A brief review of the methods and techniques used in the innovative internal logistics processes and systems

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Abstract. In the last period, logistics knew a strong technological evolution that has changed the way it operates and determined its transformation into innovative logistics, especially in the case of internal logistics. Innovation in internal logistics processes and systems consists in the use of different Industry 4.0 and digitization technologies. So, it is necessary to use modern methods and techniques to support the transformation of internal logistics processes and systems into innovative ones. This paper presents an analysis of recent studies, briefly presenting the evolution of the concept of logistics, the concepts of process and logistics system and Industry 4.0. Also, the most common methods and techniques used in the realization of innovative internal logistics systems are presented and some conclusions are presented regarding their use.

1. Introduction

1.1. The evolution of the logistics concept

The concept of logistics has two origins: mathematical and military. The term “logistikos” was first used by the Greeks in 428 BC, and in the early 20th century, the British mathematician and logistician Bertrand Russell highlighted a link between logistics and mathematics logistics [1]. On the other hand, in the military field, the term logistics refers to the flow of objects in time and space. Today, the term is used in industry and refers to the methods of transport, storage and handling of objects [2]. Logistics is a process that ensures the flow of materials, the supply of the organization and its activities to the customer. It can be represented schematically as in Figure 1 [3]. According to the explanatory dictionary of the Romanian online language [4], it defines the concept of logistics as a set of methods and means that deal with the organization of the operation of a service carried out in an enterprise.

![Figure 1. The logistics process](image-url)
1.2. Internal logistics processes and systems

The logistics process includes the flow of goods, services and information related to the movements of goods and services, called logistical information. The internal logistics process in a production organization involves logistics flows, including materials, ongoing activities and final products [5].

The logistics system is the set of means by which it acts to perform, physically, all manufacturing operations, transport, but also storage, allowing the movement of materials from suppliers to beneficiaries, after they have undergone the necessary transformations to become finished product. Logistics systems carry out activities and processes of supply, transport, handling, storage, control and distribution. Through these activities the supply of raw materials and materials, the manufacture of the product and the distribution of the finished product are achieved [6].

According to the degree of involvement of the human operator, the internal logistics systems are classified as follows:

- classical systems: are those systems where the human operator performs all handling activities;
- mechanized systems: are those systems in which the human operator intervenes on the system for a manual control;
- automated systems: are those systems in which the human operator cannot intervene and all functions are performed by systems [7].

Today, internal logistics is playing an increasingly important role in the industry. Handling equipment means the handling of materials from the warehouse to various operations within the enterprise until the final product is ready for delivery to the customer [8].

This paper aims to present the concepts of logistics, Industry 4.0 and Logistics 4.0 and a short review of the main methods and techniques used in innovative internal logistics processes and systems.

2. Industry 4.0 and Logistics 4.0

2.1. Industry 4.0 concept

The term Industry 4.0 was first introduced at the "Hannover Fair" in 2011. The first industrial revolution was the introduction of mechanical manufacturing equipment powered by the force of water or steam. The second industrial revolution concerns the use of electricity, which allowed the use of the conveyor belt and the assembly line. The third industrial revolution brought automation of production through the use of electronic systems and communication technologies [9;10]. In figure 2 [11] the evolution of the technologies of the four industrial revolutions is presented.

![Figure 2. The evolution of the four industrial revolutions [11]](image)

Overall, Industry 4.0 encompasses the development and integration of innovative information and communication technologies in industry. The main goal is to create smart grids and process along the
chain, thus enabling them to use organizational processes more efficiently, to improve customer benefits by providing them with new products and services.

The Industry 4.0 concept is based on new technologies, such as: internet of things (IoT), big data, cyber-physical systems (CPS), robots; augmented reality, cloud, machine learning, additive manufacturing, real-time optimization. Figure 3 shows the main technologies of the Industry 4.0 concept [12].

![Figure 3. Industry 4.0 Technologies](image)

As Industry 4.0 emerged, some companies began to use advanced control tools activated by real-time monitoring systems that allow the development of precise planning models to enable managerial decision-making. Although we are seeing a growing trend in the automation of human labour in almost every industry, human workers still play an important role in production and logistics systems [13].

