

Packaging management system based on digital technology

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Abstract

Choosing the right packaging and upgrading existing packaging systems is a growing challenge in industry practice, mainly due to the significant expansion of product structures, the rise of e-commerce and the variety of seasonal packaging. In the article, the literature related to the topic will be reviewed, and then the operating principle of the concept of a packaging management system will be presented, which supports the review and continuous improvement of the packaging system already established at the company's site. The packaging management system concept is presented in 3 main parts. These are: selecting the right packaging for a new product, proposing packaging improvements for an existing product, and checking packaging using digital twin technology. This paper presents a systematic literature review of the field under study and the 3 main areas of the packaging management system we have identified, with a process description. This study summarizes the initial results of a PhD research. In the future, a detailed conceptualization of the 3 areas identified is planned. This publication is a summary of the results achieved so far.

1. Introduction

Digital twins have already been used in many areas, but there are still significant applications in logistics. This paper based on our previous publication [1], in which the potential applications of digital twin technology in logistics were analyzed and an important research direction for digital technology was identified. This research area includes the packaging management, due to the topicality of the topic, the lack of adequate research on the subject, and the personal motivation which based on the interest of the postgraduate specialist packaging development

engineer training at the Institute of Logistics of the University of Miskolc. In the industrial practice, the selection of appropriate packaging and the improvement of existing packaging systems are becoming increasingly challenging, mainly due to the significant expansion of product structures, the rise of e-commerce and the variety of seasonal packaging [10,15]. Thus, a literature review was conducted to explore the aspects of the international literature that have been covered in this area. Databases and keywords were identified for the study. This databases Scopus and ScienceDirect were used for the research.

Applied keywords:

- „digital twin” AND „packaging” AND „logistics”
- „packaging management” AND „logistics”

For the literature research, searches were started using the defined keywords. Reduce the Scopus database to the first search keywords were the following: title, abstract, keywords which resulted in a single search hit, while increase the search on all fields resulted 85 articles. Using the ScienceDirect database, the first search keywords listed 272 publications. For the second search, which was for the keywords: packaging management and logistics, resulted 107 publications in Scopus, while ScienceDirect resulted 57. The research was made in March 2022, from the year 2000 to 2021. On the Figure 1, you can see the results of this analysis. The articles based on the packaging management systems have been published so far covered the entire supply chain, such as article [16].

