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Bennet Zander, Kerstin Lange, and Hans-Dietrich Haasis

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Impacts of a Smart Factory on Procurement Logistics

Bennet Zander [1], Kerstin Lange [1], and Hans-Dietrich Haasis [2]

1 – Jade University of Applied Science

2 – University of Bremen

Purpose: In order to keep up with the automation Smart Factories will bring into the market, procurement logistics has to be redesigned to ensure self-organizing production. The purpose of this paper is to examine the future changes of the procurement processes as well as the further role of logistics service providers in the procurement network with references to the building industry.
Methodology: Using an in-depth literature analysis focusing on the needs of a Smart Factory and the state of art of its procurement logistics current gaps are identified. Subsequently, a modified concept for the delivery of the inbound materials is developed.
Findings: The outcome shows, that the traditional truck delivery of the needed goods to a Smart Factory fails to deal with the in-house processes. Solutions have to be generated which provide packaging-free transport to move the already unpacked materials to the production lines more quickly. Furthermore, efficiency gains are identified, which can be generated through the newly adapted procurement logistics concept.
Originality: To-date, Smart Factory research has predominantly focused on internal production processes, without taking the externally required procurement logistics processes into closer consideration. However, significant changes due to wireless communication technologies can be expected in the ordering, transportation, unloading and storage of goods.

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1 Introduction

Driven by the age of Industry 4.0, production companies increase their research in developing a Smart Factory concept to create an autonomous production and logistics environment in which manufacturing systems, tools and vehicles communicate with each other independently (Ruile, 2019). Following, production forecast, resource planning, production control and performance analysis can be carried out through cyber-physical systems (Büchi, Cugno, Castagnoli, 2020; Botthof, Hartmann, 2017). In addition to manufacturing, the manual warehouse, goods receipt and goods issue processes are also to be automated (Wang et al., 2016; Achillas et al., 2019).

However, as these processes are predominantly integrated into the procurement, production and distribution logistics of external third-party logistics providers (3PL), they also have to deal with the requirements of implementing an integrated digital supply chain (Ileri, Bülow, Jansen, 2019). Accordingly, the perspective role of 3PLs in Smart Factories needs to be analyzed. Will they still be necessary in future concepts or could they be replaced by cyber-physical systems, and, if they are still needed, which areas of responsibility they could take on? This research aims to address these gaps.

The focus of this paper is on examining the future changes on procurement logistics processes for the supply of a Smart Factory, as significant changes can also be expected in the ordering, transportation, unloading and storage of goods. In addition, architecture and interface solutions in the collaborative work between the supply chain parties are identified. In this context, the analysis partially refers to the building industry in order to get a more specific reference framework besides the theoretical background.

The paper is structured as follows: After a brief description of the purpose in chapter 1, the applied research methodology is explained in chapter 2. In chapter 3 the terms Logistics 4.0 and Smart Factory Logistics are distinguished and future changes on procurement logistics are defined. Subsequently, chapter 4 provides a modified concept for the delivery of inbound materials to illustrate advantages and efficiency gains, which can be generated through the newly acquired information. The paper concludes with a summary and an outlook in chapter 5.

2 Research Methodology

An in-depth literature analysis according to Baker (2000, pp. 219-247) was performed to identify the state of art of the logistical needs of a Smart Factory regarding procurement logistics. The literature review was conducted using IEEE Xplore, EBSCOhost and Google Scholar in April 2020 focusing on German and English literature from 2014 onwards. The following variety of key words was used:

- (<Smart Factory> OR <Intelligente Fabrik> OR <Intelligent Manufacturing>) AND
- (<Procurement logistics> OR <Inbound logistics> OR <Beschaffungslogistik>)

The key words were first applied to the title, then to the abstract and finally to the text. Publications only addressing production processes based on Industry 4.0 were disregarded for the sake of this paper's limitation to procurement logistics. Furthermore, the found journals were selected with regard to the VHB-JOURQUAL 3 ranking. However, this was only for a prioritized selection of the articles listed with a JQ3-rating A-B. Articles from journals that are not mentioned in one of the ratings were not excluded in principle. The search resulted in 310 papers, which support the scientific knowledge progress and thus represent the final relevant database for the analysis and concept development (see figure 1).

