time series forecasting models demonstrate high efficiency in various areas of the economy [11, 12].

The integration of application methods and the possibilities of big data research into the process of sales planning, and demand forecasting in the supply chain began to be widely used in marketing to understand and meet the needs and expectations of customers [13,14].

Most enterprises use methods based on machine learning [15] and deep learning [16, 17] to design their forecasting information systems.

Forecasting demand for different product categories is an important task for retail, especially on special calendar days that differ significantly from demand on normal days. Such forecasts are input data for solving the ordering goods task with the help of machine learning and artificial neural networks [18].

A model of Evolving Neural Network prediction by integrating Genetic Algorithms and a Neural Network was developed in the articles [19,20]. Long-term forecasting in evolving data streams is described in [21].

The authors of the articles [22-24] presented a decision support system from a digital transformation view in the Industry 4.0 perspective for inventory management, combining fuzzy multi-criteria methods, genetic algorithms, and artificial neural networks and Computers & Industrial Engineering.

III. Demand forecasting

The goal is to develop a specialized information system for forecasting and ordering raw materials, allowing for the optimization of raw material stocks and the reduction of the risks of underfulfillment of orders for finished products.

Tasks that have to be solved for searching the goal:

- Based on the analysis of the current state of the problem, review of literary sources, develop the architecture of the information system that would allow solving the problem of forecasting raw material stocks.
- Research the data arrays contained in the raw material warehouse accounting system.
- Find the optimal ratio of the weight function coefficients.
- Check the relevance of the resulting model on real data (using the example of flexible packaging production).

Demand forecasting is never completely accurate, but it is necessary because it helps to make effective financial decisions on production and marketing costs. Planning helps control the number of raw material stocks, budget, and pricing policy.

Forecasted data helps to make effective financial decisions about operational, production, and marketing costs. In addition, a clear picture of the expected demand will allow you to plan personnel costs and redistribute resources during peak periods of activity.

Developing a pricing strategy focuses on determining the right price, taking into account current market activity and demand for products, which is key.

Demand forecasts help us to adjust pricing policy depending on the situation and set up tools for its implementation in advance (promotions, discounts, promos, etc.). By analyzing the market and potential opportunities, you can set competitive prices and use appropriate marketing strategies for the cost of goods.

By predicting future demand, you can calculate the optimal amount of goods in warehouses without creating excess stocks. In this way, you will avoid overpaying for excess storage, or, on the contrary, you will be able to prepare in advance for the excitement during increased sales. Demand forecasting is advisable to use regardless of the field of activity — be it retail, pharmaceutical company, construction, food company, etc.

Most authors distinguish three types of demand forecasts:

- Short-term.

- Medium term.
- Long-term.

Factors affecting forecasting [25]:

- Selected forecasting period.
- Seasonality of goods.
- Current inventory levels.
- Scale of orders.
- Competition in the goods market.
- Consumer Trends.
- Price.
- Product availability.
- Geography.

Factors can be major or accessory. Some factors can significantly affect income, and others — only to a small extent [26].

Demand forecasting should integrate the analysis of past trends, market conditions, customer feedback, and other factors to determine the expected sales volume of the product after the order. Companies use product demand forecasting to plan their production and marketing accordingly.

Product forecasting is an important part of product management. By forecasting demand, companies can ensure they have sufficient raw material stock to cover expected orders without excess raw material stock and risk of financial losses.

This makes it possible to optimize raw material stocks and reduce the risk of underfulfillment of orders for finished products.

Forecasting demand for certain products can help businesses forecast sales growth and evaluate their pricing strategy and adjust it if necessary to maximize profits.

A business must make informed decisions about managing its raw material inventory, supply chain processes, and product manufacturing. Order forecasting is prediction process of the number of product orders a business is likely to receive in a given period. Therefore, enterprises need to have a sufficiently accurate forecast of orders to ensure they can meet customer demand while minimizing inventory and production costs.

Enterprises must maintain sufficient levels of raw material stocks and avoid their shortages, reducing the risk of excess or shortage of raw material stocks. At the same time, it is necessary to take into account the expiration date of raw materials and the terms of delivery of raw materials to the warehouse in order to have time to fulfill the order on time.

Companies can reduce costs by ordering the right amount of raw material inventory, reducing inventory holding costs, reducing waste, and avoiding depreciation. This can help them increase their profits.

