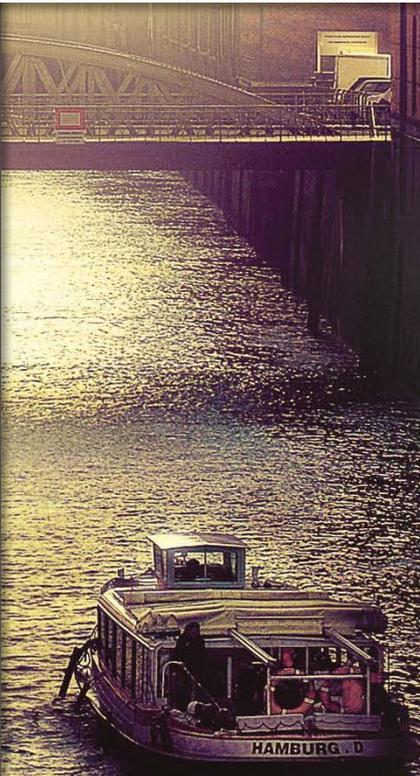


Marit Hoff-Hoffmeyer-Zlotnik, Susanne Schukraft,  
Dirk Werthmann, Stephan Oelker, Michael Freitag



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# Interactive Planning and Control for Finished Vehicle Logistics

Marit Hoff-Hoffmeyer-Zlotnik<sup>1</sup>, Susanne Schukraft<sup>2</sup>, Dirk Werthmann<sup>2</sup>, Stephan Oelker<sup>1</sup>, Michael Freitag<sup>2</sup>

1 – University of Bremen

2 – BIBA - Bremer Institut für Produktion und Logistik GmbH at the University of Bremen

*Logistic processes on sea and inland ports play an important role in the context of finished vehicle logistics as the vehicles are turned over for import and export here. Due to increasing dynamics and complexity, the planning and control of these processes requires high flexibility and reactivity. For example, changing dealer demands or delays of trucks, trains and ships may require a short-term replanning of the logistics processes on sea and inland ports. In this context, this paper describes the procedures and challenges within finished vehicle logistics. Furthermore, an approach for developing highly flexible and efficient logistics planning and control processes for sea and inland ports is introduced. On the one hand, this approach involves an interactive planning tool that visualizes the outcomes of different planning alternatives computed by discrete event simulation. On the other hand, a concept for a novel control system for order allocation will be presented that is based on tracking and tracing of vehicles and workers. This includes a novel method for tracking and tracing as current methods are not suitable in terms of accuracy or cost-efficiency. It is envisioned that the introduced concept will offer significant improvements in terms of reactivity to spontaneous changes and efficiency in travel paths compared to current practices.*

**Keywords:** maritime; port logistics; port transshipment

## 1 Motivation

In the context of global competition, ever increasing efficiency and flexibility are crucial factors for all industrial and services sectors. This also holds for finished vehicle logistics. Finished vehicle logistics is a part of transport logistics which deals with the transportation of finished vehicles from the site of production to the dealer or end user. Finished vehicle logistics are usually taken care of by a series of logistic service providers (LSPs) that are responsible for different parts of the route of transportation (Holweg and Miemczyk, 2002; Werthmann et al., 2016). Sea and inland ports play an important role in this context as the vehicles are turned over for import and export here. In addition, vehicles might also undergo technical services at the ports. These are value added services that are also arranged by the LSPs (Holweg & Miemczyk 2002). Due to the complexity of the logistic processes at sea and inland ports, LSPs are confronted with several challenges: The planning of the logistic processes is based on forecasts provided by the manufacturer's production department. Due to the dynamic order situation these forecasts are often not accurate enough and short-termed changes are common (Holweg and Miemczyk, 2002). Moreover, the forecasts can be further distorted by incidents of the resident technical services centers or of third parties which arrange the delivery or take-away of vehicles by truck, train or ship.

