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Logistic aspects of industry 4.0

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Introduction

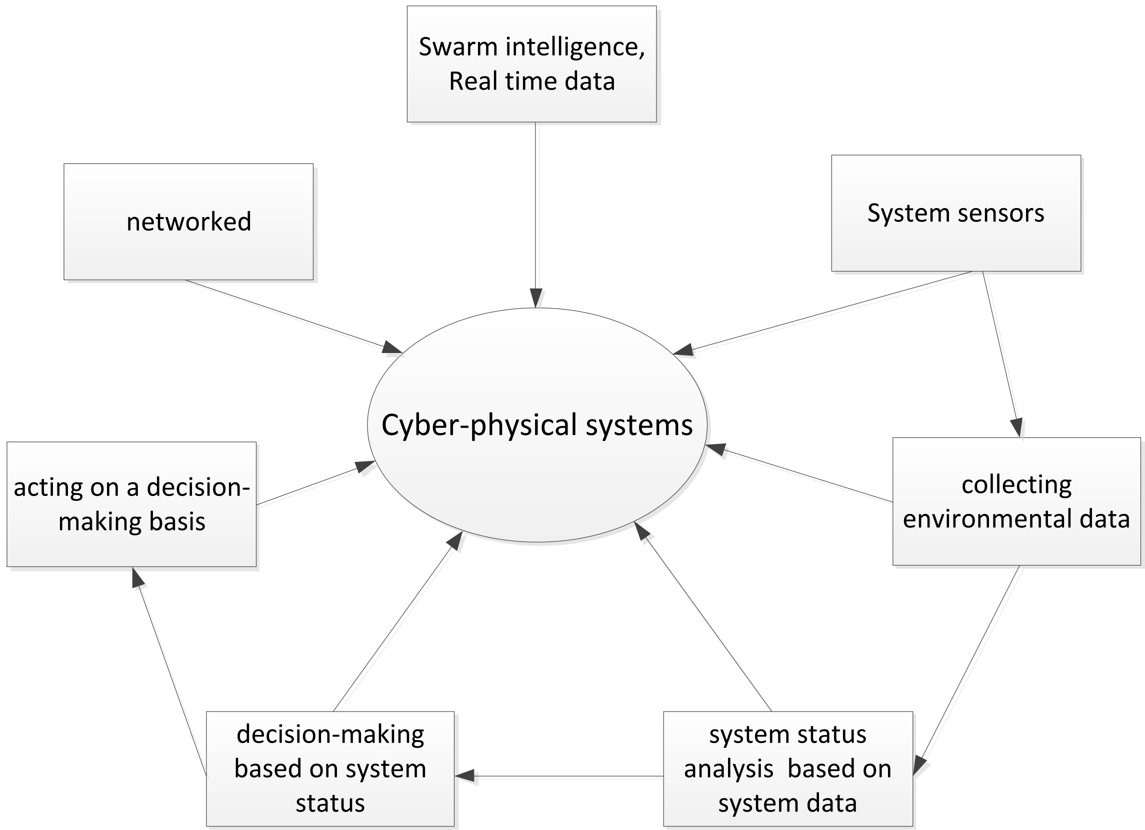
- An industrial revolution can be talked about when the efficiency of production systems is significantly increased due to a new technology solution. The design and operation of systems is becoming increasingly knowledge and resource-intensive, so a breakthrough can only be achieved by increasing the complexity of the systems [1].
- The **first industrial revolution** mobilized the mechanization of production, using the power of water and steam, that is, the revolutionary developments were made possible by the emergence of mechanical production systems.
- The **second industrial revolution**, with the help of electricity, introduced mass production, followed by the digital revolution.
- During the **third industrial revolution**, electronics and information technology (IT) began to automate processes. Automation offered an alternative to the human work needed to operate, accelerating and decoupling the core manufacturing processes. It was this time when the first PLCs (Programmable Logical Controllers) were also appeared in the industry.