It helps companies plan production processes and supply logistics, and optimize their pricing strategies, ensuring they can meet customer demand while minimizing inventory and production costs.

Product order forecasting can help businesses improve customer satisfaction and stay competitive. When enterprises have the right number of raw materials in stock, they can fulfill customer orders quickly and efficiently. The result is an increase in customer satisfaction and loyalty.

Using real-time data and advanced forecasting techniques, companies can gain a clear understanding of their inventory levels and demand patterns, allowing them to make informed inventory ordering decisions.

Demand forecasting in raw material supply chain planning ensures:

- Reducing the shortage of raw materials, i.e. ensuring the required number of stocks.
- Avoiding excessive stocks.
- Avoiding unnecessary costs for storage of raw materials or goods.
- Planning production schedules.
- Competitive prices for goods.
- Planning of personnel costs and, if necessary, redistribution of resources during periods of sales hype.
- Reducing the duration of the order fulfillment time.
- Assessment of future income from product sales.
- Cash flow management.
- Substantiation of new investments and enterprise expansion plans.
- Increasing the level of service satisfaction and customer loyalty.

Based on predictions of market fluctuations, demand trends, changes in consumer capacity, or other external factors, enterprises will be able to monitor contingency plans, reduce potential risks, and respond to dynamic changes in advance.

Consider the process of planning orders for raw materials for the production of packaging products. The production process of packaging film has many stages. Accordingly, the specific order production is stretched over time and requires accurate planning of production processes. The deviation of one stage of production from the norm in terms of quality or postponement of the production of products due to the lack of raw materials (for example, clean film) will lead to material and reputational losses.

The essence of raw materials control comes down to constant monitoring of raw material balances in warehouses, and forecasting orders for base films for some time ahead, since the delivery of raw materials, in turn, is stretched from two weeks to several months. Forecasting relatively constant orders gives a more stable result for the production of the finished product. To forecast irregular random orders, a stochastic model can be used, which will analyze the production and sales of finished products over a fairly long period, for example within the last year, in terms of generalized types of base films, and (the model) will take into account the experience of sales managers who can contribute adjusting quantities into the model to improve and refine the final predictions.

The information system consists of a raw materials warehouse accounting subsystem, a primary information generation subsystem (SAP R/3 with Oracle Database), an analytical forecasting subsystem, and a data analysis and visualization subsystem (Fig. 1).

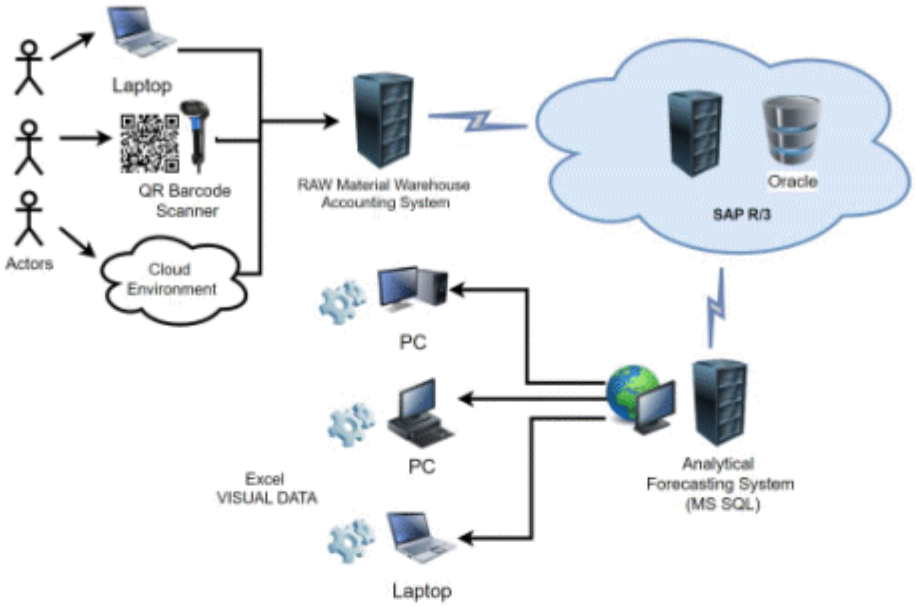


Fig. 1. Information system architecture

The proposed model combines the above principles. The software is built based on MS Excel and MS SQL Server. The input unprocessed data of the model, such as customers and quantities of finished products ordered, statistical data about finished products, and raw materials are stored in the MS SQL database. The results of the query script (data processing and selection of statistically significant results) are exported to MS Excel.

