The Internet of Load Carriers
Design of a Cloud-based Service System for Smart and Connected Load Carriers

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Abstract: Nowadays, a main problem of special load carrier supply chains is the lack of transparency. This can lead to under- or overstock as well as the loss of load carries. To address this problem, the present research proposes the digitalization of the load carrier supply chain by equipping special load carries with sensor systems and using the generated data to offer financial, special-load-carrier, and data-based services. Especially data-based services are proposed to increase transparency and to enable companies to optimize their supply chain. Supply chain digitalization by means of smart load carriers combined with new services within a cloud-based service system can gain competitive advantages for involved companies, and enable new business models. Thus, the proposed services can improve overall quality, save time, and reduce cost while increasing sustainability for load carrier manufacturers and their customers.

1 INTRODUCTION

The increasing number of product variations as well as the coordination of complex supply chains combined with shorter product life cycles pose significant challenges for manufacturing companies. Therefore, the current research aligns with industry activities focusing on the combination of the latest technologies and web-based services to increase transparency, efficiency, and flexibility of logistics processes as well as to counteract increasing complexity. These approaches are developed within the scope of industry 4.0 (Kagermann et al., 2013) (Gunnlaugsson et al., 2011). One of the main problems of special load carrier supply chains is the lack of transparency. Often, load carriers pass undetected through the supply chain, which leads to problems such as under- or overstock as well as the loss of the load carries themselves. The digital transformation of load carriers into cyber-physical systems allows the collection of process relevant data, which in turn allows for the provision of services based on that very data (Prives et al., 2012). This enables traditional load carrier manufacturers to expand to new business fields and to transform their traditional business model into an e-Business, by offering new data-based services to optimize the supply chain of their customers. This article provides a conceptual design of a cloud-based service system for smart and connected load carriers, which aims to improve transparency and optimize the supply chain.

2 BACKGROUND AND EXISTING SOLUTIONS

Load carriers are used for the transport of components and products in value-adding networks. Special load carriers are developed, and produced in order to accommodate the needs of specific transport goods (Gudehus and Kotzab, 2012), e.g. their design is tailored to exactly fit the dimensions and condition of a door panel center console. Thus, the lifecycle of specific load carriers is dependent on the production cycle of their respective transport goods. The use of special component load carriers is associated with high costs for the companies. In particular, the complexity of manufacturing, development, and management processes of special load carriers incur high costs for comparably short utilization cycles (Kampker et al., 2015). Additionally, most process steps are not automated and are therefore highly susceptible to errors. Furthermore, the transparency

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of today's load carrier circulation within and between companies is insufficient. Improving the transparency of existing process structures requires a great deal of manual effort. These challenges mainly affect the automotive industry with its short-cycle product changes, highly individualized products, and vulnerable just-in-sequence logistics.

Load carriers are used in supply chain processes among automotive suppliers, logistics service providers, and Original Equipment Manufacturers (OEM), for instance. In the past years, modularization concepts have been developed in various research projects in order to allow reuse.

Modularization concepts allow the disassembly of load carriers into single models and the reconfiguration to a different load carrier. These modularisation concepts were evaluated in various projects (Kampker et al., 2011); (Rosenthal, 2016) and partly implemented in practice (Meißner, 2015). Therefore, the reuse of single models for another use cycle and the benefit of the easier exchange of modules has been validated.

Further projects followed different approaches to improve load carrier management through technologies of the Internet of Things (IoT). So-called smart load carriers and their management processes were investigated in several projects. For example, a temperature sensor was combined with Radio Frequency Identification Systems (RFID) and integrated into load carriers for monitoring the ambient temperature. Sensor systems combined with communication technologies such as Universal Mobile Telecommunications System (UMTS) were also implemented and studied (Seidler and Konstantinos, 2015); (Wang et al., 2011). In another project, intelligent load carriers for intralogistics have been researched. These are capable of initiating and controlling the entire order picking process independently (Roidl et al., 2014). Additionally, they automatically trigger replenishment processes (Hoffmann, 2014). The research consortium "FORFood" has developed an intelligent thermo-container for food that enables efficient monitoring and tracing within the food supply chain. Identification, communication, and sensor technologies have been integrated into the load carriers, which allow for the acquisition of relevant data (e. g. ambient and internal temperatures of the container) as well as their automatic transmission to IT systems and other process elements (Wang et al., 2011).

