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The Integration of Smart Systems in the Context of Industrial Logistics in Manufacturing Enterprises

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Abstract

The integration of smart systems in industrial logistics can be seen as a major opportunity to strengthen the productivity and international competitiveness of macro- and micro-economic entities within the European Union and on a global scale, as well. Thereby, a smart system can be understood as a system that uses a combination of human-based processes supported by real-time data from actors and sensors by applying an embedded approach. After reflecting on the term smart system, this paper discusses the potential of smart systems integration by focusing on the research area of industrial logistics in manufacturing enterprises. Moreover, the authors present a framework for the usage of smart logistics in manufacturing enterprises. Therefore, based on a literature review and multiple case studies, the authors outline a set of exemplary research initiatives in the field of smart systems integration and discuss preliminary research findings. Finally, future perspectives for both research and practical applications are presented.

Peer-review under responsibility of the scientific committee of the 3rd International Conference on Industry 4.0 and Smart Manufacturing

Keywords: Logistics 4.0; Smart Logistics; Smart Systems; Industrial Logistics

1. Introduction

Current Industry 4.0-related research initiatives are primarily focusing on the investigation of the integration of smart systems in industrial logistics because this is considered as one of the main opportunities to enhance the logistics performance and/or decrease the logistics costs of both, larger corporations, and small and medium-sized enterprises.

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By focusing on the concept of smart systems integration (SSI), this paper exploratively demonstrates a set of possible applications of SSI in the context of industrial logistics in manufacturing enterprises. Therefore, the general structure and the overall research process of this paper are structured as displayed in Table 1.

Table 1. Paper structure.

Introduction	Topic relevance Paper structure
Main part	Step 1: State-of-the-art literature review on Smart Systems Integration (SSI) Step 2: Conceptualization of SSI in the area of Industrial Logistics Step 3: Evaluation of exemplary research initiatives regarding the SSI in Industrial Logistics
Conclusions and implications	Practical projects Future research

In the first step of the main part (section 2), this paper reflects the term SSI by evaluating the current state of the art in the literature on smart systems integration (SSI) in industrial logistics research, step 2 (section 3) introduces a conceptual framework of SSI in industrial logistic, and step 3 (section 4) demonstrates a set of exemplary research initiatives regarding the SSI in industrial logistics. Finally, in section 5, this paper presents conclusions and implications for practical projects and future research initiatives, as well.

2. Material and methods: Literature review on Smart Systems Integration

In general, there is no precise definition for SSI in the current literature. In the context of this study, the authors deduce a definition by referring to the conceptual approach by the European Technology Platform on Smart Systems Integration (EPoSS) in 2017, which defines smart systems as systems that aim to combine cognitive functions with sensing, actuation, data communication, and energy management in an integrated way. Moreover, within this conceptual approach, the application fields of smart systems are divided into 1) transport and mobility, 2) health and well-being, 3) manufacturing/factory automation, 4) internet of things, 5) energy, 6) natural resources and 7) security [1]. However, all the previously outlined fields of application can be directly or at least indirectly related to the research area of industrial logistics in manufacturing enterprises. Therefore, most findings and conclusions from the EPoSS study are relevant for industrial logistics research.

By using the search string “(TITLE-ABS-KEY ("smart systems integration") AND TITLE-ABS-KEY (logistics))” in Scopus for a first explorative indication, the combination of the keywords resulted in a total of only three relevant research studies, whereby only one study was published within the last five years. Specifically, the identified study by Müller et al. focuses on the necessary adaptation of European transport systems to respond to a multitude of ecologic, economic, and social changes by using a set of strategies and development roadmaps based on the usage of smart systems [2].