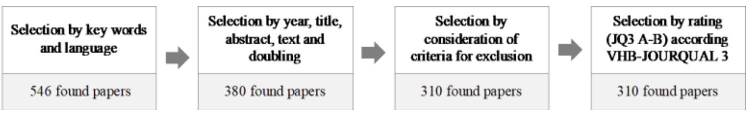

Figure 1: Literature selection sequences

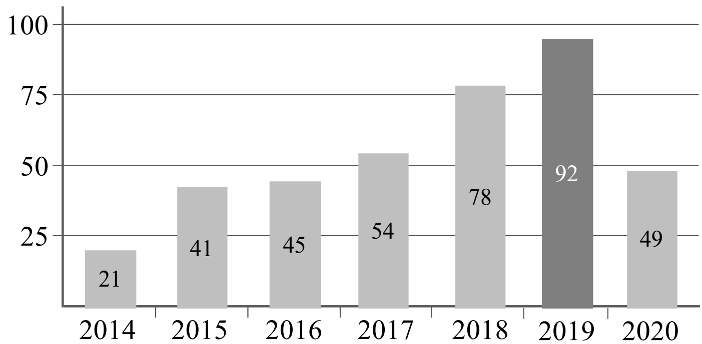

Figure 2: Number of publications since 2014

In the course of the second selection process step, the number of publications per year was also identified (see figure 2). The steady increase shows that the examined topic seems to gain popularity and is explored more deeply the further the 4th Industrial Revolution progresses. Another increase is expected this year since half of all previous year's publications were promulgated in the first four months of 2020.

The final 310 identified publications were then evaluated by using a qualitative data analysis according to Flick (2014) to perform text mining and a content analysis. The analysis used the following two fields in particular:

Field 1: (<Definition> OR <Summary> OR <Concept>)

Field 2: (<Logistics Service Providers> OR <3PL> OR <Outsourcing>)

Applying field 1, the procurement logistics requirements of a Smart Factory were determined in order to define its properties. Building on this and with further consideration of field 2, it was possible to analyze the perspective roles and responsibilities of 3PLs in a Smart Factory and was intended to identify whether they are still necessary.

3 Smart Factory Logistics

3.1 Definition of Terms

The 4th Industrial Revolution includes changing production and logistics processes, management strategies as well as business models. Industry 4.0 has created new opportunities that must be managed and governed to positively impact both business and society (Büchi, Cugno, Castagnoli, 2020). Essentially, Industry 4.0 means the transformation process of a factory into a "Smart Factory", in which its products, workstations and transport vehicles communicate with each other directly and in real time via the internet (Obermeier, 2019). To ensure this, an environment is created in which both manufacturing and logistics systems as cyber-physical systems organize themselves largely without human intervention (Yao et al., 2017). In this vision, the production process is controlled by the products itself. Accordingly, the product carries its production information in a machine-readable form, e.g. on an RFID-chip (Liukkonen, Tsai, 2015). The product knows its physical quality and production status and can thus use this data to manage its way through the factory and individual production steps itself (Kiefer et al., 2018).

In order to characterize a Smart Factory, special reference values are required. These can be distinguished in application, objectives and tasks (Schack, 2007). In this paper, the construction industry is chosen as the area of application for the further procedure, as it is currently undergoing a major change due to the influences of Industry 4.0 (Oesterreich, Teuteberg, 2016). With the help of newly developed technologies, it will be possible in the future to autonomously produce entire renovation packages for houses in Smart Construction Factories. The manufactured products are facade and roof elements which include typical design elements of houses like windows and doors, which can be additionally supplemented with solar panels or heating and ventilation systems. The objective of a Smart Construction Factory is the standardized, cost-effective and faster production of renovation packages for residential properties compared to conventional construction methods (Vestin, Säfsten, Löfving, 2018). The term task refers to the production itself. In this connection, production planning must consider how all incoming goods, warehousing, production and outgoing goods processes can be controlled automatically by cyber-physical systems (Yao et al., 2017).

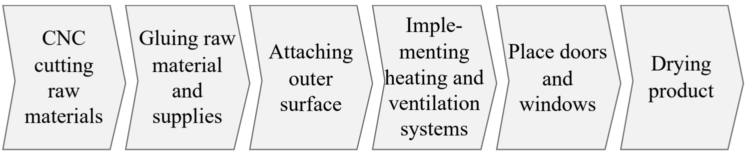

Figure 3: Production steps of a Smart Construction Factory

Figure 3 shows the automated production steps for the facade panel manufacture. In the beginning, the insulation material, e.g. expanded polystyrene (EPS), is cut according to the dimensions of the house with its integrated holes for doors, windows, heating and ventilation systems. This is followed by the gluing process to fabricate a well-insulated panel. Afterwards, the outer surface, e.g. timber, gypsum plaster or bricks, are attached to the wall, before the heating and ventilation systems can be implemented. In the last step, doors and windows are integrated into the facades, so that a finished element is produced, which finally has to dry and then can be attached to the building shell (Landscheidt, Kans, Winroth, 2017).