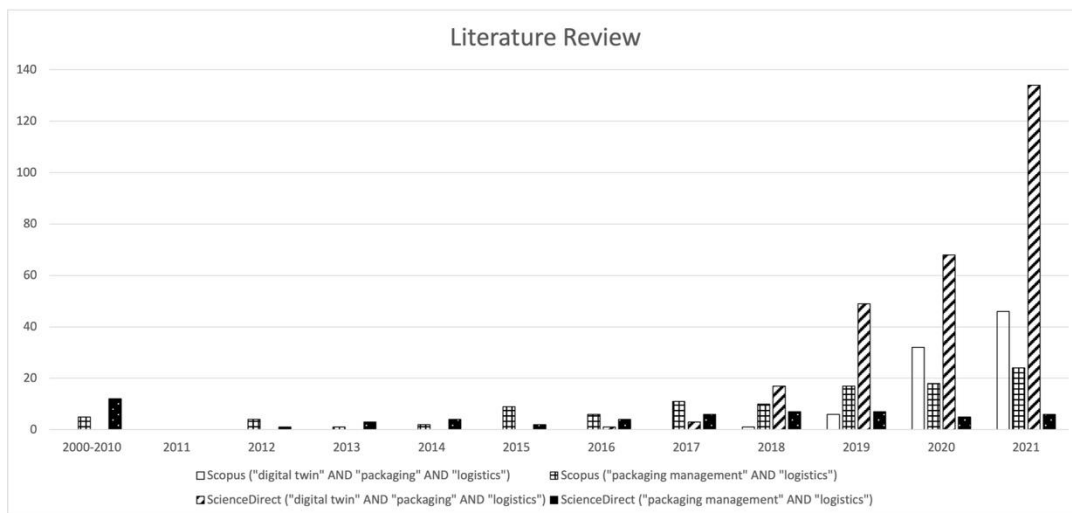


Figure 1: Literature review results

Furthermore, the articles so far have typically been product specific, such as [17], where the food supply chain and intelligent packaging are presented, with implications for food. The Scopus-indexed publication [6] deals with a reliability model that analyses sensor data from packaging systems and discusses the IoT (Internet of Things) model generated from sensor data [6]. Although this paper mentions the lack of research on the development of digital twin and digital technologies, it does not detail it. The journal [2] deals with the use of automotive packaging, where comparisons of different sustainable packaging systems are presented, but does not deal with the digital technologies and their benefits of use. The journal [7], published in 2021, deals with the generation of packaging waste and its importance. This publication explains that research on the product-packaging supply chain is still in its early stages. Our aim in this paper is to investigate and present the digitization aspects of the logistics packaging field. Due to its many advantages, the industry is increasingly preferred returnable packaging, but this advantage can only be fully used if the system is properly managed. The aim of the present study is to create models that allow the investigation of different packaging systems and the selection of the appropriate packaging system. Reusable transport packaging such as pallets, trays, crates or refillable liquid and gas cylinders play an important role in modern logistics. The use of these products in the supply chain can bring several benefits, including reduced packaging and waste, better protection and security of products, more efficient handling, better possibilities for outsourcing, combining and standardization moreover lower CO₂ emission over the life cycle of the packaging material [2].

2. Packaging management system concept

The loss reduction opportunities available in the field of packaging management, as well as several external forces are pushing companies to make a greater effort in this direction. Examples of relevant impacts are changes in consumption patterns, lengthening of supply chains, new materials and technologies, environmental protection, regulation, and corporate responsibility obligations. The best possible management response to these complex operating environments will come about through the interaction of several functional areas within the company, representing different aspects, combining, and integrating in different ways at different times. This is a large and increasingly important element of complex management [3]. Packaging is an integral part of modern life. Due to the large quantities of packaging materials used and the ease of recovery, the reuse and recycling of packaging waste has become a top priority for the European Union. The aim of recycling waste is to recycle it [4].

Individualized design of mass custom manufacturing systems is difficult, as it involves adaptive integration of both new and old machines to create unstable families. A systematic virtual model that reflects the real world of the manufacturing system is essential to bridge the gap between design and operation of manufacturing systems. A digital twin-driven solution makes design faster and more customizable [5]. The digital twin combines physics-based system modelling and distributed semi-physical simulation to provide engineering solution analysis capabilities and create a credible digital design of the system in the pre-production phase. Realistic process models are essential to enable early and effective evaluation of design decisions, both in terms of product quality and

system performance. Computer-aided simulation tools play a significant role as they deal with the validation of manufacturing systems. One promising approach to address complex problems is the digital twin, which realizes the interplay between the physical world of manufacturing and the cyber world [5].

The digital shadow integrates data from all available sensors and IT systems into a single virtual representation, including the display of all associated services [18]. Packaging development is more efficient with the use of digital shadow.

The use of digital twin technology can facilitate the development of lighter, more environmentally friendly packaging materials. To improve sustainability, companies are exploring the use of a range of new materials, including recycled materials. Companies not only need to manage transportation, but also control damage and contamination that could compromise future cargoes [8].

The optimal choice of packaging has a wide meaning that extends to the manufacturing and logistical processes within the manufacturing plant. Properly selected packaging is an essential link in the entire logistics chain. It performs a few functions from the production line to the point of delivery to the customer and storage. The most common types of cargo are small, requiring packaging that is durable, spacious, and properly sealed, thus facilitating the logistics of the manufacturing process. Reusable packaging has become the common standard because it is practical and economical [9].

2.1. Structure of a packaging management framework

Figure 2 shows the structure of a packaging management framework that will be developed later. To create the system, it is necessary to clearly define the study participants, the most important tools, databases, and the connections between them. Based on Figure 2, the framework

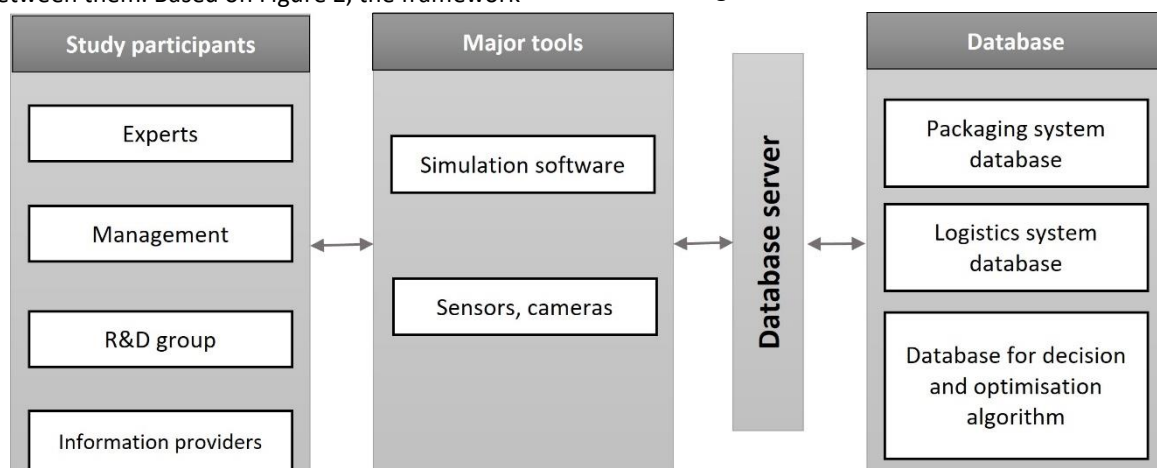


Figure 2: Structure of a packaging management framework

can be divided into three parts. The study participants are the experts, the management, the research and development (R&D) team and the information providers.