Another challenge is the constant increase of turnover rates of finished vehicles at sea and inland ports. At the vehicle compound in Bremerhaven, the turnover of vehicles increased by 13.9% in early 2017 (DVV Media Group GmbH, 2017). In order to keep pace with the increase in workload and the complexity of the dynamic processes, a planning and control system is needed that offers large flexibility and efficiency.

The present planning and control systems are usually IT supported but do not provide the needed flexibility. Usually, there is no infrastructure that supplies the IT-systems with automated real-time information from the compound. Instead, manual scanning and information transfer is in use, which is error-prone and delivers information with a time lag (Werthmann, Ruthenbeck and Scholz-Reiter, 2012; Böse, Lampe and Scholz-Reiter, 2006). In addition, the software structures have often evolved historically so that the coordination of planning and control is poor. Overall, the IT support exists in form of rather fixed and inflexible structures and as the exact situation on the compound is not known, it is impossible to generate optimally tailored planning and control solutions.

In this context, this paper presents a possible approach on how to create an integrated planning and control system to improve the flexibility and efficiency of logistics processes at sea and inland ports. The approach is based on a planning and control system that supports the processes for finished vehicle logistics based on real-time information. Furthermore, the system is supposed to be interactive so that it is possible to involve employee's expertise.

The envisioned planning and control system will be developed in a cooperation between the BIBA – Bremer Institut für Produktion und Logistik GmbH, the logistic service provider BLG AutoTerminal Bremerhaven GmbH & Co. KG and the software enterprise 28Apps Software GmbH. It will be developed in the scope of the IHATEC project "Automobillogistik im See- und Binnenhafen: Interaktive und simulationsgestützte Betriebsplanung, dynamische und kontextbasierte Steuerung der Gerät- und Ladungsbewegungen" which translates to "Automobile logistics in sea- and inland ports: interactive and simulation-based operation planning, dynamic and context-based control of device- and load movements".

## 2 Procedures and Challenges within Finished Vehicle Logistics

### 2.1 Procedures

The term finished vehicle logistics includes all logistics processes that are necessary in order to transport a finished vehicle from the site of the manufacturer



Figure 1: Throughput process of imported vehicles at a vehicle compound that offers technical services (based on Böse et al., 2008)

to the dealer or end user (Holweg and Miemczyk, 2002). These two sites may be located on different continents. Thus, all means of transportation, but mainly truck, train and ship, can be involved. Ports are responsible for the import and export of the vehicles and therefore finished vehicle logistics are especially complex here. An overview of the throughput processes of imported vehicles at a vehicle compound is given in figure 1.

The complete process can be roughly described as follows: The manufacturer engages a logistic service provider for the transportation from the production site to the compound at the port (Werthmann et al., 2016). At the compound the vehicles are unloaded, temporarily parked for checks on completeness and damages (Klug, 2010), supplied with value added services such as remodeling, washing or removal of waxing at the technical service centers (Holweg and Miemczyk, 2002; Ruthenbeck, Lappe and Lampe, 2010), stored until further transportation, temporarily parked for the process of loading and finally loaded onto a ship for export or truck or train for import (Böse, Piotrowski and Bernd Scholz-Reiter, 2008). The further transportation is carried out by LSPs. Before the vehicles of either ex- or import reach the end destination, they might be turned over at further vehicle distribution centers (VDCs) where similar logistics processes take place (Werthmann et al., 2016).

Any movement of vehicles that happens on the compound is carried out by a team of handling employees. As the area on vehicle compounds is rather wide spread, the handling employees are transported to the vehicles by shuttle services (Böse, Piotrowski and Bernd Scholz-Reiter, 2008). The shuttle services follow the handling employees when they transpose the vehicles and pick them up again in order to bring them to another lot of vehicles that needs to be transported.

## 2.2 Challenges

The planning of logistic processes at vehicle compounds that involve not only pure logistic processes but also quality checks and value added services is rather complex. The ways of transportation can be unique to single cars. Different batches of vehicles require different services which can vary in number. Some vehicles might not require any value added service and again while others require customer specific services.