The active tables provide information on the production of finished products for the year by month. We can view active orders that are currently being processed, as well as available forecasted flexible packaging production volumes for the next six months. Managers can analyze the quantities and make necessary adjustments to the monthly forecasts. (Fig. 2).

The program automatically takes into number the available balance of raw materials in warehouses, the ordered quantity, and the requested quantity according to forecasts. The corresponding result is reflected in the breakdown of orders for raw materials and finished products. The lack of raw materials is displayed with a minus sign and tinted in pink. For products, a special utilization ratio is entered, which is recorded as a percentage. For products with a higher utilization ratio, the program gives a more successful forecast for raw material orders, for products with a lower utilization ratio, the decision of the manager is the decisive factor for ordering raw materials (human factor, the person makes the final decision). The "status" field provides patterned (patterned) recommendations regarding orders and availability of raw materials. The field has a recommendation nature and is filled based on a weighting function (programmed in SQL) that takes into account the utilization rate.

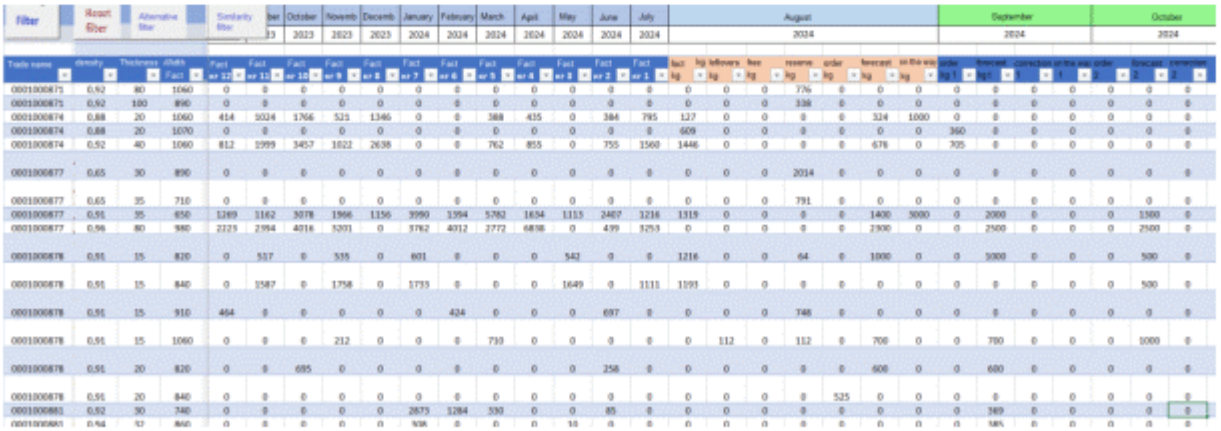
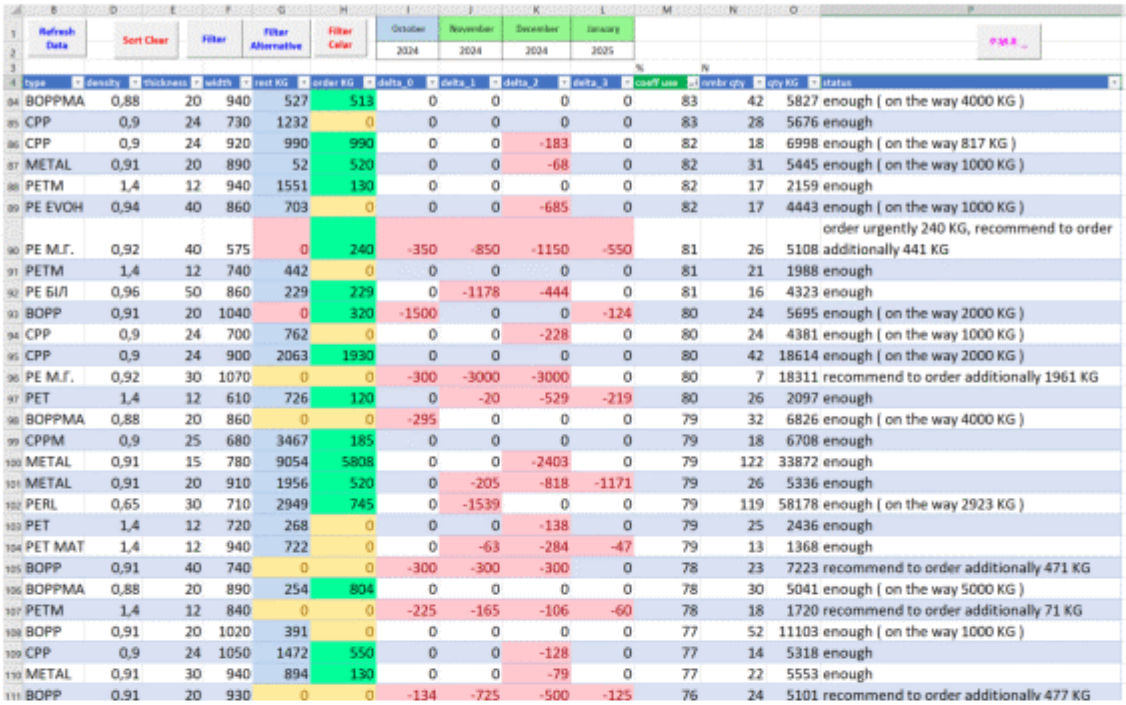