Among the digitalization of production systems and manufacturing processes, it is also significant to fundamentally adapt internal and external logistical service processes to a Smart Factory. In this context, two types of logistics, "Logistics 4.0" and "Smart Factory Logistics", have to be distinguished, as their reference areas differ (see figure 4).

Logistics 4.0 describes the effects of Industry 4.0 and current megatrends on the logistics industry and supply chain management. In a broader sense, this means the support and shaping of Industry 4.0 through the cross-company and cross-sectional function of logistics (Schneider, Hanke, 2020). It is a key approach to the efficient organization of physical and information logistics and a prerequisite for exploiting the potential of digital technologies here (Zsifkovits, Woschank, 2019). The most important technologies include RFID, Artificial Intelligence, automated guided vehicles (AGV), Big Data and Internet of Things (ten Hompel, Kerner, 2015; Haddud, Khare, 2018).

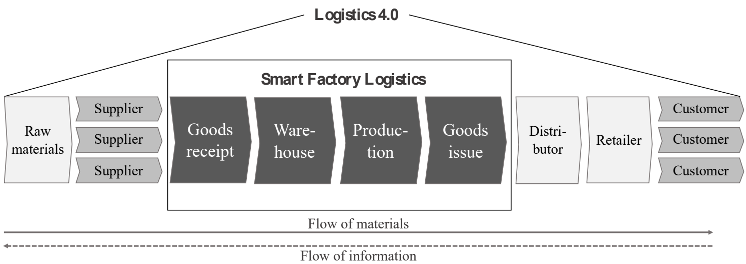

Figure 4: Smart Factory Logistics as part of Logistics 4.0

In Logistics 4.0, members of various vertical value chains integrate themselves into a horizontal value network. As a result, the efficiency (e.g. through automation, response time and error reduction) and effectiveness (e.g. through production individuality) of material and information flows in the supply chain can be increased sustainably (Wehberg, 2018; Steven, Klünder, Reder, 2019). However, this logistical network is exposed to environments characterized by increased volatility and unpredictability. Thus, the need for robustness, flexibility and resilience must become the focus of attention for future logistics system designs. Besides, the aggregation and processing of the gathered data is an important aspect of Logistics 4.0 (Kirch, Poenicke, Richter, 2016).

Smart Factory Logistics, as a combination of Smart Factory and Logistics 4.0, has its origin in organizing the internal transport and information processes of a production factory. It embodies a multi-agent system in supply chain management, since it implements the modern vision of autonomous agents and software objects (Wang et al., 2016). The agents are able to react to events, analyze situations, make decisions and communicate with other agents, which increases the productivity and efficiency of the factory (Cimini et al., 2019; Fiedler, Sackmann, Haasis, 2019). However, even if there are various publications using the term Smart Factory Logistics, no broadly accepted definition is mentioned in science so far. The already considered aspects in literature are now discussed in order to establish an own definition subsequently.

As stated above, products, workstations and transport vehicles of a Smart Factory are linked to each other and independently decide on the correct order of production steps according to available capacities. Their physical logistics processes can be divided into goods receipt, warehouse, production and goods issue (see figure 4) since the general production flow does not differ from a conventional factory (Barreto, Amarala, Pereira, 2017). Within the framework of Smart Factory Logistics, it is crucial that these areas are digitally connected using Logistics 4.0 technologies (Mehami, Nawi, Zhong, 2018; Efthymiou, Ponis, 2019). From an operational point of view, transport vehicles have to supply the production stations with the needed materials at the right time and in the right sequence and also ensure immediate transportation after the production steps. Manufacturing stops can be avoided, which should make the production more efficient (Pei et al., 2017).

In regard to the given description above, an own definition for Smart Factory Logistics is proposed: "Smart Factory Logistics describes the logistics organization of the transport and information processes in a Smart Factory using Logistics 4.0 technologies to enable decentralized control." Thus, efficient Smart Factory Logistics can only work if Logistics 4.0 has been integrated along the logistics supply chain (see figure 4). After the term has now been defined, the impacts on the processes of today's procurement logistics will be analyzed in the further course of the paper. The next chapter deals with the changes, which have to be made in the delivery and unloading of goods, in order to allow autonomy of the in-house processes of the Smart Factory.

