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A CONCEPTUAL FRAMEWORK FOR SUPPLY CHAIN DIGITALIZATION USING INTEGRATED ERP SYSTEMS MODEL APPROACH

Elżbieta MILEWSKA[1*], Stefan SENCZYNA[2]

[1] Silesian University of Technology; elzbieta.milewska@polsl.pl, ORCID: 0000-0001-8053-4333
[2] The Katowice Institute of Information Technologies; stefan.senczyna@edu.wsti.pl, ORCID: 0000-0002-0729-0026
* Correspondence author

Purpose: The aim of this research was to apply solutions that improved the way of managing the information and material flow that occurs in the logistics network. An advancement that is obtained by building and powering an information distribution module. The model was spread among many ERP systems implemented in enterprises directly into the logistics network. Complex that it will be scalable, also mapping the very component logistics structures and basic data management in developed storage and logistics.
Design/methodology/approach: The foundation of the proposed solution was the use of a feedback mechanism that occurs both at the level of a single enterprise, a group of enterprises performing a similar role towards the group (layer) as well as at the level of the entire logistics network. Therefore, a multi-level control system was created between planning and supervising the production activities of many economic entities. The adaptability of a single enterprise and a group of enterprises was achieved through inference and the alternating and cyclical implementation of two phases (planning and supervising production activities). A limitation was also adopted for the model, which assumes that data transfer takes place only between ERP systems and is subordinated to the structure of the data that is being integrated.
Research limitations/implications: It is expected that further research will be conducted to automate data flow. Additionally, they will focus on value stream analysis for the explored business processes.
Originality/value: The created model reflects the complex structure of the logistics network, which connects production sites with product distribution sites through material flows. It allows you to simulate and compare the results obtained from various process mining scenarios and perform a comprehensive assessment of the value stream in the network.
Keywords: logistics networks, supply chain management, information model, process mining, flexible adaptation, production networks, industry 4.0.
Category of the paper: Conceptual paper.

1. Introduction

Logistics networks are complex organizational structures within which activities are undertaken to coordinate the flow of information and materials. These structures encompass a group of enterprises of varying sizes, performing diverse functions within the group, and utilizing different management systems. Logistics processes within these enterprises generate interactions between entities in a seemingly chaotic manner. Attempting to organize the flow of materials within a logistics network involves organizing an inherent, multi-level control system (Chukalov, 2017; Marker, 2024; Pérez-Lara, 2020).

In logistics networks, small changes in commodity demand, identified at the end of the supply chain, closer to the end customer, can trigger a domino effect, also known as the bullwhip effect (Hsieh, Chang, 2021; Ivanov et al., 2019; Özçelik et al., 2021; Spiegler et al., 2025). This phenomenon leads to significant demand fluctuations that originate at earlier stages of the supply chain and destabilizes material flows throughout the system. Instead of optimizing, the system responds with excessive increases or decreases in orders, leading to inventory buildup or raw material shortages at various levels of the supply chain (Suryawanshi, Dutta, 2022).

A logistics network is assumed to encompass a group of different enterprises, each managed using ERP (Enterprise Resource Planning) systems. These systems support specific areas of each entity's business, including warehouse management, distribution and sales, production management, human resources, payroll, and finance and accounting. Furthermore, they integrate business processes between organizations (Hülsmann, Wycisk, 2005; Trelleborg, 2024). Despite the use of IT tools, the flow of information and materials within a logistics network is subject to significant risk of various disruptions (Koh et al., 2003; Xue et al., 2013). Potential causes of irregularities include:

1. Process Standardization – ERP systems rely on the use of standardized business processes. However, implementation does not always result in these patterns being adapted to the specific needs of the entity. Attempting to impose a universal framework on diverse activities while simultaneously rejecting the differing preferences of companies within a single logistics network can lead to reduced process efficiency across the entire system, coordination errors between companies, or delays in the flow of goods (Bajdor, 2018).
2. Process rigidity (lack of flexibility) – ERP systems assume a specific sequencing of activities and a hierarchy of applicable procedures (Zülch et al., 2002), modifying which can be difficult. Responding to changes in a dynamic logistics environment may require generating not only diverse but also multi-level responses (Chukalov, 2017; Marker, 2024; Pérez-Lara, 2020). These responses should be adapted to both the severity of events and the time of their occurrence or recording. Overly rigid procedures within

an ERP system, or too late feedback, can exacerbate supply disruptions or significantly impede an entity's adaptation to market conditions (Cohen, Levinthal, 1990; Mandal, 2019).

