Evaluation of a Service System for Smart and Modular Special Load Carriers within Industry 4.0

Johannes Zeiler[a], Anja Mecklenburg and Johannes Fottner[b]
Chair of Material Handling, Material Flow and Logistics, Technical University of Munich, Garching, Germany

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Abstract: Current research approaches in the field of logistics discuss the transformation of load carriers into smart objects. These so-called cyber physical systems collect data, aiming for process optimisation and increased transparency. Though special load carriers are commonly used in the automotive industry and have great potential in terms of digitalisation, they are mostly neglected. Understocking and overstocking, as well as production stops due to missing or damaged containers can result from insufficient transparency in supply chains. This paper presents the benefit and usability evaluation of a service system with smart and modular special load carriers, which aims to counteract this lack of transparency by providing databased services. In the therefore concluded web-based survey, experts evaluated the identified benefits in terms of impacts on the process, the customer and the environment. The presented results show that the benefits generated by the service system are suitable for optimising the conditions for the logistic process, the customer, the environment and the transparency within the supply chain. Although the already implemented functionalities of the service system are still limited in usability, the theoretical concepts and its functionalities have great potential in terms of future applications.

1 INTRODUCTION AND PROBLEM STATEMENT

Nowadays the consumer expects broad variety and individuality in products. This diversity, combined with shorter product life cycles, requires sophisticated production environments and supply chain processes. In addition, the number of companies participating in a supply chain is increasing, and mutual dependencies are intensifying in order to achieve customer satisfaction (Handfield et al., 2013). Due to the increasing complexity, the coordination of supply chains poses a significant challenge for manufacturing companies. The keywords Industrial Internet, Internet of Things (IoT) and Industry 4.0 summarise new approaches, which aim to develop more flexible and adaptive logistics systems by integrating innovative technologies into logistics objects (Porter & Heppelmann, 2014). Improvements in the latest communication and computer technologies, minimising the size of devices while ensuring high connectivity and computing power, make these smart logistic objects – capable of collecting process-relevant data – possible. Process-relevant data, combined with smart software services can be used to increase the transparency, efficiency and flexibility of the supply chain (Kagermann et al., 2013).

This paper discusses the supply chain within the automotive industry, where suppliers and Original Equipment Manufacturers (OEM) use special load carriers for transportation. Manufacturing companies use special load carriers for the transportation of complex shaped or sensitive parts such as interior door panels for cars. Parallel to the development process of the product, these containers are developed and designed to transport and protect the product. Only small quantities of special load carriers are needed, a fact which (along with economic reasons) favours a simple, welded-steel construction with a complex interior product mounting. Normally the

[a] https://orcid.org/0000-0001-8878-1101
[b] https://orcid.org/0000-0001-6392-0371

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OEM pays for all special load carriers within a supply chain and provides a pool of containers, normally located at the premises of the OEM, for the other supply chain partners. An example of a delivery process could be as follows: When a supplier's container stock is running low, it requests a delivery of empty special load carriers from the pool. After the delivery of empties, the supplier fills the requested containers with the manufactured parts. A truck transports the filled special load carriers to an interim storage facility run by a logistics service provider. As soon as the logistics service provider receives an order from the OEM, it re-sequences the parts and refills the special load carriers in the requested sequence according to the production line. The logistics provider delivers the refilled containers directly to the assembly line of the OEM. There, the workers install the parts and transport the empty special load carriers back to the OEM's empties storage facility (Zeiler & Fottner, 2019).

One of the main problems with the current container management is the lack of transparency concerning the flow of special load carriers within the supply chain. The containers pass through the participating companies mostly without any identification process, which poses a significant challenge for the control and monitoring of container loops. Furthermore, employees sometimes remove special load carriers from the regular process due to maintenance or other purposes, without documentation or notification of the supply chain partners. Due to this lack of transparency, the stored number of containers often deviates from the numbers logged in the container management system, which leads to over- and understocking. It is also common for this shortage of stock to result in costly special deliveries and additional carton packages, in order to guarantee uninterrupted production. To increase transparency, employees perform a weekly count of special load carriers and save the numbers into proprietary container management systems which are not synchronised between the partners in a supply chain (Zeiler & Fottner, 2019).

One way to address these challenges is the transformation of special load carriers into Cyber Physical Systems (CPS). This transformation allows the collection of relevant data on the shop floor level and opens up new possibilities for data-driven services to optimise the supply chain (Geisberger & Broy, 2015). The joint project iSLT.NET (network for smart and modular special load carriers), described in more detail in (Zeiler et al., 2018), was dedicated to the transformation of special load carriers into smart and connected containers. Among other things, the project investigated the potential of innovative product- and databased services based on the integration of technology (such as sensor, identification and communication technology) and the modularity of the physical special load carrier. In (Zeiler & Fottner, 2019) we also introduced the architecture of a cloud-based service system for smart and modular special load carriers. This architecture was designed to achieve a cross-company integrated communication and identification system for smart and modular special load carriers, so as to enable data-driven services to be used throughout the supply chain. Subsequently we present the range of services based on data collected by smart and modular special load carriers in (Romer et al., 2018).