Moreover, such vehicle compounds are rather large in size and therefore the distances between sites of unloading, storing and loading are crucial. As sev-

eral shipping berths, railway platforms and truck disposition areas exist, there are several options on how to assign the different deliveries to certain sites of unloading.

In order to manage the processes at a vehicle compound, planning and control systems are used. While the planning system is responsible for generating a plan for the processing of incoming orders, the control system interferes in case of unexpected events during the processing and generates specific solutions for these cases in order to prevent further deviations from the planned scenario.

As the operator of the vehicle compound receives forecast information from the vehicle manufacturer on which deliveries to expect at what time, it is appropriate to manage the assignment of loading and unloading sites via the planning system. The vehicle movement processes can be interrupted quite easily by unexpected events. Consequently, long-term planning of these processes is not appropriate as it would involve re-planning at high frequency and thus, the managing of vehicle movements on the compound should be left to the control system. On current vehicle compounds, however, the situation is different.

### 2.2.1 Planning

The planning of loading and unloading sites suffers from unreliable forecasts which impede optimal planning (Holweg and Miemczyk, 2002). Moreover, due to a lack of digitalization, there is no detailed real-time map of the situation on the compound available, which, if existent, would make short-term re-planning possible (Werthmann, Ruthenbeck and Scholz-Reiter, 2012). The current IT-support can thus never generate solutions that are tailored exactly to the situation on the compound. Instead, current planning is usually largely dependent on the experience-based knowledge of the employees. If unexpected changes occur, such as delay or failure of ship or railway, time intensive manual interventions are necessary, which usually involve high administrative efforts and do not guarantee efficient solutions. The planners know about the impossibility of generating optimal solutions and therefore they tend to choose rather safe planning options. For example, rather too large parking areas are selected for storing the vehicles of a certain ship or rather more handling employees than actually needed are assigned to the unloading process. By doing so, valuable resources are wasted and make the operations on the compound less efficient.

### 2.2.2 Control

The control system includes the management of the vehicle movements. However, also here the same lack of a detailed real-time map of the situation on the compound states a problem. For this reason, plans for vehicle movements are generated at the beginning of each shift. The software generates plans with minimized distances. However, the plans with due vehicles movements are printed out on paper and handed to the team leader of each driving team. As they are printed on paper they cannot be updated easily (Werthmann, Ruthenbeck and Scholz-Reiter, 2012). If unexpected changes occur, there is no quick connection to the central board of control such that the planned processes are usually not re-planned but rather carried out in an inefficient manner.

Moreover, as the successful movement of vehicles is also documented manually on paper, the central board of control is not informed about the change of location in real-time and updates are thus only possible towards the end of a shift or during breaks. Moreover, the manual recording of vehicle movements involves media breaks and is thus error-prone. If a vehicle is parked in a different location than documented, time-consuming search actions are necessary.

As no reliable control system exists that could generate and distribute ad-hoc orders to the handling employees, the usage of shuttle busses is the best option for the transport of the handling employees between different tasks. An optimal solution, however, would be the development of a system in which the handling employees transport themselves from one driving job to the next by carrying out a driving job itself. By doing so, any empty runs carried out by the shuttle services could be eliminated.

### 2.2.3 Integration of Planning and Control

Up to date, the software for the planning and control processes is usually not integrated and also within the two parts of planning and control, often different software programs are used. Moreover, different departments and sections of the compound might use different programs. An IT-based integration of all systems usually does not exist and therefore the coordination between different departments and sections on the compound is left to personal consultation between managers, which makes the process prone to errors and negligences.

In order to stay competitive in the future, a concept needs to be developed that significantly improves the efficiency and flexibility of the current planning and control processes. The concept should include real-time information of the status of berths, platforms and truck disposition areas, i.e. whether they are engaged or not and if engaged which delivery or further transportation is currently in progress. Moreover, the location of single vehicles needs to be included such that vehicle movements can be managed via ad-hoc controlling. Overall, the system needs to offer interfaces for human-technology interaction. In the following, the authors will outline an approach towards such a concept.