Fig. 2. Statistics of the production of finished products of flexible packaging

We empirically chose the coefficients and distribution of the weight function based on regional characteristics and long-term observations of the specific production of flexible packaging (Fig. 3).

The main parameters include the characteristic patterns of statuses. For example, with a negative balance in warehouses, an urgent order is recommended. For products whose usage relevance exceeds 60%, additional ordering is recommended. It's not preferable to accumulate stocks of raw materials in the warehouse with less than 6% relevance.



	type	density	thickness	width	rest KG	order KG	delta_0	delta_1	delta_2	delta_3	coeff use	nmbr qty	qty KG	status
84	BOPPMA	0,88	20	940	527	513	0	0	0	0	83	42	5827	enough (on the way 4000 KG)
85	CPP	0,9	24	730	1232	0	0	0	0	0	83	28	5676	enough
86	CPP	0,9	24	920	990	990	0	0	-183	0	82	18	6998	enough (on the way 817 KG)
87	METAL	0,91	20	890	52	520	0	0	-68	0	82	31	5445	enough (on the way 1000 KG)
88	PETM	1,4	12	940	1551	130	0	0	0	0	82	17	2159	enough
89	PE EVOH	0,94	40	860	703	0	0	0	-685	0	82	17	4443	enough (on the way 1000 KG)
90	PE M.Г.	0,92	40	575	0	240	-350	-850	-1150	-550	81	26	5108	order urgently 240 KG, recommend to order additionally 441 KG
91	PETM	1,4	12	740	442	0	0	0	0	0	81	21	1988	enough
92	PE БЛ/І	0,96	50	860	229	229	0	-1178	-444	0	81	16	4323	enough
93	BOPP	0,91	20	1040	0	320	-1500	0	0	-124	80	24	5695	enough (on the way 2000 KG)
94	CPP	0,9	24	700	762	0	0	0	-228	0	80	24	4381	enough (on the way 1000 KG)
95	CPP	0,9	24	900	2063	1930	0	0	0	0	80	42	18614	enough (on the way 2000 KG)
96	PE M.Г.	0,92	30	1070	0	0	-300	-3000	-3000	0	80	7	18311	recommend to order additionally 1961 KG
97	PET	1,4	12	610	726	120	0	-20	-529	-219	80	26	2097	enough
98	BOPPMA	0,88	20	860	0	0	-295	0	0	0	79	32	6826	enough (on the way 4000 KG)
99	CPPM	0,9	25	680	3467	185	0	0	0	0	79	18	6708	enough
100	METAL	0,91	15	780	9054	5808	0	0	-2403	0	79	122	33872	enough
101	METAL	0,91	20	910	1956	520	0	-205	-818	-1171	79	26	5336	enough
102	PERL	0,65	30	710	2949	745	0	-1539	0	0	79	119	58178	enough (on the way 2923 KG)
103	PET	1,4	12	720	268	0	0	0	-138	0	79	25	2436	enough
104	PET MAT	1,4	12	940	722	0	0	-63	-284	-47	79	13	1368	enough
105	BOPP	0,91	40	740	0	0	-300	-300	-300	0	78	23	7223	recommend to order additionally 471 KG
106	BOPPMA	0,88	20	890	254	804	0	0	0	0	78	30	5041	enough (on the way 5000 KG)
107	PETM	1,4	12	840	0	0	-225	-165	-106	-60	78	18	1720	recommend to order additionally 71 KG
108	BOPP	0,91	20	1020	391	0	0	0	0	0	77	52	11103	enough (on the way 1000 KG)
109	CPP	0,9	24	1050	1472	550	0	0	-128	0	77	14	5318	enough
110	METAL	0,91	30	940	894	130	0	0	-79	0	77	22	5553	enough
111	BOPP	0,91	20	930	0	0	-134	-725	-500	-125	76	24	5101	recommend to order additionally 477 KG

