Journal of civil engineering and transport **transEngin**

2026, Volume **8** Number **2** **ISSN 2658-1698, e-ISSN 2658-2120**

DOI: 10.24136/tren.2026.008

OPEN ACCESS

VISUALIZATION OF PROCESSES IN THE CONTEXT OF CONTEMPORARY LOGISTICS MANAGEMENT CHALLENGES

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Reviewed positively: 24.04.2026

Information about quoting an article:
Kuśmińska-Fijałkowska A., Łukasik Z., Kozyra J., Olszańska-Wesoły S., Błaszczyk J. (2026). Visualization of processes in the context of contemporary logistics management challenges. *Journal of civil engineering and transport*. 8(2), 117-125, ISSN 2658-1698, e-ISSN 2658-2120, DOI: 10.24136/tren.2026.008

Abstract – Logistics plays a key role in the effective management of the flow of raw materials, materials, and information, which affects the competitiveness and operational efficiency of a company. Process visualization is an important tool that supports decision-making, enabling rapid problem detection and real-time process optimization. The integration of different IT systems allows for full synchronization of activities and improved efficiency, although it brings with it challenges such as ensuring data security and system compatibility. The article discusses the importance of process visualization in a manufacturing company in the context of contemporary logistics management challenges. An algorithm and a visualization application for the automated production process of carbonated bottled spring water were developed. The environment used for the implementation is the SCADA (Supervisory Control and Data Acquisition) system.

Key words – electrical and civil engineering, process visualization, automation, transport, intralogistics processes, management.

JEL Classification – C61, L6, L8, L9, O43

INTRODUCTION

The logistics process in a company is a key factor in the mechanism of business management. Logistics, which can take on different definitions depending on the context, is responsible for comprehensive management, planning, and the flow of resources and information. Logistics can be classified according to the scope of the function performed and the area of activity. Modern enterprises operating in a dynamically changing economic environment must constantly adapt to new market, technological, and organizational conditions. Constant changes in production and logistics processes make it crucial to make quick and accurate decisions based on current data. In this context, process visualization is becoming increasingly important. „Visual thinking allows you to compress the information you convey into short and easily digestible nuggets of knowledge so that the information reaches the recipient and is not rejected by them at the outset" [1]. Process visualization allows you to immediately spot delays and inefficiencies. Systems equipped with graphical interfaces present the current status of each stage of the logistics process. Thanks to appropriate markings, alerts, trends, and flow charts, it is easier to identify bottlenecks and errors in the system. This form of data presentation significantly reduces the time needed for analysis and supports communication between departments within the company.

1. LITERATURE REVIEW

Logistics management focuses on the practical implementation of logistics principles in companies. According to the official Dictionary of Definitions and Terms published by the Council of Supply Chain Management Professionals (CSCMP), „logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption to meet customer requirements" [2]. Freichel S. L. K. and Rütten P., Wörtge J. K. point to three main groups of challenges in supply chain transparency: inadequate processes and technologies, lack of communication and trust, and insufficient metrics for monitoring and decision-making. The authors emphasize that traditional logistics systems often fail to provide adequate visibility of processes [3].

Process visualization is a graphical interpretation of logistics activities taking place within a company. Using modern technologies and modern IT systems, visualization enables more effective monitoring, control, and optimization of logistics processes. In his article, N. Wang shows that visualization is not only about aesthetics but also a specific tool that supports operational efficiency, predictability, and transparency of processes [4]. Van Assen and de Mast, in turn, point to the validity of real-time performance measurement based on digital visualization, which has a positive impact on faster response to changes and improved operational efficiency in the enterprise [5].

According to Gürdür D., Raizer K., and El-Khoury J., appropriately designed visualization tools, such as management dashboards, significantly support decision-making by stakeholders, especially in complex logistics environments. Furthermore, they emphasize that effective visualization requires the integration of data from different layers of logistics systems (supply chain, automated warehouses, production). Only then can a consistent representation of the entire system's operation be achieved [6].

Arnold Dieter described intralogistics as a concept that 'encompasses the organization, control, implementation, and optimization of internal material flow, information flow, and goods handling in industry' [7]. To ensure the proper and harmonious functioning of a manufacturing company, all logistics processes should be consistent and interdependent. Each stage influences the next, so their synchronization is crucial for maintaining production fluidity and timely order fulfillment.