3. Local optimization (versus global) – ERP systems optimize resources and processes at the enterprise level. Taking into account the needs generated by other entities within the logistics network requires additional system parameterization. Its absence can lead to optimized decisions for one company being detrimental to other network participants and negatively impacting the flow of material resources throughout the entire system (Liu et al., 2009; Schary, Skjøtt-Larsen, 2001; Suryawanshi, Dutta, 2022).
4. Low quality of exchanged data – Business needs and the capabilities of integrated ERP systems determine the scope, method, and frequency of data exchange between enterprises (Trelleborg, 2024). Furthermore, correct interpretation of messages requires consistent and precise resource naming and completeness of the transmitted content. Limited access to data sources, delays in delivering updates, or different data storage methods can disrupt data transfer and synchronization, and impact the security of the monitored system (Omitola, Wills, 2018). It is also important to remember that any change to data in one enterprise affects other entities in the network (Flintsch, Bryant, 2006; Holmström et al., 2019).
5. System integration issues – Companies within a single logistics network may use different ERP systems, which are not always compatible with each other. Different communication formats, different data structures, the use of unidirectional data exchange mechanisms (instead of bidirectional), limitations in multithreading, and the use of incremental exchange not only degrade performance but also significantly limit the scalability of integration and its resilience to software version changes (Ben-Daya et al., 2017; Schuh et al., 2017; Trelleborg, 2024).
6. Adaptation Difficulties in Logistics Networks – ERP systems typically assume a linear flow of resources, while actual goods turnover can be more complex. Logistics networks contain multiple channels and a variety of interactions between companies. Oversimplification of the flow structure, as reflected in ERP systems, can lead to inappropriate management of complex control systems (Rai et al., 2006).

Furthermore, each ERP system should meet the assumptions of a follow-up control system with respect to the limited resources of the enterprise. For the purposes of this article, let's consider an information distribution model spanning multiple ERP systems implemented in enterprises belonging to a logistics network. Let's also assume that all these systems simultaneously implement the assumptions of a follow-up control system with respect to the entire logistics network. We will analyze this case study based on the following conditions:

- the dynamics of material flows occurring in the production process supported by the ERP system will be taken into account,
- the solution will encompass a single, selected logistics network, comprising integrated enterprise systems,
- the modeling will focus on information distribution within the logistics network.

Let's also assume that centralized logistics network management will be implemented using the ATP (Available to Promise) concept, meaning that flow harmonization will be based on demand forecasts (de Carvalho et al., 2023; Gansterer, 2015). The benefits of this solution include:

- streamlining the sales process and building customer trust and satisfaction by providing information on realistic product delivery times,
- monitoring material quality and identifying product genealogy,
- and reducing excess inventory and the risk of product expiration.

The effect of modeling the flow of information and materials in the network will be presented below.

2. Mapping material flows in the ERP system

Companies aim to provide products and services that meet consumer needs and expectations. By offering valuable solutions, they achieve their business goals and help customers achieve them. However, companies must understand the specific needs of their customers to provide the desired solution. Products and services offered should address identified market needs. However, it's important to remember that these needs are subject to evaluation, so companies should constantly adapt their offerings to changing expectations and flexibly respond to market dynamics (Mandal, 2019). Effectively meeting customer needs not only builds a positive company image and customer loyalty but, above all, contributes to economic success.

Adapting to additional security is particularly helpful for manufacturing companies that process products, semi-finished products, and other resources into finished products or services. IT systems are a key element in managing business entities (Büyüközkan, Göçer, 2018). They serve as one of the channels that feeds changes in customer needs and controls the flow of information and documents within the company, with detailed attention to the production area. Tools that integrate various types of company activities are also ERP systems. They combine a single manufacturing activity with supporting, distribution, and sales processes, products, and services. They improve recruitment, training, and final billing, and also support invoicing, expense control, budget management, and accounting.

It should be noted that the functionality of ERP systems specifically encompasses the supervision of manufacturing processes, supporting production planning, quality control, and inventory management of raw materials and finished products. Unfortunately, this support is contingent on a detailed representation of production processes within the system's data structure and the ongoing updating of changes in this area (Alcácer, Cruz-Machado, 2019; Flintsch, Bryant, 2006). Based on system data, a production schedule is generated, job assignments are issued to employees, and inventory levels are precisely determined for each product. Using the system allows for effective resource planning, monitoring and analysis of operational activities, and synchronization of material flows. Enterprise-wide, these actions translate into increased efficiency, minimized inventory, and improved company competitiveness through flexible product adaptation to market needs and the potential for product or service personalization (Taddei et al., 2024; Wiggins, Ruefli, 2002). An example of the production processses and material flows is illustrated in Figure 1 below.

