Digitalization in Industrial Logistics: Contemporary Evidence and Future Directions

Manuel Woschank, Alexander Kaiblinger, Philipp Miklautsch
Chair of Industrial Logistics
Montanuniversitaet Leoben
Erzherzog Johann-Strasse 3/1, 8700 Leoben, Austria
manuel.woschank@unileoben.ac.at, alexander.kaiblinger@unileoben.ac.at,
philipp.miklautsch@unileoben.ac.at

Abstract

Industrial logistics is mainly concerned with the analysis, design, and ongoing optimization of material and information flows in industrial enterprises. In recent years, the digitalization movement has created a multitude of new opportunities to ensure long-term competitive advantages through the systematic improvement of logistics performance and/or a stepwise reduction of logistics costs. In this paper, the authors analyze the current literature on digitization in the field of industrial logistics with a particular focus on action-oriented research findings. Thereby, the authors systematically investigate recent studies on 1) technologies and technological concepts of digitalization in industrial logistics, 2) enablers of digitalization in industrial logistics, 3) risks of digitalization in industrial logistics, and 4) opportunities for digitalization in industrial logistics. Moreover, based on the secondary-data-based content analysis, the authors identify promising areas of action for future research initiatives.

Keywords
Industry 4.0; Logistics 4.0; Smart Logistics; Digitalization; Digital Transformation; SME; Industrial Logistics

1. Introduction
The fourth industrial revolution (Industry 4.0) postulates that the systematic integration of digitalization technologies in production and logistics processes of industrial enterprises will lead to higher performance and/or lower costs and, therefore, contributes to the long-term growth and to the sustainable assurance of competitive advantages (Matt et al. 2020; Woschank et al. 2020a). In this context, recent studies generally distinguish between Industry 4.0 concepts and technologies (Woschank and Zsifkovits 2020; Zsifkovits and Woschank 2019) respectively, between an implementation-orientated ("digital transformation") view and a technology-based ("digitization") perspective (Ralph et al. 2020). However, there still seems to be a missing understanding regarding the possibilities of digitalization initiatives in the specific area of industrial logistics in industrial enterprises. To the best of our knowledge, recent literature does not offer a profound classification of Industry 4.0 technologies that can be regarded as suitable for the application in industrial logistics operations, like the optimization of material flows and/or information flows, factory planning, layout planning, etc.
From a techno-economics perspective (Zunk 2018), this paper systematically analyzes the current literature on digitization in the field of industrial logistics in manufacturing enterprises. Moreover, the authors develop a framework that identifies promising areas of action for future research initiatives and practical-orientated optimization projects.

2. The Role of Industrial Logistics in Manufacturing Enterprises
In the understanding of the authors, industrial logistics in manufacturing enterprises primarily focuses on the processes of planning, implementing, controlling, and continuously optimizing efficient material flows and the related information flows to satisfy customer requirements (Christopher 2016; Grant et al. 2006). Thereby, the major goal of industrial logistics can be defined as delivering the right product or service, in the quality and quantity, at the right costs, at the right time, to the right place. In this context, 'right' is defined by the customer requirements and/or by the overall corporate strategy. Summarized, industrial logistics is concerned with the movement of moving materials from the supplier to the company (inbound logistics), the movement of materials to customers (outbound logistics), and, of course, the movement of materials within the organization (internal logistics). Materials are all things that need to be

handled to manufacture the company's products. These materials can be both tangible, for example, raw materials, and intangible, e.g., information and/or knowledge (Zsifkovits 2013; Grant et al. 2006; Waters 2006). Moreover, the authors postulate that industrial logistics operations bear a significant potential, and, therefore, should not be limited to basic logistical functions, such as transport, transition, and storage. The logistics performance of a manufacturing enterprise can be an important competitive factor and a unique selling proposition compared to the competitors. However, the rather conservative concepts of process improvement in industrial logistics are starting to reach their boundaries. Consequently, industry and research must increasingly search for new approaches to improve material and information flows. As mentioned in the introduction, digitization initiatives offer a wide range of opportunities for industrial logistics, which will be investigated in this paper (Woschank 2012; Engelhardt-Nowitzki and Oberhofer 2006). Furthermore, from a theoretical perspective, researchers must continue to contribute to the improvement of the theoretical framework of industrial logistics. It must be noticed that to the best of our knowledge, there is still no comprehensive theory of industrial logistics. Therefore, future research projects should continue to contribute to a more holistic theoretical framework by transferring suitable organizational theories (e.g., behavioral decision-making, resource-based view, institutional economics, etc.) to the theoretical foundation of industrial logistics in manufacturing companies (Zsifkovits 2013; Nyhuis 2008).