In summary, isolated aspects of smart, modular special load carriers have already been investigated, but there is no sustainable overall system that combines the technical dimension of a smart, modular special load carrier (e. g. identification, communication, sensor integration, and reconfiguration) with organizational and economic dimensions (e. g. cross-company platform, self-regulating load carrier flows and suitable business models including a cloud-based service-system). The aim of the research project “iSLT.NET” is to fill this gap. In addition to technological aspects such as the design of computational components for smart, modular special load carriers (iSLT) and its cloud-based service system, this research project explores the potential of load carriers and data-based services for the partners in a supply chain.

The manufacturer-independent use of smart special load carriers in an open network between the load carrier manufacturer and its customers has not yet been realized and thus the potential of a company-wide service system has yet to be unlocked (Gebhardt Logistics Solution GmbH, n.d.).

3 SPECIAL LOAD CARRIERS AS A CYBER-PHYSICAL SYTEM

In order to implement a network of smart, modular load carriers in the supply chain, it is necessary to transform load carriers into cyber-physical systems. Cyber-physical systems are smart systems that include engineered interacting networks of physical and computational components (Griffor et al., 2017). Cyber-physical systems uses sensors to directly capture, interpret and store physical data, which can used as the basis for active or reactive interactions (Geisberger and Broy, 2015). It is widely recognized that cyber-physical systems have great potential to enable innovative applications and impact multiple economic sectors in the worldwide economy (Griffor et al., 2017).

Figure 1 depicts three levels of a cyber-physical system according to the concept of the internet of things. In the lowest, the first level, conventional load carriers are produced through the assembly of standardized modules, until they are used in equipping, transport and extraction processes between OEM and supplier.

In the second level, load carriers are additionally equipped with smart hardware components (e. g. sensors and microprocessors), information and communication technologies and are refine into smart, networked products (Porter, 2014). As part of the IoT, each individual physical load carrier has its own identity, collects relevant data independently