3.2 Future Changes on Procurement Logistics

Procurement logistics comprises the connection between the supplier's distribution logistics and the manufacturer's production logistics system.

Its objects are raw materials, supplies and merchandises that have to be made available to the manufacturer as needed. Correspondingly, it is the function of procurement to provide, maintain and develop delivery capacities (Pfohl, 2018; Fleischmann, 2018). Due to digitization of the information flows along the logistics supply chain as part of the Smart Factory development, procurement logistics has to be restructured.

The literature analysis showed that the required changes can be classified into two groups. On the one hand, it is important to consider the ordering processes by the Smart Factory. On the other hand, it is necessary to identify how the physical delivery and unloading of goods by the suppliers will be regulated in future. In order to better illustrate this, the next section is again related to the building industry.

The material ordering of a Smart Construction Factory could be done automatically by ERP-systems (Glas, Kleemann, 2016) or cloud-based Kanban systems (Shahin et al., 2020) according to the pull-principle (Waibel et al., 2017). Depending on the building type of the house, the order is either placed as soon as the minimum quantity has been reached in the warehouse or as part of an individual order after receiving the product order from the customer. Raw materials, e.g. EPS, and supplies, e.g. glue, mounting plugs or fiberglass mats, are rather ordered by the stock replenishment system, whereas individual large orders of merchandise materials with a higher value and importance, e.g. ventilation systems or solar panels, could be placed by separate orders through the product, e.g. the facade or roof panel, itself (Roy, 2017). The product independently searches for the best possible supplier by checking his available stocks and own free production capacities using IoT based Kanban methods. Afterwards, it places an order

and informs him about the required materials, delivery times and sequences (Büchi, Cugno, Castagnoli, 2020).
These processes demonstrate the importance of complete data transparency and accessibility along the horizontal and vertical value chain. Production capacities are timed by the Smart Construction Factory in a way that it is almost impossible to build up own intermediate storage stocks (Roth, 2019). The merchandise materials required for production should be delivered directly to the production line to avoid storage costs and simplify internal processes (Wagner, Herrmann, Thiede, 2017).
The suppliers have to ensure that the required materials are provided in the way they were ordered in terms of quantity, quality, time and location. For a high degree of user-friendliness and to ensure controllability in real-time by the Smart Construction Factory, the process must be as transparent as possible (Bogaschewsky, 2019). After the order has been sent to the supplier, he starts to compile the required materials. In this process, it is crucial that the goods are clearly identifiable so that they can directly be assigned to the built facade or roof panel. A possible option could be the use of RFID-chips (Lu et al., 2017). Furthermore, loading equipment and packaging materials also play an important role, as the in-house processes of Smart Factories in general do not envisage the unpacking of incoming materials in order to keep the processes simple and fast. Accordingly, suppliers should organize the transport with minimized packaging and load securing (Jodin, Landschützer, 2017).
Basis of the self-controlling delivery process is the stabilization of the delivery flow using calculated flexible timetables and GPS tracking. Truck track-

ing should already start during the loading at the supplier's site. Time deviations from the schedule are no longer processed by employees but are recognized and corrected by systems in real-time automatically (Prasad, Babu, 2016). When a truck approaches the Smart Construction Factory, the estimated time of arrival is compared to the calculated time. If a delay is recognized the assigned time window is released and made available to another truck in approach. In this way, the unloading system capacities can be used more efficiently. When the truck reaches the factory, the system should already have sent the delivery note to the incoming goods department. Thus, the truck receives a direct entry permit for the first unloading point and does not need to register at the registration office (Roth, 2019).

Another significant change is expected in the physical unloading of incoming goods at the Smart Construction Factory. Although this will still be realized mainly by loading ramps, no people are involved in the new unloading process (Seder et al., 2019; Mohamed, Al-Jaroodi, Lazarova-Molnar, 2019). Generally, Smart Factories are based on a self-unloading function of the truck by the use of integrated rollers in the loading area (Jodin, Landschützer, 2017; Pfohl, Wolff, Kern, 2020). In contrast to classical unloading no employees of the incoming goods department unload the truck with established systems, e.g. forklifts, and drive into the truck themselves. The used rollers are connected to the floor of the goods receipt as a kind of conveyor belt. As a result, unloading only takes a few minutes. Afterwards, the goods can be separated and checked (Pagnon, 2017). Optionally, there are further autonomous unloading techniques with picking robots or forklifts (Brigant et al., 2018; Custodio, Machado, 2019; Doliotis et al., 2016). An automated unloading process is merely possible if the suppliers are informed in advance about the unloading techniques and adjust the truck loading accordingly. Especially in construction, the materials differ greatly in size, volume and weight, which leads to different unloading techniques for the respective categories.