This paper presents the evaluation of the service system with smart and modular special load carriers within an industrial environment. Therefore, the following chapter briefly addresses the existing research approaches around smart and modular load carriers, including the methods to evaluate their benefits. Afterwards we present the services offered by the service system that are relevant for our study. Based on these introductions we describe and categorise the benefits provided by the service system, as well as our evaluation approach. Subsequently we introduce the conducted survey and discuss our findings concerning the service system with smart and modular special load carriers. The last chapter summarises the present paper and contains suggestions for possible future work.

2 REVIEW OF EXISTING RESEARCH APPROACHES

In recent years, different studies and projects developed modular concepts for special load carriers. These concepts allow the dismantling at the end of the first utilisation cycle, and the reconfiguration and reuse of individual modules for the next cycle. Within the research project ReBox-Pool (Schuh, 2012), selected benefits of modular special load carriers were evaluated. In this, the research work assessed the modular special load carrier in terms of a reduction of logistics costs, by introducing an exemplary application. In order to measure its savings potential, a case study in the form of expert interviews with users and manufacturers of the modular special load carrier – using a qualitative and quantitative method approach – was conducted. Furthermore, field reports from some of the project participants provided further insight into the concept's prospects of success in real-life applications. The results show a possible cost reduction, but also make clear that further aspects and possible challenges, such as a high cost-price of the special load carrier and short-term changes in process requirements, must be considered. Two other pieces of research, carried out by Attig (Attig, 2011) and Rosenthal (Rosenthal, 2016), investigated to what extent the modularisation of special load carriers is reasonable and cost-efficient and what the economic potential of this modularisation is. Attig for example developed a model for the evaluation of load carriers with a focus on life-cycle costs. In his model, the author uses various case studies, expert interviews and an analysis of potentials to illustrate the benefits of a modular special load carrier. The application of this evaluation model has shown that modularity and the pooling system show potential for successful and expedient use within the producing industry (Attig, 2011). However, the described research approaches concentrated on the physical container, and neglected the challenges of modularity when integrated into a service system, which provides databased services such as automated damage reporting. This integration may require, for example, the digital traceability of the individual modules.

The first step towards a smart container can already be realised with a simple AIDC (Automatic Identification and Data Capture) procedure such as RFID (Radio Frequency Identification). As early as 2006, Volkswagen AG investigated the potential of special load carriers equipped with passive RFID tags (Pelich, 2006). By implementing a prototype during the evaluation process, Volkswagen automated the event-based tracking of containers on the plant premises, and demonstrated an increase in process transparency. A further step towards a smart container was made by the FORFood project, which developed a smart thermal container for fresh and frozen food logistics (Prives, 2016). In this case, the focus was on the efficient traceability of the containers throughout the entire supply chain, and on monitoring the closed cold chain. To achieve this goal, the containers were equipped with RFID and temperature sensors, which enabled them to record the internal container temperature and transmit the measured values automatically to the back end. Using this setup, temperature changes inside the container could be detected along the supply chain and evaluated by the user via a developed Android app. During the evaluation of the smart thermal container, the researchers assessed the functional and non-functional system requirements via laboratory tests, field tests and computer simulations. Besides this, the feature-based comparison was used to analyse the effectiveness of the thermal container. The evaluation methods indicated that the developed concept meets the relevant industrial requirements and is feasible within cold chains. It was also shown that the smart thermal container increases food safety and makes the logistics process more efficient (Wang, 2014). Another type of smart container is the “inBin” (Emmerich et al., 2012). The “inBin” is a load carrier equipped with an energy harvester, energy buffer, microprocessor, radio module, display and sensors. These features enable the container to communicate with people and machines in its environment, and to monitor the ambient conditions. For example, the smart container supports the human user during order-picking via its display (Roidl et al., 2014). In order to evaluate the behaviour of many “inBins” (1000 to 20000), the researchers performed simulation experiments using the implemented “inBin” platform as an example. The results showed that to ensure no negative effects on radio traffic, the upper limit on the maximum number of “inBins” for a warehouse depends strongly on the communication strategy. In addition, several economic calculations were carried out to evaluate different energy-harvesting methods. The research project "Service-oriented logistics concept for a multifunctional container system" developed a further concept for a smart load carrier equipped with identification technologies and sensor systems (Lammers et al., 2013). Among other things, the user could monitor the temperature and identify the last location in case the container became lost. For a first prototype, the identification technologies RFID, barcode and QR-Code (Quick Response Code) as well as sensors for pressure and temperature were attached to a universal load carrier. With this prototype, the researchers carried out experiments to evaluate and confirm the reachability of their targeted benefits. Another interesting use case of a smart container is the "Intelligent Fruit Logistics" by Verdouw et al. (Verdouw et al., 2019). In this project, IoT devices with an LPWAN (Low Power Wide Area Network) module, a GPS (Global Positioning System) chip and a QR code were integrated into the fruit crates of the Euro Pool System. With this setup, the author evaluated the functionalities of the developed IoT platform. The results showed that the platform successfully processed the collected position data and enabled the user to track the fruit crates along the fruit supply chain. In a further research project on smart special load carriers, the scientists concentrated on a smart returnable transit item (smaRTI) which, as part of Industry 4.0, can interact with its load (components), machines and smart production systems, and is able to make independent and decentralised decisions (Neal et al., 2019). For the experimental part, a RFID reader was attached to the container to identify the loaded components, as well as a WIFI communication unit to transmit data to the back end or to another CPS. On top of that, a large number of sensors, a battery, an OLED display and a data processing unit were installed. For the hardware and software, the researchers carried out a suitable proof of concept under laboratory conditions, to investigate the identification of loaded components via RFID, and to monitor the handling process steps using the sensor system of the smaRTI.