Fig. 3. Software for monitoring raw material balances in warehouses and order forecasting

Based on the practical needs of the production of flexible packaging, the planning of raw material supplies and control of stock balances is carried out for the current month and the next three months.

Orders for the production of flexible packaging are submitted for processing and planned according to the time of execution according to the productivity of machines (printing, laminating, cutting, etc.).

To facilitate decision-making on the formation of raw material orders for the warehouse, an analytical model is used based on a weighting function, which gives the degree of compliance with the order in percent. The higher the percentage, the more relevant the raw material film is for ordering both for production needs and for stockpiling.

The weight function returns the degree of relevance - the coefficient of use "COEFF USE":

ROUND(0.5 * [rel_perc] + 0.5 * [qf_perc])

A verbal description is provided in the "STATUS" column. It contains recommendations indicating the recommended quantity (need) for ordering raw materials for storage.

The status "order urgently" is determined by the conditions:

([QTY_REST]+[qd_all]<[qty_raw_all])AND([delta_0]<0)

The status "recommend to order additionally" is determined by the difference between the total available quantity of raw materials in warehouses and the necessary ordered quantity for production, and the amount of raw materials on the way:

[qty_raw_all] – [QTY_REST] – [qd_all]

The following weighting function from rating ranges is used for verbal descriptions of results:

1) ROUND(0.5 * [rel_perc] + 0.5 * [qf_perc]) >= 60
2) ROUND(0.5 * [rel_perc] + 0.5 * [qf_perc]) < 60 AND ROUND(0.5 * [rel_perc] + 0.5 * [qf_perc]) >= 37
3) ROUND(0.5 * [rel_perc] + 0.5 * [qf_perc]) < 37 AND ROUND(0.5 * [rel_perc] + 0.5 * [qf_perc]) >= 6
4) ROUND(0.5 * [rel_perc] + 0.5 * [qf_perc]) < 6

Where:

- ROUND – the rounding function.
- 0.5 — coefficient in the formula on the assumption that the contribution of calculation forecasts and managers equally affects the weight function.
- [rel_perc] — statistics, the rate of use of film-raw materials over the last year, calculated based on finished products.
- [qf_perc] — coefficient of forecasting by managers. The coefficient of use of film-raw materials based on forecasts is calculated from long-term forecasts of finished product orders by managers.

- [QTY_REST] — currently available remaining raw material film in warehouses, kg.
- [qd_all] — all raw materials on the way — amount by month, kg.
- [qty_raw_all] — all requested raw materials - amount by month, kg.
- - [delta_0] – quantity (shortage) of raw materials in the current month.

Let's consider the generalized coefficients and their components in more detail.

The coefficient [rel_perc] is calculated by the following formula:

```
ROUND([rel_perc_0])
+ 4 * IF([qty_raw_all] > 0, 1, 0) ' if there_
is an active order, then we add another 4% to_
the relevance
+ 3 * IF([AVG_DENOMINATOR] = 12, 1, 0)
'denominator, if 12 - then something was done_
every month
```

Where:

- [rel_perc_0] — % of film use according to 2 criteria (number of meetings and kilograms) by categories of films-raw materials for the LAST YEAR - 12 months.
- [qty_raw_all] — all requested raw materials - amount by month.
- [AVG_DENOMINATOR] — denominator, indicates the availability of this type of film by month if 12 - then something was done every month (1 for each month).