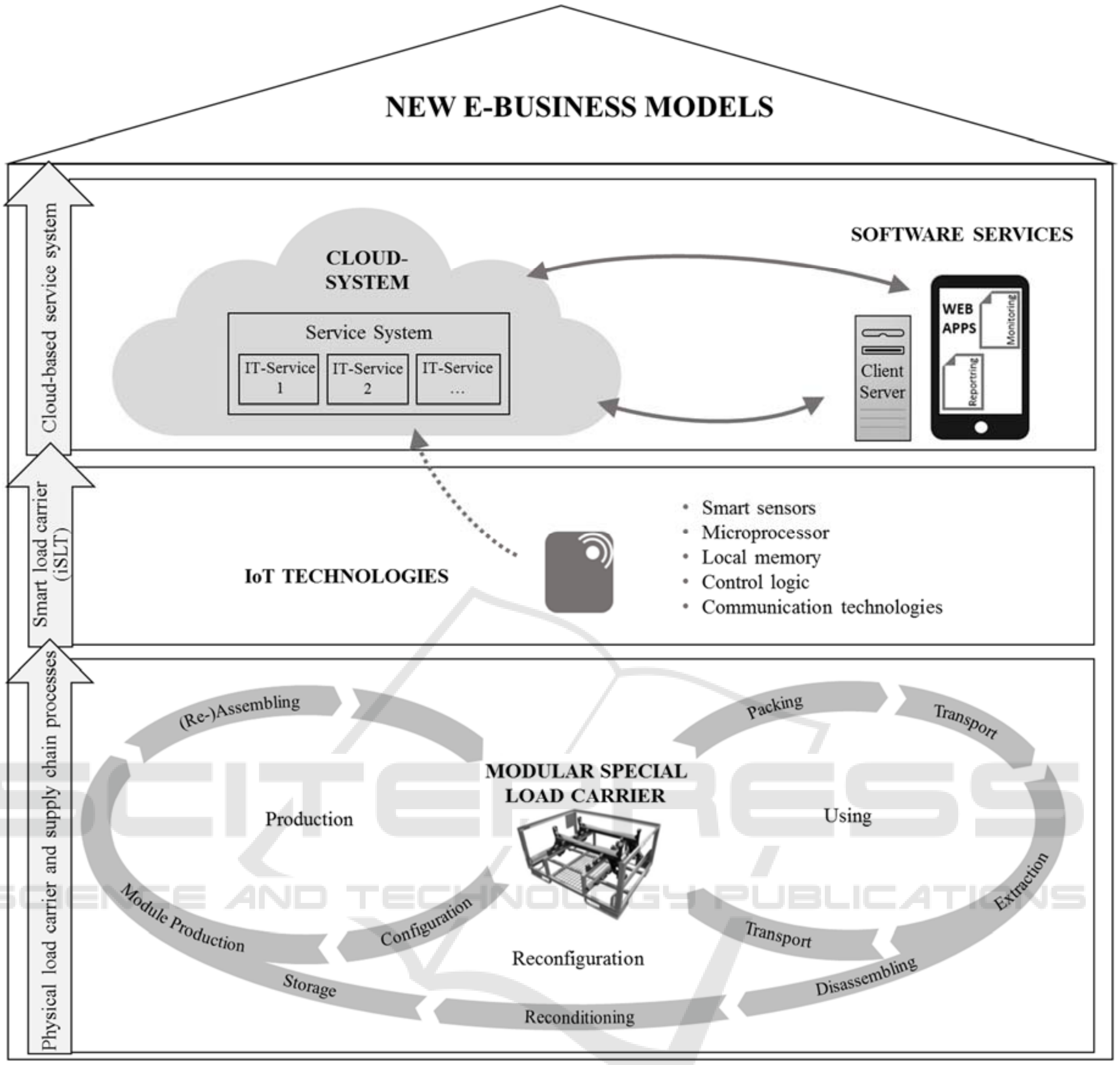

Figure 1: Special load carrier in cyber-physical systems (based on Meißner and Romer, 2018).

within the supply chain, and is connected with other logistical objects (Mattern and Floerkemeier, 2010). For instance, the IoT components enable the iSLT to continuously record current location data via Global Positioning System (GPS), status data via vibration sensors, and temperature data. In order to transmit the collected data to other systems a rule-based communication technology, such as Low Power Wide Area Network (LPWAN), Global System for Mobile Communications (GSM) or Bluetooth Low Energy (BLE) is used. Thus, the communication technology is adaptable to the existing infrastructure of the client.

Cloud systems systematically process the quantities of generated data in the third level. The collected data streams are combined, evaluated, and made available to the user as software services via web applications (web apps). The fusion of the physical with the digital world creates a cyber-physical system for load carrier management. With the gain in transparency regarding the material flows and automotive supply chain processes, customers can be offered a wide range of new services via the cloud-based service system for controlling and optimizing their supply chain (Porter 2015).

This enables load carrier manufacturers to generate an additional form of service-based revenue. Especially data-based services are the trigger for implementing new e-business models (Daniluk and

Holtkamp, 2015). The smart special load carrier creates completely new value-added offers by combining functions of the physical load carrier with product-related software services. The basis for the implementation of data-based services is the development of a cyber-physical system and the systematic design of a modular and extendible cloud-based service system in order to provide a wide range of services. New challenges also arise with this transformation. To ensure a stable and secure service system, the system's architecture as well as the smart special load carriers have to promise resilience, availability, security, safety and scalability. New partners must be integrated in the supply chain, as well as a concept to assign the newly created responsibilities has to be established. The aim is to ensure that the five characteristics of a trustworthy system are well implemented for the new e-business opportunity.

