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# THE ROLE OF FORECASTING IN THE DEVELOPMENT OF PACKAGING SYSTEMS

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***Abstract:*** *As the competitive market becomes increasingly customized, companies strive to sell high-quality products to meet unique customer demands. We are living in the era of the 4th industrial revolution, where a lot of data is available in supply chain management from various sources and in different formats. Big Data and the Internet of Things (IoT) offer numerous opportunities for the proper utilization and interpretation of this data. Methodologies for forecasting provide assistance in making informed decisions and improving service quality. This document focuses on the role of forecasting in the development of packaging systems. To facilitate the selection of the appropriate packaging system, a conceptual simulation testing method has been developed and is presented in this paper, aiming to conduct impact assessments.*

***Keywords:*** *forecasting, simulation, packaging*

## 1. INTRODUCTION

The selection of the appropriate packaging system has become an increasingly significant challenge in today's dynamic market, primarily driven by the necessity to meet rapidly changing customer demands. Forecasting can be employed in planning demand effectively by utilizing past data to create predictions for various products, including packaging. Forecasting demand poses several challenges, ranging from selecting the right method or group of methods based on specific data to ensuring that the chosen method has appropriate parameter settings for the given data. Automation opportunities in forecasting extend from method selection and optimal parameter determination to the enhancement of forecast accuracy.

Effective forecasting requires a proper understanding of the data. This allows for the categorization of data into types such as seasonal or periodic [1]. This article highlights the importance of data and the role of forecasting in the supply chain, with a specific focus on packaging. Conducting impact assessments is essential for choosing the right packaging, and the technique of simulation modelling provides excellent support for this purpose.

## 2. THE IMPORTANCE OF DATA IN FORECASTING

Data is often referred to as the oil of the information age. Data is not clean, it's unorganized, and it's unstructured, making its integration into a typical format essential for analysis. A significant portion of efforts is dedicated to cleaning the data and preparing for subsequent steps, such as data integration and modelling. In the supply chain, data collection occurs at various stages of the product, from the supplier through the manufacturer to the wholesaler or retailer and finally to the customer [2].

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Sharing forecasting information helps align demand and supply more effectively in the supply chain. The sharing of forecasting information enhances the performance of the supply chain. Forecasting is a statement that predicts the occurrence of an event with certain levels of reliability. Forecasting using system-level computational analysis includes data collected with observations of numerous related characteristics at the same time or regardless of temporal differences. Forecasts are prepared at a more detailed level, generating forecasting scores. In the era of Big Data, supply chains can generate a massive amount of data. Big Data technologies and analytics provide more accurate forecasting information and offer opportunities to transform business models. Due to the widespread use of information technologies and social media networks, data collection is much simpler and more convenient than in the past [3].

The Internet of Things (IoT) essentially encompasses a global network where devices with unique identifiers called sensors, are interconnected, and their task is data collection. These data transmitted over the internet are stored in a database. Various models assist in solving different problems, including forecasting. Forecasting fundamentally means predicting the occurrence of any activity before it happens. Forecasts are adjusted when necessary, and decisions are occasionally corrected according to business requirements. Forecasting methods can be classified into two types: qualitative, also known as judgment-based and quantitative. The choice of type depends on the accuracy of the forecast [4].

Simulation solutions can regulate the level of uncertainty, the impact of project structure on forecast accuracy, and the time horizon where actions provide accurate and reliable results. Several simulation solutions can be used to forecast output results. In the next chapter, we will present the steps of forecasting simulation necessary for the operation of the packaging management system.

## 3. THE ROLE OF FORECASTING IN THE OPERATIONAL PROCESS OF PACKAGING MANAGEMENT SYSTEM

The application of simulation techniques is crucial for the operation of the packaging management system. Simulation enables us to obtain output results more quickly than it would happen, allowing potential issues to become visible. The steps of this process will be summarized in the following.

Steps of the Examined Process:

1. **Definition of the system under study:** In this initial step, it is crucial to designate the logistics subsystem to be developed [5].
2. **Determining the Purpose of the Examination:** At this early stage of the process, it is essential to precisely define what we aim to achieve through the examination. This involves identifying the decision criteria for packaging selection, as well as their weight and the requirements imposed on packaging systems. Key decision criteria uncovered in the literature include [5]:
    - **Lead Time:** The average duration between two points in the defined system. The duration of logistics operations can significantly vary depending on the type of packaging system, and selecting the appropriate system can shorten this period. A shorter lead time enhances competitiveness by enabling faster response to customer demands and minimizing losses [6].