As previously shown, different research projects have already investigated and evaluated individual aspects of smart load carriers. In spite of this, there is still a lack of a holistic system that combines the technical dimensions of a smart and modular special load carrier (e.g. identification, sensor integration and reconfiguration) with a cross-company and databased service system (e.g. container stocks monitoring, condition monitoring and process optimisation). Therefore, the previously mentioned project iSLT.NET developed and implemented a cross-company service system based on smart and modular special load carriers for the supply chain. This paper presents the still missing categorisation and evaluation of the service system's benefits, which were conducted within the scope of the "Mittelstand 4.0 Kompetenzzentrum Augsburg".

3 DESIGNED SERVICE SYSTEM WITH SMART AND MODULAR SPECIAL LOAD CARRIERS

The designed service system, which was conceived to meet the challenges of the classic container loop, offers data, load-carrier and finance-based services in addition to the physical smart and modular special load carrier. For this purpose, the special load carrier – consisting of standardised individual modules – is equipped with identification, communication and localisation technologies as well as sensors (e.g. to measure temperature, acceleration and tilt) to monitor the surroundings. Only the data and load-carrier-based services, shown in Figure 1, are briefly explained below. The financial services, which aim to transform investment costs for the physical containers and services into running costs by using approaches such as pay-per-use, can be found in detail in (Zeiler & Fottner, 2019). In the ensuing section, the potential

Data-based services

- Order tracking
- Identification/authentication
- Tracking
- Load carrier management
- Automated inventory management
- Tracing
- Circulation optimisation
- Condition monitoring
- Damage report
- Damage tracking
- Product configurator

Load-carrier-based services

- (Re-)Configuration
- Flexibility of quantities
- Ad hoc delivery
- Repair
- Maintenance
- Cleaning

Previously existing service
New service

Figure 1: Extract of services offered by the designed service system (Zeiler & Fottner, 2019).

benefits of the presented services for the container loop are discussed in detail.

The designed databased services build on the digitalisation of the information flow and the recording of process-relevant data, which is made possible by the identification, communication and sensor technology integrated in the smart and modular special load carrier. Hence, with the *order tracking* service, the user can monitor the production status of the containers ordered from the load-carrier manufacturer. In addition to the production status (from order received to order delivered), customers can also view the current number of smart and modular special load carriers already produced. The automated *identification* and *authentication* service offered by the service system can, for example, be used for logging purposes (e.g. for quality control), for the automatic comparison of delivery quantity and content, or for monitoring the sequence of products in just-in-sequence processes. Furthermore, the *tracking* service enables the identification of the current position of smart and modular special load carriers within the supply chain. Based on the collected data, the digital service called *load carrier management* allows a cross-company live monitoring of stocks in the container loop. Another service offered by the service system is the *automated inventory management* service, which in combination with the built-in identification technology, enables automatic goods receipts and goods issues of smart and modular special load carriers. Similar to the *tracking* service, the *tracing* service provides the history of position data for each container, and analyses and evaluates the idle time of smart and modular special load carriers within the supply chain. A further data-interpreting service is the c*irculation optimisation* service, which collects and analyses all available data to avoid, for example, bottlenecks in the supply chain. The service system also provides a *condition monitoring* service. It enables the customer to retrieve relevant data about the surroundings of the smart and modular special load carriers. For this service, information on ambient temperature, transport acceleration (e.g. for vibration measurements) and tilt are collected. Requirement-dependent threshold values (e.g. for impact shock or temperature) can be activated, and corresponding push notifications triggered when exceeded. To improve the management of damaged containers within the supply chain, the service system offers a *damage report* service. It allows the digital documentation of the damage suffered by the container, and the initiation of repair measures. Here, the focus lies on the digitalisation and efficient storage of damage reports. Directly profiting from these digitalised reports, the analysing service *damage tracking* helps the customer easily identify patterns of damage to containers. In this sense, the user can detect a non-optimal configuration of special load carriers or other problems in the supply chain. The service system also provides a web-based *product configurator*, which supports the customer during the development and design of the smart and modular special load carrier, aiming to simplify and accelerate these processes with an easy-to-use online configurator. It also allows the costumer to select his services and suggests the therefore required hardware.