## 3 Approach towards a Planning and Control System

The overall aim of the concept introduced in the following is to raise the efficiency and flexibility of the turnover processes at compounds within finished vehicle logistics through creating an interactive and adaptive planning and control system. The aim is to design a system that, on the one hand, supports the employees in terms of planning processes. Planning processes involve the planning of berths and tracks for incoming ships and trains, the allocation of parking spaces to incoming vehicles as well as allocation of employees to incoming tasks. On the other hand, the control processes need to be supported in a more efficient manner. Control processes mainly involve the vehicle transport on the compound. The aim is to allocate tasks to the employees in dependence on their current location and on the vehicles current locations. By doing so, the ratio of non-value added transfer of employees to the next vehicle to be transported should be reduced significantly. In both cases, it is the aim to involve the employees in the form of human-technology interaction. This, on the one hand, allows the employees to integrate their expertise that cannot be formalized in an adequate way in the implementation of the software. On the other hand, human-technology interaction allows to leave the employees with certain rights for co-decisions. These aspects are very important from a work-psychological point of view (Cotton et al., 1988).

Overall, the concept aims at a significant improvement of the planning and control processes of sea and inland ports. This also includes the consideration of human-technology interaction to reach a new level of employee oriented planning and control of vehicle compounds.

### 3.1 Planning Tool

The planning tool is expected to fulfil the following requirements: It should be able to compute the efficiency of different planning alternatives, such as choosing different berths for incoming ships or different tracks for incoming trains, and consider parameters such as resource efficiency. On the one hand, resource efficiency holds for technical resources such as shuttle services or parking spaces, on the other hand, it also accounts for human resources, such as handling employees that are responsible for the vehicle movements. By fulfilling these functions, the planning tool can be used for routine planning sessions and also in case of sudden changes that ask for adaptation of the planned scenario. Sudden changes can, e.g., be caused by the delay or failure of a ship or train as well as failure of local resources.

The planning tool is supposed to be interactive. An interactive tool has the advantage that experience-based knowledge of employees can be integrated into the solution. Often it is the case that employees, after many years of intensive work experience, have acquired a certain instinct for useful solutions which, however, cannot be formalized in such a way that it can be integrated in the program code of a software. By choosing for an interactive system, the employees can still integrate their experience-based planning knowledge and restrict the amount of planning alternatives to a number that can be computed by the planning software in a reasonable time.

The planning tool is also supposed to work on a visual and thus mostly intuitive basis. The aspired solution is a multi-touch table. On that table, the layout plan of the port and vehicle compounds will be shown. By touching the screen, different selections can be made, for instance where a ship will berth or a train will arrive. Compared to usual displays, a multi-touch table is relatively large and freely accessible from all sides. Thus, it is especially suitable for interdisciplinary planning meetings where employees from different departments can discuss different planning alternatives while visualizing them on the multi-touch table. In comparison to a simple touch display, a multi-touch table can recognize multiple contacts at the same time (Kin, Agrawala and DeRose, 2009). This is important so that multiple people can interact with the tool at once and thus generate a scenario together.

The computation of planning alternatives is supposed to happen simulation-based. The simulation should evaluate all chosen planning alternatives on the basis of a multi-criteria evaluation and quantify the results in terms of key figures.

Most important criteria that will be considered are due date reliability, throughput times, required employee capacity and space requirement. Furthermore, the simulation based evaluation enables the consideration of disturbances such as delays, failures and other short-termed changes. In addition to the key figures, the simulation software will also compute the impact of all planning alternatives on the following processes and shifts so that those solutions are preferred, which are compatible with a larger time horizon.