Introduction

- From the perspective of production, the forthcoming **fourth industrial revolution or otherwise Industry 4.0** means the **accelerating growth of the efficiency of production systems**.
- The fourth industrial revolution can be achieved because such technological innovations and methods have become available that enable the development of even more complex systems, where the entire supply chain can be operated in an automated way. This includes **online cyber-physical systems, the Internet of Things (IoT) and cloud-based solutions**.
- **Cyber-physical systems** connect real objects through the collection and processing of information. Cyber-physical systems can be represented in many fields of engineering, like services [2], traditional [3,4] and networking manufacturing [5].
- Through the **fourth industrial revolution**, the newly emerged technological innovations and methods also enable the development of complex logistics systems where the entire supply chain can be operated in an automated way.
- **Reliability and quality assessment of logistics networks** are also becoming very significant and complex problems. Therefore, an innovative solution is also going to be presented which is based on Industry 4.0 infocommunication solutions and the application of risk management and quality assurance tools, one that enables the optimal selection of logistics service providers in the network from a reliability point of view.

Cyber-Physical Systems and Cyber-Physical Production Systems

- **Cyber-Physical Systems** are able to collect data from their environment using sensors and act after analyzing their situation [9]. Cyber-physical systems are networked, a significant part of them are interconnected, so it is possible to use swarm intelligence (the application of a common strategy in operation), which results in even more efficient operation.
- **Cyber-Physical-Production Systems** (CPPS) do not only incorporate production tools into intelligent networks, but **integrate the entire supply chain**. Smart production tools share information about their utilization and status (for example, maintenance) and decide on their own issues independently. **Shared information** is achieved by using coordination simulation and optimization tools, and optimally, in a completely independent manner. In order to increase efficiency, utilize capacities, reduce resources, improve quality and reduce lead times, the goal is to coordinate processes [8].
- The emergence and application of cyber-physical systems in the logistics processes leads to further significant changes in the operation of the economy. Of course, it should not be forgotten that logistics is a human-machine-based system based on material handling machines, machine systems, IT systems and networks, the techniques and technology of these and the appropriate standard of human vocational training.



The main components and characteristics of cyber-physical systems

Smart factories

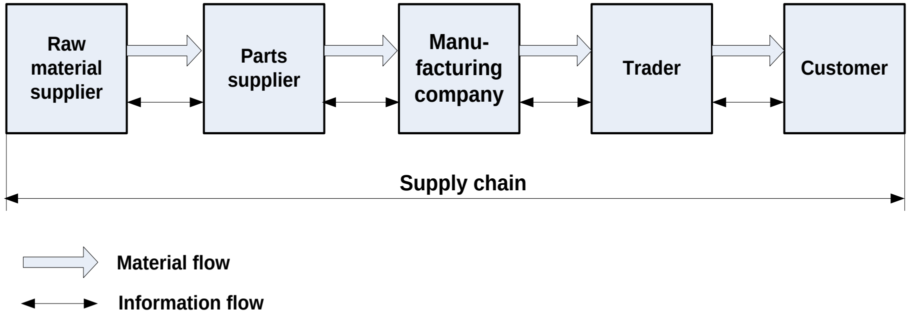
- **The prerequisite for the proper utilization of industry 4.0 solutions in the field of production is to create smart factories that have independent, shared intelligence and are in close contact with each other.** By using detailed and interconnected models of elements, the complex system of these clever components can be optimized for comprehensive goals.
- In the future, the production process in the manufacturing network can be automatically adjusted to the urgency of incoming orders. According to the adaptive production, orders can be processed continuously and transferred to procurement and logistics systems. The operating network accordingly ensures the optimization of material and energy flow along the entire value chain. **Intelligent machines continuously share information about current inventory levels, issues, errors, and the changes in demand.** In process management, the goal is to increase efficiency, optimize lead times and increase capacity utilization [6].
- To make this compilation work requires not only the "smart" elements to be **networked**, but also makes it necessary to **coordinate** these in a "cybernetic space". This is feasible with model-based optimization and development with the use of simulation tools.

		Today's factory		Factory of the future	
	data source	main characteristics	main technologies	main characteristics	main technologies
component	sensor	precision	smart sensors and failure detection	knowledge of own operations, predictive ability	monitoring of all features, life expectancy forecasts
machine	controller	manufacturability and performance	state-based system monitoring and diagnostics	knowledge of own operation, predictive ability, comparability ability	real-time preventive status indicators
manufactur-ing system	networked	performance and total asset efficiency	Lean operations: work and waste reduction	self-configuration, self-maintenance, self-organizing ability	risk exemption, performance

Comparison of today's factory and the factory of the future

Increasing the efficiency in logistics networks

- **Nowadays, not isolated companies, but rather more or less co-operative supply chains compete with each other in order to meet the customer needs ever more efficiently.** The need to organize supply chains is justified by the increase in the economic role of supply [11].