4 SERVICE SYSTEM DESIGN FOR THE REALIZATION OF PRODUCT PLATFORMS

The operator plays a central role in setting up and managing the network's service system for smart, modular special load carriers. Through its integrated product platform, it offers physical iSLT as well as data-based, load-carrier-based and financial services. The services can be booked individually via a digital marketplace. Data-based services of the smart, modular special load carrier are accessible to the customer via web applications (web apps) or through IT interfaces with systems such as SAP. Figure 2 summarizes the iSLT's range of services. These go far beyond the traditional four services of the load carrier industry, namely repair, modification, maintenance, and cleaning. Based on IoT technologies, innovative financial and data-based services can be developed specifically for the load carrier industry.

Financial services define different financing strategies for special load carriers. In addition to the classic financing model, which is the purchase of load carriers, financial services include rental, full-service leasing, and pay-per-use. In these cases, load carriers are left to the customer for an agreed upon period of time. Rental and full-service leasing pursue the goal to convert the previous investments for the procurement of load carriers into current rental or leasing interest rates. In the case of a pay-per-use model, the customer is only charged fees depending on the real use of the load carriers, e. g. for the actual cycles through which load carriers pass between OEM and supplier. With the financial service "repurchasing", purchased special load carriers can be sold to the operator after the end of use. One-off investments can be compensated proportionately with the residual value.

In addition to various financing models, the service system also includes load-carrier-based services, which are made possible in particular by means of a modularization concept with reconfiguration and standardization of individual modules. The primary goals are to provide a load carrier that meets specific customer requirements and to ensure retained functionality of special load carriers during usage within the supply chain.

In the configuration process, standardized modules are assembled to a special load carrier in accordance with customer requirements and then delivered. Due the service "reconfiguration" standardized modules of special load carriers can be disassembled and exchanged for customers' evolving requirements.

Various services offer customers a flexible usage cycle. Time and quantity flexibility enables customers to use special load carriers in a timely and demand-oriented manner. Special load carriers that are no longer required before the end of the contract, can be returned. If more load carriers are required than agreed on due to unexpected demand, additional units would be made available through "ad hoc delivery" service in the short term.

Thus, it is necessary to reserve individual modules.

At regular intervals, the condition of special load carriers needs to be assessed in "maintenance" service as a preventive measure and appropriate processing measures have to be carried out. These include, for example the exchange or oiling of hinges needed for folding the special load carrier. This service can be tracked and planned precisely by the cloud system.

The "cleaning" service – especially crucial for inlays - prevents soiling of transported goods. Damage to special load carriers detected during usage can be repaired with the "repair" service. Supported by the modular structure of the special load carrier, spare parts can be ordered and defect modules can be replaced more quickly and easily.

Data-based services are established on the analysis of data, collected during the iSLT lifecycle. A "configurable product model" supports load carrier planners in designing iSLT. Using the web-based product configurator, modules can be digitally assembled according to the modular principle of the load carrier. This simplifies and accelerates the deve-

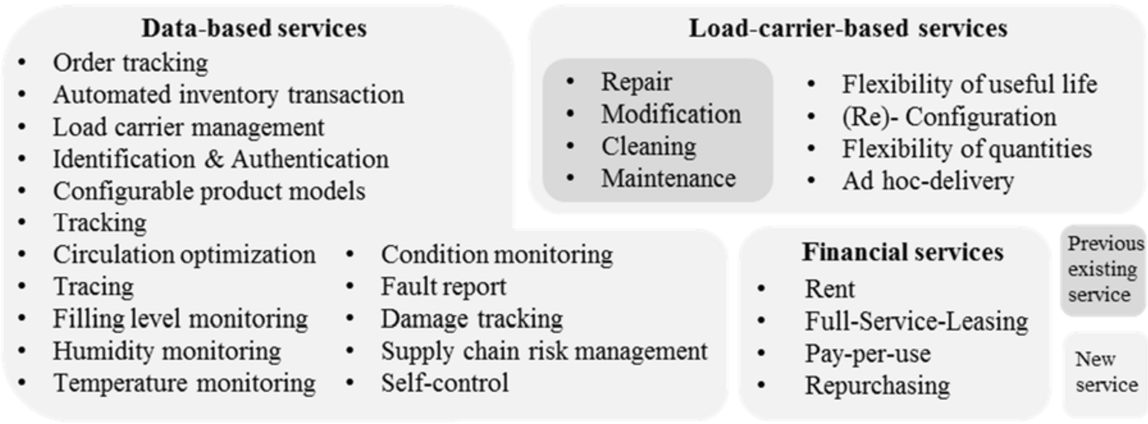

Figure 2: Range of services in the service system (Meißner and Romer, 2018).

lopment process of load carriers considerably.