Load-carrier-based services are also a part of the service system and build on the modularisation of the container and its standardised modules. One of these services is the *configuration* and *reconfiguration* service (e.g. for modification purposes). It enables the customer to assemble the smart and modular special load carrier from standardised modules according to their requirements within the web-based product configurator. Subsequently, the containers' supplier can easily assemble the order since the modules are kept in stock. The modular design and return options permit the simple and flexible adaptation of stocks of smart and modular special load carriers during the utilisation cycle (*flexibility of quantities*). Besides this, the standardised modules (in combination with sufficient stock levels) permit *ad hoc deliveries*, which increases the availability of containers within the loop. The traditional range of services for special load carriers include *maintenance* (e.g. oiling of hinges), *cleaning* and *repair*. The designed service system extends these classical services by digitalising the documentations, allocating the containers more easily and by continuously monitoring the maintenance intervals and usage for each individual container.

4 DESCRIPTION OF THE IDENTIFIED BENEFITS

Based on the presented services of the smart and modular special load carrier, the provided benefits for the container loop were grouped into process-related, customer-related, ecological, economic and safety-related categories. In this contribution, we refer to the evaluation of potential benefits with effects on the process, the customer (OEM) and the environment.

4.1 Process

Potential benefits with effects on the process not only influence the procedures and structures in the individual logistics process steps, but also enable changes in their quality. Some services of the service system *increase transparency of current stocks, locations, movements and conditions* of the containers. The so-called load carrier management in particular ensures a transparency of stocks and helps to avoid temporary under- and overstocking. The common problem of load carrier loss can also be minimised, as the tracking service continuously tracks the location of the containers.

In addition, the smart and modular special load carrier with its service system enables *increased automation and standardisation of processes*. This means specific services replace or supplement manual tasks. As a result, activities and processes can be simplified for the employee, thus leading to a reduction in errors. An example of this is provided by the services tracking, tracing and automated inventory management, which can avoid the time-consuming manual counting of containers and incorrect inventory accounts. In addition, deviation from standardised process steps or handling errors, such as unauthorised outdoor storage, can be detected automatically. The modular structure of the special load carrier with the services configuration and reconfiguration can also contribute to the standardisation of process sequences, such as the repair process, and reduce construction defects through gained experiences with standardised modules. Furthermore, a standardised digital damage report and product configurator can considerably simplify the damage-rectification and ordering process.

A further potential benefit is the *assurance of delivery times and product condition* within the supply chain, via the tracking and tracing of containers and continuous condition monitoring. This means that if thresholds are exceeded, the affected companies can take countermeasures to ensure that undamaged goods are delivered on time. Exemplary measures include replacement deliveries and repairs to avoid an interruption of the supply chain. Another service that can contribute towards ensuring the required product conditions is the regular and digitally supported cleaning of containers to prevent contamination of the load carrier and thus of the products.

Furthermore, the service system of the smart and modular special load carrier has the potential to *reduce damage and repair costs* in the long term. For example, the subsequent analysis of the location and condition data helps to identify the causes of malfunctions and any damage that occurs. In the end, the damage and consequently the repair efforts can thus be reduced. In addition, utilisation time measurement, i.e. a measurement of the frequency of use of individual load carriers, can help to enable a consistent use of all load carriers. Moreover, the digital documentation of the damage and maintenance process can help to identify the causes of damage, avoid long-term serious damage, enable the optimisation of load carriers and increase the efficiency of the repair process.

4.2 Customer (OEM)

The smart and modular special load carrier aims, among other things, to *increase customer satisfaction*. The order tracking service creates a communication interface between the load-carrier manufacturer and the customer, which increases the customer's confidence and their planning reliability. The product configurator can increase customer satisfaction with its intuitive and easy-to-use online order-creation process and the configuration of the special load carrier. In addition, the standardised ordering process speeds up the entire process and thus leads to shorter procurement times. Regular maintenance, cleaning and repair can also contribute to customer satisfaction.

A further potential benefit is the *clear assignment of responsibilities*, which can also be proven retroactively. This changes the approach in the case of incidents and damage, as the service system can determine the company causing the damage based on the collected data. Consequently, the companies can better allocate the costs and determine the resulting obligations for all parties involved. In addition, they can easily identify and remedy the causes of damage.