Experts: The experts are fully familiar with the packaging management system and carry out the necessary tests. Their tasks include a thorough knowledge of the three main areas, these are: selecting the right packaging for a new product, selecting the right packaging for an existing quality defects. They will also be responsible for data collection, data processing and evaluation tasks according to the type of test selected. The use of software and simulation programs supporting the packaging management system is also part of the scope of the duties.

Management: Management sets the development guidelines. Its task is to make strategic and tactical decisions, to negotiate with new companies and to conclude contracts based on the recommendations of experts.

R&D group: The R&D group develops the methods and procedures approved by management and required for testing.

Information providers: Information providers are those who provide the additional information needed to perform the study. In the first place, the data, and parameters of the possible packaging systems for a product are given to the needs of the experts.

The most important tools related to the system are the simulation software, sensors, and cameras.

Simulation software: The events belonging to the planned packaging system are investigated using a discrete event-driven simulation framework. This allows the virtual model of the plant to be combined with real plant control for the actual simulation [11]. Thus, the complete operation can be tested and optimized. With the discrete, event-driven simulation system, it is possible to improve and simulate logistic processes, optimize material handling, machine utilization and labour demand

with statistical analysis capabilities. The use of object-oriented tools with 3D modelling capabilities can increase manufacturing accuracy, efficiency, and improve throughput and system performance [12]. Simulation processing begins with a preliminary analysis to identify problems, and then simulation plans, checks, and validations are created to create them. After collecting and examining the data of the packaging materials, the software process them, so the problem is identified, and simulation plans are created [13].

Sensors, cameras: Other important tools are sensors and cameras. In some cases, it is necessary to collect and manage data from the real system and based on this data we can propose a better, more efficient system, and we can also propose how to detect and manage quality defects when inspecting packaging.

Figure 2 shows that the database consists of 3 main parts, these are: the databases of the packaging system, the databases of the logistics system, and the databases belonging to the decision and optimization algorithm.

Database of packaging systems: Contains the data necessary for the design and implementation of the packaging system.

Logistics System Database: Contains input data that is important for testing.

Decision and optimization algorithm database:

Contains the objective functions required for decision and optimization. It is recommended to use a decision method if a new system with one type of packaging is developed and if a new packaging system is chosen for the existing system. We can talk about optimization if we want to design a packaging system for several variables and different products.

A new method of database management is Big Data Analysis. Big Data management aims to ensure a high level of data quality and availability for business intelligence and Big Data analytics applications. Efficient big data management mainly helps companies to find valuable information from a large set of different unstructured and semi-structured data. As part of managing Big Data, companies need to decide what data they want to retain, discard, or analyse for compliance reasons to improve processes. Thus, the process requires data classification, and smaller data sets can be analysed quickly and efficiently [14].

Our idea about the basic concept structure has been designed so that any company can adapt to its own needs after providing the appropriate data. You can choose from three main areas depending on whether you want to do new packaging, upgrade your existing one, or fix bugs. In our