Due to the low number of results, the authors revised the search string and found that the usage of “logistics” in combination with “smart systems” provides the best fit to the overarching goal of the paper – that is, to evaluate the state of the art of smart systems integration concepts in the specific area of industrial logistics in manufacturing enterprises. To evaluate the state of the art in scientific literature, the authors focused on the guidelines for systematic literature reviews as suggested by Hokka et al. in 2014 [3]. To ensure only the inclusion of still applicable papers, only research from the last five years in the areas of engineering, business and management, and sociology was searched. The authors included only English-written articles in the literature review and used Scopus as the main database for this research strategy, as, to the best of the authors´ knowledge, it provides the most comprehensive information on scientific articles regarding industrial logistics research. Consequently, the search string was formulated as follows: (TITLE-ABS-KEY ("smart systems") AND TITLE-ABS-KEY (logistics)) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016)) AND (LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "BUSI") OR LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (LANGUAGE , "English")). The literature review resulted in 14 relevant studies. Moreover, the authors performed a forward and backward research based on the identified studies as well as a review of articles in similar databases (e.g., ISI Web of Science, Emerald, Science Direct). The search processes did not lead to significant differences regarding the identified papers. Figure 1 describes the chronological distribution of the identified studies for SSI in the context of industrial logistics in manufacturing enterprises. Due to the relatively small number of articles identified, all were included in the subsequent full-text screening. During the full-text screening, the articles were clustered into three categories, according to their content.

The first category of the identified studies can be assigned to the area of "decision-making support by SSI (DMS_SS)". In this context, Bukowski describes the usage of smart systems for logistics decision-making based on the maturity assessment of imperfect knowledge. The introduced method uses system analysis and focuses on processes that are responsible for obtaining, processing, and using data and information as well as knowledge. The developed framework can be used for a quantitative assessment of knowledge acquired from Big Data analysis. Therefore, decision-making processes can be rationalized under the condition of risk and uncertainty [4]. Mahalakshmi et al. describe a method for productivity improvement in green warehouses by using multi-objective-optimal-trajectory-planning of a warehouse unit to minimize the ecological impacts of logistics operations. Moreover, the authors investigate the implementation of two different optimization algorithms (MOPSO and MODE) to enhance supply chain productivity and profits [5].

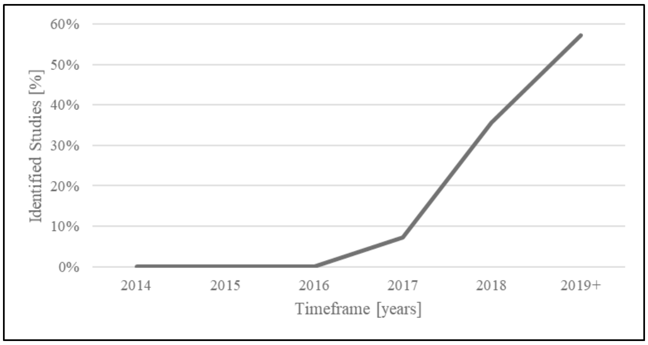

Fig. 1. Identified studies for SSI in the context of industrial logistics.

Ferreira et al. introduce a smart system for the measurement and the subsequent analysis of logistics racks which are used for the transport and storage of parts in the automotive sector. Thereby, they describe a smart system which consists of a Computer-Aided Design (CAD) system for the software-based development of the units, a machine vision system which is based on pattern recognition techniques for the initial parametrization and further improvement, and cloud-based machine learning techniques which allow anticipating failures, identifying problems, and improving management and planning [6]. Bosna et al. and Gebresenbet et al. describe the development of a smart logistics system (SLS). Furthermore, the SLS is evaluated based on field tests in Spain, Germany, and Sweden. Thereby, the focus is placed on the implementation of a smart box tool that captures the process information and a web-based information platform for the monitoring of the material and information flow. The detailed process captures 41 logistics-relevant parameters that can be used to increase the overall system performance of a pruning biomass system [7,8].

The second category of the identified studies is defined as "IoT integration and supply chain alignment by SSI (IoT_SS)". Krithika and Zareena analyze the application of IoT technologies in supply chains. Thereby, they focus on the application of information technology, robotics, internet technologies, business automation, augmented reality (AR) and virtual reality (VR) technologies, etc., in the areas of demand forecasting by using predictive analytics, procurement chatbots, navigation systems, and location tracking. In a nutshell, they conclude that the previously described smart systems, devices, and technologies bring new ventures to the business, cut costs, deliver a higher level of service, and increase customer accuracy by allowing companies to be able to manage devices, scrutinize data, and systematize workflows [9]. Nikolova-Jahn et al. investigate the alignment of information systems for logistics processes in supply chains and propose a framework of a logistics information resource management system that can be used to create better conditions for the information exchange by ensuring a better interaction, lower chances of incompatibility, and faster system performance [10]. Cai et al. analyze a system for the analysis of the gait movement for patients which is used to remotely observe a person´s health condition by using Inertial Measurement Unit (IMU) sensors. This concept can further be transferred to the industrial environment for the analysis of ergonomic working conditions [11]. Ramrez and Lopez investigate the integration and implementation of a smart system that comprises a real-time location system, voice recognition, and augmented reality enabled by the internet of things. Primarily, the prototype is used to track astronauts, but can easily be transferred to different industries such as healthcare, transportation, and logistics, manufacturing, and construction to make them more productive and efficient [12]. Ferrández-Pastor et al. propose an IoT-based distributed computing architecture for the development of smart systems for farmers in both, current and new facilities. The paper describes the implementation of the IoT architecture, operating rules, and smart processes supported by a set of decision trees [13].