4.3 Environment

The third considered category of potential benefits relates to the environment. The service system can *calculate a CO_2 balance* from recorded data collected from the production, use and recycling of the load carriers. Thanks to this balance, the companies can measure their sustainability. This means that appropriate measures can be taken and validated in order to improve the balance. One of the main aspects of the project is the reconfiguration of load carriers. By reusing the modules for other transported goods, the involved parties generate a *contribution to sustainable logistics*. The regular maintenance and repair of the load carriers can support sustainability. This prevents or delays serious damage, and thereby often the scrapping of the load carrier. In the long term, this method extends the lifetime of the load carriers and saves materials.

In order to evaluate the fulfilment of the identified benefit potentials, an evaluation concept was developed. The concept uses various methods, e.g. laboratory experiments, surveys and checklists, to assess the suitability and applicability of the service system for smart and modular special load carriers. Within the scope of this publication, the results of a conducted survey are presented.

5 CONDUCTED SURVEY TO EVALUATE THE SERVICE SYSTEM

Figure 2 shows the design and the basic structure of the survey for the qualitative evaluation of the service system, which was an internet-based expert interview. Since the experts must be familiar with the service system, and have at best already used the implemented prototype, only a limited group of people exist that can answer the required questions in full. Therefore, only 12 persons could be identified for the interview, most of them experts from the automotive industry. At the time of the survey, 11 of the 12 people interviewed were in contact with the service system on a daily basis, or at least very frequently. The aim of the survey was to evaluate the potential benefits of the service system with smart and modular special load carriers, based on the experiences, assessments and opinions of the group of experts. They evaluated the conceived services as well as the prototypically implemented service system. The expert interview used the mixed-methods approach, which combines a qualitative and

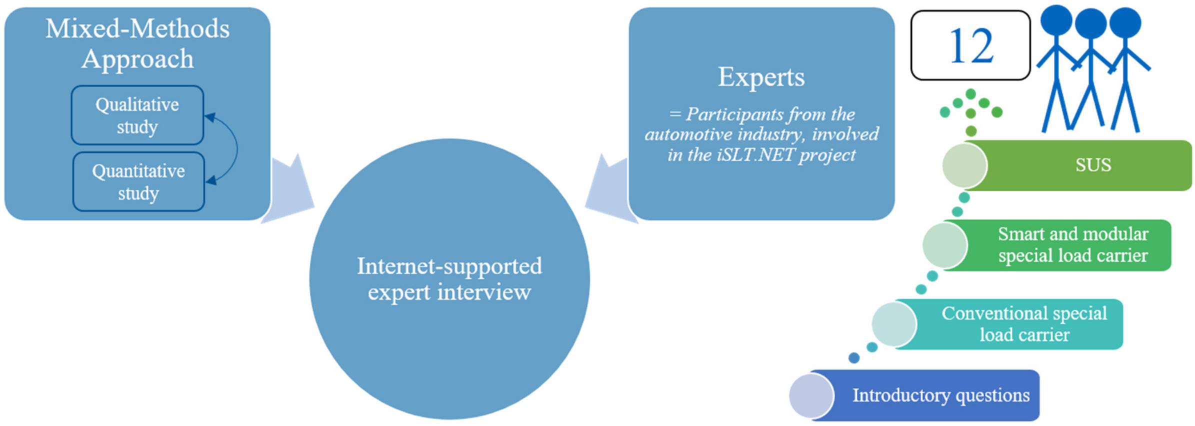

Figure 2: Design of the conducted survey.

study. The survey started with introductory questions concerning person and attitude towards digitalisation. These questions served to typify the respondents and helped to classify and justify further answers. The questionnaire continued with questions about the conventional special load carrier to obtain a general assessment of the performance of the previous system. The next section addressed the smart and modular special load carrier to specifically assess the identified potential benefits and possible future scenarios. To finish the survey, the established System Usability Scale (SUS) was used to evaluate the usability of the already implemented services of the system. Due to the extent of the paper, only an excerpt from the survey's results is presented below. Since not all experts have always answered each question, the results of the survey are presented in percentage, with the number of answers given per question (n) varying between 10 and 12.

5.1 Potential Benefits with Effects on the Process

The results of the survey show that the increase in transparency of logistics processes using smart and modular special load carrier promises great benefits and, according to the experts, forms the basis for many other potential benefits. In this context, the experts evaluated the benefits of monitoring the temperature, degree of vibration (including impact shock) and location. Eighty percent of the interviewees (n = 10) saw a large to very large benefit for the transparency of the supply chain by continuously monitoring the location as well as by monitoring the degree of vibration. For temperature monitoring only 20 % of the experts saw the same extend of benefit. The comments showed that they were not completely convinced of the temperature monitoring, as only a few temperature-sensitive goods are transported in the automotive industry. Regarding the monitoring of vibrations (including impact shocks), the experts mentioned several times that damaged containers or transported goods can thus be more easily noticed and (e.g. by reordering) replaced. Concerning automation, 80 % of the experts (n = 10) believed the replacement of the manual inventory by an automated inventory management based on location tracking to be quite likely to happen. In their opinion, this system could also achieve error-reducing effects in the operational process.