3. Literature Review

In this paper, the authors used a systematic literature review to determine the state-of-the-art in academic research regarding digitalization initiatives in industrial logistics. Based on the guidelines for systematic literature reviews the authors followed the subsequent steps: 1) Definition of the research objective, 2) framing of the research subject (conceptual boundaries), 3) data collection by using inclusion/exclusion criteria, and 4) validation of the research results (Woschank et al. 2020a; Durach et al. 2017; Gough et al. 2017; Hökkä et al. 2014; Petticrew and Roberts 2006). In general, the authors focus on the investigation of the recent literature on digitalization initiatives in the specific area of industrial logistics in manufacturing enterprises. The authors want to understand how this research topic evolved during the last years as well as how the results can be used as a starting point of new research initiatives. The research subject (conceptual boundaries) was defined by using the terms "digitalization", "digital transformation" and the more generic term "Industry 4.0". The authors used Scopus as the main source for the systematic database queries because it was identified as the most relevant database for scientific publications in the areas of industrial engineering and management sciences from a techno-economics point of view (Woschank et al. 2020a; Zunk 2018). In this context, a comparison with similar databases (e.g., Web of Science) did not lead to significant deviations in the resulting research studies (Woschank et al. 2020a). By combining the keywords "digitalization", digital transformation", or "industry 4.0" with the Boolean operator "OR" in the areas of "industrial logistics", "smart logistics", or "logistics 4.0" we focused on high-quality studies published in conference proceedings, as articles, or as book chapters in the timeframe from 2015 to 2020 in English. Therefore, the metasearch query was formulated as follows: (TITLE-ABS-KEY ("digitalization" OR "digital transformation" OR "digitization" OR "industry 4.0") AND TITLE-ABS-KEY ("industrial logistics" OR "smart logistics" OR "logistics 4.0")) AND (LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "ch")) AND (LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "BUSI")) 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) OR LIMIT-TO (PUBYEAR , 2015)) AND (LIMIT-TO (LANGUAGE , "English")).

In sum, the authors identified a total of 66 research studies for the subsequent analysis (November 5th, 2020). Consequently, the descriptive data of the identified studies will be analyzed in the next paragraphs. Regarding the type of research study, four studies (6.06%) are book chapters, 35 studies (53.03%) are conference papers, and 27 studies (40.91%) are articles. Four studies (6.06%) were published in 2016, five studies (7.58%) were published in 2017, eleven studies (16.67%) were published in 2018, 24 studies (36.36%) were published in 2019, and 22 studies (33.33%) were published in 2020. Thereby, out of the 66 research studies, 29 studies (43.94%) are published as open access documents. By focusing on the investigation of research collaborations, the data revealed that only two studies (3.03%) were written by one single author, eleven papers (16.67%) were published by two authors, 24 studies (36.36%) were published by three authors, 14 studies (21.21%) were published by four authors, ten studies (15.15%) were published by five authors, and five studies (7.58%) were published by more than five authors. The majority of studies (23 studies; 34.85%) were published by only one affiliation, 19 studies (28.79%) were published by two affiliations, 16 studies (24.24%) were published by three affiliations, five studies (7.58%) were published by four affiliations, and only two studies (3.03%) were published by more than five cooperating affiliations.

In the next step, the 66 studies were analyzed based on the quality criteria for systematic literature reviews. Thereby, an independent research team classified the total studies by screening the title and abstract in studies with "high appropriateness", "medium appropriateness", and "low appropriateness" regarding the predefined aim of this paper.

Papers without significant differences were included or excluded in/from the research process. Papers with significant differences were reevaluated by the research team to get unambiguous research results (Woschank et al. 2020a; Durach et al. 2017; Gough et al. 2017; Hökkä et al. 2014; Petticrew and Roberts 2006).
The process resulted in 20 high appropriate studies (30.30%) for the subsequent full-text analysis. Based on the grounded theory approach, and by using quantitative content analysis (Breuer et al. 2019; Equit and Hohage 2016; Mayring 2015), the research team developed the following four categories for the subsequent in-depth analysis: 1) Technologies and technological concepts of digitalization in industrial logistics, 2) enablers of digitalization in industrial logistics, 3) risks of digitalization industrial logistics, and 4) opportunities for digitalization industrial logistics.

