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Original Research

INTEGRATED PLANNING OF LOGISTICS PROCESSES IN THE FIELD OF WAREHOUSING WITH SIMULATION SUPPORT

Miriam Pekarcikova*, Peter Trebuna, Jana Kronova, Marek Kliment

Technical University, Faculty of Mechanical Engineering, Slovakia

Abstract: An innovative approach to solving wholesale logistics problems in industrial practice can yield significant results, reflected in the high flexibility and efficiency of business processes and systems. The article focuses on analysing parameters and designing a warehouse management solution for the food industry. It deals with the more efficient management of logistics flows with an orientation to supply, storage, modelling, simulation and virtualization, as digitalization correlates with its use in optimizing business processes and systems. The topic is oriented towards the use of digital software in searching and finding alternative and optimal storage solutions in the food sector. A new approach to solving common business problems moves businesses to a high level of achieving goals. The enormous variety of foods available in retail stores has a great impact on the processes of food manufacturers. The number of different processes related to production means that food businesses are increasingly complex, and raw material and packaging warehouses must be well-managed to maintain control over the amount and location of stocks. A great impact on production processes, respectively. Its complexity is influenced by the diversity of requirements and seasonality within the calendar year.

Keywords: logistics, simulation, strategy, warehousing, inventory.

1. INTRODUCTION

If a company in the food industry wants to achieve good results, costs must be controlled and minimized, and performance must be high and consistent. A company that does not achieve good results in any area of its activity will soon get into trouble with its customers, like companies in other business sectors. The specifics of the food industry are that a high level of performance must be maintained daily with relatively low profit margins. A food company

* *Corresponding author: miriam.pekarcikova@tuke.sk*

Miriam Pekarcikova, ORCID: 0000-0002-6898-3774
Peter Trebuna, ORCID: 0000-0003-3666-5066
Jana Kronova, ORCID: 0009-0004-7102-5755
Marek Kliment, ORCID: 0000-0002-3486-6107

cannot afford to have a spare production line and maintain high safety stocks due to the limited consumption period. The production process must be at a high level on the part of all processes, input materials and other activities related to the transformation process and must be flexible to customer requirements.

Economies of scale in the food industry mean that the more a company produces, the cheaper each item will be. The price of input materials and packaging materials for the manufacturer is reduced by the increased volume of inputs. Therefore, the volume also increases the costs of energy, depreciation, distribution, etc., which also has an impact on reducing production costs. This is a generally theoretical approach to the question posed in this way. Enterprises that operate in the food industry have large processes, i.e. in the short term, some generally valid rules do not apply, but in the medium and long term, it will be necessary to deal with some rules if the enterprises are to remain competitive.

2. LITERATURE REVIEW

Integrated planning and management of logistics systems and networks based on digital models, methods and tools, which are built on a common flexible information and communication platform, is the future or even a reality if a company wants to achieve a high level of competitiveness. Increasing demands on the complexity and diversity of production mean achieving high agility in planning, management of logistics processes and visibility along the entire value chain. This fact can be applied primarily in the context of the food industry. In this case, however, there are specifics that need to be considered more demandingly due to the nature of production.

2.1. Supply cycle optimization with an emphasis on limited shelf life

The first models focused on inventory management were created decades ago in the form of Harris's EOQ model (Economic Order Quantity, "How Many Parts to Make at Once", 1913, the first inventory model). They were helpful for the correct setting of the order size and the timing of its implementation. Years after the introduction of this model, other theoretical variants and extensions of this model began to emerge, trying to find answers to the following questions:

- What should the order size be?
- When should the order be placed?

The MRP system is still a widely used material requirements planning technique. A major disadvantage of MRP is the lack of sufficient visibility of orders sufficiently in advance in the context of proper production and purchasing planning. The input data processed in MRP is based on forecasts. Subsequent adjustments are made close to the point of order visibility. The impact on reducing flexibility in responding to customer demands results from the fact that items that enter the product at the end of the production cycle are often ordered at the beginning of the planning period. The length of the planning horizon, the so-called cumulative planning horizon, which includes the procurement and production period, in turn affects the accuracy of order planning in quantity and time. This subsequently requires modifications that may mean exceeding the customer's tolerance time, when he can accept this excess (Katana MPR, 2025; MRPeasy, 2025).