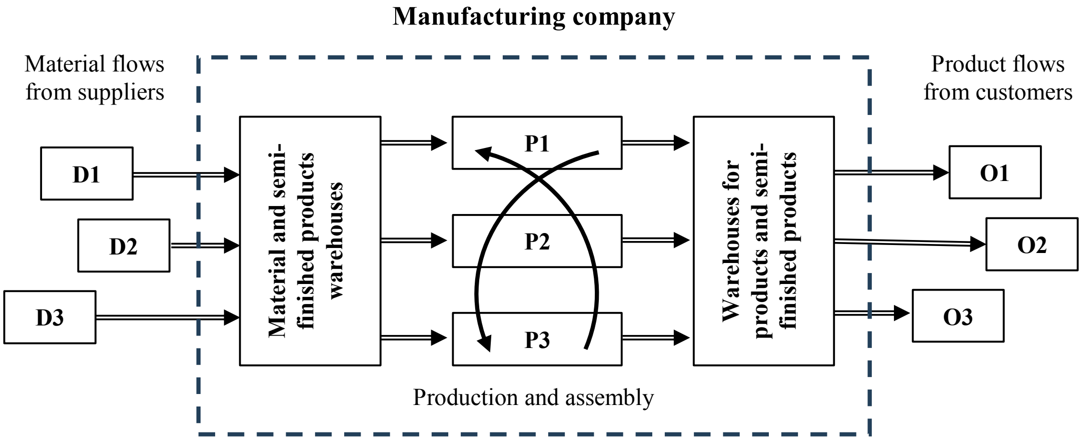

Figure 1. Process flow and material flow in a manufacturing enterprise.

Source: own study.

It is assumed that the use of ERP systems in the area of production management requires the following preparatory activities:

- declaring the machine park in the system, in the form of machines and technical equipment, along with the assigned parameterization describing their production capabilities,
- declaring human resources, including employee skills and availability calendars,
- entering material resources, including assigning units of measurement, key characteristics, source of origin, default storage location, and billing method,
- declaring the production technology for manufactured products,
- a method for converting market demand (product orders) into production process events, i.e., generating a production schedule that controls the load on the company's machine and employee resources,

– a method for converting market demand (product orders) into material requirements for raw materials and semi-finished products used in the production process and generating material flow within the company,
– the method of transmitting job instructions to direct production employees, the frequency of generating production schedules in the ERP system, the frequency of updating data describing resource status, and the method of managing the company's production capacity.

Figure 2 shows the information flow pattern in a manufacturing company supported by an ERP system.

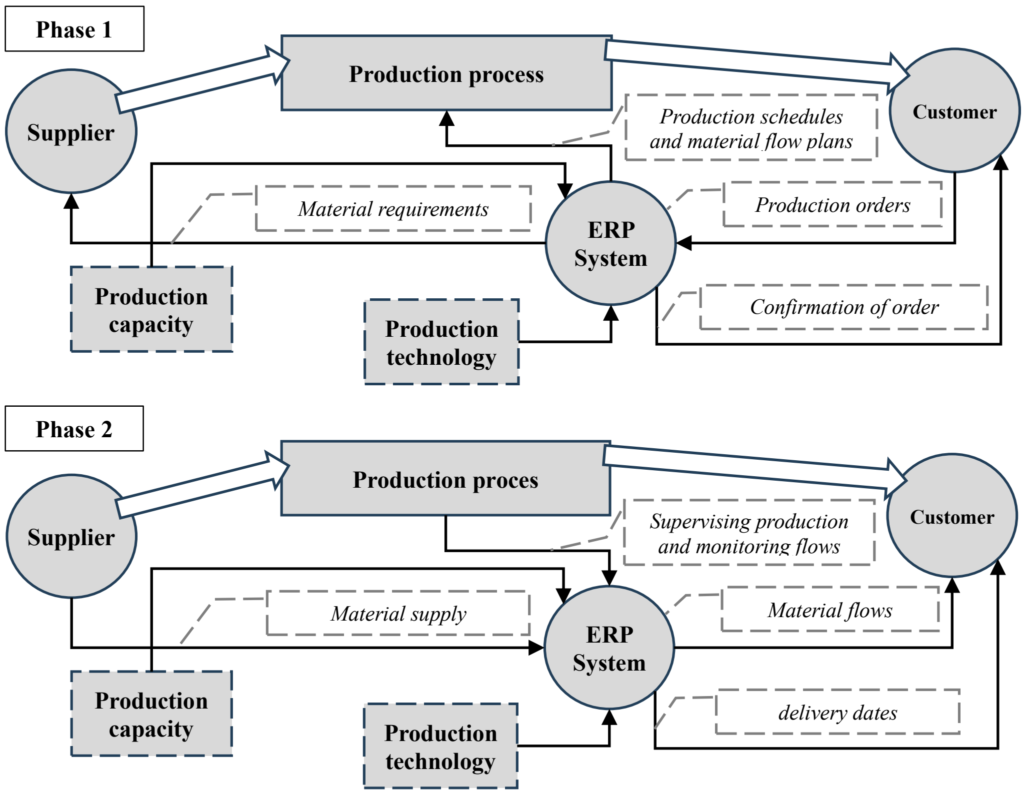

Figure 2. Two phases of ERP system support – production planning and supervision.
Source: own study.