3.1 Technologies and Technological Concepts of Digitalization in Industrial Logistics

Greif et al. stated that the construction industry is one of the least digitalized industries. In collaboration with a leading supplier of building materials, they developed a concept for a lightweight digital twin for bulk silos. According to this concept, silos should be equipped with a filling level sensor and a communication device. A transformation from a product supplier to a service provider can be achieved due to the obtained information. Furthermore, a new routing approach is developed. Based on this approach, a decision support system is described. To evaluate the concept a simulation model is created. As a preliminary result, the historical data of the last three years indicate a truck costs reduction of 25% as well as a CO_2 emission reduction (Greif et al. 2020). In an investigation on Industry 4.0 technologies in the field of logistics in automotive plants, the following technologies were identified by Markov and Vitliemov: IoT, blockchain, cloud storage, machine-to-machine communication, AGVs, advanced robotics, and AI (Markov and Vitliemov 2020). Based on the activities in logistics centers and a literature review, Yavas and Ozkan-Ozen identified twelve criteria for the concept of a logistics center 4.0. In particular, the following criteria are mentioned: Smart handling, zero-emission, smart mobility, freight exchange platforms, digital information platforms, intelligent transportation systems, information security, real-time location systems, logistics center alliances, as well as digital connectivity. A survey with seven participating logistics experts regarding the interdependencies of the criteria was evaluated by a Fuzzy DEMATEL approach. The results show that smart mobility, digital transformation platforms, and intelligent transportation systems have the most influence on the above-mentioned criteria. Digital information platforms were also highlighted as very important (Yavas and Ozkan-Ozen 2020). From the Industry 4.0 pillars, Verma et al. derived seven pillars, which are relevant for logistics. In this context, they mentioned CPS, big data analytics, IoT, cloud computing, system integration, autonomous robots, and simulation as important pillars (Verma et al. 2020). Moreover, Elfirdoussi et al. summarized a set of Industry 4.0 technologies that are relevant for logistics processes. The following technologies are worth mention: AI and OR, IoT, internet technologies (such as EDI, web portals, web services, or big data), and cloud computing (Elfirdoussi et al. 2020). In the Norwegian Logistic 4.0 Lab at the NTNU, a new logistics concept was developed based on the principles of cloud manufacturing. Thereby, the authors differentiate between material handling modules (MHM), smart objects (SO), and an intelligent cognitive engine (ICE). MHMs and SOs are aware of their position and status and are connected with the ICE. Transportation or handling requests of an SO are coordinated by the ICE. Idle MHMs will be considered for the job. The MHM which seems to provide the best solution according to their decision parameter will be suggested or selected for the job. Besides communication devices, indoor positioning technologies (IPT) are needed to realize such a decision support system. Connected Systems like this create big data, which can be used for detailed data analytics. With the use of machine learning (ML) algorithms, in this cloud material handling system, dynamic routing and advanced scheduling will be enabled (Sgarbossa et al. 2020). In connection with high-valued goods, Frontoni et al. elaborated a concept for an Italian shipping company to combine a set of lean approaches and Industry 4.0 technologies. Therefore, they suggest RFID technologies for automated identification. To increase physical security and safety aspects, infrared barriers and anti-masking detectors should be used. The combined data should be collected in a SaaS solution so that only one interface must be used. Access control, data encoding, as well as data analysis, should be handled by this system. (Frontoni et al. 2020). Teucke et al. suggest a sensor-based approach to observe negative environmental impacts on the product quality during transport processes in the automotive supply chain. The usage of mobile sensors near to the products, gateways which collect the sensor data and transmit data to a central sensor database, RFID technologies for identification, GPS technologies for tracking, and a cloud-based platform which analyzes the data and reports critical events to the stakeholders by using EPICS standard based on Cyber-Physical Logistics Systems (CPLS) are described in this paper. Based on the results of a discrete-event simulation, different scenarios in an exemplary supply chain (no defects / random defects with no monitoring / random defects with monitoring) were simulated. Thereby the researchers found that earlier recognitions of quality problems and shorter reaction times can lead to more stable stocks and reduce logistics-related costs (Teucke et al. 2018).

Ellefsen et al. sought to assess the maturity of AI applications in European companies within warehousing and production processes. Therefore, they performed a literature analysis on AI maturity models and their applications in logistics, combined a maturity model for AI with a maturity model for Logistics 4.0 to assess AI readiness, elaborated a questionnaire regarding the current situation of the development of AI applications in logistics, and analyzed two Norwegian and two Polish companies by conducting a multi-case study. All investigated companies can be classified as AI novices. Moreover, the whole industry seems to be in an earlier stage regarding AI applications. To prove this hypothesis further research will be needed (Ellefsen et al. 2019). Schmidtke et al. performed a literature review and presented requirements, technical potentials and innovations, constraints, and a new approach regarding the role of the human in internal logistics operations. The current research on technologies for continuous material and information flow in internal logistics focuses on cellular transport systems, AGVs, intelligent containers, mobile terminals, and cloud IT platforms which should be used to ensure a continuous recording of data (Schmidtke et al. 2018). Lee et al. presented and assessed the effectiveness of a framework for an IoT-based warehouse management system (WMS) for a low-volume, high-product mix warehouse. Therefore, they carried out a literature review on challenges of warehouse operations in the era of Industry 4.0 and research on IoT for WMS, elaborate a framework for an IoT-based WMS and developed a fuzzy inference engine to select the proper order picking method based on product details. The developed framework was tested in a manufacturing company within the scope of a case study. The framework uses RFID identification technology, wireless sensors for tracking and tracing, and an EPC information server for data storage. Host applications poll the data from this server and integrate the fuzzy inference system as well as online JavaScript reports (Lee et al. 2018). By using a literature analysis Barreto et al. created a definition of Logistics 4.0 which includes the usage of CPS and IoT in logistics processes. The CPS includes wireless embedded sensors and actuators, control processing units, and communication devices. IoT facilitates the way CPS can interact due to better communication and cooperation technologies. Intelligent WMS which used RFID and tracking and tracking technologies, intelligent transportations systems that use mobile end devices, cloud-based services, and GPS, as well as machine to machine communication ensure “Smart Logistics”, which is defined in the same approach as “Smart Products” and “Smart Services”: systems that relieve the employees of repetitive work so they can focus on more intelligent and creative tasks (Barreto et al. 2017).