Overall, the authors envision the entire planning tool to function as follows: On the multi-touch table, the employees can make a selection of possible planning alternatives. The multi-touch table and the discrete event simulation are connected via a software interface that forwards the chosen planning alternatives to the simulation tool. The simulation computes the outcomes via a multi-criteria evaluation and returns key figures as well as implications on following processes and shifts. Both, key figures and long-term implications are sent back to the multi-touch table where they are visualized for the employees. Based on the presented results, the employees will make a final decision on which planning alternative to implement in practice. In order to deliver reliable results, it is required that the planning tool is integrated into the overall IT-system of the vehicle compound such that the possible planning options and simulation results are always based on up to date information.

Summarizing, an interactive simulation based planning tool will be designed that can integrate experience based knowledge of employees and visualize different planning alternatives and their performance. The usage of an easily accessible multi-touch table will support interdisciplinary planning meetings in an adequate manner. The planning tool is supposed to allow for simulation based verification in case of planning insecurity as well as for simulation-based computation of planning alternatives in case of sudden changes, like delay or failure of external or internal resources.

### 3.2 Control System

The control system is supposed to fulfil the following requirements: In order to raise flexibility and thus efficiency, the current system of static job lists and fixed driving teams should be substituted by a control system that assigns tasks individually, based on the current order situation and location of handling employees and vehicles (see figure 2). By doing so, not only a given order sequence and thus

due date reliability can be pursued, but also route optimization and elimination or minimization of empty runs. This can be reached if the assignment of driving tasks is arranged such that the handling employees transport themselves from one driving task to the next by carrying out driving tasks. Figure 2 exemplarily shows the potential of individual order assignments in the form of reduced shuttle transports based on the current location of handling employees and vehicles. By considering multiple objects like route optimization and due date reliability at once, the idea is to follow an integrated approach in the design of the novel system such that the best possible solutions can be provided.

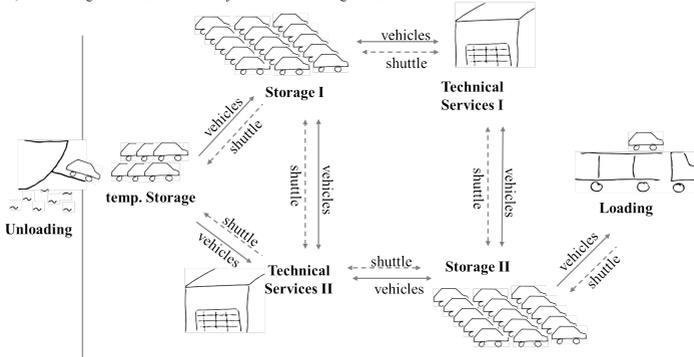
For the realization of the control system, a tracking and tracing system needs to be designed that generates real-time data of the location of employees as well as vehicles and communicates them to the control system. A special requirement is the urgent need for a very high spatial accuracy that can locate objects within an area of adequate size, preferably on parking lot exactness. In addition, an exact information on longitude and latitude will not be sufficient as vehicle compounds can include multi-storey car parks. Thus, information on heights above ground is also crucial in order to determine on which storey a vehicle is parked. For this reason, usual GPS-based localization systems are not precise enough. Even if an external height sensor would be added, the basic GPS-localization might not be feasible as multi-storey car parks usually involve metal structures that impair the GPS-signal (Böse, Lampe and Scholz-Reiter, 2006).

Alternative active localization systems are proprietary, which will create dependencies. Moreover, these systems are cost intensive. Tag costs are in the mid-double digit euros, maintenance costs will incur and a concept would need to be designed such that the tags can circulate in a closed-loop system. Therefore, it will be investigated if different tracking and tracing methods such as differential-GPS (DGPS) and WLAN-Fingerprinting are adequate for usage in vehicle compound applications. The aim is to combine different sensor technologies, such that an adequate localization will be reached.

Based on the data of the tracking and tracing system, a control algorithm will be designed. This control algorithm will compute an allocation of vehicle transfer tasks to handling employees by considering the different objectives of due date reliability and route optimization. The control algorithm will be developed and validated in two stages. In the first stage, it will be validated by a discrete event simulation and iteratively improved in parallel. In the second stage, the control algorithm will be tested in a field test and checked for its capabilities in reality.