The agility of the MRP system can be increased by optimizing the disconnection points of the logistics chain, i.e. by creating intermediate warehouses, so-called sur tanks within the supply network. This issue is addressed in detail by researchers (Ptak & Smith, 2016) who are the authors of the publication Demand Driven MRP (2016). This is a model of a demand-driven

MRP system, which is built on a strategic calculation of disconnection points with a determined level of inventory at these points, where defined signal levels (red, yellow, green) signal the need to procure inventory at a specific time, size and location, thus eliminating the so-called bullwhip effect.

DDMRP is an innovative method of planning and managing the supply chain. In 2010, pilot applications were implemented, which are currently gaining momentum with a wide scope in the food industry. They are introduced in companies such as Michelin, Coasa, Nestlé, Moog, Shell, etc. By creating specific disconnection points by introducing DDMRP, it is possible to eliminate 4 main causes that cause demand variability:

- volatility, i.e. instability,
- uncertainty,
- complexity, or complexity,
- ambiguity.

2.2. The impact of seasonality on demand variability

Seasonality or seasonal effects the three following conditions met:

1. Demand growth occurs within the same time frame for each seasonal cycle.
2. Seasonal fluctuations are measurably larger than random fluctuations in demand.
3. A cause can be found that explains the demand fluctuations.

The best way to forecast and account for seasonality is to compare the structure of demand over several years. When choosing a forecasting technique, it is important to find the appropriate one that provides the greatest accuracy in matching the structure of demand. The following criteria play a role in the selection:

- adaptability to performance requirements,
- possibility of forecast errors,
- necessary tools for processing the analysis,
- costs of data collection and preparation for the analysis,
- detectability of parameters that describe the performance of the system to be predicted,
- purpose of the forecast and the importance of a single item,
- forecast time frame,
- transparency for the user.

2.3. Principles of picking of perishable stocks

The basic question regarding the policy of picking of perishable stocks is what is the best picking method that should be used. The choice of one or the other depends on various factors, e.g. type of warehouse, stored products, logistics processes, etc. There are several options for perishable stocks. From practical experience, it can be stated that the following are of greatest importance from the point of view of the most efficient organization and control of inputs and outputs of stored items:

- FIFO/First-In-First-Out - the first product that enters the warehouse will be used first to satisfy demand,
- LIFO/Last-In-First-Out - the last product that enters the warehouse will be used first to satisfy demand
- FEFO/ First expired, first out, or LSFO/Least-Shelf Life-First-Out - the product with the shortest shelf life or usability will be used first to satisfy demand

The automation of warehouse activities allows businesses and companies to develop more effective management methods that help eliminate possible errors that arise.

2.4. Logistic chain disconnection point in the food industry

The logistic chain disconnection point is a point or level of the value chain of a company to which the entry of a customer or production order is limited. Usually, it is a so-called intermediate warehouse for which the company's supply strategy is defined in terms of MTO, MTS, ETO, ATO, etc. The flexibility of the company depends on the position where the disconnection point is located, i.e. how quickly and in what ways it can satisfy the customer's needs or personalize the product. The efficiency of all processes that are implemented from the disconnection point to the customer depends on the correct planning and scheduling of production and logistics activities in production and distribution (Saniuk et al., 2022; Nyhuis & Wiendahl, 2009). The processes before the disconnection point depend on the quality of supplier-customer relations, since this point can be located directly at the supplier. On the one hand, the company reduces the costs associated with, for example, with purchasing, storage and maintaining stocks, but on the other hand it depends on the supplier's delivery times. As mentioned above, it is necessary that this period does not exceed the customer's tolerance time. A suitable tool in this sense is the aforementioned DDMRP, built on pillars that are proven in practice and commonly implemented and used in every business system.

For the above reasons, it is necessary to emphasize the importance of the disconnection point of the logistics chain, specifically its location in the logistics or. value chain of the company. It is therefore a strategic decision that should ensure flexibility in the long term to reflect on demand while taking into account the complexity and specific nature of the products, the form and organization of production and the logistics network, which includes:

identification of influencing factors, problems and activities,

- definition of methods and tools for achieving the optimal solution,
- presentation of qualitative evaluation rules and parameters,
- arrangement in a goal-oriented logical flow.