The third category of papers deals with “automation and transportation issues by using SSI (AUT_SS)”. Cheng et al. introduce a prototype of a learnable smart system for precise positioning of unmanned transport machines which consists of robotic arms, land vehicles, and unmanned aerial vehicles. The system can automatically deliver light cargo to a designated place. Moreover, the prototype can be used to evaluate the feasibility and performance of a learnable unmanned intelligent transportation system (ITS) [14]. Muthuramalingam et al. investigate the impact of IoT to build smart systems within an ITS. Based on the combination of storing and processing sensor data and computing by using analytics, an ITS was conceptualized for the support of automation of railways, roadways, airways, and marine which should enhance the customer experience by enabling efficient transport, tracking, and delivering of goods. Later, the proposed concept is tested within a case study resulting in superior performance compared to the conventional system [15]. Kumar et al. describe the design of a smart logistics transport system by focusing on a MapReduce model using the Hadoop environment to compute the shortest path for the speedy delivery of goods. Thereby, the proposed algorithm gives a reliable shortest path between any source and destination city with less CPU time compared to a set of similar approaches, like the Bellman-Ford algorithm, the Thorup algorithm, the Gobow algorithm, and the Dijkstra's algorithm [16]. Müller et al. describe European strategic processes towards a competitive, sustainable, and user-friendly electrified road transport. The action plan further proposes the integration of smart systems to reduce CO_2, pollutant emaciation and to increase global competitiveness by a sustainable and economically competitive European transport system based on joint initiatives of the European Technology Platforms ERTRAC (the European Road Transport Research Advisory Council), EPoSS (European Technology Platform for Smart Systems Integration) and the ETIP SNET (former SmartGrids) [2].

To summarize the three directions of research, the information found during the literature review were further visualized in Figure 2 to provide a visualization of the analysis.

Decision Making Support by SSI
- Bukowski [4]: assessment of knowledge gained from Big Data analysis
- Mahalakshmi et al. [5]: minimization of ecological impacts of a warehouse by using multi-objective-planning
- Ferreira et al. [6]: optimization of operations done with rack units
- Bosna et al. and Gebresenbet et al. [7,8]: capturing of material and information flows and visualization of corresponding logistics parameters

IoT Integration and Supply Chain Alignment by SSI
- Krithika and Zareena [9]: describe a smart system by integrating I4.0 technologies for SCM
- Nikolova-Jahn et al. [10]: propose a novel framework for the development of an information exchange platform for SCM
- Cai et al. [11]: analyze a system to remotely track a persons‘ movements, that can be used to optimize industrial ergonomics in the future
- Ramrez and Lopez [12]: investigate a smart system to track astronauts and describe its applicability in other sectors, among others the manufacturing industry
- Ferrández-Pastor et al. [13]: describe a smart system for farmers

Automation and Transportation Issues by using SSI
- Cheng et al. [14]: present a prototype of a learnable smart system for locating unmanned vehicles and its benefits to IST
- Muthuramalingam et al. [15]: develop and test IoT utilization within a smart system within an IST
- Kumar et al. [16]: develops a novel routing algorithm
- Müller et al. [2]: presents an action plan for the european transportation system, incorporating smart systems

Fig. 2. Overview of the research streams identified.