### 3 Approach towards a Planning and Control System

a) Order assignment based on static job lists and driving teams



b) Individual order assignment based on location of vehicles and employees

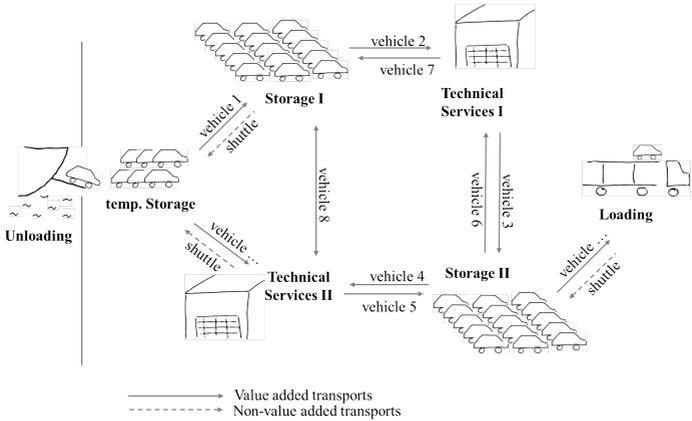


Figure 2: Assignment of tasks based on current order situation and location

Moreover, an IT-architecture will be specified that defines where the control algorithm will finally be implemented. It can either be implemented directly within the central IT-system or in a connected subsystem.

Based on the tracking and tracing system and the control algorithm, vehicle transfer tasks should be communicated to the handling employees. This communication is envisioned to happen via mobile devices. On these devices, the handling employees will receive information about the location and order sequence of vehicles to be moved. Via Auto-ID the vehicles will be identified by the mobile devices and once a vehicle transfer has been completed, the Auto-ID system can check whether the handling employees transferred the vehicle to the correct destination. If so, a status report will be generated and sent automatically, informing the control system about the new position of the transferred vehicle. Furthermore, depending on the situation, order modifications can be communicated and implemented in the system at short-term such that the process accuracy can be improved overall.

Most likely, smartphones will serve as mobile devices. It is envisioned that the final system will be app-based and the aim is to exploit the sensor technology that is included in the smartphones for a precise tracking of the vehicles. This would also allow recording of all routes that the handling employees used and to identify possible bottle necks in terms of routing. The extent of route usage can be visualized via heat maps.

For daily operation, a concept is needed that arranges the availability of the mobile devices. One possibility is that the devices are provided by the compound operator. In this case a charging concept is needed that guarantees a permanent service despite limited battery runtime. In case smartphones are used, another possibility is a "bring your own device" concept. In this case, each employee would be responsible for readiness of the device for each shift.

A main focus of the control system design lies on optimal human-technology interaction. This includes an appropriate and context-sensitive user interface that is intuitive to use. First ideas are that head-up displays can be integrated for a user-friendly and safe manner to display information for the handling employees.

The introduction of the novel control system will imply fundamental changes within the daily work routine of the employees. Therefore, work- and organizational psychological aspects will also be considered in order to increase the acceptance of the employees for this new concept and to ease the transition phase from the old working processes to the new ones. Therefore, the control

algorithm will be designed to involve human interaction and to give employees a preferably high decision-making and managing scope. In particular, for every new job, employees will be given a list of possible jobs out of which they can freely choose one.

Overall, through the immediate way of communication it will be possible to design an extremely dynamic and adaptive system such that the flexibility and efficiency of the vehicle transfers will be raised significantly.

#### 3.3 Interaction of both Systems

The planning and the control system are interconnected via the main IT-service of the vehicle compound (see figure 3). The main IT-system takes incoming orders as input. Incoming orders can be related to ship- and rail traffic, dealer demands and technical services. The orders are forwarded as planning information to the planning software where a planning alternative is selected based on the interplay of the multi-touch table, the simulation model and the employee. The data of the selected planning alternative is fed back to the main IT-system. The main IT-system integrates the orders into the order pool and forwards the updated order pool to the control system. Here, the new orders are integrated into the schedule of the handling employees. The updated schedules are communicated to the handling employees. Moreover, whenever a task is completed, a status report is communicated back from the handling employees' mobile device to the main IT-system.