Attention should also be paid to the specificity of demand, as the food industry covers a wide range of products. The diversity of products should also be seen in the great variety of packaging, labels and markings, which, among other things, include information on the date of minimum durability. In this regard, the author (Van Donk, 2001) draw attention to the specificity that many products have a so-called technical minimum shelf life, which is reasonably long. Deliveries to retail outlets are not accepted with the same dates of minimum durability, which results in products that are technically still fresh, but commercially outdated and in fact perishable extremely quickly.

2.5. Storage in the food industry

A warehouse performs one of the most important functions in connection with the points of disconnection of the logistics chain. It usually does not add value to the stored items (except for technological stock), but on the contrary, it increases the costs associated with the activities associated with it, with the maintenance of warehouse spaces, the implementation of an information system that ensures the management of warehouse processes, service, etc (Marasova et al., 2020). The main requirement for effective storage is:

- maximum use of the warehouse volume through the compact design of warehouse systems that ensure permanent access to warehouse items,

- introduction of semi-automated and automated warehouse solutions aimed at reducing manual operations, especially in refrigerated and frozen warehouses,
- resistance of warehouse equipment and equipment used for picking to cold.

The trend in the food industry is a constant increase in demand for fresh and frozen food. This is reflected in the increased energy consumption of warehouses. Constantly rising energy prices are pushing logistics to find more efficient ways to implement storage processes. Average energy costs in cold storage facilities are around 25% of operating costs. An important task of logistics in the food industry is to ensure the cooling of food along the entire supply chain.

3. DATA AND METHODOLOGY

Companies that want to be competitive in the future must develop strategies that focus not only on reflecting on past mistakes and recognizing their own weaknesses but also on clearly defining business goals and visions. A key element in shaping such strategies is the use of tools such as modelling and simulation, which allow testing different scenarios, predicting the consequences of decisions, and optimizing processes before their actual implementation. Such an approach provides deeper insight into complex system relationships and supports effective strategic decision-making. Special attention is required for products with a limited shelf life, such as food, which place high demands on planning accuracy, distribution speed, and minimizing downtime. For these commodities, it is essential to create strategies that take into account not only production and storage capacities but also time-critical logistical aspects such as refrigeration, delivery times, and limited consumption windows. The use of simulation software is particularly important in the following phases (see Fig.1).