3. Conceptual framework of SSI in industrial logistics

To increase the understanding of SSI in industrial logistics, first, the basic concepts of smart systems are introduced by the authors in accordance with the conceptual framework of smart logistics by Zsifkovits and Woschank [17]. According to the conceptual approach by the European Technology Platform on Smart Systems Integration (EPoSS), smart systems have several essential capabilities, incorporating the Operational Technology (OT) level with Process Technology, Equipment, Materials, and Manufacturing; including it in the Information Technology (IT) level, comprising Computing and Storage; Safety, Security and Reliability; Connectivity and Interoperability; and Architecture, Design, and Integration of Systems and their Components. [1] As one of the key areas of application of smart systems is the Digital Industry, it is not surprising that these essential capabilities coincide with and are the basis to fulfill the main principles of Industry 4.0, which can be classified as interconnectivity, digitalization, and autonomization approaches [18,19]. These principles also reflect the main challenges of another key application area of smart systems, which is Transport & Smart Mobility. In its Strategic Research Agenda, EPoSS states four main challenges for this area, covering the economic and ecologic sustainability of transport; secure connected, cooperative and automated mobility and transportation; human-vehicle interaction; as well as the ramp-up of necessary infrastructure for smart mobility and transportation. Taking these two key application areas and their overlaps into consideration and aligning the EPoSS approach with the conceptual framework for smart logistics by Zsifkovits and Woschank, which is based on enablers and technological concepts such as the Internet of Things (IoT), the Physical Internet (PI), and Cyber-Physical Systems (CPS) [17,20,21], the conceptual frame for smart system integration in industrial logistics is provided.

The basic capabilities of smart systems, combined with the more specified technological concepts of smart logistics enable the implementation of the aforementioned and central principles of Industry 4.0 in logistics of manufacturing companies. In this context, interconnectivity can be assured by the implementation of applications for an intelligent and lean supply chain execution that comprises all relevant stakeholders, digitalization can be established by integrating intelligent logistics based on modern information and communication technology (ICT) and autonomization can be achieved by implementing ITS in combination with autonomous transport vehicles, as well as self-controlled production planning and scheduling systems. All these principles aim at bringing together the worlds of IT and OT, enabling the exploitation of optimization potentials in the movement of physical goods in manufacturing companies regarding the three goals of logistics, which are time, costs, and quality. Since these three target variables only cover the economic dimension and this narrow-minded view is too short-sighted according to the deepest conviction of the authors, the target variables environmental impact and the human factor were added and the logistics triangle was extended to the logistics pentagon [22-28].

A study performed by Capgemini Consulting in 2014 identified the business impact of selected smart features in smart supply chain systems [29] and thereby provides insights into how Industry 4.0 principles relate to the fulfillment of the logistics goals. The major tangible impacts of digitization in supply chain operations were described in the terms of visibility, reliability, and agility. Visibility of any material movements enables early recognition of failures and resolution at the source of inefficiencies and risks, other than just fighting the symptoms of inefficient operations. This makes networks more robust and responsive to perturbations and improves the reliability and precision of forecasts of both demands and stock levels. Because of this, digitally connected supply chains will be leaner, transparency and automation will thus lead to a decrease in cost. They will also be more agile and reactive and/or proactive, by facilitating adaptation to changing requirements. Furthermore, in a smart factory environment, decentralized production control, integrated databases, and advanced analytics will positively impact process cost, batch size flexibility, lead time, and product quality.

In Figure 3, the conceptual framework is visualized, underpinned by examples found in the literature review, the Capgemini study, and the EPoSS paper.