Let's consider the coefficient [rel_perc_0] in more detail. The constants-coefficients in the following weighting function are derived from the applied needs and methods of using the raw material film in production, guided by the following provisions:

- If the number of uses in a year is more than 36 times, then this film-raw material can be recommended for a permanent order, we standardize it with the value of the coefficient "38".
- Percentage within the film type — between the max and min values — we normalize the peaks by the average value multiplied by six (that is if there will be orders for the film in about a month), we normalize by the value of the coefficient "38".
- If it is used more than 12 times a year OR more than the average AVG in the film type category, we normalize it with the value of the coefficient "9".
- If more than 1200 kg are used per year, we normalize the fuel by the value of the coefficient "6".
- If during the last 30 days, something was made from this raw material, then we add 2% — for the "freshness" of the order, we normalize the value of the coefficient "2".
- The algorithm for forming the weight function for [rel_perc_0] will look like this.

The algorithm for forming the weight function for [rel_perc_0] looks like this:

```
38*IF([cnt] >=36,1.0, ROUND([cnt] / 36 ) )
+38*IF( MAX([qty]) OVER([film_type]) >= 3 *
SUM([qty]) OVER([film_type]) / COUNT([qty])
OVER([film_type])
,IF([qty]>=3*SUM([qty]) OVER([film_type]) /
COUNT([qty]) OVER([film_type]), 1.0
,ROUND(([qty])/(3*SUM([qty])OVER([film_type]
)/COUNT([qty])OVER([film_type])), 2) )
,ROUND(([qty])/MAX([qty])OVER([film_type]),
2) )
+9*IF([cnt]>= 12, 1
, IF([qty] >= SUM([qty]) OVER([film_type]) /
COUNT([qty]) OVER([film_type]) , 1, 0))
+ 6*IF(c3.[qty] >= 1200, 1 , 0)
+2*IF(DATEDIFF(DAY,[time_beg_max],
GETDATE())< 30, 1 , 0)
```

Where:

- [cnt] — the number of times (production orders) of using this type of film [film_type].
- [qty] — quantity of KG of raw film within the film type [film_type].
- [film_type] — raw material film type.
- [time_beg_max] — production date of the last order containing the raw material film type [film_type].

Also, an important auxiliary analytical function is performed by the number of orders "NMBRQTY" according to production orders for the year, and the total number of manufactured products "QTY KG" using this type of raw material. Predicted deviations - the need for cheese in KG in the current and next three months are reflected in the columns "DELTA_0", "DELTA_1", "DELTA_2", and "DELTA_3".

These indicators allow the manager to see the actual amount of film-raw material used and to estimate the need for an order for the warehouse.

All the constants in the formulas of the weighting functions are derived first empirically from assumptions and considerations, and then refined to a greater or lesser extent during the practical use of the software by managers during the last two years of flexible packaging production.

Figure 4 shows in the form of a graph the use of metalized film of METAL RAW raw materials for the manufacture of finished products of flexible packaging based on it. The blue graph shows the actual usage of METAL RAW over the past year. The red graph shows the planned number of products that needed to be produced by month. The gray graph shows the forecast number of METAL RAW raw material by month with the forecast from the current month to the next 3 months. The forecast model includes statistical actual data from previous months and forecasted quantities of requested raw materials, which managers predict manually (manual). The month of September at the moment of writing the article does not have the fullness of actual and planned values, accordingly, we see a decline on the graph. The forecast schedule has a positive trend for the next 3 months.

Trends in the use of BOPP RAW raw materials are followed in a completely similar way in Figure 5.