Integrated IT systems also play an important role, allowing real-time monitoring of raw material availability, machine performance, and delivery delays. 'Information systems in logistics enable the collection of information necessary for effective business management' [8]. The implementation of modern IT systems and optimization strategies enables better control over processes and increases the company's competitiveness on the market [9].

The authors in article [10] used visual analytics tools to analyze a fleet of logistics vehicles. They presented methods for visualizing parameters such as routes, fuel consumption, and fleet profiling in order to optimize logistics decisions. In the article [11], researchers created a system model and visualization of the supply chain. Visualization supports understanding of the impact of long-term disruptions and, according to them, enables early response. In scientific work [12], a new visual analytics platform was proposed, integrating data from IoT and ERP sensors in real time. The implementation enables dynamic optimization of routes and inventory. Experiments were conducted at a distribution company, resulting in a 12% reduction in delivery times. The article [13] presents an AR dashboard system developed to support warehouse operators. AR glasses are used to display real-time visualizations of inventory levels and picking plans. An analysis of the integration of management approaches (ISO 9001, OHS, ISO 14001) with visualization tools for monitoring and controlling logistics processes is presented in a scientific paper in which the authors argue for a systematic approach to visual monitoring [14].

2. THE ROLE OF LOGISTICS IN A COMPUTERIZED ENTERPRISE

Manufacturing companies focus most of their activities on maintaining continuity in the production process, striving to optimize processes and minimize costs and losses caused by operational downtime. Therefore, logistics focuses on the flow of raw materials or semi-finished goods from the moment they enter the company, through production, to the moment of further distribution of the finished product.

The choice of the right IT system for a manufacturing company depends on many factors. Small and medium-sized organizations choose simpler and easier-to-use systems that generate lower costs and have lower infrastructure requirements [15]. Larger companies, on the other hand, choose systems that offer a broader and more advanced range of activities. An important factor in choosing an IT system is also the anticipated

growth that will enable it to serve a larger number of users. In addition, manufacturing companies require a certain degree of flexibility from their technological systems, which allows them to adapt their processes to changes in the organization's structures.

One of the most popular IT systems is ERP (Enterprise Resource Planning). It provides a comprehensive overview of a company's resources on a single platform, which significantly facilitates the processes of planning and controlling the flow of materials within the company. An additional feature is the ability to monitor data in real time, which allows for the optimization of the production process, the detection of any deviations from standards, and the identification of potential equipment failures. This makes it possible to avoid production downtime and financial losses (Figure 1).

The Manufacturing Execution System (MES) is responsible for managing production schedules, monitoring machines and equipment, and controlling production quality and efficiency, particularly in highly complex technological processes. The main objective of using MES systems in companies is to optimize production time and reduce machine downtime (Figure 1).

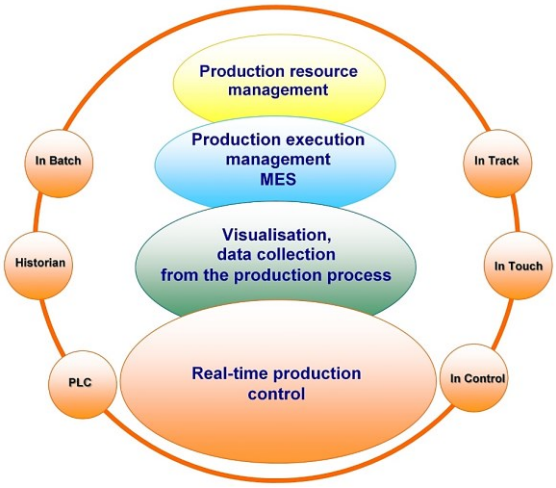

Fig. 1. Structure of a computerized industrial enterprise

SCADA (Supervisory Control and Data Acquisition) enables the control and supervision of advanced processes that take place in a company in real time. It is an important factor in modern logistics, used, among other things, in the context of warehouse automation, production process control, and equipment monitoring [16]. In addition, it enables the collection of data from sensors, PLCs (Programmable Logic Controllers) and actuators, allowing for further processing, visualization, and analysis of data. Visualizations help people understand complex processes, enable faster decision-making, and facilitate the identification of deviations from the norm. The SCADA system can be integrated with ERP or WMS systems, allowing for full synchronization of operational activities.