- One of the most cost-effective solutions to enhancing competitiveness and reducing inventories is provided by networking and network-like operation. Today, due to the complexity of the supply chain, it is more appropriate to use the term of a **supply network**, since chain members must build a complex network of activities to produce a single product.

Increasing the efficiency in logistics networks

- **The sharing of information on the production systems requires the development of a new business model for cooperation between organizations. This is achieved through integration with suppliers and customers in the value chain.** The new business models should focus primarily on developing new collaboration models with business partners and handling customer specific expectations, which will require new forms of information sharing with customers and suppliers.
- **Tracking a cross-company relationship system is a very difficult task. The collection and processing of good quality data in appropriate quantities requires a high level of IT and automation. Appropriate and quick response to any mistakes on the market is a great advantage as costs can be better planned.**
- **Industry 4.0 provides an effective solution to this problem, as in addition to manufacturing systems, it aims to increase the efficiency of supply networks as well [12]. It assumes high level of flexibility and transparency in real time, in other words, the operation of real-time optimized new value creation networks.**

Increasing the efficiency in logistics networks

- **The quality of the relationship between members of the supply network is basically determined by the use of integrated information systems and advanced forecasting methods**. The effectiveness of the link depends on the accuracy of the sales information provided by the buyer and the supplier's willingness to keep the inventory:

$$M_h = f(l_m; K_k)$$

- Where:
  - M_h - the effectiveness of the link between members of the network,
  - I_m - the quality (accuracy) of the sales information provided by the buyer,
  - K_k - the inventory keeping ability of the supplier.

- Based on the above, we can state that **the level of cooperation between the members of the network can be increased by providing the supplier with more accurate sales information from the buyer**, as the supplier's willingness to maintain the inventory increases in a straightforward manner.