2.2. Logistics 4.0 concept

Today, most businesses are undergoing a digitalization process with the fourth industrial revolution. The focus of digital transformation is mainly on production, so terms like "Factory of the Future" or "Smart Factory" are used similarly to this concept. However, there are many reasons to consider the impact of digitization in logistics and the importance of the supply chain for Industry 4.0 [14].

There are several equipment and types of automation commonly used in logistics:
- Automated loading and unloading systems;
- Automatic guided vehicles;
- Automated storage systems;
- Conveyor belts;
- Robots;
- IT systems for planning, managing operations and systems;
- RFID systems;
- Bar code systems;
- Item selection devices [15].

We use the term "Logistics 4.0" to refer to the combination of the use of logistics with the innovations and applications added by CPS. Logistics 4.0 is bound by the same conditions as smart services and products. It can then be considered an approach based on the technology used to define "Smart Products" and "Smart Services" defined as "Smart Logistics". Smart products and services are those that can perform tasks normally performed by humans. In addition, they make it possible to delegate activities so that employees can focus on tasks that need more intelligence than automated processes or the intelligence that a simple smart product or service can have.
"Intelligent logistics" is a logistics system that can improve flexibility, adjust to market changes and will bring the company closer to customer needs. This will make it possible to improve the level of services, optimize production and lower storage and production prices. "Intelligent logistics" will change according to current technology, is time-dependent and therefore defines the state of technology [16].

3. Methods and techniques used in internal logistics processes and systems

With the development of the Industry 4.0 concept, the methods, techniques and tools in the area of internal logistics processes and systems have been developed. The most common technical methods and tools in the studied literature, used in the development of innovative internal logistics processes and systems are presented in Table 1.

| Method                                | Techniques and tools             | Article     |
|---------------------------------------|----------------------------------|-------------|
| Logistics flow optimization           | Simulation                       | [18, 20]    |
|                                       | Mathematical modelling           | [20]        |
| Development of autonomous logistics systems | Navigation techniques, proximity sensors | [22]        |
|                                       | Navigation techniques (MY3 wheels) | [23]        |
|                                       | Microprocessor, RFID reader      | [24]        |
| Augmented / Virtual reality           | 3D image                         | [27, 31]    |
|                                       | Roivis, Virtual Retinal Display  | [31]        |

A brief description of the main features of each innovative method and application situations are given below.

3.1. Logistics flow optimization

Simulation is defined as a process by which a model of the real system is built. One of the most recognized software is Tecnomatix Plant Simulation developed by Siemens PLM to model, simulate, analyse, visualize and optimize production systems and processes, material flow and logistics operations. Plant Simulation can display both 2D and 3D production sequences [17]. Recently, simulation is also used for research and development purposes in universities. The simulation allows the imitation of a suggested solution to achieve the company's objectives, i.e. to increase production efficiency.

In his work, Viharos [18] uses a general model of discrete event simulation developed by Siemens Software shown in the figure 4 [18]. The purpose of developing this simulation model is to plan and evaluate reconfigurable assembly systems. He has developed a heuristic algorithm that can manage a wide variety of systems composed of robotic stations. With this algorithm, it was able to set the number of orders in real time and reduce the time to make products. The purpose of this algorithm is to reduce the manufacturing time of the products.
Figure 4. Example of a model of an automatic layout system in Plant Simulation [18]

Mathematical modelling is the process of developing the mathematical model. A mathematical model describing a system that uses mathematical concepts and language. Mathematical models are used in the analysis of logistics systems. A model helps to explain a system, studies the effects of different components and makes predictions about their behaviour. Mathematical modelling has become increasingly important for logistics systems as they have become more complex [19].

For example, Vavrik [20] proposes a logical mathematical model used in performing the simulation to optimize the transport route. This mathematical model, shown in figure 5, is performed before collecting process data and according to this mathematical calculation the number of vehicles required can be determined.