Furthermore, as the incoming goods are already equipped with an RFID-chip on arrival to be in contact with the product and transport vehicle in the factory during the truck transport, the immediate carriage to the production line can start after unloading (Zakoldaev et al., 2019; Jurenka, Cagáňová, Horňáková, 2018). If production capacities are not available at this time, a corresponding automatic intermediate storage is effected.

4 Concept Development

Winkler/Allmayer (2014, pp. 415-435) state that "accurately planned and designed interorganisational interfaces raise the effectiveness and efficiency of organisations, whereas problems at the interorganisational interface disrupt the value-added processes within supply chain partnerships." Since the internal goods receipt and goods issue processes of an ordinary factory mostly interact with the procurement or distribution network of external 3PLs, their network is linked to suppliers and customers via the service providers. This, in turn, means for the Smart Factory that a Logistics 4.0 concept for the entire supply chain can only be realized if Smart Factory Logistics works accordingly (Fürstenberg, Kirsch, 2017). It is therefore important to analyze the future role of 3PLs in the logistics organization of a Smart Factory.

The area of collaborative work in Smart Factories has not yet been examined in detail in science and hence created a research gap. Only 35 of the identified 310 papers in the literature analysis mentioned the terms of field 2 in their processing. As they do not provide specific solutions, a modified collaborated concept to avoid interorganisational problems is developed in the further part of the paper.

The procurement objective of a Smart Factory is to have all internal goods receipt and transportation processes controlled by cyber-physical systems and to completely dispense with the influence of humans in operation. In future, they should take over only control and programming functions (Spöttl, 2016). As mentioned in the third chapter, unloading is done by automatic systems which belong to the manufacturer. This implies that the 3PL and their up to now offered services will no longer be needed in the visionary goods receipt and warehouse concept of a Smart Factory. However, the question is which new areas of responsibility for 3PLs might occur. In the end, even a Smart Factory or Smart Construction Factory could be dependent on an upstream external logistics center in which the unpacking, sorting and storage processes can be pre-handled for the production. If the suppliers cannot realize the needed implementation of RFID-chips and supply with already unpacked materials because it complicates their own processes, the Smart Factory has to do it itself. But, this again fails due to the complexity issues and lean principle of Smart Factories, in which unpacking and storage processes are not intended. In this case, 3PLs could operate a supply center in the immediate vicinity of the factory where they take over all outsourced processes, e.g. RFID-chip attachment, unpacking and separation, quality check, storage and just-in-sequence (JIS) pre-sorting, which cannot directly be realized by the suppliers or Smart Factory. When materials are now ordered by the product the 3PL can deliver them in the desired quantity, sequence and condition without packaging material. The corresponding visualized overview for the procurement logistics concept of a Smart Factory including 3PLs is seen in figure 5.

The figure provides an overview of the physical flow of goods along the procurement process as well as the systemic order process in opposite flow of direction. The systemic order process shows which systems communicate with each other using which communication technologies. Initially, the information is given to the supplier via pull orders by the 3PL, as they also have a precise overview of the production status in the factory at all times. As soon as the materials are unloaded in the logistics center and RFID-chips are added, they take over the communication. Now the materials are stored until they are released by the intelligent product to be delivered JIS to the Smart Factory. As already described, the later truck unloading can now be handled without packaging materials through cyber-physical systems and the materials can thus be assigned to the production lines by AGVs without intermediate storage (see figure 5).