Example of a possible application in logistics networks

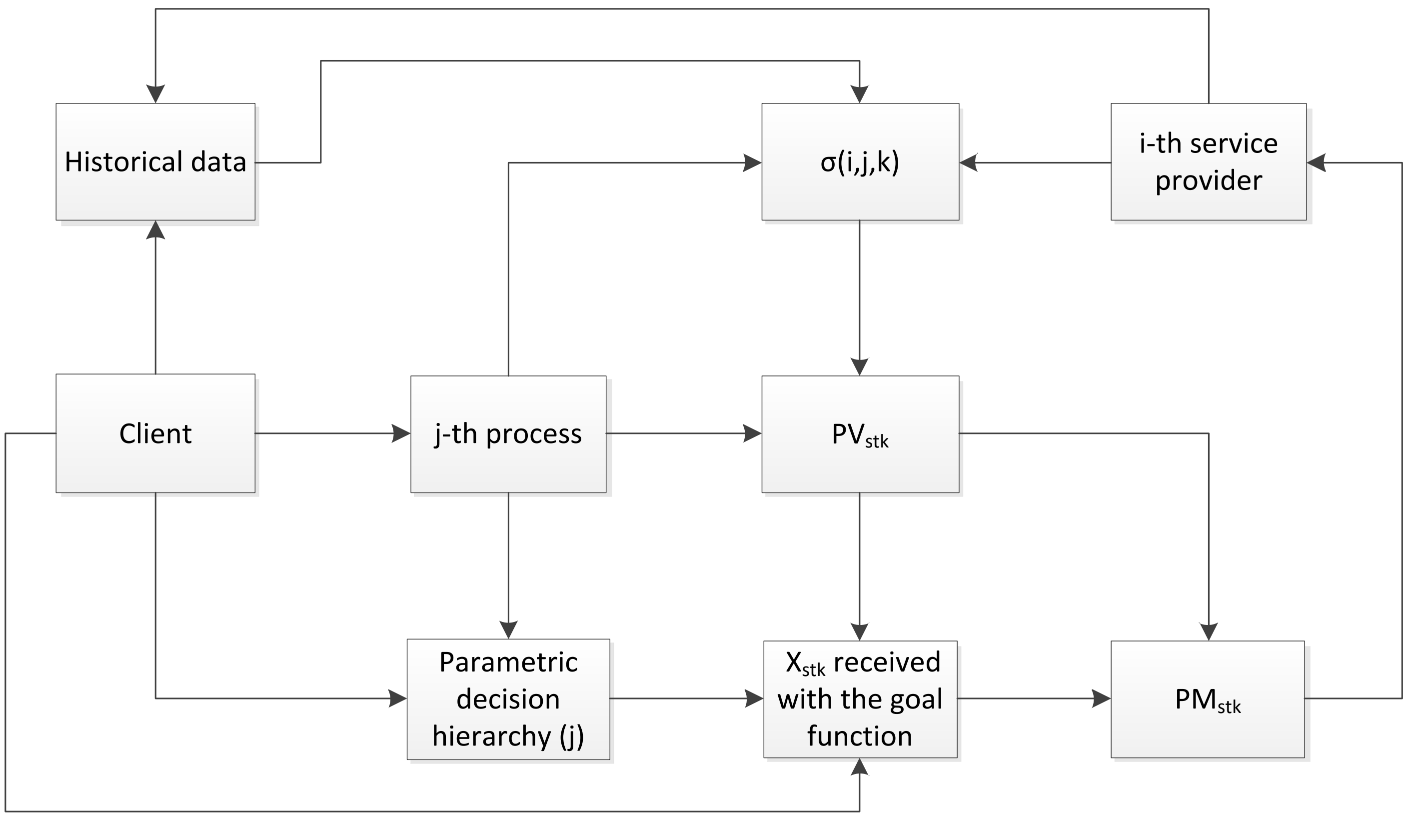
- Ensuring the proper operation of modern factories today is almost unimaginable without the existence of such logistic systems which operate in a harmonized manner with the production processes.
- In the followings, an example for an advanced methodology will be presented, one that makes possible the **optimal selection of logistics service providers in the network from a reliability point of view**, building on the **infocommunication solutions of Industry 4.0 and on the tools of risk management and quality assurance**.
- One of the key pillars of the methodology that is going to be presented is the application of the process capability concept. The concept of process capability is derived from statistical process control (SPC), which by now became one of the essential tools of quality assurance at a large number of production companies.
- It is important to emphasize that the process capability approach is increasingly being used in the service sector as well, especially as part of Six Sigma, so its use is also gaining momentum in the field logistics [13].

Example of a possible application in logistics networks

- The central idea of the procedure being presented is that **with the knowledge of the right historical data, a cumulative critical process capability index can be calculated for any arbitrary combination of logistics service providers and logistics processes**:

$$kc_{pk} = \sum_{j=1}^{m} \frac{q_j \cdot p_j}{P} \cdot \sum_{i=1}^{n} \sum_{k=1}^{r} c_{pk}(i,j,k) \cdot pr_k \cdot x_{ijk}^{stk} \rightarrow Max$$

- The meanings of the variables in the goal function are the following:
  - q_j: the quantity of the goods that has to be handled in the j-th process,
  - p_j: the average value of a single unit of the goods which has to be handled in the j-th process,
  - P: the total value of the goods which are going to be handled in the examined processes during the relevant time interval,
  - $c_{pk}(i,j,k)$: the calculated value of c_{pk} for the j-th process at the i-th provider in relation to the k-th risk parameter,
  - p_{rk}: the weight of the k-th risk parameter (this can be determined with the use of the risk model which is going to be presented later),
  - x_{ijk}^{stk}: the binary decision variable that is used for the selection of the relations included in the solution