3.2 Enablers of Digitalization in Industrial Logistics

Based on a systematic literature review, Cuenca et al. described that a successful digital transformation is related to four main factors: Clear process definitions, defined implementation steps, people training, and standardization of the implementation process (Cuenca et al. 2020).With an explorative approach based on a systematic literature review, Dallasega et al. carried out six workshops with 37 SMEs and 67 participating experts to define requirements for digitalization in logistics for small and medium-sized enterprises (SME). The resulting 548 statements were clustered into nine main prerequisites: Lean and agility, real-time status, digitization, connectivity, and networks, tracking, PPC and WMS, culture, people, and implementation, security and safety, ease of use, transportation; and automation. Advanced planning techniques will be necessary to ensure flexible supply chains with reduced stocks and increased material efficiency. Quick access to short-time information is a prerequisite to minimize supplier risks, monitor infrastructure, and enable predictive maintenance. The necessity for enhanced customer-supplier-communication is outlined to share capacities, materials, infrastructure, and information. This includes all-time availability of information, visualization of data, and its storage in a uniform database. PPC technologies must become more flexible to react to short-time changes in demands, WMS will need to record inventory levels automatically and visualize stocks and accurate locations in the picking process. The need for top management commitment is as important as the need for qualified personnel and training in digital skills. In terms of security systems to increase workplace safety and systems to increase data security are mentioned. High usability of the introduced smart systems is necessary to ensure efficient communication and acceptance of the tools. Experts pointed out, that the use of automation in production and logistics processes has to be enlarged to reduce physical workload (Dallasega et al. 2020; Woschank et al. 2020b; Dallasega et al. 2019). Schmidtke et al. point out that data transparency and appropriate standards and regulations must be developed further so that cross-technology communication can be ensured. Once these data are available, internal possibilities to analyze and generate information out of it must be established. To gain acceptance for these technologies, employees have to be familiarized with new technical innovations (Schmidtke et al. 2018). In the study of Delfmann et al., the scientific advisory board of the Bundesvereinigung Logistik (BVL) formulated eleven central research questions that must be answered in the context of Logistics 4.0. Concerning the ongoing decentralization, they proposed that new models of decentral decision-making and performance measurement metrics will be necessary. New ways of developing, assessing, and launching logistics products and services may be needed due to the high speed of innovation. Further standardization of supply chain management will be supported by the decoupling of near-real-time operations from the normative planning. Further KPIs to assess flexibility in the supply chain must be developed and will extend current indicator systems. To guarantee the functionality of distributed logistics services across companies, neutrally designed platforms, as well as clearly defined rules and processes, must be established. New and standardized approaches will be necessary to ensure that decentral decisions of actors with different economic objectives contribute to the overall strategy. Due to rising investments in logistics infrastructure, new models of ownership to share resources as well as new approaches to assign orders to these resources are required. A system for skill development and informal learning must be created for all groups of personnel to ensure optimal utilization of cognitive skills. On the other side, machines must also be able to learn communicational and behavioral aspects to interact with humans (Delfmann et al. 2018). Moreover, Barreto et al. point out that cybersecurity is one of the most critical requirements for Logistics 4.0 systems to work. (Barreto et al. 2017).

3.3 Risks of Digitalization in Industrial Logistics

The survey conducted by Markov and Vitliemov focused on the major challenges regarding the implementation of digitalization technologies. The results show that cyberattacks via internet-connected assembly lines may shut down production processes. Another high rated challenge describes incorrect data in blockchain portals, which can lead to increased costs (Markov and Vitliemov 2020). In addition to the degree of implementation of Industry 4.0 technologies, a survey by Verma et al. focused on Industry 4.0-related risks. Thereby, the following risks were identified: (Cyber) security, privacy, and trust, high investment and setup costs, lack of technical skills and standardization, lack of infrastructure, as well as the digital transformation of the legacy system, and the resistance to change (Verma et al. 2020). According to a survey by Kucukaltan et al., cyberattacks will be a real threat to connected machines and personal data. Consequently, professionals believe that security and protection costs will increase (Kucukaltan et al. 2020). The role of the human in Logistics 4.0 is furthermore discussed by Schmidtke et al. The authors mention that some manual activities will be replaced by machines due to efficiency, security, and quality issues. Therefore, many workers fear losing their jobs in the ongoing digitization and automation movement which has negative effects on the workers' motivation and causes resistance to change. At the same time, a lack of skilled workers is recognized in logistics. Moreover, the absence of competence in IT security is mentioned (Schmidtke et al. 2018). Ellefsen et al. point out that the ethical and societal issues of the rising intellectual capacity of machines are still unknown and must be considered. Furthermore, it will be a challenge for future employees and managers to gain suitable technological knowledge. This assumption is supported by the fact that respondents in the multi-case studies described above were not able to answer basic questions about the technology currently used in their companies (Ellefsen et al. 2019).

3.4 Opportunities for Digitalization in Industrial Logistics

As already mentioned, Greif et al. showed in their simulation study that a digital twin of bulk silos can contribute to a reduction of transportation costs and CO_2 emission (Greif et al. 2020). In the literature research, Cuenca et al. pointed out two main benefits of IoT devices in logistics, namely flexibility and robustness. Flexibility is achieved by using the local intelligence of the system, meaning that the systems can gain the ability to quickly adapt to new situations, change functionalities, execute new solutions, or supply different products. Moreover, the ability to detect and monitor failures and conduct recovery processes is supposed to improve the robustness of the system (Cuenca et al. 2020). Based on Industry 4.0 technologies in logistics, Markov and Vitliemov described a set of scenarios evaluated by twelve Bulgarian automotive experts, according which the most likely benefits of Industry 4.0 in the automotive industry are an increased customer satisfaction due to transparency in production and cost savings due to real-time information and shared data between all participants in the supply chain. Furthermore, they pointed out that AVGs could reduce transportations by up to 20%, but this does not automatically imply an increased production rate of 20% (Markov and Vitliemov 2020). Kucukaltan et al. formulated potential impacts based on the usage of Industry 4.0 technologies by logistics service providers. In a survey, 24 Turkish professionals stated the following implications: Regarding human resources, it was proposed that the number of employees working at the operational level will decrease. Also, the use of AGVs and robotics will cause a reduction in workforce, whereby AGVs simultaneously will lead to increased efficiency in delivery processes. AR technologies will reduce workforce failure. Human-robot collaboration in logistics is also seen as probable. Regarding financial management, costs in general and especially maintenance costs, as well as resource consumption, will decrease. The fourth industrial revolution will also lead to a faster acceptance of new technologies. The latest technology-related operational activities indicate that automated identification will be a standard; therefore, fast end secure access control will be enabled. Intelligent, automated planning, and control systems will be mainly used. With cloud solutions, new platform-based business models can be used and will lead to increased efficiency in logistics. Especially in logistics and supply chain networks, Industry 4.0 technologies will increase the transparency of supply chains and inventories. Moreover, businesses will commonly use electronic