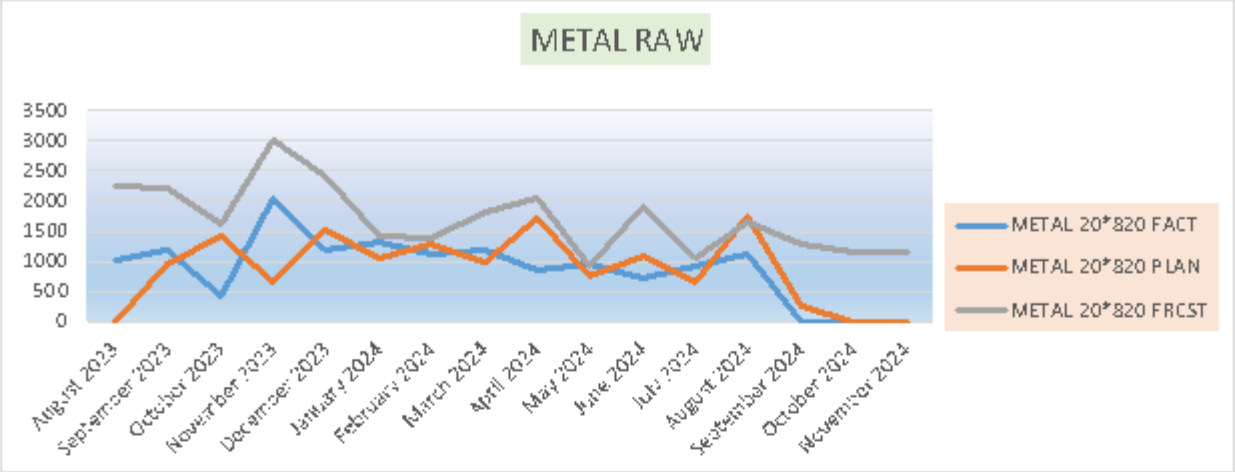


Fig. 4. Graphics of the use, planning, and forecasting of metalized film of METAL RAW raw material

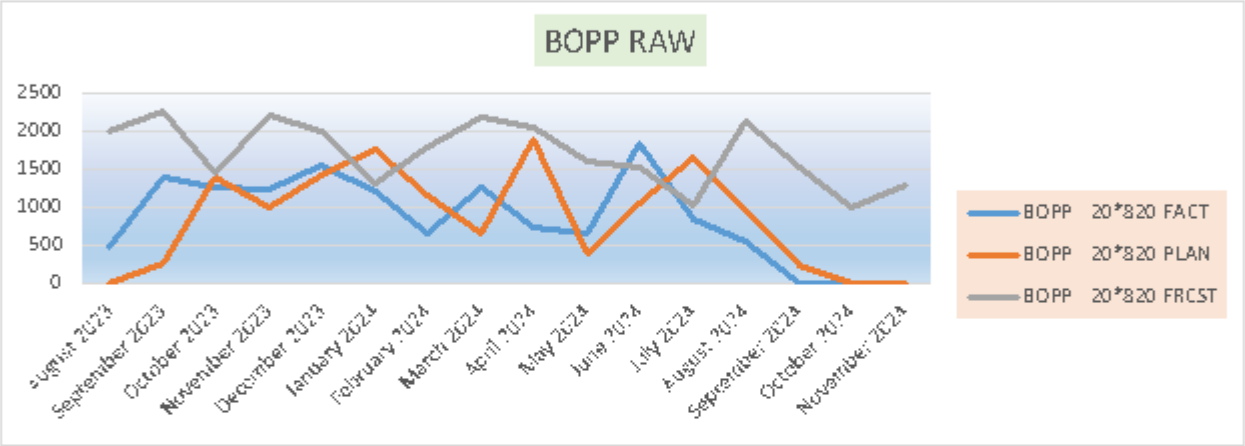


Fig. 5. Graphics of the use, planning, and forecasting of the BOPP RAW raw material metallized film

IV. CONCLUSION AND FUTURE WORK

An information system based on MS SQL Server and MS Excel has been developed, which implements a comprehensive approach to solving the problem of optimizing orders and raw material balances in warehouses.

An analytical decision-making mechanism based on a weighting function that provides the degree of raw material relevance for an order has been proposed.

Recommendations have been given for choosing weighting function coefficients.

The research results have been implemented in a business process at an enterprise engaged in the production of flexible packaging.

The advantage of this system is the user-friendly interface, in particular the advisory component regarding the need and number of orders.

An information system for forecasting and ordering raw materials can help operations by determining how long it takes for products or components to arrive after an order, when inventory needs to be reordered, and how much inventory needs to be in stock to meet peak demand. Demand forecasting will help you keep enough raw materials in stock without wasting precious storage space for unnecessary products.

Sophisticated inventory management software can help you automate inventory forecasting as well as other tasks such as setting reorder points.

Today, when customer expectations and behavior are changing more frequently than ever, having flexible and accurate demand forecasting software empowers companies and helps them respond quickly to change.

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