By means of "order tracking", the progress of the order is made transparent for customers. Customers not only receive information regarding the general status of their order from reception to delivery, but also get online insight for the number of produced load carrier.

The "load carrier management" controls the load carrier cycles of customers across company boundaries and manages the respective iSLT stocks. By means of the "automated inventory transaction" service, load carrier movements in companies can be recorded automatically in goods receipt and goods issue. Manual transactions in proprietary systems can be replaced for OEM and supplier.

With the "circulation optimization", requirements for special load carriers can be automatically determined and planned in advance. On one hand, load carrier planners can react with additional procurement to avoid bottlenecks in their supply chain. On the other hand, they can return load carriers to reduce stocks within the supply chain.

In addition to the "identification and authenticity" of each load carrier, locations of load carriers within the production plants and on the transport route can be identified through the “tracking” service. Quantity and types of load carriers within a plant is transparent. Depending on the technology used, load carriers can be located with an accuracy of a few meters as well as evaluated and analysed via "traceability". Extensive searches in the plants as well as shrinkage can thus be avoided.

The "humidity or temperature monitoring" services provide users with information on the ambient conditions of load carriers. Users can define customized threshold values depending on transportation requirements and be informed about deviations by "fault reporting". If temperature thresholds are exceeded during the use of load carriers, a message is sent to the user in the form of a "supply chain event". Therefore, users can react directly and efficiently to impending problems. If damage to the transport goods is suspected, replacement production and delivery can be initiated as a preventive measure in order to avoid bottlenecks in production processes for critical delivery concepts such as just-in-time delivery.

The "filling level monitoring" continuously measures the filling level of a special load carrier. Integrated cameras or infrared sensors recognize if the load carrier is empty or still fully loaded. If goods are left unintentionally in the load carrier during the removal process on the production line, a message in the form of a "supply chain event" warns the user which enables immediate reaction. The “condition monitoring" service records all condition data of iSLT and evaluates them over specific periods of time. Tilt, vibration or collisions can be measured continuously via sensors. In the event of damage, the user receives information about the state of load carriers. “Fault reporting" can be used to initiate quality assurance measures in the process. The service is closely linked to the "damage tracking" service. Here, defect patterns for load carriers can be identified and repairs or changes to the configuration can be planned and tracked.

Furthermore, automated rules can be defined in the "Supply Chain Risk Management" service. E.g., if threshold values of load carriers within the supply chain are exceeded during transportation, then transport goods can be blocked and spare parts from the supplier can be ordered. This reduces the risk of a disruption of the supply chain or even a total production line break-off. With the "Self-Control" service, customer-specific data can be stored on the devices of the special load carrier. For example, this can be used to decentralize communication between smart objects and to provide necessary information for process control.

5 CONCEPT OF THE SERVICE SYSTEM IN A SUPPLY CHAIN

Customers can flexibly book or cancel services via the cloud-based service system's marketplace throughout the productive operations. In order to be able to provide such an extensive range of services, every special load carrier is equipped with an IoT-device, which consists of sensors as well as components for communication and identification. These components are customized to meet individual demands as indicated by their booked services.