environments. Sustainability applications will be improved, and innovation capabilities of logistics companies will increase. Real-time data and data analytics improve customer experience and operational efficiency, also reducing the bullwhip effect. The results also suggest a less damaged information flow due to the cloud-supported networks (Kucukaltan et al. 2020). Moreover, a cloud material handling system, as described by Sgarbossa et al., integrates non-electronic devices into a cloud-based system. Machine learning algorithms enable the adaptability of transport orders in real-time as well as efficient, dynamic, and complex planning. Also, capacity sharing between many companies will be possible (Sgarbossa et al. 2020). Lean production concepts in combination with Industry 4.0 technologies should lead further to a cost reduction, a reduced lead time, and a higher physical security level. Therefore Frontoni et al. developed a security concept for higher-value goods (Frontoni et al. 2020). Also, the use of sensor-based quality measurement in combination with supply chain event management could generate savings in logistics-related costs as previously mentioned (Teucke et al. 2018). With the use of AI in logistics, jobs will become easier and safer. At the same time, productivity, and quality of life should increase (Ellefsen et al. 2019). Using a literature review and conceptual research, Strandhagen et al. tried to link sustainability, business models, and Industry 4.0 as well as Logistics 4.0. They proposed a model for Logistics 4.0 and its relation to logistics business models as well as the relation to sustainability and pointed out that there is a circular relationship between these three aspects. Changes in requirements due to regulations or customer pressure will affect key logistics activities and will lead to more sustainable actions and business models which could also be economically beneficial (Strandhagen et al. 2017).
Schmidtke et al. point out that Logistics 4.0 will have positive effects on energy and resource efficiency, reduction of waste, service-driven business models, one piece flow, product quality, and highly customized products which imply an increased customer loyalty. Furthermore, assistance systems will increase workplace security for the employees (Schmidtke et al. 2018).The results of the conducted case study by Lee et al. show that the use of an IoT-based WMS improves the efficiency of the receiving process, order fulfilment performance, inventory accuracy, and efficiency of order picking by proposing a suitable order picking method (Lee et al. 2018).According to Barreto et al., a Logisitcs 4.0 system which includes resource planning, WMS, TMS, intelligent transportation systems, and information security could lead to reduced time to market, raise asset employment, prevent out-of-stock situations, increase the ROI, ensure more safety in processes and pave the way for more sustainable logistics operations through added transparency (Barreto et al. 2017).

4. Discussion

Based on the identified studies, the authors extracted and summarized core statements to gain an overview and derive trends of digitization in the field of industrial logistics in the current scientific literature. Figure 1 presents the statements which were clustered by the authors in the following four categories: 1) Technologies and technological concepts of digitalization in industrial logistics, 2) enablers of digitalization in industrial logistics, 3) risks of digitalization in industrial logistics, and 4) opportunities for digitalization in industrial logistics. Moreover, the collected statements of the different categories were also summarized into subgroups by the authors. The framework developed by the authors is visualized in Figure 1. Thereby, the underlined topics were missing in the identified studies and, therefore, added by the authors.
It is worth mentioning that according to Yavas and Ozkan-Ozen, the aspects of Industry 4.0 are highly related (Yavas and Ozkan-Ozen 2020), therefore, an isolated viewpoint is not suitable. The technologies and technological concepts of digitalization in industrial logistics were further clustered into data science, virtual environments, IoT devices, automatic identification, CPS, location, interfaces, and decentralized applications. Thereby, the identified technologies and technological concepts can be considered as a starting point for further research. Data science is starting to turn data into real value (van der Aalst 2016). Moreover, big data and real-time data generated by other technologies will be turned into increased knowledge by using data mining, AI, ML, and OR algorithms. Dynamic planning, scheduling, and routing can be supported and optimized, allowing decision support systems to be realized (Elfirdoussi et al. 2020; Greif et al. 2020; Kucukaltan et al. 2020; Sgarbossa et al. 2020; Yavas and Ozkan-Ozen 2020). Under the term of virtual environments, the authors summarized the following technologies: Digital twins, simulations, augmented reality, and virtual reality. Virtual environments can be used to test various scenarios and cases which would not be possible or would cause high costs in reality. The data of a real system will be represented in a virtual model or the real system will be enhanced by additional information from the virtual one. In warehouses, AR technologies could be used to reduce workforce failures (Kucukaltan et al. 2020). Technologies that enable so-called augmented reality are used to combine real and virtual content in 3D and real-time. Users can interact with virtual objects placed in a physical environment and are not dependent on the use of conventional GUIs (Billinghurst et al. 2015).