Gwiazdowski P. [17] lists the activities enabled by SCADA:

- real-time data exchange with a PLC controller or I/O module,
- real-time information processing,
- displaying information on the screen in a legible form,
- real-time access to a database with technological information,
- management, alarm signalling,
- preparation and generation of reports on the progress of the technological process,
- archiving of information from technological processes.

Integrating IT systems used in logistics with SCADA is a desirable activity. The integration of IT systems in logistics is becoming a foundation for companies seeking to streamline their processes. It enables the combination of various tools, such as WMS, ERP, and TMS, which ensures smooth data flow and automation of activities [18]. The integration of systems that increase process efficiency and enable automation and control over the flow of resources and information in a company contributes, among other things, to:

- **full visibility of processes-observing** all processes taking place in the company in real time and immediately reporting failures, shortages, or delays;
- **automation of information transfer between systems** – direct transfer of data between systems, without the need for manual entry;
- **more efficient management** – enabling more accurate demand forecasting, delivery planning, and production process planning.

The WMS (Warehouse Management System) is responsible for optimizing warehouse operations, reducing order fulfillment times, and improving order fulfillment efficiency. Process visualization will be most effective in companies with an extensive warehouse network, where great emphasis is placed on facilitating inventory management, material rotation, and tracking the location and status of inventory (Figure 2).

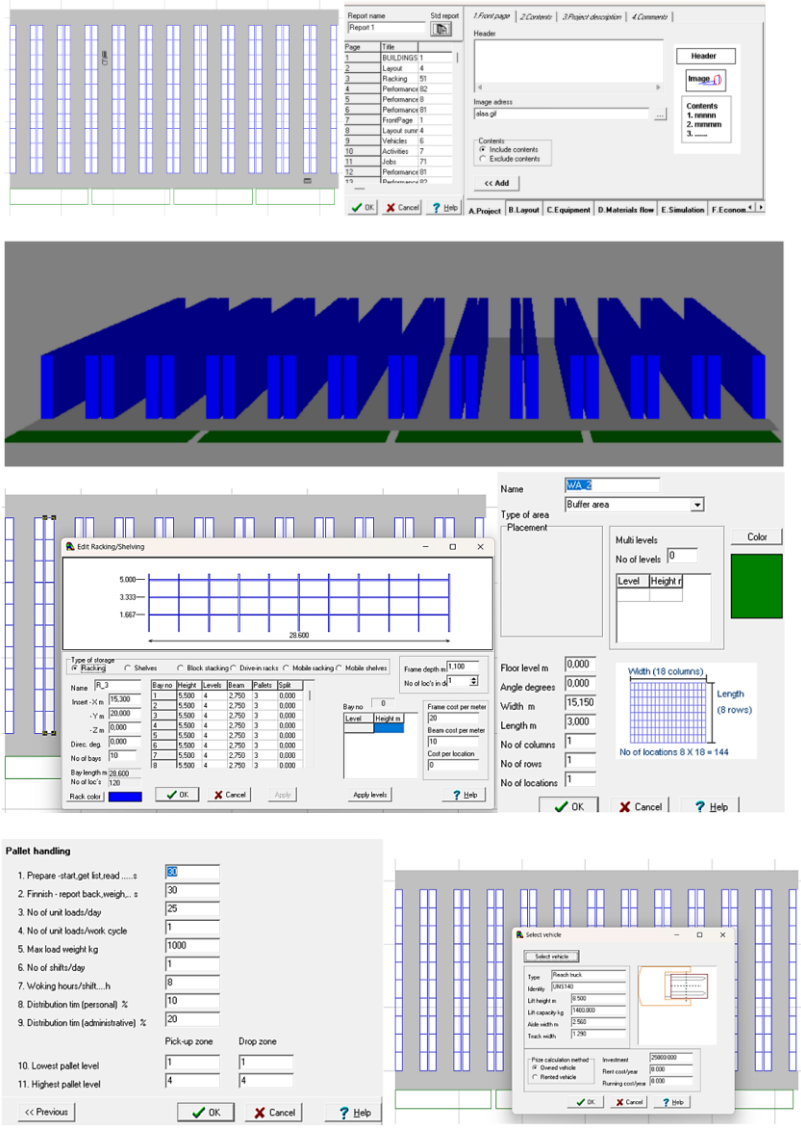

Fig. 2. Visualization of an automated warehouse in a company (own study)

The Internet of Things (IoT) is a system that, by connecting devices to the internet, enables automatic data exchange in real time-without the need for human intervention-providing real-time data from machines, devices, or sensors that enable faster operational decisions to be made regarding the processes being carried out [19].

