CONTRIBUTION TO A FULLY AUTOMATIC CONTAINER TERMINAL AS PART OF THE LOGISTICS FACTORY OF THE FUTURE

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ABSTRACT
To withstand international pressure of competition logistics added value processes will have a similar level of automation as production added value processes.

This paper describes possibilities for automation and to increase efficiency of logistic processes on and around container terminals as a part of the logistics factory of the future, which is the vision of a fully automatic process along the whole logistics chain. The presented approaches will be turned into praxis in cooperation of BIBA and container terminal operators.

Keywords: automation, container terminal, logistics

1. INTRODUCTION
A rising transport of goods is caused by increasing globalization. Most of the consumable goods are packed in standardized packing as parcels and are transported in containers from Asia to Europe.

Efficient processes are demanded on the terminal and around the terminal to obtain cost-effective processes as costs for container ship berths in harbours are high, capacities on the container terminal and on the traffic routes are limited. These reasons result in a high demand on rationalization and automation, which also is identified by the study RoboScan (Pfeffermann 2007). In RoboScan 60% of the companies, who have taken part summarized their need for investments, which is not put into praxis as appropriate solutions are not available.

Logistics factory of the future focuses on research and development activities, which aim for smooth processes in logistic networks. Hence this concept is part of the logistics factory of the future.

The following paper is parted in three main sections. The first section describes the vision for the logistics factory of the future. Afterwards the container terminal as part of the logistics factory of the future is focused. The first section describes a process on a container terminal in which the usage of sensors increases safety for transporting containers. The second section focuses on alternative approaches for a container transport systems to get over horizontal barriers. The third section is concerned with processes behind the container terminal as loading and unloading of containers in Container Freight Stations.

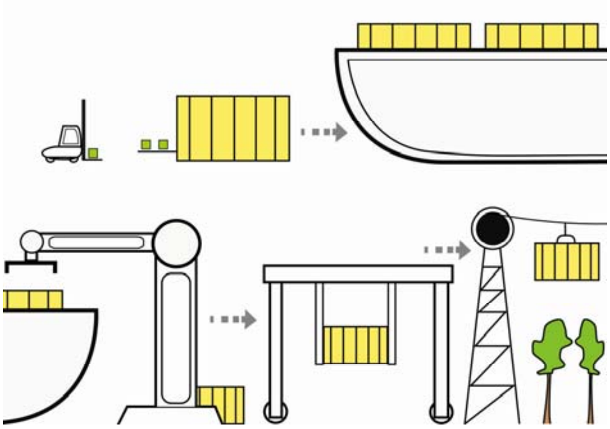
Figure 1: Logistics chain in the logistics factory of the future

2. LOGISTICS FACTORY OF THE FUTURE
A logistic network describes the way of a product from its origins to the finished product and recycling after its use. Various organisations and companies are involved in this product life cycle, which add new features to the products by means of value added actions of the production or service areas. The so called entities of these networks can be described as logistic factories. From a macroscopic perspective their field of activities and their operational sequences cover three areas: the input of commodities and goods, the provision of value added services (the so called through put) and output to the next station of the supply chain.

A closer view of a logistic factory shows a variety of different processes. Business processes significantly characterise the operative corporate task of an organisation. As a result, processes vary in different countries, between different branches and also between different companies within one branch. Therefore the efficient realisation of productive business processes is especially important for a strong competitive position. The term logistic factory describes companies that only carry out logistic activities (i.e. distribution or warehousing) or those with mostly classical production that have logistic functions (i.e. component manufacturing, assembly or food production, etc.).

According to the survey conducted by BIBA in 2007, the area of logistics and robotics has great need for modernisation. Automation solutions are needed desperately and the determination to invest in this area is high. The RoboScan study also shows a central meaning for new technologies. Technical components, for example image processing, automatic identification of objects and the combination of robotics with advanced sensor technology, are required. It is not only interviewees of the study that have recognised the many possibilities for the efficient development of processes. With the concept of the logistic factory of the future, researchers have already begun to adapt their requirements and visions.

Hence, logistic processes within the area container terminals are a part of the logistics factory of the future.