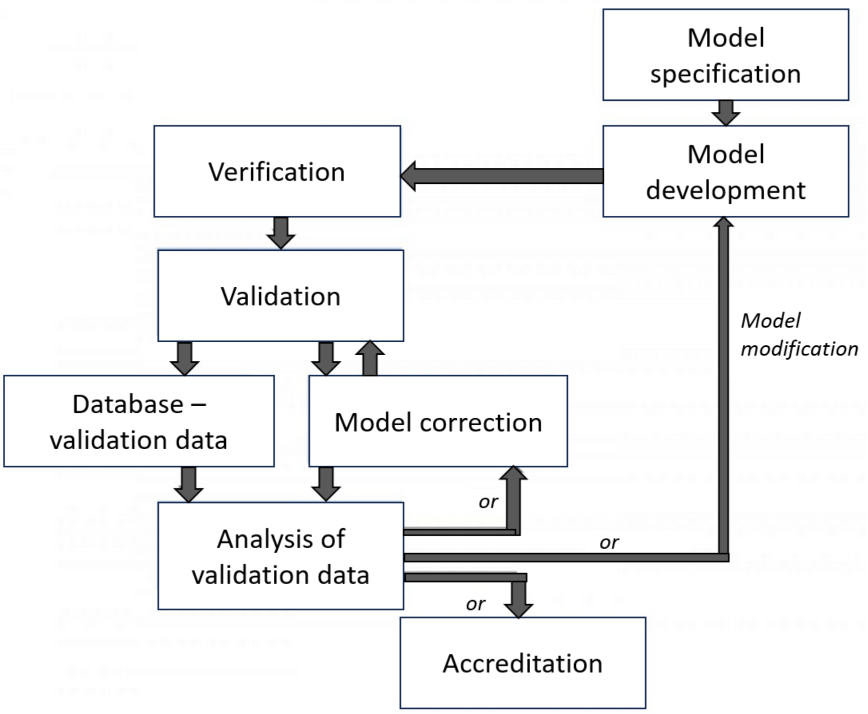

Figure 1. Methodological procedure for applying simulation tools

Simulation tools in this case allow to verify the behaviour of the supply chain under different scenarios of demand, distribution failures or seasonal fluctuations, thus significantly reducing the risk of waste and at the same time increasing the reliability of supply. Companies from the food sector are increasingly turning to distribution simulations, discrete modelling or systems analysis, which allow to test different distribution strategies, plan transport routes, optimize warehouse stocks and assess the sensitivity of the system to unexpected changes.

Discrete simulations (DES) are particularly suitable for the analysis of operational processes, such as order sorting, unloading planning, utilization of warehouse equipment or loading queues in distribution centres. Conversely, systems analysis allows the examination the broader relationships between demand, production capacities, warehouse stocks and cash flow over a longer time horizon. These approaches are often complemented by agent-oriented modelling, which allows simulating the behaviour of individual entities (e.g. business partners, customers, or warehouse workers) and their interactions within the entire supply chain (Grznar et al., 2020; Straka et al., 2020; Fedorko et al., 2021).

4. RESULTS AND DISCUSSION

4.1. Digital tools for the modelling and simulation of processes

The TX Plant Simulation software was chosen for the case study solution because it is object-oriented and allows you to simulate discrete processes and systems with a focus on logistics, etc. The created simulation model can be defined in a specific time horizon, which allows you to replay the future state on a minute-by-minute basis, which would take hours or days in real time. It is advantageous to test alternative solutions based on a criterion function, which allows you to monitor, evaluate and increase the efficiency of the use of machines, equipment, workers, transport equipment, warehouse capacity, etc. Since visualization is an indisputable part of digital trends, this software allows you to work in a high-quality 3D space, use 3D models from the library, or import them in an allowed format (JT format) and use them in the virtualization of simulation models. The TX Plant Simulation software supports connection with virtual reality (Bangsow, 2010; Bangsow, 2012; Bangsow 2015). This functionality was used in solving a case study in the context of visualization and virtual inspection of a proposed warehouse project in a virtual reality environment. It is an effective tool for managerial decision-making, as it allows for the prediction and qualification of possible outcomes from different scenarios, which helps managers gain valuable knowledge and understand the effects of their potential decisions on the performance of the value chain in terms of time and costs.

The strength of a well-processed simulation model is its ability to reflect the system performance in detail and provide relevant information for decision-making. Since the simulation model represents a simplified model of the real system, it cannot be trusted blindly. This leads to the need for so-called virtual trust. Important in this sense is the connection of the process data of the real system to the simulation model, which leads to the creation of a digital twin. To achieve a realistic simulation model, the accuracy of the process data must be as high as possible. The process data defines the simulation model, and if this data is invalid, the model becomes invalid as well. This fact must therefore be considered. Based on the possibilities of precise modelling and statistical analysis, an accuracy of at least 99% of the throughput values is usually achieved with TX Plant Simulation models in real projects, depending on the level of detail (Bangsow, 2010). This fact has been verified on the created model. Another option, which is important from a managerial point of view, is the visualization of the complete model in a virtual reality environment through TX Plant Simulation via the 3D module.