The figure above highlights two phases of ERP system support offered to manufacturing companies. Phase 1 is designated as production planning, while Phase 2 encompasses the supervision of manufacturing operations. It is assumed that in the first phase, the company accepts orders for finished products, placed by both individual and institutional customers. Their cyclical aggregation allows for the creation of "production orders". Based on the "production technology" and "production capacity" declared in the ERP system, "production schedules" are then generated and "material flow plans" are created. These plans confirm the timely fulfillment of orders in line with customer requirements and enable decisions that stimulate material flow. In the second phase of support provided by the ERP system, control and supervision activities are carried out. Previously planned activities are verified. Decisions related to "material supply" are enforced, "material flows" within the enterprise are monitored, and "the production process is supervised", which includes operational activities in manufacturing, quality control, internal transport, and warehousing. Due to the dynamic changes in the environment, calculations regarding "delivery dates" for customer orders are repeated. The enterprise's attempt to adapt to changing market conditions results in the ERP system continuously creating successive versions of the production schedule. These are successively recalculated, taking into account current work conditions, including the quantitative and temporal availability of resources. To increase the flexibility of the enterprise's operations, the ERP system enables the concurrent execution of phases one and two. As a result, it provides a solution that is a constantly modified response that takes into account market impulses and environmental events (Mandal, 2019).

3. System integration of the logistics network

The logistics network described above encompasses collaborating companies striving for profit. Mutual cooperation occurs along the entire supply chain, from raw material sourcing, through manufacturing, to distribution, sales, and service of finished products to the end user (Hülsmann et al., 2008). Each company within the logistics network aims to optimize its business processes (Kück, 2016, 2017). These activities, supported by ERP systems, focus on, among other things, minimizing inventory and shortening production times. However, it should be noted that the support provided by ERP systems is primarily implemented at the level of the individual business entity. This means that production management is based on internal factors, and environmental conditions, market signals, or information about the activities of collaborators reach the company with significant delays or may even be ignored in the implementation of business processes. These limitations in data exchange between entities within the logistics network can lead to various problems. Coordination of production activities and synchronization of the flow of material resources carried out solely within one company, without taking into account the interdependencies of the entire network, may cause congestion, delays or interruptions in supplies, affecting other parts of the network (Hofmann, Rüsch, 2017).

The solution to this problem is the integration and synchronization of ERP systems across the entire logistics network (Chukalov, 2017; Pérez-Lara, 2020; Trelleborg, 2024; Zekhnini et al., 2021). This enables enterprises to seamlessly exchange information, making collaboration more effective and resource planning and management more efficient. As a result, bottlenecks in material resource flows are significantly reduced and enterprises' flexibility in response to changing market conditions is increased. For the purposes of this article, this problem was analyzed based on a specific case of a logistics network, in which three layers of enterprises were distinguished. This logistics network is presented in Figure 3.

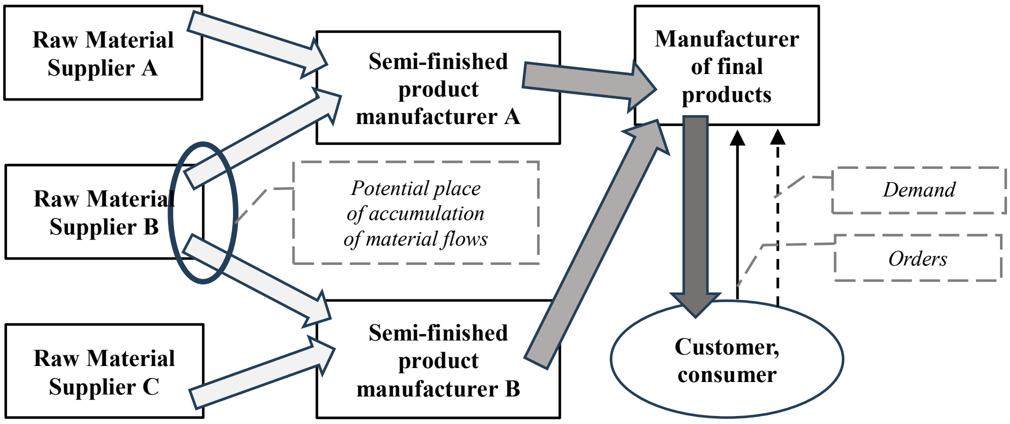

Figure 3. Information flow in the logistics network.

Source: own study.