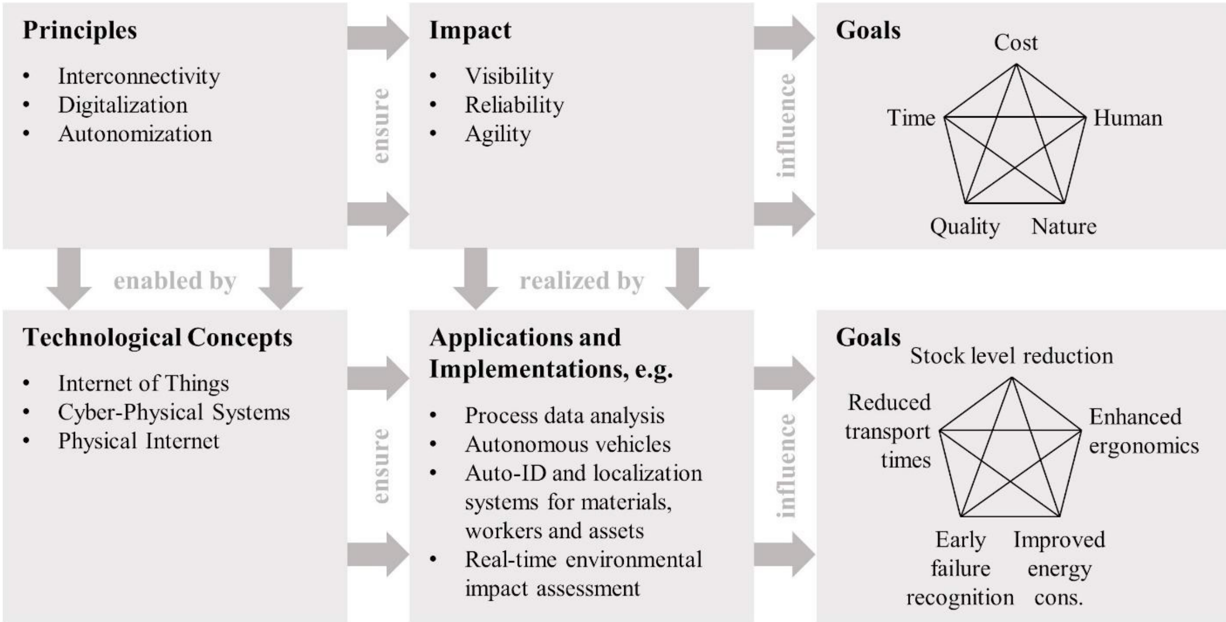

Fig. 3. Conceptual model.

4. Exemplary research initiatives regarding the SSI in industrial logistics

In this section, the authors briefly introduce exemplary research initiatives for SSI in industrial logistics to increase the practical understanding of SSI in manufacturing enterprises. Thereby, the authors focus on the description of the following research initiatives which were conducted by the Chair of Industrial Logistics at the Montanuniversitaet Leoben in the timeframe from 2015-2021:

- SME4.0: Industry 4.0 for SMEs
- KOMOLAS: Cooperative and Modular Intelligent Load Carrier Systems
- INTRALOG: Monitoring and Continuous Optimization of Intra-logistics Systems
- CIMATT: Constant identification and material tracking in the steel industry
- LOGILAB: Learning, teaching, and research laboratory

The project **SME4.0** systematically developed Industry 4.0-related solutions based on smart systems. The term Industry 4.0, as an ongoing digital revolution within the manufacturing industry, tremendously impacts value creation processes in manufacturing enterprises. Large companies have rapidly recognized the challenges and respective barriers of Industry 4.0 and therefore they are intensively working on the implementation of Industry 4.0-enabling concepts and technologies. However, small- and medium-sized enterprises (SMEs) face the challenges of low capacities in terms of skilled workforce, low financial strength, and, therefore, have a high risk of potential failures regarding the implementation of Industry 4.0 initiatives [17,30]. To overcome the challenges and barriers that SMEs face regarding Industry 4.0, relevant fields of action were identified and developed. SMEs can be supported by developing SME-suitable concepts based on smart systems for production, logistics, and organization and management. Key findings of the research projects were models and frameworks that can be used to accelerate the transition of Industry 4.0 from research to practice securing the jobs and ensure the ongoing development of the manufacturing industry [17,30]. One example of such a model is the maturity model for the Industry 4.0-readiness for SMEs.

After reaching their destination in the supply chain, load carriers frequently are not used anymore, must be disposed, recycled, or transported back to the initial supplier. Therefore, an increased development towards cooperative and modular intelligent load carrier systems could create new possibilities for cross-company usage and thus contribute to the continuous development of supply chains. Within the project **KOMOLAS** (Cooperative and Modular Intelligent Load Carrier Systems), the authors investigated the potential usage of cooperative and modular intelligent load carriers as smart systems in the automotive industry. The research results can be used to achieve a reduction of transports and resulting emissions and thus have a positive impact on the environment. The developed reference process and the underlying key performance indicators can further serve as a framework for continuous process development. Moreover, an 'innovation and development roadmap' was deduced as a strategic tool for ongoing projects that provides recommendations for the implementation of cooperative and modular intelligent load carrier systems by focusing on the areas of 'ongoing trends', 'load carrier systems', 'organizations', and 'processes'. Moreover, the roadmap further contributes to long-term strategic development goals, e.g., as defined within the Horizon 2020 strategy [31].