To monitor and therefore assure delivery times and product condition, the service system offers, amongst other things, the functionality to send a notification when a set threshold for the previously discussed status values is exceeded. The experts (n = 11) considered this message useful for all three status values: idle time (82 %), vibration (82 %) and temperature (73 %) (see Figure 3). As far as temperature is concerned, the experts mentioned the fire hazard during battery transport as a valid example within the automotive industry. The experts also added that a threshold message is particularly useful in the event of excessive vibration of fragile transported goods (e.g. glass). With regard to the threshold notification for idle time, they remarked that inventory management could be improved, and that forgotten and thus unused containers could be detected.

When threshold notifications are triggered, a company can take different measures in order to ensure delivery times and product conditions along the supply chain. In this context, the interviewees were asked what action(s) they would take if they were noticed that the threshold was exceeded.

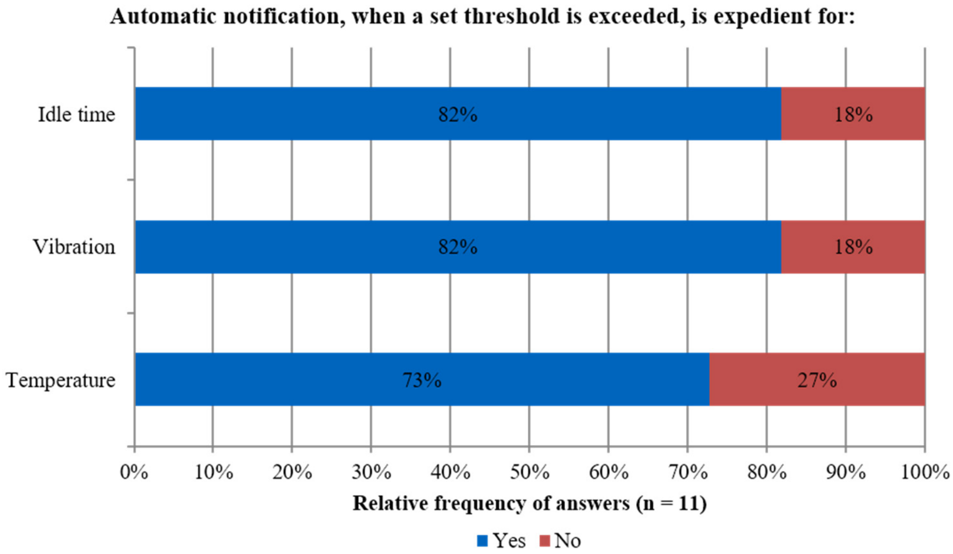

Figure 3: Threshold message for idle time, vibration and temperature.

Regarding the available options, the experts mainly tended to choose measures that intervene less strongly in the logistics process. These include, for example, waiting for subsequent cause analyses or contacting the supplier to obtain more information. On the other hand, the experts avoided choosing the two most interventionist options: stopping the transport process to check the transported goods, and reordering the shipment immediately. Experts also noted that the behaviour depends strongly on the situation and the area of application. Overall, all experts would take measures based on the status information provided by the service system. In the following questions, the interviewees were asked, if they see further use for the location and condition monitoring with a view to a reduction of damages and repair costs. Most of them concurred that short-term damage prevention is not possible with the available data. However, they all agreed upon a possible benefit for the long run, by analysing the data and therefore preventing future damage by optimising the load carrier or handling steps.

5.2 Potential Benefits with Effects on the Customer

Customer satisfaction generally depends on the quality of the product and the associated processes. The first customer-contact is the order of the load carrier via the product configurator. Seventy-three percent of the respondents (n = 11) rated a simplification of the ordering process due to the product configurator as possible. However, they emphasised that special requests must nevertheless be still discussed individually. This means that the product configurator simplifies the ordering process only to a certain degree and, therefore, coordination loops between customer and manufacturer cannot be completely avoided. Another service, which aims to increase customer satisfaction, is the order tracking service during the production of the load carriers. The survey's results show that order tracking can increase planning security and customer confidence and therefore rise customer satisfaction (see Figure 4). However, some interviewees mentioned that because of the increased transparency there is also the risk of causing a negative attitude in the event of a delayed delivery.

All respondents considered it helpful to have a clear assignment of responsibilities, for example, to determine the company responsible in the event of damage or incidents. In the eyes of the experts, monitoring the conditions and locations of the load carriers were both equally important in identifying who is responsible in such cases. All of the interviewees agreed that they would apply the service system to identify the company responsible for damages or incidents in their daily work routine. However, they would not use it only for financial reasons, but also to support the investigation of causes and thus the optimisation of processes.