The process of integrating IT systems involves certain challenges. The greatest difficulty is ensuring an adequate level of data security, which results from the need to transfer huge amounts of information. Another significant challenge facing a company seeking to synchronize its systems is the careful alignment of structures. Many companies still use older technologies, which can lead to errors when connecting IT systems. It is therefore important to check that the programs are compatible with each other.

3. VISUALIZATION AS THE FUTURE OF LOGISTICS

In times of dynamic technological development, logistics is becoming a field based mainly on data. The ability to interpret, present, and use data in decision-making processes is becoming crucial. Contemporary logisticians should not only develop their professional competences in supply chain management but also expand their skills related to understanding the principles of data visualization design. Logisticians, working with interdisciplinary teams, increasingly need to know the terminology related to data visualization and understand the benefits of its proper design. Based on knowledge of the principles of designing clear and intuitive visualizations, it contributes to faster data analysis and more effective work of the entire team.

Modern logistics places increasing demands on the knowledge and skills that logisticians must master. The training of logisticians should therefore include not only traditional aspects of logistics, such as inventory, transport, and warehousing management, but also skills related to modern visualization tools.

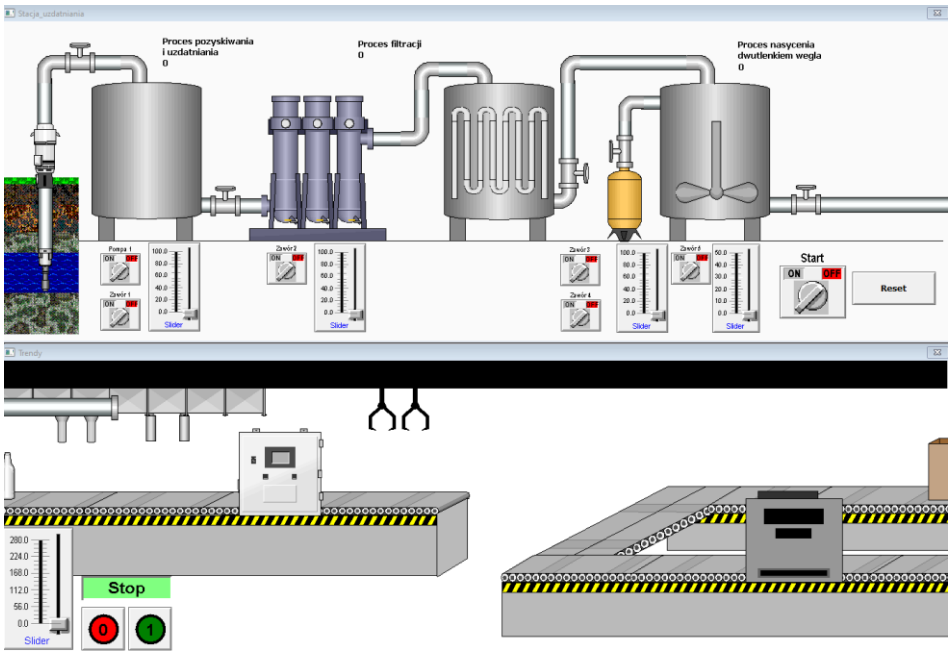

Fig. 3. Visualization of the production process of carbonated bottled spring water (own study)