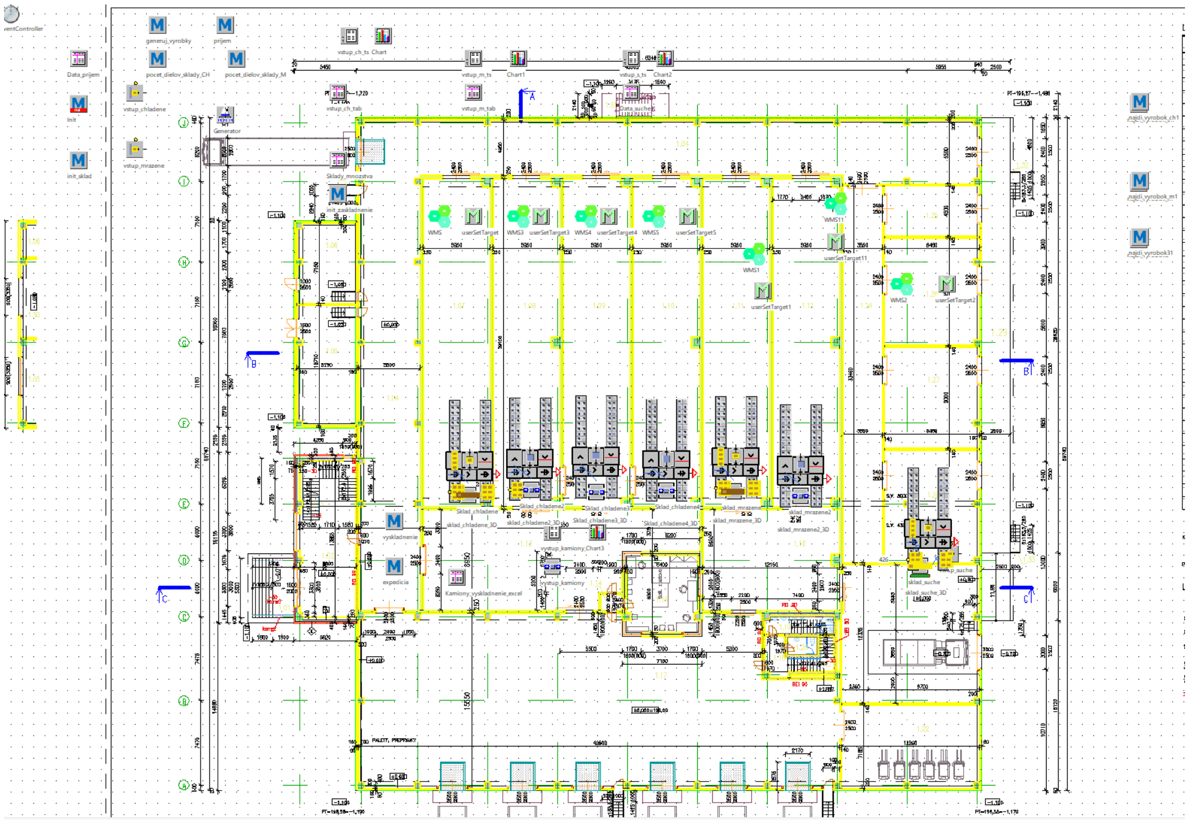

Figure 2. Process model of the Calmar warehouse in the Tx Plant Simulation simulation - layout solution