5.3 Potential Benefits in Terms of Environmental Impact

The introduction of a CO_2 report is also part of the service system. This report provides information about the CO_2 balance of the reusable modules. A

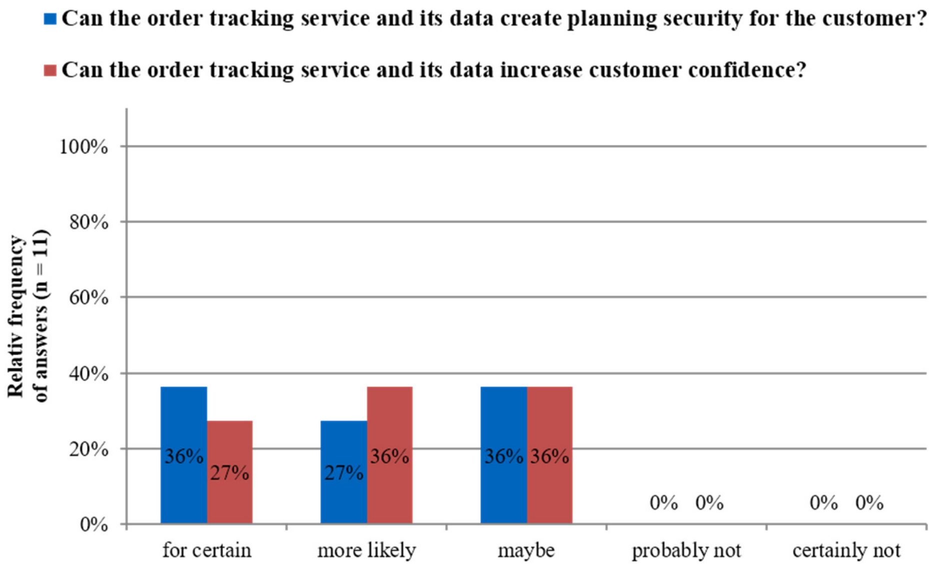

Figure 4: Increase in planning security and customer confidence generated by order tracking.

majority (80 %) of the experts (n = 10) would be interested in such a report. According to the experts, they would use it to publicly promote their ecological footprint. In addition, they also desired a CO_2 report for reasons of personal interest. The CO_2 balance can measure the sustainability of the load carrier for the first time, which aroused curiosity among the experts. The people interviewed mentioned that the CO_2 balance would also influence certain decisions in the company, such as supplier sourcing. The experts also wondered whether regular maintenance would extend the lifetime of the load carriers, and therefore contribute to sustainability. Only half of the respondents (n = 10) thought that the lifetime will be extended, but they also mentioned that there are not yet sufficient studies available on this topic. Although the reuse of special load carrier modules for a different product can directly contribute to sustainability, the CO_2 report itself cannot. However, public relations and regular data comparison are ways of increasing environmental awareness both internally and externally. Ultimately, this can also help to improve sustainability.

To conclude the survey, the experts (n = 10) directly compared the conventional special load carrier and the newly developed smart and modular special load carrier on a scale of 1 to 6, with regard to development and production, handling and container management. They saw the biggest improvements within the container management, which was rated nearly two points higher for the smart and modular special load carrier (5.1) than for the conventional one (3.2). The interviewees assessed the handling as almost equally good for both load carriers (5.2 for the new and 5.0 for the conventional one). According to the experts, the smart and modular special load carrier promises optimisation and is rated with just about one point better (4.9) in development and production than the conventional one (3.8).

6 CONCLUSIONS

Currently, there is still a lack of transparency within container circuits, which can lead to problems such as understocking, overstocking and supply chain disruption. This paper focused on the evaluation of benefits of a service system with smart and modular special load benefits, which was designed to make the container flow more transparent, and to solve occurring problems more efficiently. The potential benefits of the service system were categorised in terms of process, customer and environment, and subsequently evaluated with an internet-based expert interview. The evaluation results show that the previously identified benefits were considered realistic and that the smart and modular special load carrier with the associated service system can contribute to an improvement of processes, customer satisfaction and sustainability. Some benefits are easier to achieve, and are therefore preferred by the interviewed experts, as their implementation requires less restructuring within the logistics processes. Services that contribute to an increase in transparency have great potential to reduce errors, identify causes of damage, assign responsibilities, and increase the efficiency of the supply chain. Regarding the required measures when exceeding a set threshold (e.g. transport vibration): the experts gave priority to steps that intervene less in the logistics process. The service system also has the potential to improve customer satisfaction by increasing planning reliability and building up a relationship of trust. The service system's contribution to an improvement of sustainability is promising and the experts have a keen interest in it. However, some of the improvements are still conceptual and (according to the experts) the current prototypical implementation of the service system is lacking in terms of usability, the offered services promise to be highly beneficial.

Concerning future research work on this topic, we are pursuing an ongoing assessment of the service system with further evaluation method. In this respect, first laboratory experiments have already been conducted. Additional research is required to supplement the implemented service system with further services, technologies and participants, in order to increase the positive effects for all users.