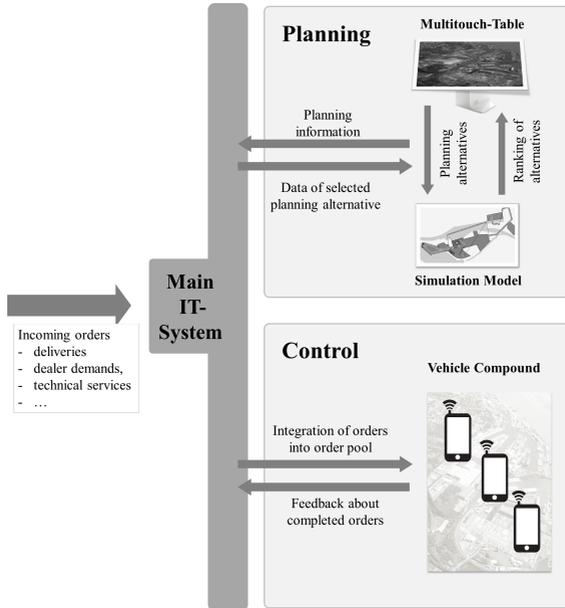


Figure 3: Architecture of the integrated planning and control system

## 4 Chances and Risks of the Interactive Planning and Control System

The novel planning and control system offers huge chances in terms of efficiency. This, among others, applies to the driving distance which consumes time and fuel costs, to the amount of parking spaces needed and to the coordination effort that is required for planning. The interactivity and the up-to-date technology that is used significantly raise the flexibility of the system and enables short-term reactions to occurring change demands caused by third parties, like delivering trucks, trains or ships. The same applies to other deviations from the forecasted information, such as changes in deliveries or order requests.

However, the novel planning and control system also poses certain risks that have to be considered for the implementation. Thereby, one important issue is related to the social component of the handling employees' work routine. So far the handling employees act in teams and thus are in contact with their colleagues throughout the shift. With the novel control system, handling employees will receive individual tasks such that the social component of small chats in between different work orders are eliminated. Therefore, the handling employees might find it difficult to positively receive the new system. For this reason, work-psychological aspects are considered such that employees will have certain rights for co-decisions within the control system. Furthermore, the introduced approach will also consider employees' right since the tracking and tracing system does not only track and trace the vehicles but also indirectly the handling employees.

## 5 Conclusion and Outlook

The introduced novel planning and control system involves up-to-date technical equipment and interactive modules for the employees. Therefore, the approach gives a good prerequisite for making operations at vehicle compounds more efficient and flexible in the long run. The integrated nature of the planning and control system will make the system easier to maintain than the currently common heterogeneous systems.

After development, the interactive planning and control system will be implemented for pilot testing on the vehicle port of Bremerhaven. It is one of the largest vehicle ports worldwide and combines all levels of complexity of the application

scenario. Vehicles can be delivered and transported further via ship, rail and truck over a total of 18 berths, 16 rail loading ramps and 4 truck disposition areas. The terminal is spread over a large area of 2.400.000 m<sup>2</sup>, which includes a total of 95.000 parking lots. A broad range of technical services is offered for import and export vehicles and in 2015 the total annual turnover accounted for 2.3 Mio vehicles (Sommer, 2016). With these characteristics, which are analogue to the application scenario, the port of Bremerhaven is well suited for a first pilot test of the interactive planning and control system.

With a rather complex design of the general scenario, the developers of the novel planning and control system will ensure that the system can be easily transferred to any other vehicle compound that is of similar or smaller complexity compared to the general scenario. This can be either smaller sea or inland ports but also dry ports or hinterland compounds.

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