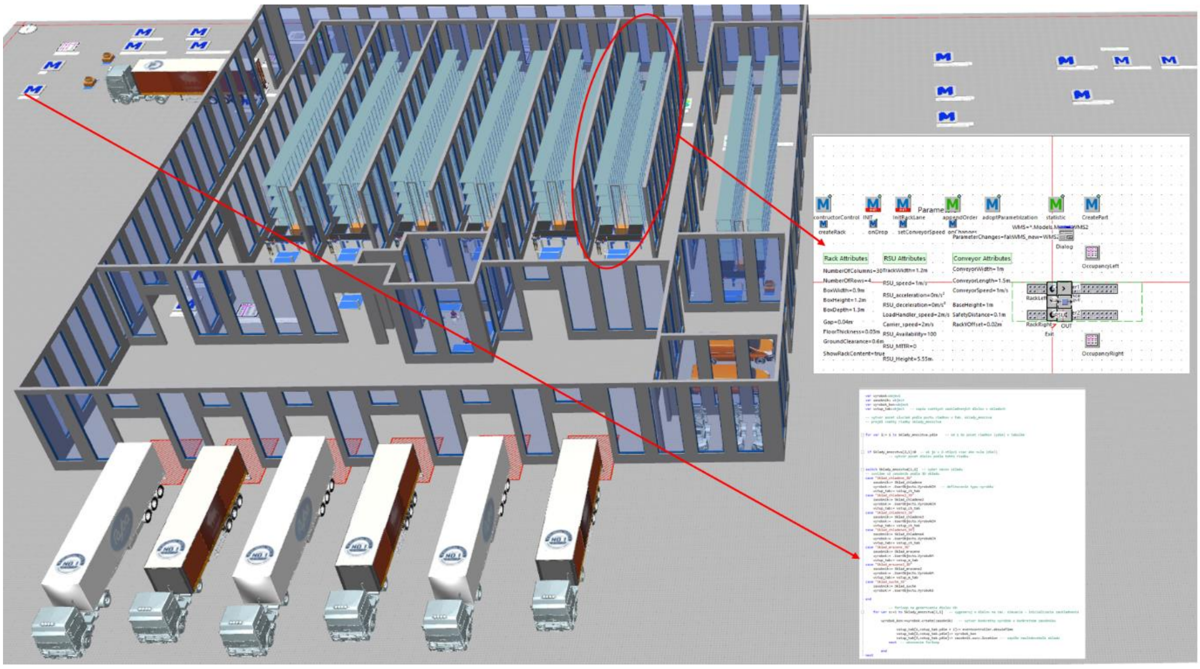

Figure 3. Simulation model of the Calmar warehouse in 3D with a demonstration of the simulation methodology

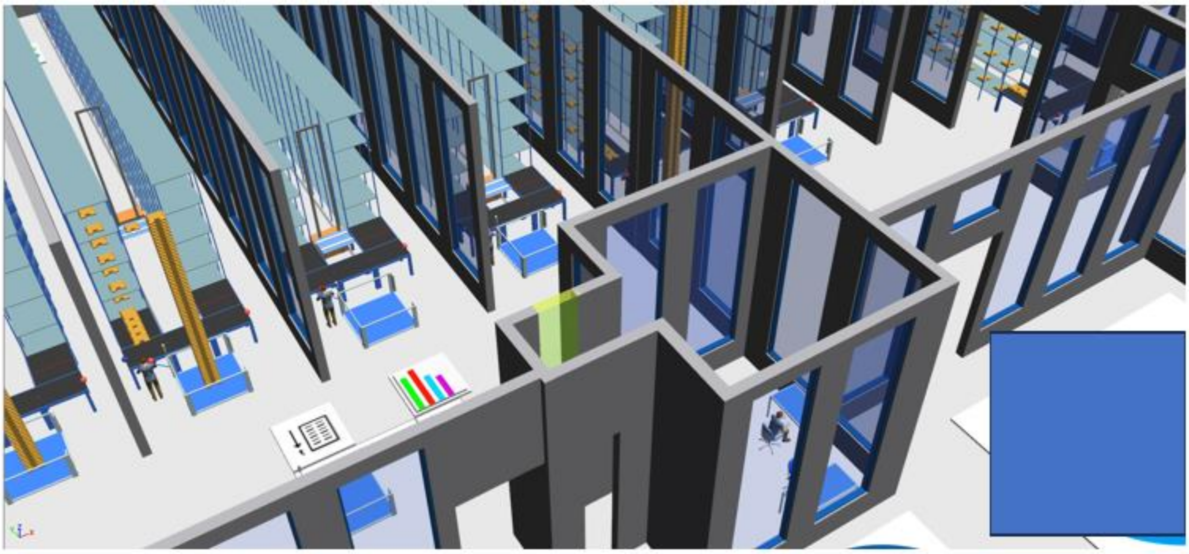

Figure 4. Optimized simulation model of the Calmar warehouse in 3D - internal layout