The design shown in Figure 3 presents a graphical interpretation of the logistics processes in a company that produces carbonated bottled spring water. The graphical representation of the process was created in the SCADA (Supervisory Control and Data Acquisition) engineering environment. The visualization shows the process of obtaining water using a submersible pump, which is then directed to a treatment plant, where it undergoes a purification process aimed at reducing the hydrogen sulfide content. The next stage is filtration, both sand and membrane, to remove excess iron. After passing quality tests, the water is saturated with carbon dioxide, which gives it its sparkling properties. The finished product goes to a storage tank, from where

it is sent for bottling. Bottling begins with the preparation of machines that collect glass bottles and rinse them with ozonated water. This ensures effective disinfection and eliminates the risk of microbial contamination. At the same time, water from the tank is fed into the bottling line. After the rinsing process is complete, the bottles are filled with water. They are then sent to a capping machine and labeled. Quality control is carried out at every stage-any irregularities, such as incorrect filling levels, are immediately detected, and defective products are sent for recycling. Finally, the finished bottles-capped and labeled-are packed into cartons, which are sealed and sent to the warehouse to await shipment.

The process discussed above is presented using an algorithm (Figure 4), which shows the connection between the beginning and end of the logistics process. By analyzing the algorithm, one can see the connections and dependencies between the successive phases of the process.

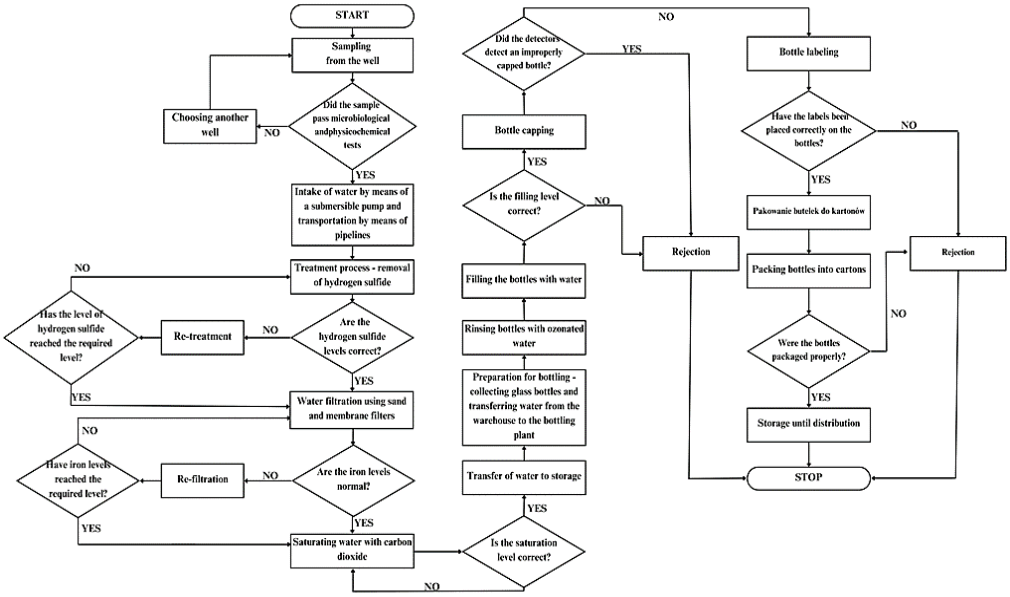

Fig. 4. Algorithm of the production process for carbonated bottled spring water

The visualization application for industrial processes in the company has been divided into the following parts:

1. **Creating process windows** - opening and saving application windows, adding and modifying objects (Figure 3).
2. **Defining variables and creating animation links in the visualization application** - using variables in the SCADA environment, connecting and interacting objects using the Animation Links option. (e.g., animation of water flow through pipes) (Figure 5).