Figure 3 presents a case study of a logistics network limited to several cooperating companies. The problem of resource congestion most often occurs at the level of raw material suppliers ("Raw Material Supplier B"). This highlights the need for effective resource management and process synchronization between different companies in the logistics network. The independent operation of companies ("Semi-finished product manufacturer A" and "Semi-finished product manufacturer B") can lead to order congestion, delivery delays, and ultimately disruptions in the production process of semi-finished products, despite each manufacturer using planning methods supported by ERP system functionality. The main challenge, therefore, is coordinating raw material supplies and synchronizing production plans for semi-finished products between entities in the logistics network. It is assumed that this will interfere with orders and resource flows, especially in the deeper layers of the supply chain (at the raw material level). However, as long as each company strives to maximize the utilization of its resources without full insight into the needs and constraints of other network participants, bottlenecks in material flows will continue to occur.

Market observation allowed the authors of this article to identify the following solutions that address the problems outlined above:

- communication and synchronization of production plans,
- centralization of forecasting and planning,
- application of artificial intelligence (AI) and predictive analytics,
- VMI (Vendor-Managed Inventory) systems,
- virtual supply chains (Digital Twin).

Each of the points mentioned will be briefly characterized below.

3.1. Communication and synchronization of production plans

Electronic data interchange (EDI) between companies and their ERP systems is one of the most popular solutions, although it requires significant commitment from both parties to establish the terms of cooperation and the method of information exchange. This solution is based on regular, two-way communication, which includes data describing sales forecasts, orders, and sales documents. Data exchange takes place via a common platform, the implementation of which is based on the integration of individual companies' ERP systems. It enables the automation of business processes, enabling precise data synchronization, reducing errors, and accelerating transaction processing.

3.2. Centralization of forecasting and planning

A more advanced approach is centralized production forecasting. This is a comprehensive approach based on the harmonization of strategic, operational, and financial plans and relies on the connection of data from different companies. It partially overlaps with the traditional sales and production planning model, which prioritizes balancing supply and demand needs (Abbaspour Ghadim Bonab, 2022). However, this approach focuses on synchronizing demand forecasts with production and inventory management to maximize the productivity of the entire logistics network (de Carvalho et al., 2023; Rüßmann et al., 2015; Schuh, 2017). It uses advanced forecasting and scenario planning methods to anticipate future conditions and adapt strategies. It enables stakeholders to anticipate risks and opportunities while ensuring the harmonization of daily operations with core business objectives. A consistent data structure eliminates organizational barriers and allows for informed decision-making. The solution requires a centralized management structure and significant financial outlays (Hülsmann, Grapp, 2005).

3.3. Application of artificial intelligence (AI) and predictive analytics

Modern technologies, such as artificial intelligence and advanced analytical tools, can support demand forecasting and production planning processes. They take into account changing market conditions and historical sales data within the logistics network. AI algorithms can automatically analyze data in real time, highlighting potential bottlenecks in material flows (Nawaz et al., 2019; Scholz-Reiter et al., 2014).

3.4. VMI (Vendor-Managed Inventory) systems

One option is to implement a VMI system as an inventory management model, in which the supplier assumes responsibility for monitoring and replenishing the customer's inventory in their warehouse. The supplier has access to customer inventory data and, based on this, decides when and in what quantities to deliver products to ensure continuous supply and avoid shortages or surpluses. In the example shown in Figure 3, suppliers such as "Raw Material

Supplier A" and "Raw Material Supplier B" take control of the inventory of their customer, "Semi-finished Product Manufacturer A," thus reducing the risk of raw material overstocks or surpluses (Laaper et al., 2017).

3.5. Virtual supply chains (Digital Twin)

Creating digital twins of logistics networks can help model and simulate the flow of materials within the network (Kritzinger, 2018; Rodič, 2017; Saanen, 2002; Tao et al., 2017, 2018; Tu et al., 2018). The solution involves successively collecting and integrating data from a real-world facility or process, and then building an advanced model that reflects the functioning of the logistics network. It is crucial to combine data describing the physical flow of materials with its digital equivalent, which allows for simulation, analysis and optimization of network behavior, detection of problems and prediction of future events, such as accumulations or disruptions (Agostino et al., 2020; Barykin et al., 2021; Frazzon et al., 2018; Koh et el., 2003; Luo et al., 2024; Suryawanshi, Dutta, 2022).

The solutions described above have been used in logistics networks for many years. They are based on centralized forecasting and integrated production planning within a group of companies. However, it is important to remember that logistics networks are complex and flexible organizations that change over time, both in terms of structure and the way communication is transmitted within the network. This development stems from changing trends in consumer behavior, but also from technological advances and the way business processes are implemented. Furthermore, ERP systems, as tools supporting production management, are constantly being modified, adapting their functionality to changing legal regulations and environmental changes. Therefore, the following question arises: is it possible to minimize material flow peaks (which occur in the deeper layers of the network) in flexible networks and in a dynamically changing environment, while using the minimum organizational effort possible.