- **Total Operating Cost:** The design of material flow systems and their operating costs, as well as the procurement and maintenance costs of the packaging system, heavily depend on the choice of packaging. It is in the company's clear interest to choose packaging systems that minimize the total operating cost.
- **Quality of the Packaging System:** The alignment with expectations can be a important consideration in choosing a packaging system. Only packaging systems that meet the essential requirements can participate in the study. This factor is a component determined by the company, with values ranging from 1 to 10 (1 being the worst, 10 being the best rating). Considerations include the availability, recyclability, modernity, and compatibility with the current system of the packaging system [7].
- **Usability within the Examined Process:** This indicator is used to measure the expected number of times the packaging system under consideration can be expected to be used repeatedly in the selected logistics process. The packaging system can be divided into two main parts. One is plastic and the other is wood based. Plastic devices have a lifetime of about 100 cycles in the supply chain, while wood devices have a maximum of 15-20 cycles [8].
- **Environmental Impact of the Logistics Process:** Environmental protection is increasingly significant today. Sustainability, particularly concerns related to disposable packaging waste, is driving significant changes in consumer packaging. Regulatory authorities are progressing, and companies and retailers are proactively taking steps to improve the sustainability of their packaging and fundamentally rethink their packaging systems. For packaging material processors with the right focus and innovation capabilities, the new environment can offer substantial growth and new partnership opportunities in revisiting packaging [9]. The environmental impact of the logistics process is subjectively determined by the examining experts on a scale from 1 to 10, where 1 represents the worst and 10 represents the best rating.
- **Determination of Weighted Decision Criteria:** Determining the weight of decision criteria aligned with corporate interests involves various methods according to the literature. The weighting process can occur on an ordinal scale or an interval scale. When solving multi-criteria decision tasks, accurately determining the priority sequence of evaluation criteria or, alternatively, weighting the priority sequence is a crucial element. The Guilford method is recommended for interval scale data due to its widespread acceptance, reliability, accuracy, and applicability. For its application, a minimal analyst group is required. In the current system design, this procedure is conducted by the expert group, with a suggested minimum of 5 members. The method involves comparative work on pairs of factors, with weight values automatically added [10]. Using the Guilford weighting paired comparison method, the ranking of evaluation factors can be determined, and transformation to the interval scale can be achieved. For any pair of evaluation factors, it is possible to determine which is preferred over the other, expressing the decision-makers' preferences with scores of 0 or 1 [11].

- **Definition of Requirements for the Packaging System:** In relation to possible packaging systems for the examined types of products, conditions can be formulated that affect the outcome of the selection process (e.g., the operational cost of the examined system must not exceed a specified value).

3. **Definition of Relevant Objects for the Selection of Packaging Systems**: In the context of the defined logistics system, it is essential to identify operations and objects relevant to the selection of packaging systems. Examples include the formation, dismantling, and quality control of packaging systems, which are points where the formation and/or dismantling of packaging systems may occur.
4. **Material flow graph**: Based on the relevant objects and the material flow relationships between them, a material flow graph can be constructed to illustrate the optimization task.
5. **Uploading packaging database**: The packaging system database comprises several data tables, including:
   - **Parameters of Examined Packaging Systems**: This data table contains essential information about packaging systems, such as size, load capacity, capacity, procurement cost, maintenance cost, quality, usability, and environmental impact data. The completion of this table is the responsibility of the information providers.
   - **Compliance Data of Examined Packaging Systems**: This table demonstrates which specific packaging systems can be used concerning a material flow object based on the requirements determined by the company. Filling in the data in this table is the task of the experts.
6. **Loading Data into the Logistics System Database:** The database of the examined logistics system contains several data tables:
   - **Time Factors of Examined Packaging Systems:** This table indicates the unit formation, dismantling, and handling times of the examined packaging systems concerning material flow objects. Experts are responsible for filling in the data in this table.
   - **Data of Material Handling Equipment:** This data table includes information about the speed, size, operating cost, maintenance cost, and capacity of material handling equipment in the examined process. The completion of the table is the responsibility of the experts.
   - **Data of Technological Operations:** This data table contains time factors and capacity data of technological operations in the examined material flow system. The experts are tasked with filling in this table.
7. **Generation of Test Versions:** In this step, variations of packaging systems that can be assigned to the objects defined in step 3 are created. This results in all possible packaging system chains to be examined by the simulation model. A packaging system chain illustrates which packaging system is applied to which object within the defined system.
8. **Determination of Test Conditions and Objective Function:** We convert the evaluation criteria defined in step 2 into normalized objective function components and determine their weights using the Guilford weighting method. By calculating the weighted sum of normalized objective function components, we formulate an objective function where the packaging system chain variant providing the highest

value represents the optimal outcome. If necessary, conditions related to features (e.g., lead time, operating cost, etc.) can be selected. In cases where a characteristic associated with a packaging system chain does not meet the specified condition(s), it cannot be selected.

9. **Design of Simulation Test Model:** The principle of simulation is based on the simplified representation of the real system. To create the actual simulation model, knowledge of simulation techniques and understanding of other areas of the company, such as the logistics of production and service processes, are essential. Simulation tests can be conducted by developing a custom application or utilizing predefined simulation frameworks (Plant Simulation, Arena, Simul8, etc.). The use of framework systems can significantly shorten development time since predefined objects can be applied and parameterized. Additionally, the model's unique behavior can be managed using methods if needed. The design of the simulation model should consider the defined system and examination goals. It involves developing the material flow and information flow models and determining the operational method for producing the objective function defined in the previous step.
10. **Implementation of Simulation Model:** In this step, the simulation model designed in step 9 is integrated into the simulation framework.
11. **Loading Simulation Model Data:** To run the simulation model, the data tables of the simulation model need to be populated with the information determined in the previous steps.
12. **Testing and Validation of Simulation Model:** After creating the simulation model, testing is conducted to identify and rectify potential data errors, program bugs, and conceptual mistakes. In the context of an existing system, validation of the simulation model involves comparing it with reality. For a future system, it entails checking the data and processes.
13. **Running Simulation Model, Evaluating Results:** Running the tested and validated simulation model produces the value of the objective function for each packaging system chain variant. This allows for the selection of the most favorable variant. The number of examined variants significantly depends on the number of packaging system variants for objects and the quantity of objects.
14. **Verification of Results Adequacy**: In this phase, the accuracy of obtained results is verified. If feasible for the company, the examination concludes, and the process moves toward implementation. Otherwise, adjustments to the testing model lead to further examinations.

## 4. SUMMARY

This research has presented the role of data in the selection of packaging systems and introduced a simulation testing method. This method facilitates the selection of an appropriate packaging system for a specific product type. The application of simulation modelling techniques is crucial for predicting the impact of various packaging system variants on the material flow operations. In our further research, refining the developed concept and prioritizing its application in an industrial setting will be our focus.

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