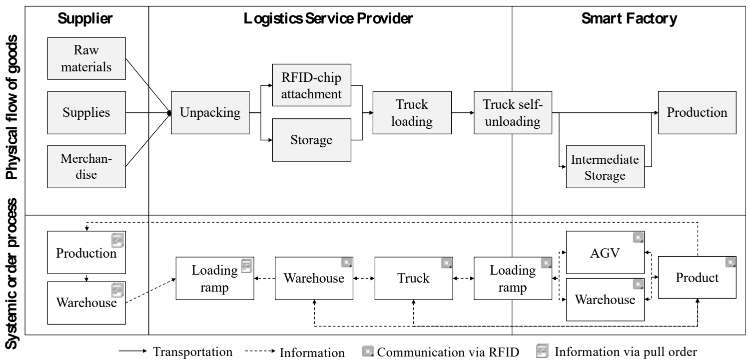

Figure 5: Procurement Logistics concept of a Smart Factory

Nonetheless, it would be ideal for the logistics supply chain of the Smart Factory to have all ordered and already unpacked materials delivered JIS directly by the suppliers. This would allow the manufacturer more control of suppliers and the delivered materials and shorter communication times due to no intermediate stage. In this scenario, only one transport to the Smart Factory is executed (see figure 6). However, this seems admittedly unrealistic after considering the concept development above. Thus, logistics centers will probably be operated by 3PLs in the future to take over the final supply. In this scenario, a second stage of transport is included and the supplier communication is handled both through the Smart Factory and 3PL (see figure 7). The transports to the customers remain the same in both scenarios, as they can be managed without another logistics center. At this stage of research, it is not possible to draw a general conclusion about which scenario should be chosen and put into practice. Scenario 1 offers direct interactions with the suppliers, whereas in scenario 2 physical processes can be outsourced to the 3PL. However, if the communication process runs smoothly, it can be assumed that scenario 2 could appear more realistic in the long term view as other outsourcing benefits, e.g. less appropriated surplus or better scalability, can be achieved as well.

The following two overviews show the possible scenarios of the procurement network from the manufacturers as well as 3PLs perception.

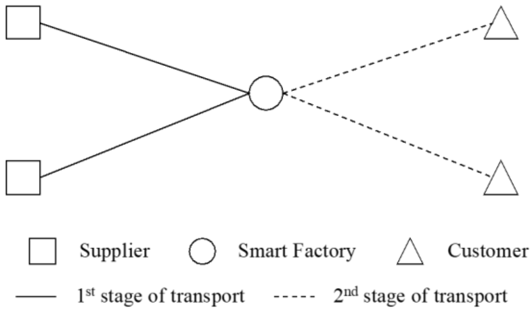

Figure 6: Procurement Network - Manufacturers perception

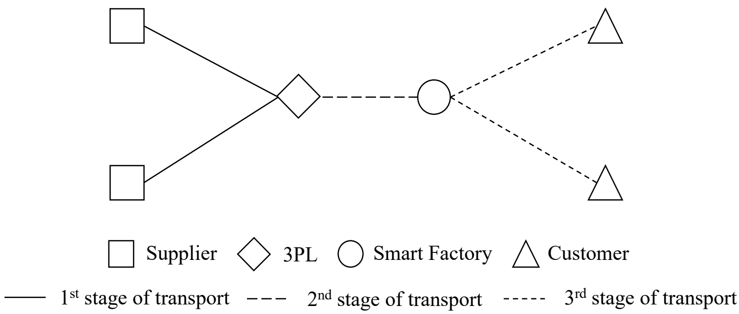

Figure 7: Procurement Network - 3PLs perception

5 Conclusion

The paper presented a literature analysis of future impacts on procurement logistics through the flexibility and automation Smart Factories will bring into the market with references to the building industry. Furthermore, it was able to develop a concept regarding the role and responsibilities 3PLs could have in its logistics organization. Although they will no longer perform directly in the factory, their new role could be in operating a logistics center in the vicinity of the Smart Factory to enable its guaranteed autonomy. By integrating 3PLs, the manufacturers are able to keep their in-house processes as lean and efficient as possible and only focus on their automated production. Thus, the procurement processes unpacking, quality check, separation, storage and pre-sorting are outsourced to the greatest possible extend, but can still be controlled by the product itself.

Interface problems could arise if manufacturers induce their suppliers to directly deliver materials without packaging as well as load securing and equip them with RFID-chips in advance. This would hardly be possible due to complexity problems in handling and transportation. In addition, if a Smart Factory was planned without outsourced processes, the manufactures would have to do the unpacking themselves and would therefore also need own employees. This could then lead to a miss of the Smart Factory Logistics goal of complete autonomy.

However, research on this topic is still in its infancy. The restriction of the investigation represents the not promulgated scientific or practical research about the future roles and responsibilities of 3PLs, which means that no specific comparison to similar publications could have been made. This would have made the concept even more detailed. More conceptual and empirical work is needed to better understand the impacts of Smart Factories and Industry 4.0 on procurement logistics in detail. Nevertheless, future research in this field is probably continuing to grow in the coming years as the actual realization of Smart Factories approaches (see figure 2). This could also close the current research limitation because both science and practice have to be aware of the role and responsibilities of 3PLs when planning logistical processes for or inside a Smart Factory. With these considerations in mind, this work is an initial exploration of the research field and further observations have to be taken.

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