Figure 5. Mathematical model developed by Vavrik [20]
Figure 6 [20] shows a simulation model in Plant Simulation in both 2D and 3D. The main purpose of the experimental simulation in this paper was to estimate an essential number of automatically guided transport vehicles that serve the operations performed in production. To make the simulation model, Vavrik went through the following steps: creating tracks for moving the vehicle; creation of the loading and unloading station; the creation of the vehicle for the transport of the semi-finished product and the creation of logical rules. Thus, by using the simulation and adjusting some parameters, it was possible to observe a decrease in the speed of the old man by 1 m / second on a straight line compared to 1.2 m / second, and on the area with curves 0.6 m / second compared to 0.8 m / sec.

![Simulation Model](image)

Figure 6. 2D and 3D simulation model in Plant Simulation [20]

3.2. Development of autonomous logistics systems

An autonomous system is a system that can perform certain functions without the intervention of an operator. Each autonomous system uses intelligent techniques such as: artificial intelligence [21], navigation techniques, proximity sensors, RFID reader.

For example, Jaiganesh [22] provides a model for designing an advanced autonomous guided vehicle using a programmable logistics controller (PLC). The differentiating feature of this vehicle is that it includes a robot arm, at the top, to streamline the transfer of materials and reduce costs. This vehicle includes a control device consisting of a DC motor, proximity sensors, programmable logic controller, a navigation system and a robotic arm. The control device is used to monitor the movement and speed of the vehicle. The DC motor was used due to its linear characteristics and ease of speed adjustment. Proximity sensors containing inductive proximity switches that have the ability to detect metal objects without physical contact were used to detect objects in the vicinity of the autonomous guided vehicle and station vehicles. A PLC was used to monitor and control the vehicle. As a navigation technique, it has been proposed to use a magnetic strip on the floor that guides the vehicle and which poses it to accelerate or decelerate or even stop. In this paper, the robotic arm is seen as an automated material handling device. The mode of operation of the proposed vehicle is: to reach the destination, the vehicle receives a signal from the common network, and with the help of proximity sensors it will be able to stop at each station. After stopping at the station, the sensor will read if the material is available or not. Figure 7 [22] shows a proposal for the construction of an automatic guided vehicle with robotic arm.
Components:
1. PLC operated brushless DC motor;
2. PLC Components;
3. Battery;
4. Front wheel;
5. Rear wheel;
6. Proximity sensor;
7. Photo sensor;
8. Robotic arm;
9. Material to be shifted;
10. Provision for accommodation of material.

**Figure 7** Scheme of the AGV proposal construction [22]

In his work, Yu [23] designed an omnidirectional prototype AGV using MY3 wheels. These MY3 wheels consist of two balls with equal diameters on a common shaft. The balls are sectioned into four spheres and each sphere can rotate freely around its own axis shown in figure 8 [23]. The MY3 omnidirectional wheel prototype consists of a mobile platform and three shelves shown in figure 9 [23]. On this mobile platform there are four wheels that are positioned evenly at a 90 ° angle to be able to perform the movements. The first shelf is used to transport materials, the middle shelf is used to transport the battery, and the lower shelf is used to transport the engine that drives the four MY3 wheels.

**Figure 8.** MY3 wheels [23]

**Figure 9.** MY3 omnidirectional wheel prototype [23]

In another paper, Mehami [24] made two different automatically guided systems for transporting objects named Karl and Jimmy. The Jimmy system, shown in figure 10 [24], is a robot composed of an mCore microprocessor board. This system consists of an RFID reader used for movement, a frontal sonar to avoid collisions and a flat surface (platform) for transporting objects. Its travel speed is 0.3 m/s. In Jimmy's case, RFID tags were used to change lanes and stop.
The Karl system, shown in figure 11 [24], is a robot that has a clamping arm equipped with a MegaPi microprocessor board. This system consists of two RFID readers, one attached to the arm with clamp to identify the products and the other reader is attached to the base to move, switches to limit the rotation of the arm and body. Its travel speed is 0.1 m / s.

3.3. Augmented and virtual reality
The term augmented reality first appeared in 1992 in the work of Tom Caudell [25]. Augmented Reality (AR) can be defined as a system that includes a combination of the real world with the virtual world, interactive in real time, recorded in 3D and their overlap in the real world [26].