4. Modeling information flow in the network

In an attempt to map the processes occurring between the economic entities of a logistics network, the authors constructed a model of information distribution and material flow (Figure 4). The applied notation allows for both the depiction of simple logistics networks comprising several companies and the reconstruction of complex structures represented by multiple companies performing diverse functions within the group. The scalability of the solution and the universality of the notation were achieved by using the following graphical elements (Figure 4):

- **Enterprise: Raw Material Supplier/Semi-finished Product Manufacturer/Finished Product Manufacturer**
  The rectangle represents the economic entity within the network. Enterprises perform various functions for the group: they supply raw materials or other resources necessary for production, transform raw materials into semi-finished products, or transform semi-finished products into finished products. It is assumed that production processes can be carried out collaboratively and that the transfer of semi-finished products can occur multiple times within the logistics value chain (Kroeger et al., 2025). Based on the activities undertaken, each enterprise belongs to a specific layer that manages data according to its role.
- **Information and Material Flow Streams**
  The block arrows used in the diagram illustrate both information flow streams and material flow. They refer to the exchange that occurs between network participants. It is assumed that material flow follows pre-established routes, while information flow refers to data describing sales forecasts, orders, production schedules, and inventory levels. This means that information about raw material demand, production progress, deliveries, and schedules is continuously updated and shared with interested network participants. Processing occurs within the layer to which the enterprise belongs, i.e., among suppliers, semi-finished product manufacturers, or final product manufacturers. In such a system, data exchange management should prevent the formation of bottlenecks or bottlenecks in the flow and reduce delivery delays and inventory shortages. Furthermore, the communication design should flexibly respond to changes in demand and disruptions caused by external factors.
- **The scope of data transfer between ERP systems**
  The logistics network is presented as a system composed of multiple nodes, each representing a specific process participant (supplier or manufacturer). It is assumed that the flow of information between individual entities is carried out using management support tools for the companies comprising the logistics network. Furthermore, it is consistent with the principles used in the ERP systems in use and subordinated to the data structure being integrated. This means that central data management in the logistics network requires ensuring consistency in the data structure describing all stages of the supply chain, i.e., raw material procurement, production, distribution, planning, demand, and customer service (Hülsmann, Grapp, 2005).

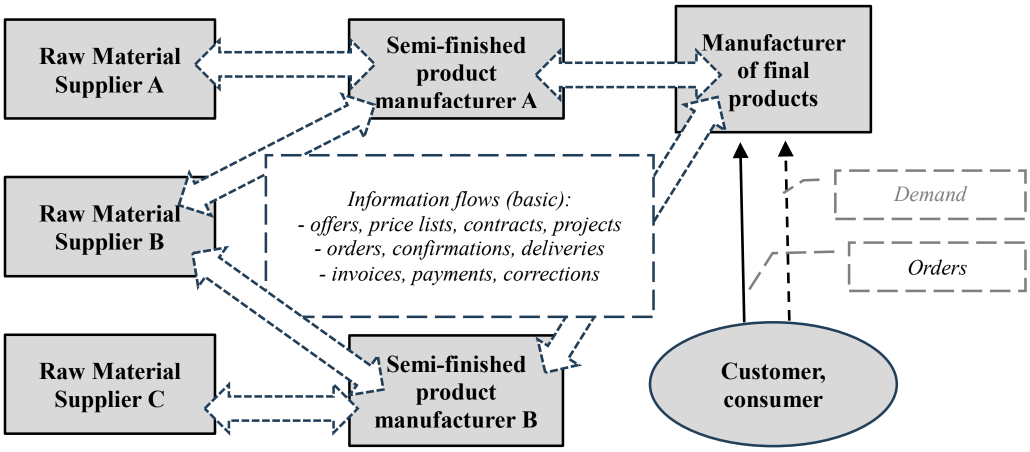

Figure 4. Model of information distribution and material flow in the logistics network.

Source: own study.

4.1. Scaling the distribution model

It is assumed that the distribution model, presented in Figure 4, can be scaled. Additional elements of the logistics chain may include distributors, retailers, or end customers. Expanding the model may also include information flow and material flow. It is important to remember that faithfully representing the structure of the logistics network ensures increased flexibility and adaptability of the entire group. This results in a synergy effect, where coordinating the collaboration of separate business entities, leveraging their unique experiences, allows for mutual complementarity between companies, fosters innovation and efficiency, achieving better results, and increases the operational efficiency of the organization. Furthermore, closing the feedback loop in the network control system allows not only for more stable operation of network entities but also for more precise interaction with external factors. Unlike a single enterprise, a network has a significantly wider range of diverse possibilities for inducing reactions that respond to changing business conditions. The network also better absorbs strong environmental influences and more effectively compensates for disruptions in production processes. By implementing a control system within the network, organizations can adapt to changing market needs, be more flexible in meeting individual customer demands, and actively influence fluctuations in the network's production resources. The modeling assumptions described here are presented in Figure 5 below.