"Condition monitoring" and "humidity and temperature monitoring" services are enabled in the IoT-device by means of a GPS-module, sensors for vibration, collision, and temperature as well as a communication module for LPWAN. During use and transportation within the supply chain, the device transmits the location, temperature, humidity, vibration, and collision information in predetermined time intervals to field-gateways, which are installed outdoor and in production plants within the company's manufacturing premises. Subsequently, data is transferred to the central cloud where it is processed and stored. The cloud constantly monitors customized thresholds with the load carrier's status and location by using transmitted data provided by the special load carriers. If a damage occurred to the load carrier during full load transport to OEM, as shown in Figure 3, the cloud system determines the collision limit violation and generates actively a warning as a "Supply Chain Event" to the user. The active warning includes information about the type of limit-violation, location, iSLT number, and transport part number. The generated warning message by the data-based service can be accessed via the web platform or sent directly through an interface to the company´s IT-systems (e.g. SAP or mobile app). By using a central cloud system the warning message can be sent to any mobile device all over the world, if web access and a mobile app for smart load carriers is available on the device. Based on the warning message and the provided information, the user can react quickly and reorder the damaged parts to prevent a production break down. The user can also trigger special processes for the damaged and fully loaded iSLT. In this example, as soon as the load carrier arrives, a quality check takes place followed by the repacking and repair of the damaged load carrier. This described workflow of the data-based service "condition monitoring" within the service-system is depicted in figure 3.

To guarantee data sovereignty and the security of sensitive information, the required data access rights for each service and company have been identified. Accordingly, despite cross-company collection and usage of data, confidentiality is ensured because each supply-chain partner only has access to personally relevant and individually authorized data.

Service packages, such as "automated inventory transaction" require an additional interface with a user´s productive systems in order to create real value for the user. Therefore, interfaces between the cloud system and the most common IT-systems (e.g., SAP) have been identified, to guarantee real-time communication and synchronization with production systems. The data-based service "automated inventory transaction" allows the automatic identification of the number of iSLT as a delivery arrives and therefore, the inventory can directly be updated in the ERP-Systems of all members of the supply chain. Furthermore, these interfaces allow for load-carrier-based services (e.g., "ad hoc-delivery") and the related reordering of load carriers to match the free capacities and physical resources of service providers with the demand of the booked load-carrier-based service. Consequently, an appointment proposal can be created automatically.

Most of the load-carrier-based services require intermediate locations, so called local hubs, which are located close to the customers. Modules of the load carrier and operating materials are stored in these local hubs to ensure an immediate response to customer requests. A reordering of iSLTs, which is offered by the service "ad hoc-delivery", requires the storage of modules, inlays, and components of the requested special load carrier in these local hubs. Assembly service providers are responsible for the disassembly and reassembly of load carrier modules in accordance with the customer's order. For this purpose operating materials and workers are required on-site for the assembly and quality control. As a result of multiple storage, logistically complex special transports can be reduced and the delivery of reordered iSLTs can be guaranteed by logistics service providers. In order to be able to manage those local hubs, a network of service providers and contract partners, who work closely together with the manufacturer of special load carrier modules, is required. Service providers for maintenance and cleaning are necessary during the use cycle of load carriers. For large customers a stationary, and for small customers a temporary and mobile cleaning