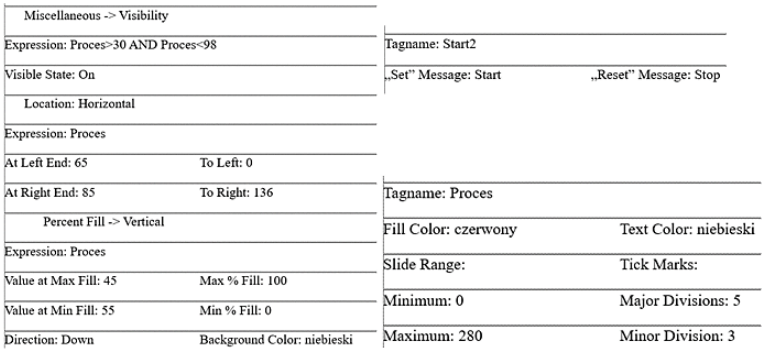

Fig. 5. Windows for defining variables and animation connections

3. **Script creation**—process automation (Figure 6).

```
IF Nasycenie==100
THEN Zawor5=1;ENDIF;

IF Zawor5==1 AND Start==1
THEN Magazyn=Magazyn+1;ENDIF;

IF Magazyn>=50
THEN Magazyn=50;ENDIF;

IF Magazyn==50
THEN Zawor5=0;ENDIF;

IF Nasycenie<100
THEN Zawor5=0;ENDIF;

IF Filtracja<100
THEN Zawor5=0;ENDIF;

IF Uzdatnianie<100
THEN Zawor5=0;
ENDIF;
```

```
IF Start==0
THEN Pompa=0; ENDIF;

IF Start==1 AND Uzdatnianie<100
THEN Pompa=1;ENDIF;

IF Reset==1
THEN Pompa=0;ENDIF;

IF Reset==1
THEN Uzdatnianie=0;ENDIF;

IF Reset==1
THEN Filtracja=0;ENDIF;

IF Reset==1
THEN Nasycenie=0;ENDIF;

IF Reset==1
THEN Magazyn=0;ENDIF;

IF Magazyn==50 AND Start==1
THEN Reset=1;
ENDIF;

IF Start==1 AND Uzdatnianie==0
THEN Reset=0; ENDIF;
```

```
IF Start2==1 AND Proces>=0
THEN Proces=Proces+2;
ENDIF;

IF Proces>280 AND Start2==1
THEN Proces=Proces-1;
ENDIF;
```

Fig. 6. Sample scripts

4. **Trends** – data monitoring and analysis (Figure 7).

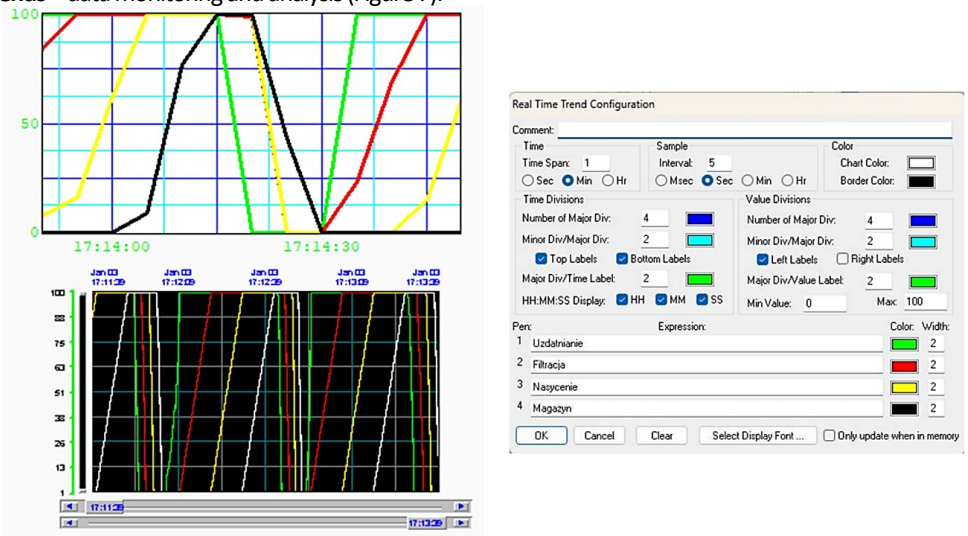

Fig. 7. Trends window

5. **Alarms** – automatic detection and notification of irregularities and failures occurring during the production process (Figure 8).