The aim of the research project **INTRALOG** was the development of software solutions for subsequent optimization of internal logistics systems. The goal was to be able to continuously further develop an intralogistics system based on pre-defined economic, ecological, and social targets. Furthermore, the authors considered the flexibility and speed of adaptation as key factors of modern and smart logistics systems within this optimization approach. The project pursued the main philosophy of being able to operate internal logistics processes at the overall optimum, by considering all related resources (facilities, personnel, energy, space/area requirements, material, etc.) with constant changes in requirements (order structures, article growth, delivery times, store optimization, legal framework conditions, etc.), and countless influencing factors. The framework for this approach was created by mapping all relevant processes in a system model, considering the corresponding costs and performance criteria. For this reason, depending on planning parameters (order forecasts, planned turnover, production planning, route planning, etc.), deployment plans could be created and simulations for probable scenarios calculated. By combining performance data and process costs in a system model, holistic optimizations can be carried out and costs can be saved because of the optimized allocation of existing resources. On average (over the entire production period) the usage of the system leads to a higher performance respectively to a higher flexibility. Therefore, the focus was placed on the daily operations and their continuous improvement in a complex and constantly changing environment.

The project **CIMATT** (Constant identification and material tracking in the steel industry) investigated the current state of the art of material identification technologies for manufacturing processes in the steel processing industry. In this industry, initiatives towards digitalization and Industry 4.0 are commonly in quite a premature state. Research is limited and the potential applications still need to be researched. There is an awareness of potential gains in productivity, efficiency, flexibility, and competitiveness, though. A lack of competence in these areas, and the harsh conditions prevailing in the industrial environment, such as high dust and dirt levels, noise, and high temperatures, make the situation more difficult [32]. Simultaneously the requirements from the industry are constantly growing. Nowadays, companies are forced to achieve complete traceability of the finished goods down to a component-based level. Improved identification and traceability at the individual product level would be the basis for adaptive quality control and thus generate a considerable potential for product and process improvement. In addition to significant cost savings within the supply chain, improved quality can also be achieved [32]. Within this project, the authors have developed three different solutions for the usage of continuous material identification and tracking technologies for manufacturing processes in the steel processing industry. The developed concepts can be described as follows: 1) Concept 1 identifies the products at rod level and uses a combination of bar code, laser marking, and inkjet print on paper, 2) concept 2 comprises identification at billet level and uses a combination of color-coding, laser marking, and inkjet print on paper, and 3) concept 3 comprises a laser-based identification at rod level [32]. The proposed alternative solutions were further evaluated in terms of technical, economic, ecologic, and social criteria parameters to be able to objectively select the fitting problem-solution.

Nowadays, Industry 4.0 provides a multitude of approaches for the development of sustainable competitive advantages, especially in the areas of smart production, smart logistics, and organization and management [17,30]. In this context, only a few studies are focusing on the potential requirements of Industry 4.0 initiatives [20,21], especially from a learning and teaching perspective [33]. Based on the concepts of interactive learning, the first learning, teaching, and research laboratory was opened at the Chair of Industrial Logistics at the Montanuniversitaet Leoben in 2014 [34,35,36]. Since then, the **LOGILAB** has been used as a smart system to simulate logistics systems and logistics processes in an environment that represents an isomorphic laboratory setting close to the industrial reality. The laboratory enables the testing and the subsequent development of emerging logistics technologies based on the investigation of logistics systems. As a part of an application-orientated knowledge transfer, students and researchers can develop and test problem-solving approaches based on real-time operations within a logistics system. Within the laboratory, the authors use action-orientated approaches for teaching and learning, as well as simulation and case studies based on the application of industrial technology. The LOGILAB allows the processing of a multitude of logistics processes. The LOGILAB further allows the holistic optimization of intralogistics systems, the bottleneck detection in logistics systems by using a "Shifting Bottleneck Algorithm", the simulation of the sequential combination of various production planning strategies, various applications based on the Industrial Internet of Things (IIoT) in industrial logistics, the testing of Auto-Ident technologies, evaluation of the usage of data glasses in the field of industrial logistics, the improvement of pick-by-light, pick-by-voice and pick-by-vision processes and the automation respectively autonomization of logistics processes (automatic coupling of material flow and information flow processes).