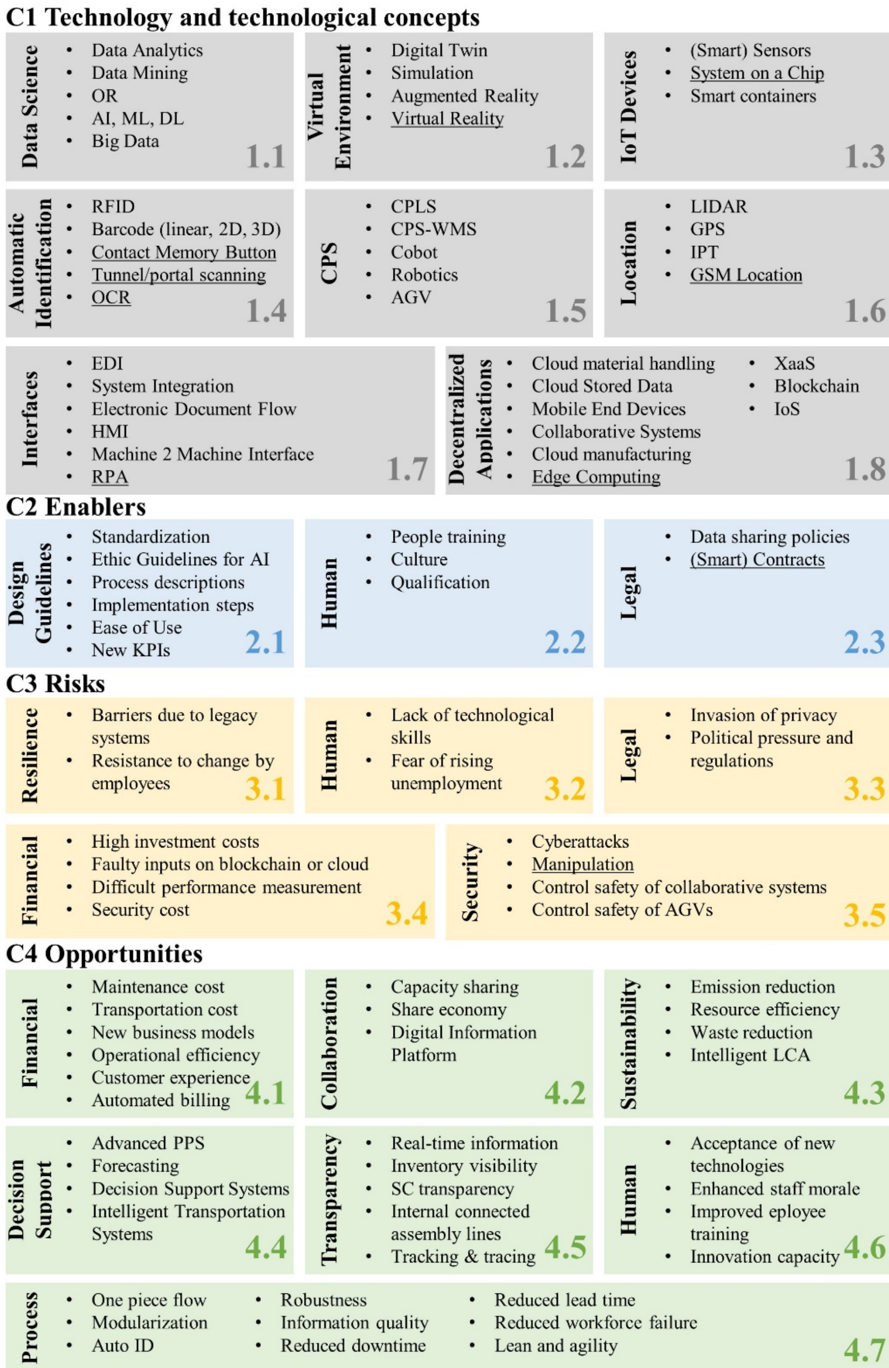

Figure 1. A framework of digitalization in industrial logistics

Virtual reality technologies can provide detailed insights that can be used for employee training. Digital twins provide real-time feedback from their physical counterparts. Information about the characteristics and capabilities of the system can be used to derive simulation models that can extend the digital twin. So, simulations and digital twins can then be the base for data science applications. In this context, a simulation study showed that a digital twin can contribute to save transportation costs and reduce CO_2 emissions (Greif et al. 2020).

The Internet of Things represents a global infrastructure, which connects objects via computer networks. Based on existing and evolving interoperable information and communication technologies, advanced services will be enabled (ITU Recommendation Y.2060 (06/12)). IoT devices have an identification number to identify the different entities, which communicate via IoT (Verma et al. 2020). In the subcluster IoT devices, the authors list several technologies that can be integrated into the IoT. CPSs are also connected via this network, but due to their extensive possibilities and the wide range of topics they cover, they are listed in a separate cluster. In this context, Frontoni et al. described a security concept that includes infrared barriers and anti-masked sensors (Frontoni et al. 2020). With the use of sensors, the physical environment can be observed by digital systems and this can be used to monitor several conditions and transmit the recorded data to a supervisory system through gateways (Teucke et al. 2018). Load carriers and containers that use digital equipment like sensors and are connected to a network are referred to as smart containers. They can monitor environmental impacts and provide this data in real-time (Delfmann et al. 2018). System on a Chip (SOC) should also be mentioned in this context. A SOC is a functional block which can be seen as a stand-alone product and consists of microprocessors, sensor technology, memory technology, etc. So, all functions for a particular programmable computer system are included in a SOC, except for some interface blocks such as display screens, keypads, battery circuitry and so on (Chakravarthi 2020). Regarding identification technologies and technological concepts, the authors summarized technologies for identifying physical objects, which are not connected via the IoT. Automatic identification is considered as the main part of Logistics 4.0 (Yavas and Ozkan-Ozen 2020). For this purpose, the RFID technology is often outlined (Dallasega et al. 2020; Frontoni et al. 2020; Yavas and Ozkan-Ozen 2020,). Also, linear and 2D barcodes are suitable to enable automatic identification. Thereby, the bulk reading capabilities is the main advantage of RFID tags compared to barcodes.