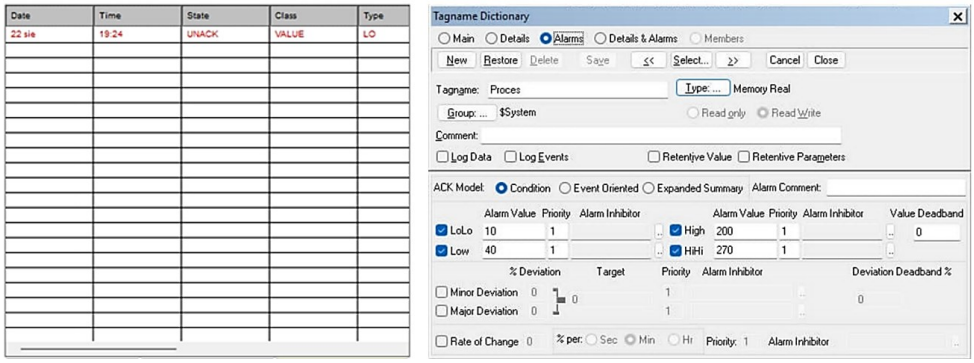

Fig. 8. Alarms window

Process visualization enables effective monitoring and management of processes in modern production and logistics systems.

CONCLUSIONS

Logistics plays an important role in business management, particularly in the areas of inventory management, transport, production coordination, and loss minimization. Today, companies are constantly striving to optimize their logistics processes, which affects their operational efficiency and competitiveness in the market. IT systems, which form the basis of modern logistics management, are also of key importance. Their integration enables the synchronization of operational activities, real-time process monitoring, and automation, which in turn increases efficiency and speeds up decision-making. Intralogistics defines the scope of logistics activities that take place within a company. These include activities such as internal transport of goods, information and inventory flow management, and inventory control. The application is designed to present information in a visual (graphical) manner. It presents the processes of extraction, bottling, labeling, and packaging of spring water for further storage and distribution. The visualization of the process allows for efficient control of intralogistics processes within the company. At the same time, it provides us with a constant overview of the changes taking place in the above process in real time. The visualization of production processes is becoming an indispensable tool for companies that want to be leaders in their industry on the market.

WIZUALIZACJA PROCESÓW W KONTEKŚCIE WSPÓŁCZESNYCH WYZWAŃ ZARZĄDZANIA LOGISTYKĄ

Logistyka odgrywa kluczową rolę w efektywnym zarządzaniu przepływem surowców, materiałów oraz informacji, co wpływa na konkurencyjność i wydajność operacyjną przedsiębiorstwa. Wizualizacja procesów, stanowi ważne narzędzie wspierające podejmowanie decyzji, umożliwiając szybkie wykrywanie problemów, a także optymalizację procesów w czasie rzeczywistym. Integracja różnych systemów informatycznych pozwala na pełną synchronizację działań, poprawę efektywności, choć niesie ze sobą wyzwania, takie jak zapewnienie bezpieczeństwa danych i kompatybilność systemów. W artykule omówiono znaczenie wizualizacji procesów w przedsiębiorstwie produkcyjnym w kontekście współczesnych wyzwań zarządzania logistyką. Wykonano algorytm, aplikację wizualizacyjną zautomatyzowanego procesu produkcji gazowanej butelkowanej wody źródlanej. Środowisko, które zostało wykorzystane do realizacji to system SCADA (Supervisory Control And Data Acquisition).

Słowa kluczowe: inżynieria elektryczna i lądowa, wizualizacja procesów, automatyka, transport, procesy intralogistyczne, zarządzanie.

AUTHOR CONTRIBUTIONS

– conceptualization, A.K-F. (Aldona Kuśmińska-Fijałkowska), Z. Ł. (Zbigniew Łukasik), J.K. (Jacek Kozyra), S.O-W. (Sylwia Olszańska-Wesoły), J.B. (Julia Błaszczyk)
– methodology, A.K-F., Z.Ł., J.K., S. O-W., J.B.;
– software, A.K-F., Z.Ł., J.K., S. O-W., J.B.
– validation, A.K-F., Z.Ł., J.K., S. O-W., J.B.;
– formal analysis, A.K-F., Z.Ł., J.K., S. O-W., J.B.;
– investigation, A.K-F., Z.Ł., J.K., S. O-W., J.B.;
– writing - original draft preparation, A.K-F., Z.Ł., J.K., S. O-W., J.B.;
– writing - review and editing, A.K-F., Z.Ł., J.K., S. O-W., J.B.;
– visualization, A.K-F., Z.Ł., J.K., S. O-W., J.B.;
– supervision, A.K-F., Z.Ł., J.K., S. O-W., J.B.;
– project administration, A.K-F., Z.Ł., J.K., S. O-W., J.B..

All authors have read and agreed to the published version of the manuscript.

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