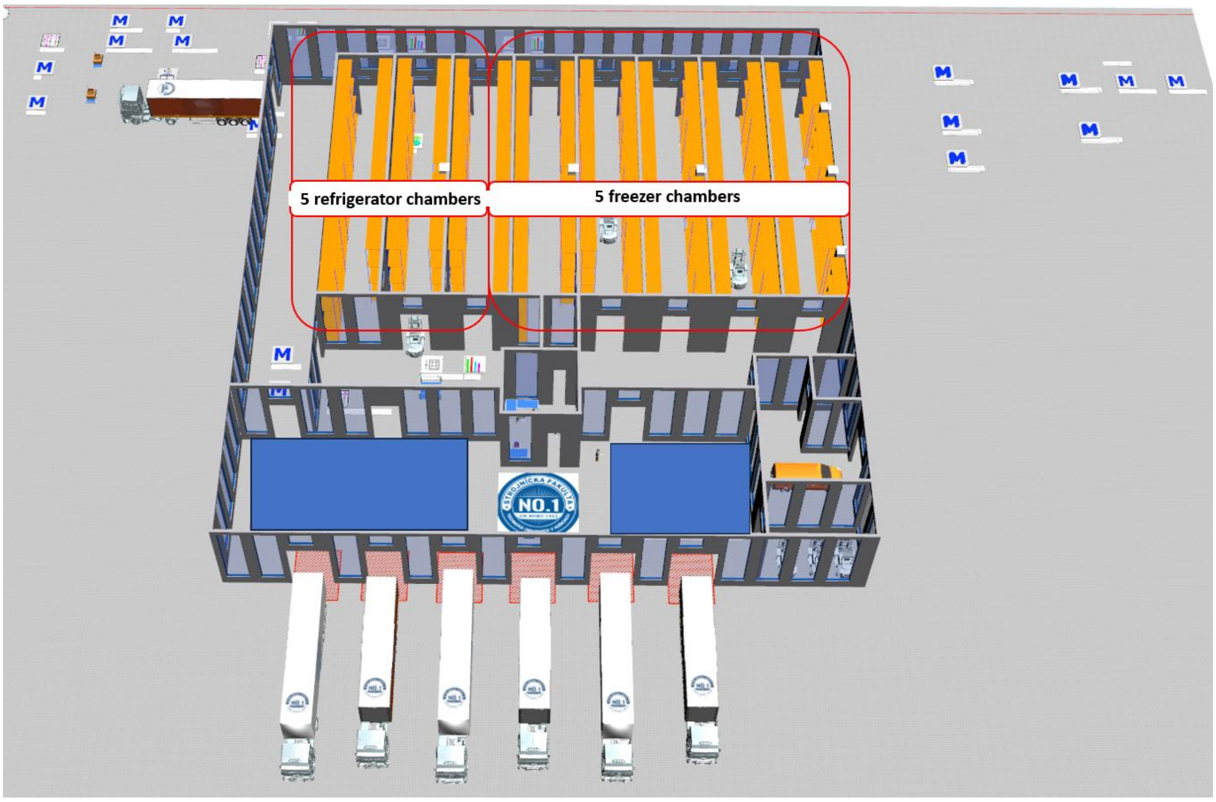

Figure 5. Optimized simulation model of the Calmar warehouse in 3D - view from above

In the presented study, the simulation software TX Plant Simulation was used in the planning phase, where a virtual model of a new warehouse for a selected company was modelled and tested. The requirements for production flexibility have increased, cost and timely delivery of products have become one of the key success factors. Procurement and inventory management have become limiting in balancing the tension between the customer's need for flexibility and the supplier's logistical performance while achieving economic efficiency and stable and quality deliveries. It becomes necessary to correctly size the amount of inventory to be kept in stock. Due to the high impact on costs, the inventory level is an important logistical objective in procurement. The warehouse must provide a reserve for fluctuating requirements from customers, the distribution network, or its own production.

5. CONCLUSION

Shortening product life cycles and increasing product diversification and market globalization require a high level of organizational flexibility. For the food industry, where goods deteriorate rapidly, strategic decision-making must be based on comprehensive logistics coordination. In addition to ensuring quality and price competitiveness, factors such as delivery accuracy, on-time delivery, and the ability to respond in real time to changes in demand or disruptions in the distribution network are also coming to the fore.

Sustainable competitive advantages in this sector are only achievable if companies develop a strategic plan that is based on a deep analysis of internal resources, product specifications and market expectations. Such a plan must be supported by a coordinated approach between individual departments, the active use of analytical and simulation tools and constant performance monitoring in order to ensure a high level of adaptability. In addition, for products with a short shelf life, it is essential to systematically manage the flow of materials in the supply chain to minimize losses, maximize product freshness and meet strict regulatory requirements.

Sustainable competitive advantage is only possible if strategic planning includes a comprehensive connection between production, logistics and demand, supported by digital technologies such as simulation and predictive analytics tools. Their implementation allows not only to optimize existing processes but also to create more resilient and adaptive systems that can face the challenges of uncertainty, seasonality and strict hygiene or environmental regulations in the food sector.

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