Contact memory buttons (CMB) or touch memory should be further mentioned. Compared to RFID, CMBs tags have larger storage capacities and are suitable for long-term storage. They are used for hazardous and radioactive waste, track aircraft maintenance, and store repair diagrams (Amde et al. 2014). For plain text markings, optical character recognition (OCR) can be used. OCR has been improved over the last years due to ML algorithms. However, tunnel or portal scanning approaches are used to realize automatic identification. Automated identification will enable fast and secure access control (Kucukaltan et al. 2020).

CPS represents a further technological concept and consists of computing power embedded in physical objects with actuators and sensors. They are connected to computer networks and control physical processes via feedback loops, where physical actions influence computing processes, and vice versa (Lee 2010). This technology is also mentioned as the main part of Industry 4.0 in the field of logistics (Dallasega et al. 2020; Verma et al. 2020). As described by Markov and Vitliemov, the usage of AGVs could reduce transportation time considerably (Markov and Vitliemov 2020). Generally, autonomous robots and collaborative robots will increasingly be used for logistics processes (Kucukaltan et al. 2020; Verma et al. 2020,;Yavas and Ozkan-Ozen 2020). The use of these technologies will lead to increased efficiency in logistic processes and decreased workforce in logistics operations (Kucukaltan et al. 2020). As mentioned, Teucke et al refer to the application of CPS used by logistics objects and processes as Cyber-Physical Logistics Systems (CPLS) (Teucke et al. 2018). WMS which makes use of connected objects, people, or processes in a warehouse as a CPS-WMS. The authors mention that the integration of these systems will be challenging due to the need for technological and administrative innovations (Lee et al. 2018).

Under the term location, the authors collected technologies for localizing objects of interest. IPT determines the position of an object. Combined with the ability to communicate, these technologies can also be seen as IoT devices. IPT uses infrared positioning systems, ultrasound positioning systems, vision-based positioning systems, or radiofrequency position systems to determine their position in a building (Sgarbossa et al. 2020). These technologies have different limitations and accuracies, so it is important to select a technology according to the intended use. Also, GPS and GSM location can be used for outdoor applications. LIDAR is a technology that emits light and detects its reflections. This enables speed and distance measurements. Thereby gained 3D information can be compared with a prior map and, thus. it can determine its position.

Interfaces are also mentioned in many studies. To enable communication between the several devices, communication protocols and standards must be defined. Therefore EDI-standards ensure communication and cooperation among different participants of the supply chain (Elfirdoussi et al. 2020). Also, machine-to-machine communication can be used to link production lines, resulting in greater transparency in production (Markov and Vitliemov 2020). On the other hand, interfaces between humans and machines must be considered, to ensure easy handling of Industry 4.0 applications. Dallasega et al. show the importance of easy-to-use systems (Dallasega et al. 2020; Woschank et al. 2020b; Dallasega et al. 2019). Furthermore, the integration of systems is the main part of logistics 4.0 to provide all business functions at a common platform (Verma et al. 2020). Companies investigated by Ellefsen et al. seemed to be interested in modernizing and automating the information flow processes. Although only bigger companies showed interest in technologies such as data analysis and real-time data, systems to enhance and optimize the digital document

flow seem to look attractive also to smaller companies (Ellefsen et al. 2019). An unmentioned technology in current literature is robotic process automation (RPA) through which, repetitive, simple tasks done on computer systems can be automated. An RPA robot interacts thereby with the user interface of one or more software systems in the same way as a human would do, so lavish interfaces are bypassed, and employees are relieved (van der Aalst et al. 2018).
Due to the use of decentralized entities in the context of Industry 4.0 decentralized software applications have to be presented. To comply with this request, cloud-based IT infrastructure, platforms, and software are introduced and provided as a service. The combination of these infrastructure-, platform- and software-as-a-service concept is called "Everything-as-a-service" (XaaS) (Schmidtke et al. 2018). The use of cloud-stored data, SaaS, and mobile end devices (e.g., smartphones) can, for example, lead to higher transparency in transport processes (Barreto et al. 2017). Edge computing is a concept where computing power is shifted away from central servers to the edge of the internet, close to sensors, mobile devices, and end-users (Shi et al. 2019). Blockchain technology could be used for secure and decentralized tracking and tracing of logistics objects throughout the supply chain (Markov and Vitliemov 2020; Schmidtke et al. 2018). Based on the concept of cloud manufacturing Sgarbossa et al. developed the already described model of cloud material handling systems, where different participants of logistics processes are connected. If other companies also are integrated into such systems a collaborative system can be achieved (Sgarbossa et al. 2020). According to the concept of IoT, an Internet of Services (IoS) can be defined. IoS should lead to the reuse and compilation of existing resources and services for new purposes (Reis and Gonçalves 2018).