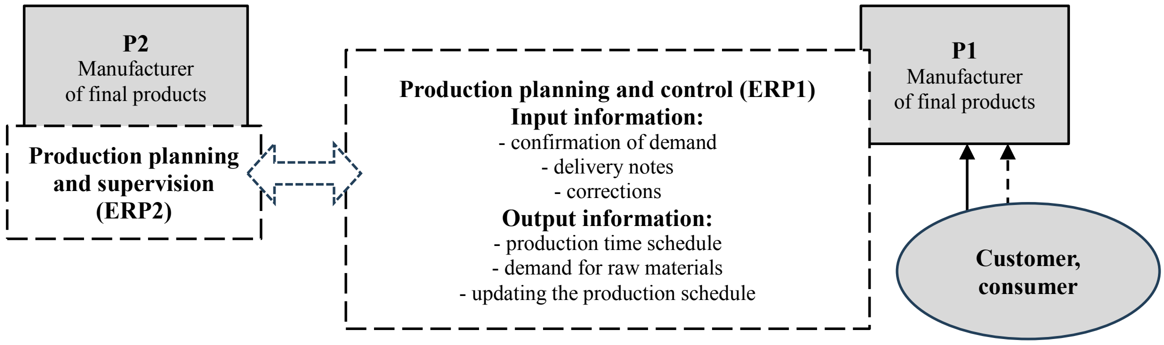

Figure 5. Assumptions made in modeling.

Source: own study.

The model (Figure 5) illustrates the distribution of information between companies P1 and P2. This information includes both forecasted and actual product deliveries by company P2. Together with the production technology recorded in the ERP1 system, it forms the basis for the production schedule generated for company P1. This means that the actual execution of production activities planned by company P1 depends on the effectiveness of material deliveries provided by company P2. Due to the influence of external factors that disrupt business processes in both companies, the expected harmonization of flow should be based on data updates in both ERP systems (ERP1 and ERP2). This requires continuous and mutual finetuning of both companies' production plans so that the schedules developed by company P2 take into account the current material consumption of company P1, while the production plans of company P1 are based on the probable delivery dates of raw materials obtained by company P2. The end result is therefore integrated and multi-level planning (Chukalov, 2017; Marker, 2024), which should be spread across different companies operating in the network and applied to the entire logistics network (or its part) leading to full harmonization of the flow of resources in the network.

4.2. Control system feedback

As mentioned above, a key element supported by ERP system functionality is the feedback mechanism, which spans the planning and supervision of manufacturing operations. The alternating and cyclical implementation of the two phases (planning and supervision of manufacturing operations) provides information that allows for drawing conclusions and implementing adaptive actions. Information about the current system's output state is used to modify input signals to bring the system's operation closer to the desired value. This increases the precision, stability, and efficiency of control, and the tuned output signal ensures automatic compensation for disturbances and the implementation of preventive measures for discrepancies. The basis for these decisions is the mapping of the manufacturing technology and the product's material structure in the system data structure. This technology is achieved by assigning a list of possible technological operations to a list of workstations, declaring employee skills, and defining a calendar for the availability of each of the company's resources.

These activities enable allocation, i.e., the issuance of a job order, which allocates human and machine resources to a task while maintaining the boundary conditions for execution and the substitutability of designated resources. A properly identified operation should enable the substitutability of resources in the allocation, and the assignment of alternative resources to a task should not result in differential production outcomes.

The following elements are involved in the activities described:

Input data:

- Forecasted product sales, representing the expected demand for products that can be produced within a given timeframe.
- Manufacturing technology, representing a detailed description of the production process (also known as a route), which indicates the sequence of technological operations, the duration of individual stages, and the required human, machine, and material resources.
- Product Bill of Materials (BOM) as a hierarchical list of raw materials, semi-finished products, and parts required to produce the final product, along with the quantity of each component. It is structured as a tree, with the finished product at the top and its components below.
- Production resources, which include: a list of direct production employees, machinery and technical equipment, tools, and production materials. It is essential to define a calendar for the availability of each resource in the ERP system to ensure their allocation to production tasks and to set deadlines for completed orders.

Output data:

- A production schedule, which represents the planned production activities, i.e., a list of allocations determined based on the resource availability calendar and production orders created in the system. It indicates the expected quantity and time of production of individual products that will meet the forecasted demand.
- Production resource utilization, which is a report analyzing the intensity of the involvement of individual company resources (machines, employees, raw materials) in the ongoing production activities. This allows for the assessment of efficiency (a measure of effectiveness, efficiency, and quality) and the identification of critical links, i.e., areas requiring corrections (e.g., staff expansion, shift changes, retooling, replenishment of machinery, etc.).
- Completion dates, which represent the designated time (date) for the completion of production or delivery of a batch of products. This allows for the synchronization of material flows within the network and the implementation of more efficient actions within the supply chain.