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REFERENCES

Attig, P. (2011). Komplexitätsreduktion in der Logistik durch modulare Sonderladungsträger. Technical University Aachen. Dissertation. Ergebnisse aus der Produktionstechnik Produktionssystematik: Vol. 2010,13. Apprimus-Verl.

Emmerich, J. S., Roidl, M., Bich, T., & Hompel, M. ten (2012). Entwicklung von energieautarken, intelligenten Ladehilfsmitteln am Beispiel des inBin. Logistics Journal Proceedings. Advance online publication. https://doi.org/10.2195/lj_Proc_emmerich_de_201210_01

Geisberger, E., & Broy, M. (2015, March 1). Living in a networked world: Integrated research agenda Cyber-Physical Systems. acatech STUDY.

Handfield, R., Straube, F., Pfohl, H.-C., & Wieland, A. (2013). Embracing global logistics complexity to drive market advantage. Trends and strategies in logistics and supply chain management. DVV Media Group.

Kagermann, H., Wahlster, W., & Helbig, J. (2013, April 1). Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Final report of the Industrie 4.0 Working Group. acatech – National Academy of Science and Engineering. https://www.din.de/blob/76902/e8cac883f42bf28536e7e8165993f1fd/recommendations-for-implementing-industry-4-0-data.pdf

Lammers, W., Thiele, B., & Pelka, M. (2013). Schlussbericht: Service-orientiertes Logistikkonzept für ein multifunktionales Behältersystem. Technical University Dortmund - Faculty of Mechanical Engineering - Chair of Materials Handling and Warehousing.

Neal, A. D., Sharpe, R. G., Conway, P. P., & West, A. A. (2019). smaRTI—A cyber-physical intelligent container for industry 4.0 manufacturing. Journal of Manufacturing Systems, 52, 63–75. https://doi.org/10.1016/j.jmsy.2019.04.011

Pelich, C. (2006). Einsatz aktiver RFID bei Volkswagen: Grundlagen, Einsätze und Erfahrungen. Presentation. Volkswagen AG, Wolfsburg.

Porter, M. E., & Heppelmann, J. E. (2014). How Smart, Connected Products Are Transforming Competition. Harvard Business Review(11). https://hbr.org/2014/11/how-smart-connected-products-are-transforming-competition

Prives, S. (2016). Systemkonzept zur Steigerung logistischer Effizienz im Lebensmitteleinzelhandel durch Einsatz intelligenter Behälter. Dissertation. Technical University of Munich, Munich.

Roidl, M., Emmerich, J., Masoudinejad, M., Riesner, A., & Hompel, M. ten. (2014). Entwicklung eines Versuchsfelds für große Systeme intelligenter Behälter. https://doi.org/10.2195/lj_Proc_roidl_de_201411_01

Romer, M., Zeiler, J., Meißner, S., & Fottner, J. (2018). The Internet of Load Carriers - Design of a Cloud-based Service System for Smart and Connected Load Carriers. In Icete 2018: Proceedings of the 15th International Joint Conference on e-Business and Telecommunications: Porto, Portugal, July 26-28, 2018 (pp. 332–339). SCITEPRESS - Science and Technology Publications Lda. https://doi.org/10.5220/0006855403320339

Rosenthal, A. (2016). Ganzheitliche Bewertung modularer Ladungsträgerkonzepte: Eine Lebenszyklusbetrachtung. AutoUni Schriftenreihe: Vol. 93. Springer Fachmedien Wiesbaden; Imprint: Springer.

Schuh, G. (2012). Schlussbericht ReBox-Pool: Logistikeffizienz durch rekonfigurierbare Sonderladungsträger. https://doi.org/10.2314/GBV:771026323

Verdouw, C., Sundmaeker, H., Tekinerdogan, B., Conzon, D., & Montanaro, T. (2019). Architecture framework of IoT-based food and farm systems: A multiple case study. Computers and Electronics in Agriculture, 165, 104939. https://doi.org/10.1016/j.compag.2019.104939

Wang, R. (2014). Konzeption und Entwicklung eines EPC-basierten Datennetzwerkes in der Lebensmittel-Supply-

Chain. Dissertation. Technical University of Munich, Munich.

Zeiler, J., & Fottner, J. (2019). Architectural Design for Special Load Carriers as Smart Objects in a Cloud-based Service System. In 2019 IEEE 6th International Conference on Industrial Engineering and Applications (ICIEA) (pp. 644–652). IEEE. https://doi.org/10.1109/IEA.2019.8714890

Zeiler, J., Romer, M., Röschinger, M., Fottner, J., & Meißner, S. (2018). Entwicklung des Sonderladungsträgers der Zukunft. ZWF Zeitschrift Für Wirtschaftlichen Fabrikbetrieb, 113(1-2), 37–40. https://doi.org/10.3139/104.111841