All but the last project were summarized in Table 2 to provide an overview of application areas, key findings, and practical challenges that had to be faced when conducting the project in cooperation with companies.

Table 2. Summarized aims, results, and challenges of the described projects.

Project	SME 4.0	KOMOLAS	INTRALOG	CIMATT
General aim	Understand and foster Industry 4.0 implementation in manufacturing SMEs	Conceptualize the usage of smart load carriers for auto-motive supply chains	Develop software to optimize intralogistics processes holistically, taking costs and performance criteria	Creation of a system for continuous tracking of materials in the steel industry
Application areas of SSI	Digital Industry	Transportation and Smart Mobility, Digital Industry	Digital Industry	Digital Industry
Exemplary key findings/implementations	A maturity model for I4.0 application in SMEs, Production optimization using modern production planning and control strategies and real-time optimization, etc.	Reference process, innovation, and development roadmap	System model taking into account all relevant parameters and costs is used now by a company developing software for operational excellence	Three different concepts, comprising bar code, laser marking, color marking, inkjet printing
Found challenges in SSI	Integration of the human factor in modern production systems	The participation of many actors in the supply chain is necessary	Multicriteria optimization of logistics targets	Missing know-how as well as dust, dirt, noise, and temperatures

5. Discussion and conclusions

The paper analyzes the potential of smart systems integration with a focus on the research area of industrial logistics. A literature review was performed, to describe the basic concepts and elements of smart systems and their role in the industry. The papers and studies were classified into the categories: Decision-making support by smart system integration, IoT integration, and supply chain alignment by SSI, and automation and transportation issues.

The major business impacts of smart systems are described, both from an internal, efficiency-focused perspective and a market/customer-oriented view.

From the main principles of Industry 4.0 which are interconnectivity, digitalization, and autonomization, and a set of enablers and technological concepts, such as the Internet of Things (IoT), the Physical Internet (PI), and Cyber-Physical Systems (CPS), a conceptual framework of smart logistics in industrial enterprises was introduced. The defined conceptual model of SSI in industrial logistics is supported by the findings from the literature review, showing the main areas of current research: the guidance and support of decision-makers, the development of technologies for autonomous transports, as well as the extension of these viewpoints from an inner-company focus to a supply-chain-wide focus.

Consequently, the authors introduce some exemplary research initiatives and discuss research findings. It can be concluded that the various approaches of Industry 4.0 will lead to a transformation of the entire industry, and the trends are already discernible at present. Accordingly, new or changed fields of work are currently developing because of technological progress and the use of new technologies such as AR or VR, which in turn affect the human factor and its transformation. Smart systems require new and enhanced competencies in people, as the human factor must be seen as an integral part of the fourth industrial revolution. Along with the implementation of Industry 4.0 concepts, the requirements for the further development of employee competencies will also increase. These transformative learning processes should enable employees to adapt flexibly to new situations and changing working processes. As part of these learning processes, (future) employees need to be equipped with both specialist competencies and, above all, transdisciplinary competencies such as flexibility, problem-solving skills, and soft skills. Therefore, also from a techno-economics perspective, adapted and/or new learning and teaching approaches, trainings, lifelong learning courses, and appropriate organizational models, like the LOGILAB, must be put in place [35,36].

Furthermore, supplementary findings can be summarized, for future research initiatives and the development of practical applications, as follows [37,38]:

- To make the best possible use of smart systems, a supply-chain-orientated view encompassing all the companies across all tiers of a supply chain, suppliers, manufacturers, service providers, and customers, should be considered.
- Special focus and additional support are required for small and medium-sized enterprises; they account for much of the value-creation and often lack the financial, human, and technology resources for smart systems integration.
- Besides the basic technologies, technology concepts like automated identification, the Internet of Things, the Physical Internet, and Cyber-Physical Systems are the foundation of smart systems and must be continually developed in a step-by-step approach.
- Standardization is critical for interoperability in smart systems. These include standards and modular interfaces in material flow, packaging and loading devices, data exchange, security, and process models.

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