5. Conclusions and Implications

In this paper, a literature review was conducted to analyze current research in the field of digitization in industrial logistics in manufacturing enterprises. All in all, 66 papers were identified by the SCOPUS search and for the subsequent abstract screening. Thereby, 20 papers were considered as highly pertinent for this research study. Based on qualitative content analysis, the studies were clustered into four categories, namely: 1) Technologies and technological concepts of digitalization in industrial logistics, 2) enablers of digitalization in industrial logistics, 3) risks of digitalization in industrial logistics, and 4) opportunities for digitalization in industrial logistics. In this paper, the technologies and technological concepts were discussed in more detail due to the fact, that they can be considered as the basis of any digital transformation. The paper concludes with a discussion of current literature and implications for future research, as provided in the next paragraphs.
First, it should be noted that an overwhelming majority of the analyzed literature conducts expert interviews or literature analysis in which risks, opportunities, and enablers of technologies used in the context of digitization and Logistics 4.0 were collected and assessed. Only two studies present simulation-based results (Greif et al. 2020; Teucke et al. 2018) of a specific application, and in one paper case studies were conducted (Ellefsen et al. 2019). Furthermore, only one paper described a real system that uses Industry 4.0 technologies in logistics (Sgarbossa et al. 2020). Moreover, most of the identified studies were published in conference proceedings by one or two affiliations and, therefore, mostly without international research cooperation.
In the reviewed literature some scenarios for digitized companies in the field of industrial logistics have been described. However, the descriptions often neglected the importance of digital transformation. None of the analyzed papers present ways to include, motivate, and pick up the blue- and/or white-collar staff. Nevertheless, some impacts of Industry 4.0 on human resources and the workforce were mentioned and qualitatively assessed (Dallasega et al. 2020; Kucukaltan et al. 2020; Markov and Vitliemov 2020). In many papers, the importance of this employee commitment is reported, but only one paper also mentions the management commitment as a decisive factor (Dallasega et al. 2020; Dallasega et al. 2020).
Although there seems to be a consensus on the positive effects of digitization on sustainability and new business models in this context, only one paper treats this topic (Strandhagen et al. 2017). No paper mentions the UN Sustainable Development Goals (SDGs). However, in the opinion of the authors, multiple technologies in logistics could have a direct impact on the SDGs, for example on 'industry, innovation, and infrastructure' as well as on 'responsible consumption and production' due to higher resource efficiency and a reduction of waste. Research that assesses the impact of the digital transformation in logistics on sustainability issues in an empirical way is missing. There is no evidence on how future logistics activities, processes, and technologies could support the SDGs and lead to more sustainable business practices. Because of this, research should be conducted to gain insights into the cause-effect relationships between new technologies and their contribution to sustainability issues within the scope of industrial logistics and new empirical methods to assess these impacts should be presented. Current literature further stresses the importance of security issues. On the one side, cybersecurity will be necessary to protect data and digital environments and, on the other, safety concepts in physical processes are of further interest due to the minimizing distance between and an increasing number of participants in collaborative systems. Missing literature in this field implies that research is needed to measure and ensure safety aspects in digital as well as physical processes in industrial

logistics. Since most of the studies examined are based on expert expectations, the authors found a lack of implementation concepts. In addition to developing such concepts, the authors recommend further studies on digitalization in the field of industrial logistics to be able to quantify the qualitatively described expectations. For this purpose, it is necessary to conduct further simulation studies, laboratory tests, case studies and field studies. Simulations are often used for investigation, prediction, and optimization purposes. Especially discrete event simulations are used in the field of logistics, thereby the capabilities of a logistics system are represented in the simulation model. In combination with real-time data representing the state of the system, a digital twin for industrial logistics could be enabled. The examined literature shows a lack of research in this area. Therefore, further research can focus on requirements, implementation concepts, the reliability and validity of such systems as well as their potential benefits.

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Biographies

Manuel Woschank received a diploma degree in industrial management and a master's degree in international supply management from the University of Applied Sciences, FH JOANNEUM, Graz, Austria, and a Ph.D. degree in management sciences with summa cum laude from the University of Latvia, Riga, Latvia. He is currently a Senior Researcher, Senior Lecturer, and the Deputy Head of the Chair of Industrial Logistics at the Montanuniversitaet Leoben and an Adjunct Associate Professor at the Faculty of Business, Management and Economics at the University of Latvia. He was a visiting scholar at the Technical University of Kosice (Slovakia), and at the Chiang Mai University (Thailand). His research interests include the areas of logistics system engineering, production planning and control systems, logistics 4.0 concepts and technologies, behavioral decision making, and industrial logistics engineering education.

Alexander Kaiblinger completed a master's degree in industrial logistics at the Montanuniversitaet Leoben, Austria. His master thesis was written in cooperation with Plansee SE in the area of simulation-based inventory optimization. At Fronius International GmbH he worked in the field of process design and improvement. In addition, he worked as a leading modeling and simulation expert at Fesios GmbH. Currently, he is a researcher and lecturer at the Chair of Industrial Logistics at the Montanuniversitaet Leoben. His research interests include modeling and simulation of logistics systems, process management, production planning, and control as well as digital factories and digital twins.

Philipp Miklautsch is a researcher and lecturer currently working at the Chair of Industrial Logistics at the Montanuniversitaet Leoben, Austria. He completed his bachelor's and master's studies in industrial logistics at this university and contributed to the VW group's green logistics strategy during his internship and master thesis at Porsche AG. Besides this, he worked as a full-stack SaaS developer at Geo-Line GmbH in the field of geographic information systems. Within his research, he investigates ways to use cloud applications in Logistics 4.0 and tries to improve the performance of green logistics measures in industrial and transport logistics.

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