Data processing:

- Demand forecasting is the process of estimating future demand for manufactured products or services. It is based on the analysis of historical order data and market trend analysis. The goal is to optimize inventory management, meet customer needs, reduce costs (Andriani, 2021), or increase the efficiency of the entire logistics network. Forecast accuracy allows for the avoidance of production in quantities exceeding current demand, but also to avoid shortages that extend customer waiting times for products.
- Allocation, i.e., the issuance of a job order, which allocates human and machine resources to a task while maintaining the boundary conditions for execution and the substitutability of designated resources. This is performed based on the product's manufacturing technology and the BOM, which determines the phasing of manufacturing activities and the operational capabilities of available resources.
- Resource availability verification, which is an ERP system activity related to the warehouse turnover of direct production materials and the analysis of records included in the work time calendars of individual employees, workstations representing the company's machine resources, and tools identified as necessary in production technology.
- Multi-criteria optimization, understood as a solution-seeking activity in which an objective function is defined along with the ranking of criteria. This optimization is responsible for executing a series of allocations and creating a production schedule that represents the best compromise for the decision-maker among the potential solution options.

5. Theoretical and practical implications

The topic of designing and operating global production and logistics networks is currently discussed in the publications of many authors. Issues related to the digitization of the supply chain (Alcácer, Cruz-Machado, 2019; Barykin et al., 2021; Ben-Daya et al., 2017; Büyüközkan, Göçer, 2018; Chukalov, 2017; Hofmann, Rüsch, 2017; Holmström et al., 2019; Hülsmann, Wycisk, 2005; Nawaz et al., 2019; Pérez-Lara, 2018; Scholz-Reiter et al., 2014; Tu et al., 2018), product genealogy tracking as well as broadly understood improvement of management processes are analyzed (Hülsmann, Grapp, 2005; Hülsmann, Wycisk, 2005; Marker, 2024; Schary, Skjøtt-Larsen, 2001).

The foundation of the solution proposed by the authors of this article was the use of a feedback mechanism that occurs both at the level of a single enterprise, a group of enterprises performing a similar role towards the group (layer) as well as at the level of the entire logistics network. Therefore, a multi-level control system was created between planning and supervising the production activities of many economic entities. The adaptability of a single enterprise and a group of enterprises was achieved through inference and the alternating and cyclical implementation of two phases (planning and supervising production activities). It was assumed that data transfer takes place only between ERP systems and is subordinated to the structure of the data that is being integrated.

The created model maps the structure of the logistics network, which connects production sites with product distribution sites through material flows. It allows you to simulate and compare the results obtained from various process mining scenarios and perform a comprehensive assessment of the value stream in the network. Moreover, it will allow companies belonging to the logistics network to obtain many benefits. These include:

- effective management of production resources of entities, considering their operational capabilities and timely availability, which are used appropriately to changes in demand,
- minimizing losses and downtime, understood as taking actions to eliminate overloads or underloads of production resources, reducing the number of changeovers, and eliminating downtime,
- increasing organizational flexibility, which allows for the adaptation of manufacturing activities and the implementation of logistics processes to changes in demand or the availability of raw materials.

Through the harmonious flow of information, it is possible to eliminate the destabilization of the material flow taking place in the logistics network. A similar approach to the problem was presented in Laaper et al., 2017 and Taddei et al., 2024.

Further research by the authors of this article will be conducted towards automating data flow. Additionally, they will focus on value stream analysis for the explored business processes.

6. Conclusions

Adapting to changing market demand is particularly difficult for manufacturing companies that transform raw materials, semi-finished products, and other resources into finished products or services. Capturing the dynamics of changing customer needs and controlling the internal and external flow of information and materials, however, is crucial for achieving business goals. This is particularly important for companies exposed to a significant risk of various disruptions, including those caused by the interactions of business entities. To harmonize the flow of information and materials within a logistics network, the authors of this article constructed and analyzed a distribution model. It was deployed across multiple ERP systems implemented in companies within the logistics network. It was assumed that it could be scaled, reflecting highly complex logistics structures and ensuring central data management across extensive production and logistics systems. The foundation of the proposed solution is the use of a feedback mechanism, which operates at the level of an individual company, a group of companies fulfilling a similar role within the group (layer), and at the level of the entire logistics network. A multi-level control system was therefore created, spanning the planning and supervision of production activities across multiple business entities. The alternating and cyclical implementation of the two phases (planning and supervision of production activities) provides information that allows for drawing conclusions and taking adaptive actions, relevant to both an individual company and a group of companies. However, data transfer between ERP systems must be subordinated to the data structure being integrated. This means that continuous updating of delivery dates and the mutual fine-tuning of production plans requires ensuring data consistency across all stages of the supply chain, from activities related to raw material procurement, production, and distribution, all the way to planning, demand, and customer service.

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