2.1. On the container terminal

Container terminal operators are forced to organize their handling of cargo efficiently as the quantity of handled cargo increases (Echelmeyer 2005).

Amongst others this is achieved by smooth processes on the container terminal. Delays on the container terminal have an effect on subsequent processes and costs increase. An example which results in a delay is an accident on the container terminal, which is avoided by safe handling of containers. Containers are unloaded by Van Carriers (VC) from the container ship and are transported by Straddle Carriers (SC) on the terminal. To lift a container a spreader is moved on top of it and a twist lock, which is a mechanical locking device, establishes a connection between the container and the VC or SC. If over sized cargo is transported special carriers (open top containers, platforms or flats) are used and an over height frame is fastened at the spreader. In the past special carriers have fallen down due to instable locking states between over height frames and the special carrier. Instable locking states are caused due to the working principle. Between the four legs of the over height frame and the four corner points of the special carrier a locking is achieved with twist locks. The locking is checked by a mechanical state device, which shows red if a locking state is detected and green if no locking state is detected. The driver of the straddle carrier is allowed to lift the container only if a locking state is detected. Instable locking states occurred in the past, caused by several tries to obtain a locking state. As a consequence the container has fallen during the lifting process or the transport of the container. Accidents on the container terminal cause economic damage and block subsequent processes. Furthermore, processes have to be designed in a way that the risk for accidents is minimized.

Therefore, container terminal operators ask for an additional component on the spreader, which is able to check the locking state between the over height frame and the special carrier to provide safe processes on the container terminal. Within the next paragraphs a concept for an electronic system is presented, which is capable to detect locking states. The system consists of an additional sensor, and a communication device.

2.2. Extension of container terminals

Container terminals’ area capacities are fully utilized as container handling has increased constantly the last decades. Most usable areas besides the container terminals have already been integrated to the terminals. Hence no further extensions of the areas are available and as an alternative areas near the container terminals are used for storing containers, which gives contribution to the traffic collapses in harbours. Containers are transported between these depots and the container terminal via trucks, which use public streets. As the capacities of the public streets have often been designed before the trend for container handling was visible, the capacities of public streets are also exploited. Moreover, reloading containers to trucks is time consuming, many truck drivers are necessary and further costs for the trucks evolve. Taking the high costs and the prediction of further increasing handling of containers into account, it is necessary to provide an alternative transport system. Direct transhipping from container ship to barges is inefficient as the way between depot and terminal is often short and the depot is not always located besides a quay. Trans shipping to trains is inefficient as the track infrastructure is not flexible.

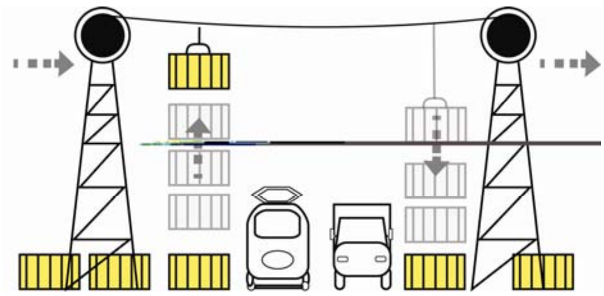
Figure 2: Cable Railway for Containers

The challenge is to design an alternative transport system, which uses the airspace for short distances between a container terminal and associated container depot areas. To achieve efficient logistic processes the system has to be fully automatic and could consist of following components:

- A fully automatic handover station, which transfers containers between straddle carrier / van carrier and the transport system and which transfers containers from the transport system to a straddle carrier / van carrier
- A buffer system, as the number of straddle carriers / van carriers on a terminal is limited and therefore a permanent availability can not be granted
- A transport system between the automatic handover stations to overcome horizontal barriers like streets and train tracks

Further requirements have to be covered by the technical system

- Bi-directional transport to provide storing and releasing
- A height of about 15m to allow the crossing of horizontal barriers as streets or train tracks
- Appropriate capacities are provided to guarantee economic efficiency
- Means of transports is variable to cover fluctuating handling of goods
- Design for standardized carriers with a maximum weight of 40 tons

Besides technical requirements, further challenges evolve from the safety demands.