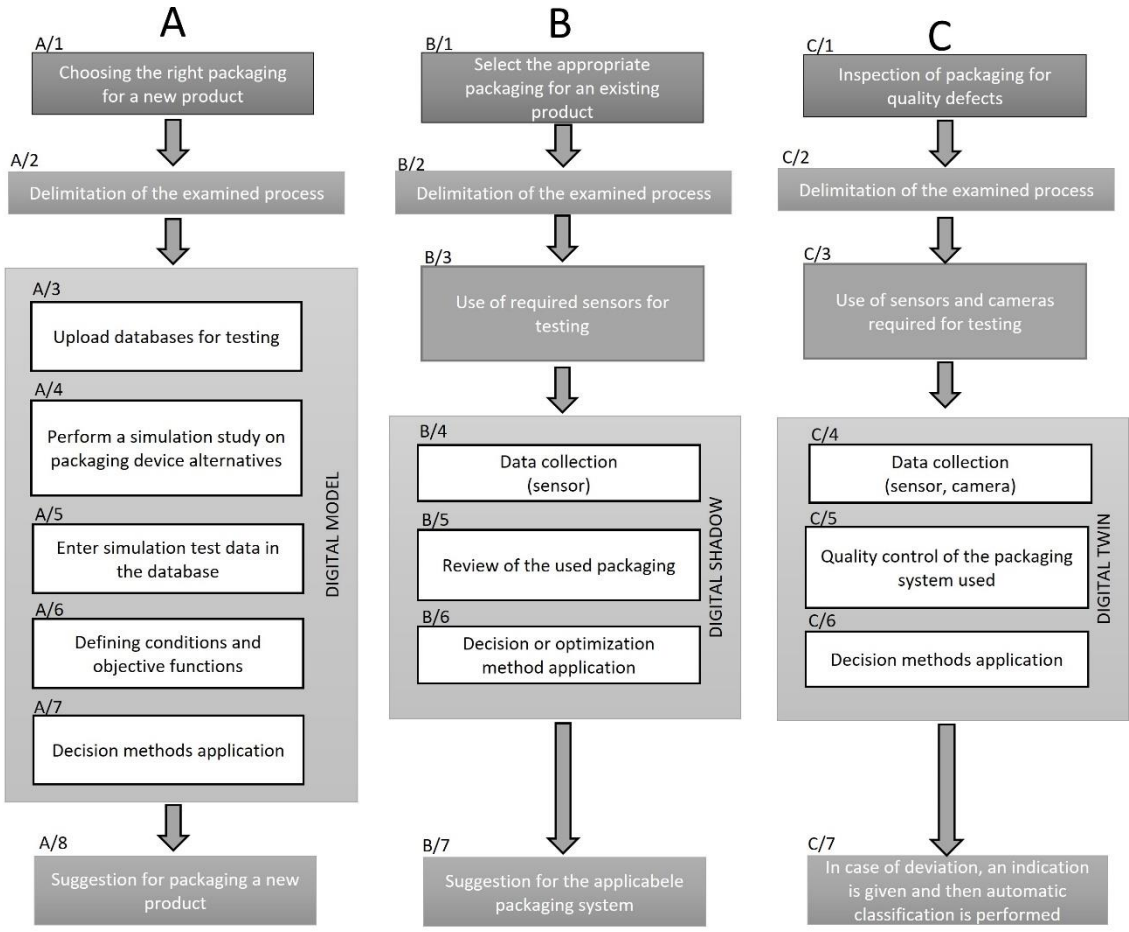


Figure 3: Important steps of the application of packaging management system

opinion, this is a suitable system for improving packaging. Our plan is to work out this in detail.

2.2. Important steps of the application of packaging management system

The article develops the concept of a packaging management system, the function of which helps to select and improve the packaging system and to ensure the quality of the applied packaging system in relation to the designated logistics process. The developed packaging management system can be divided into three main components, which are shown in Figure 3.

When selecting the appropriate packaging for a new product, a simulation test model is developed that, after uploading the data related to the packaging system alternatives, produces the data needed to select the appropriate alternative. These include lead times, operating costs, maintenance costs, and so on. This is illustrated by the model marked "A". After defining the process to be examined, databases will be uploaded. Then we examine the alternatives with the simulation test. After that, the target functions, and conditions for selecting the packaging system are selected, and finally we make a proposal for the packaging of the new product.

When selecting the appropriate packaging for an existing product, a simulation model is created that simulates the packaging of the currently operating system. During the simulation, the system reviews and then makes suggestions for optimization. This is illustrated by the model marked "B". In this case, the delimitation of the examined process is also the first step, and then sensors are used for the examination, which help the data collection. Using digital shadow, deciding on the suitability of your current packaging is the next step. With digital shadow, data collection is automatic from the used sensors. Finally, make a proposal for the packaging system.

Examination of the packaging to eliminate quality defects, cameras and sensors are used to examine the current system, and then a simulation test model is created. This is described in the model marked "C". After delimiting the examined process, sensors and cameras are used, by which the data collection is automatic. The inspection of the packaging management system eliminates and prevents quality defects. In the event of a fault, the system signals and, if necessary, a light and/or sound and/or automatic classification is performed.

3. Conclusion

The publication presented an initial concept of a packaging management system whose research needs were grounded in a detailed literature review [1]. The literature analyses results showed

that the number of articles published has grown over the years, but there are still many opportunities in this area. The publication presents a short excerpt of an innovative concept in the field of packaging management systems, based on an industry 4.0 toolkit. The system presented combines digital twin, digital shadow, and digital model solutions at the same time. After outlining the scientific gap and the concept, we plan to implement the practical development and implementation of the individual subsystems in the next phase of the PhD research.

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