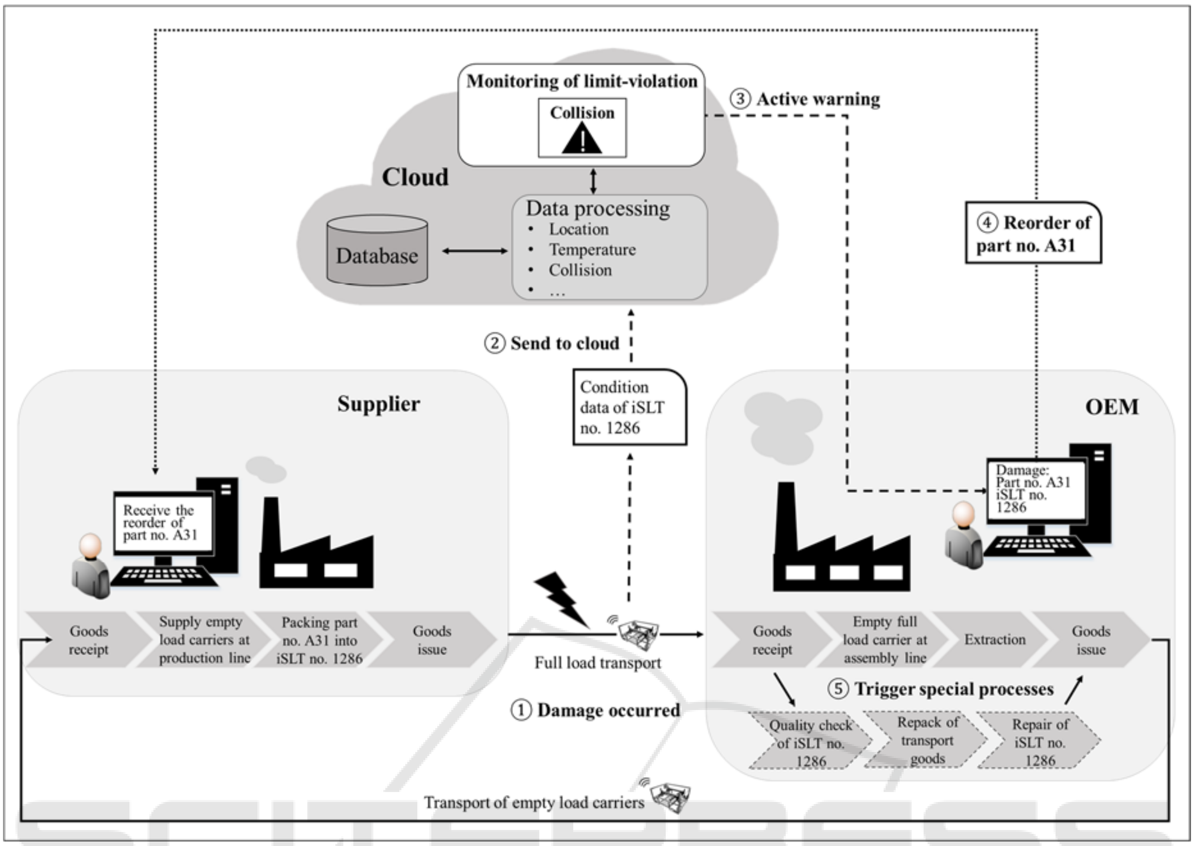

Figure 3: Process within the service system in case of a damage.

installation would be required. For non-reusable modules, defective IoT hardware or heavily damaged load carriers, when repair is uneconomical, the operator commissions disposal service providers. Financial service providers enable different billing models. IoT hardware providers develop and produce sensor modules for the load carriers and information and communication infrastructure to be installed within the users' operational supply chain. Based on the programming of the software providers, the cloud provider supplies the database, IT services, and applications via network while considering access rights and guaranteeing data security (Meißner und Romer, 2018). The operator, in this case the manufacturer, is responsible for the network and the coordination between contract partners and allocates the customers’ booked services (e.g., cleaning, maintenance, and repair) based on free service provider capacities. This matchmaking is supported by the cloud system, which provides information regarding the free capacities of service partners.

6 CONCLUSIONS

In the context of "Internet of load carriers", a cloud-based service system is necessary to offer a large number of new financial, load-carrier, and data-based services. The present research proposes a concept of a service-system, which aims to make supply chain processes more transparent, sustainable, and cost effective in the future. Modularity enables new potentials created by load-carrier-based services and facilitates the physical handling of the special load carriers during their life cycles, but also requires new infrastructure. Data-based services enhance transparency of material flows and disruptions in the supply chain, improve the management of load carrier inventories across companies, and increase process quality. For the realization of these services within this network, the integration of new partners with different key competences is necessary. Furthermore, a cloud-based service system is required in order to transform sensor data of load carriers into useful supply chain data for customer services.

This research is the result of the joint project "iSLT.NET" of a load carrier manufacturer (GEBHARDT Logistic Solutions GmbH), partners from the automotive industry (DRÄXLMAIER GROUP and BMW AG), and academic research institutions (Fraunhofer-Center for Applied Research on Supply Chain Services SCS, Chair of Materials Handling Material Flow Logistics at the Technical University of Munich, and the Technology Centre for Production and Logistic Systems (TZ PULS) at University of Applied Sciences Landshut). In the upcoming project progression, smart and modular special load carrier and its cloud-based service system (including the system architecture) will be successively detailed and prototypes are going to be realized by the participating partners in order to derive further improvements.

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