2.3. Behind container terminals

A significant amount of containers are unloaded and loaded within the harbour areas. Loading and unloading of containers is a relocation of piece good handling from the harbour into the surroundings of the harbour. Piece goods, which have been stored manually in nets into the hatchway, are nowadays stored in Container Freight Stations. Two major challenges within Container Freight Stations are the storing of inhomogeneous goods and the unloading of parcels.

Two typical scenarios from praxis are stated for visualization.

Case 1: Textiles and small articles are shipped in parcels, which are loaded loose to save the space which would be needed for pallets. Depending of the customer structure, up to 60% of incoming containers are packed in such a manner. As single parcels have a weight up to 25kg and a container has the capacity of about 1800 parcels, the worker has to conduct monotonous and physical stressful work.

The demand of ergonomic working places and the pressure to provide efficient processes, causes a request of technical systems for automatic unloading of containers. At first glance, it may be surprising that a container filled with loosely stored parcels poses a challenge for a robot. But in the classic area of robot application, which are production processes in the automotive industry, robots are involved in repetitive activities and work with exactly the same parts. The different sizes and composition of packages make it extremely difficult to introduce automation in this area. Hence, most packages are still unloaded and transshipped by humans. Over the past six years a consortium from business and research communities have developed a parcel robot. This robot was put into daily service in the spring of 2007.

The parcel robot is the first intelligent system that automatically unloads containers and swap bodies that are filled with loose parcels. In the past, this work was always done manually.

Once a parcel robot has a container positioned in front of it, it independently works out the best unloading sequence. It removes the parcels one after the other and places each onto a conveyor belt. In principle, it is similar to the job performed by a human worker.

The parcel robot consists essentially of the following components: a chassis, a telescopic conveyor belt, a 3-D laser scanner and an interchangeable gripping system - consisting of an articulated arm and a grabber.

The robot is positioned over the chassis, which does not have its own drive system. The chassis is connected to the telescopic conveyor belt. This belt is extended electronically, and positions the chassis and the robot in the container. The robot is equipped with a passive steering system, but can only move forward and backward - the container must be positioned directly in front of it. This is not a critical matter for application in places such as parcel distribution centers because the unloading situations there are always the same.

In the first step of the unloading process, the 3-D laser scanner examines the situation. An integrated computer then analyzes the sizes of the parcels and determines the optimal unloading sequence.

The articulated arm attached to the front of the robot has six joints and gives the machine its necessary freedom of movement. As a result, the robot can reach every point in its surroundings, regardless of whether a parcel is located at the top, in the middle or on the floor of the container.

The grabber itself is attached to the articulated arm and is equipped with suction cups that create a vacuum to clutch and hold the parcels. The grabber also has sensors, giving it something like the “sense of touch.” In difficult situations in which the 3-D scanner cannot provide sufficient data on its own, the data yielded by the sensors are incorporated into the decision-making process.

In principle, the parcel robot works like a person who stands, with legs apart, over the conveyor belt, picks the parcels in front of him and places them through his legs onto the belt behind him.

The parcel robot facilitates a seamless, automated connection between delivery of parcels in a transshipping center and their subsequent distribution. In the past, this connection had to be created manually. As a result of continuous automation, logistics processes can be optimized in the future and workers can be spared from doing physically demanding jobs.

At the moment, the robot does not work as rapidly as a human. But as a result of technical refinements, it can be expected that the robot will soon become considerably faster. In the future, it will unload several parcels at the same time or be able to adapt to the variety of demands posed by distribution centers around the world by using different gripping mechanisms. With the help of RFID Radio frequency identification, the parcel could electronically inform the robot how the individual handling process could optimally proceed.