Zheng [27] proposed for development a portable visual device based on binocular vision and deep learning to achieve rapid detection and recognition of cable brackets. The drinkable visual inspection device based on AR technology is used to guide the operator in the cable assembly process and contains a computing unit, a four-wheel mobile loading unit and binocular cameras that can be adjusted up and down, so as shown in Figure 12 [27]. Deep learning and visual recognition are used to read the text on the cables, and the results are sent to wearable devices for visual assembly guidance.

The AR-based cable assembly process consists of two steps:
- The first step is to design the assembly process that is done by the process engineer. In this step, the process engineer uses the AO software tool, generating an XML document for each operation to obtain all the information needed for the AR-based process. The interface of this software is shown in Figure 13.a, and Figure 13.b shows the detailed contents of the XML file automatically generated by the software.
- The second step is to visualize the assembly process.
The final interface of the AR-assisted assembly system is shown in Figure 14. Product and process information is displayed at the top left of the figure, and the 3D image of the assembly to be made is displayed at the bottom left.

Figure 14. Interface of AR assisted assembly system [27]

Following the study, the author found an improvement in assembly efficiency and better quality of the assembled product. In the future, it aims to develop a Meta-Learning system.

Virtual reality was proposed in 1989 by Jaron Lanier [28] and is considered a paradigm that through computers and human-computer interfaces creates the effect of a three-dimensional world [29] in which the user can get sensory experiences in a way similar to the real world [30].

In his paper [31], Rupert Reif addresses the use of virtual and augmented reality in various logistics applications such as: logistics planning, operator support when choosing orders, simulation and training.
The use of augmented reality in the case of planning is done with the help of the tool "roivis", with which the image of the existing system can be integrated various virtual objects (Figure 15, [31]), without interrupting production to perform tests with real objects.

When choosing commands, augmented reality is used to project orientation data (3D arrows showing the path to the storage location and pickup point) and process, in the operator's field of view using an HMD (Figure 16, [31]). Virtual Retinal Display was used for the display, and the interaction is performed through speech control. Thus, search times are reduced and errors are avoided due to optical media.

The virtual reality system is connected to a virtual reality glove and a treadmill, which together form a captivating framework due to the fact that the real processes of taking orders can now be reconstructed in the virtual environment (figure 17, [31]). The virtual reality glove is used to take over the goods from the storage place and the tape aims to generate a virtual walk through the warehouse. Thus, when the warehouse worker takes a step forward, the system identifies the movement and the tape starts. Following the implementation of this system, it was possible to observe a reduction in costs and an efficiency of the employee training process.

An evaluation of the choice of orders was also made using AR and VR by comparing four different types of takeover technologies:
- selection of paper orders with selection lists;
- pick-by-voice system;
- pick-by-voice system based on augmented reality;
- virtual reality simulation environment for taking orders.

According to the results, the highest motivation during order processing was during the use of the virtual environment (VR), followed by the augmented reality (AR) system, figure 18.a [31]. Another result based on the sensation of the subjects regarding the cognitive load of the subjects during the process of choosing the orders is presented in figure 18.b [31]. Thus, this study highlighted that the choice of orders based on virtual and augmented reality are innovative methods in the field of logistics that are accepted and provide high motivation to users.
4. Conclusions
The globalization of production and the increasingly fierce competition in the field of production systems have imposed a continuous evolution of internal logistics processes and systems and, thus, have determined the development of innovative methods and techniques in this field as well.

The methods and techniques most common in the studied articles, in connection with the development of innovative internal logistics processes and systems, are: optimization of logistics flows, development of autonomous logistics equipment and use of techniques based on augmented / virtual reality. In the case of optimizing logistics flows, the most used technique is simulation with discrete events, one of the frequently used software being Plant Simulation. In the case of the development of autonomous logistics equipment, the most used techniques are those based on navigation systems and proximity sensors. In the case of virtual and augmented reality, they are based on the combination of the real world with elements of the virtual world. These methods use visual, auditory and olfactory sensors to develop innovative internal logistics processes and systems.

The study will continue through the development and/or integration of methods and techniques specific to innovative internal logistics processes and systems in the existing Lean manufacturing laboratory at the University of Pitesti.

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