High-level data model defining the information sharing model

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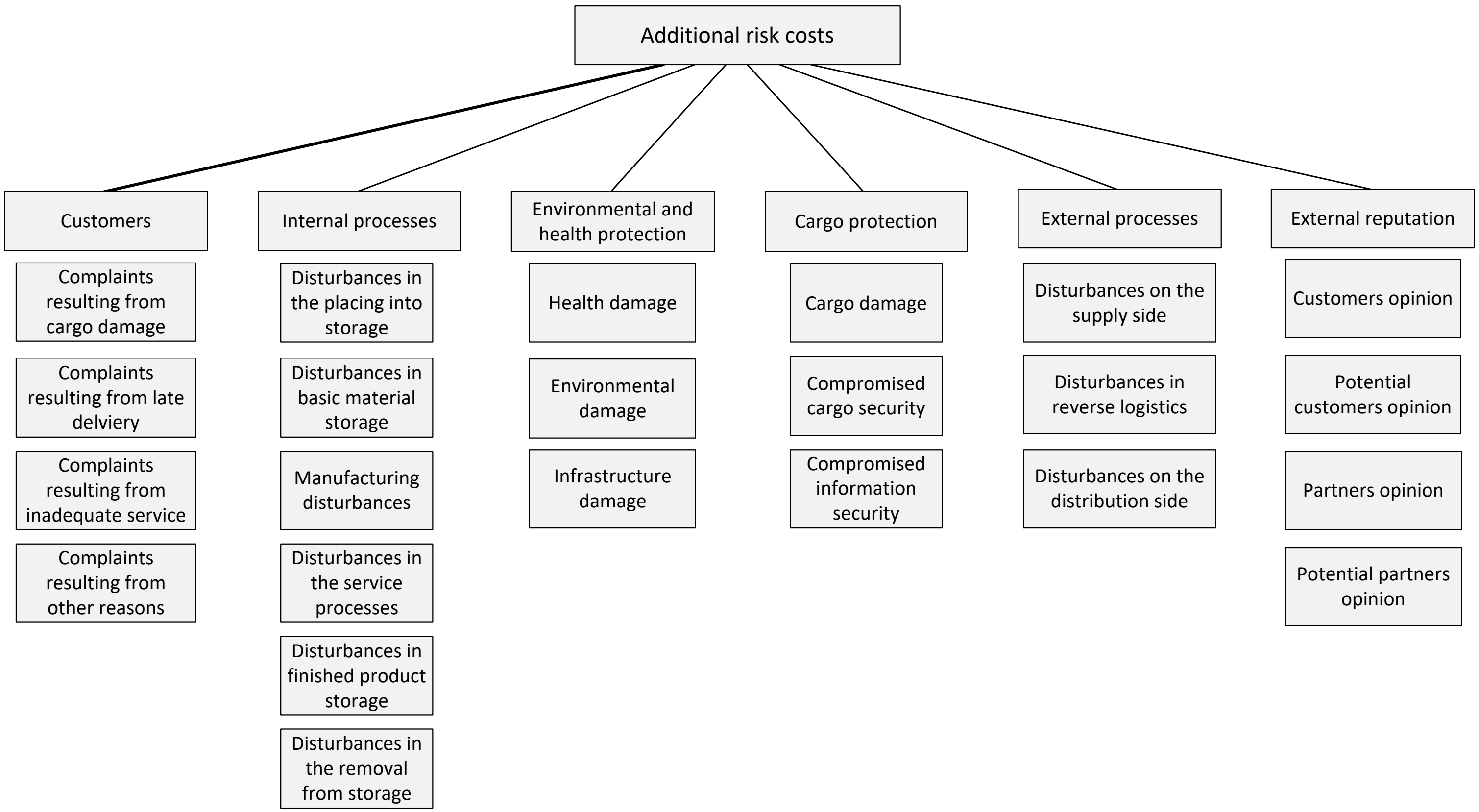

The risk model implemented as a decision hierarchy by using the AHP method

Summary

- Today, due to increasing complexity in supply chains and uncertain supply and demand, ensuring flexibility in future supply chain planning will be one of the most important tasks. One of the most important prerequisites for supply chain flexibility is the development of network-based collaborations and the use of Industry 4.0 developments.
- The study analyzed the operational processes of logistics networks and examined how the efficiency of logistics processes could be increased by exploiting the opportunities offered by the fourth industrial revolution. Based on Industry 4.0's infocommunication solutions, we introduced a methodology that allows the optimization of logistics networks using the tools of risk management.
- During the development of the presented research work, we have set the goal of developing a risk management process that is suitable for optimally assigning the service providers and the logistics processes to each other within a given network from a risk-based perspective.

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