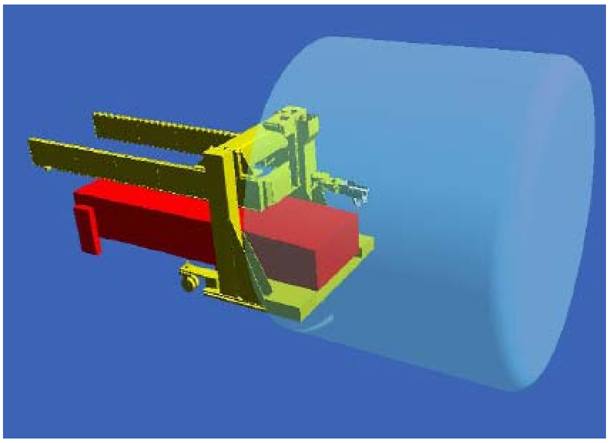

Figure 3: Simulation of working space

Case 2: Packing of bulky and heavy piece good is done often with fork lifters, which possibilities to manoeuvre inside of a container are small as containers have their opening on the slender side. This causes time consuming loading and suboptimal utilization of container space.

The main idea for part-automatic loading of containers is to compose and securing the complete content of the container before loading. Therefore, the container content is put on a loading device in front of the container, the content is secured and afterwards it is pushed into the container. The loading device is lowered and pulled out of the container when it reaches the bottom.

The loading device, which is designed, developed and built as a prototype is the basis for optimized processes within the area of container loading.

The optimization of the material flow gives the opportunity for fast reaction times due to the possibility of buffers for complete freight. This has an effect on the processing time in combination with higher quality of storing. Another advantage of using a loading device is the possibility to put the goods from all sides onto the device. Furthermore, the storage capacities are used better and the time of the containers at the loading places is reduced. New opportunities from the loading device rise the need of an appropriate software system.

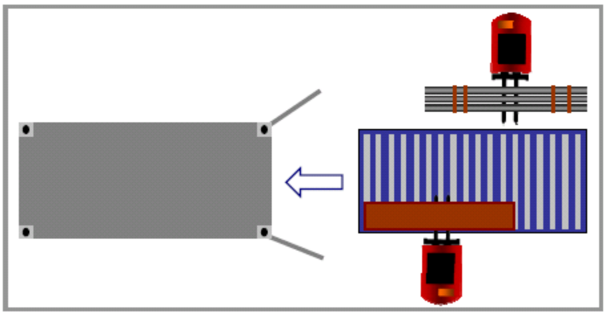

Figure 4: Loading device

Besides the development of a new loading device a new software is designed, which shall take dynamic loading planning into account. To achieve this, the loading device is equipped with sensors to acquire data from incoming goods. The acquired data, which could be freight consolidation or information for subsequent production processes, are used for the planning of the loading process. Furthermore, the data are integrated in control systems for container loading, which is responsible for sending data to subsequent processes. This results in optimized overall processes, i.e. short term break-down of planned goods or incoming but not scheduled goods. By having a flexible software system these events can be integrated into the loading plans dynamically. The impuls for computing a new loading plan might be implemented either event-based or in predefined cycles.

Event-based adaption of loading processes might be in dependence of product types, which are only loaded if a defined amount of goods is reached. In contrast to event-based adaption of loading processes time-based adaption of loading processes are similar to existing solutions. Besides the computing of loading plans it is possible to have further advantages by acquiring product specific information directly from the goods e.g. it is possible to pack goods with respect to their destination.

Both processes are a bottle neck during the processing of import and export. Hence, a technical system for automatic loading and unloading provides more efficient processes. As changing environments have to be taken into account only a cognitive system is able to fulfil the necessary requirements (Scholz-Reiter 2008).

REFERENCES

Pfeffermann, N., Echelmeyer, W., et al. 2007. Study Regarding the Developments, Potentials and Future Fields of the Activity of Robotics-Logistics for Service and Intralogistics, Springer Verlag, Heidelberg 2007

Echelmeyer, W., Tank, S., et al. 2005. Einsatzmöglichkeiten von Industrierobotern in Paketverteilzentren, Roboter in der Intralogistik, 2005

Scholz-Reiter, B., Kirchheim, A., et al. 2008. Konzept zur automatischen Entladung von Stückgütern durch ein kognitives Robotersystem, in press: Industrie Management 26 2008 (4)

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