COMBINED INFORMATION AND COMMUNICATION TECHNOLOGIES FOR LOCATION AND STATUS TRANSPRANCY ON RO-RO TERMINAL

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ABSTRACT
Against the background of a steadily growing High & Heavy traffic at international seaport terminals and the use of ever wider encountered areas, the transparency of location and status of loadings and load carriers is particularly important for efficient warehouse management on seaport terminals. But the previously practiced manual space management of cargos abuts on its limits. Depending on the size of a seaport terminal it leads to time-consuming searches for order bound roll-trailers. Further, manual unscheduled relocations of loaded or free roll-trailer result to considerable information problems concerning the exact storing positions of roll-trailer. Automated support in the collection of movements and status changes of load carriers through IT-systems is currently not realized. Thereby, the transparency regarding the location and status of cargos and load carriers is essential for efficient inventory management at seaport terminals.

To handle these information problems, the BIBA – Bremer Institut für Produktion und Logistik GmbH and a German seaport-owner are designing and modelling in a research project a system that enables automated detection of location and status of load carriers on seaport terminals. The system combines innovative information and communication technologies for identification, communication and localization tasks.

This paper shows how the Radio Frequency Identification technology and Global Positioning System can be integrated in the terminal processes of the roll-trailer operation cycle. It shows what potential this solution would increase in the operational processes for location and status transparency on Roll on/Roll off (Ro-Ro) terminals.

Keywords: load carrier management, Ro-Ro terminals, information and communication technologies

1. INTRODUCTION

The important role of sea harbours for unobstructed cargo handling via German seaports can be described with increased rates from 224 million tons in 1999 to 334.6 million tons in 2008. The sea traffic prognosis passed by the German federal government in May 2007 forecasts a continuing growth of cargo shipping from German sea harbours to reach 759 million tons in 2025. (BMVBS 2007) Although there were caused of the world economic crisis a considerable reduction of the amount of the handling of goods with approximately 21.3 percent in 2009 (DESTATIS 2009a; DESTATIS 2009 b) the seaport-owners expects further increasing cargo rates.

Besides the container traffic the Ro-Ro traffic in particular is regarded as a main driver of this development with high potential for growth. The mentioned prognosis forecasts, that Ro-Ro traffic of the German Baltic range sea harbours will grow over-proportionally with average growth rates of 4.8% and thusly increase by more than a factor of three from 27 million tons in 2004 to 71.7 million tons in 2025 (ZDS 2007). In order to successfully manage the challenges related to this growth, next to increasing harbour capacities by expanding harbour infrastructure and connection to the hinterland, better use of existing capacities is required. In this context, process improvements using intelligent storing position management systems and automatic freight or load carrier identification systems have been proposed (Oppel 2008).

A substantial part of the goods in Ro-Ro traffic are transported with specialised load carriers, which are called roll-trailers. Roll-trailers are defined by the German industrial norm DIN 30781 as carrying means for combining loadings to a loading unit and fulfilling transport, aggregation and handling functions as well as protective functions for these goods (Arnold 2002).

The transport function for bridging spatial differences requires an optimised size for efficient usage of transport spaces, e.g. fitting into ship hull spaces. Additionally, roll-trailers fulfil a storage function for bridging timely differences and, in some cases, a handling function for assembly, picking and finishing processes (Heimbrock 2001).

This contribution focuses on the operational planning and control depends on a permanently up-to-date overview of roll-trailer inventory sizes as well as state and position of the roll-trailers. In this context, innovative technologies like identification based on radio frequency and satellite based positioning offer high potentials for improved roll-trailer processes and management (Fleisch 2005).

2. OBJECTS OF INVESTIGATION

Roll-trailers that are used particularly in Ro-Ro traffic will be transported with their prime movers (tug-masters). They are used to transport high and heavy loadings whose size is too big or too heavy for the transportation with containers, but that is not depending on the lifting capacities of special heavy-height vessels. There are two different types of cargos on the high and heavy segment: self- and non-self-propelled cargos. Self-propelled cargo units like trucks, tractors or construction vehicles can be loaded on their own axes. But non-self-propelled units like locomotives, generators or wind turbines have to be loaded on a roll-trailer which can be moved with a tug-master inside the Ro-Ro vessel. The advantage of this technical solution results from the low conception of the trailer-chassis and the flexible connection through a z-shaped, hydraulically movable boom to the tug-master. It allows the transportation of voluminous loads in shipping spaces with low ceiling heights and to facilitate the handling of loads at sharp angles.

Roll-trailers are mainly a property of the shipping companies and rest at the seaport terminal until the shipping companies assign them to specific orders. Each roll-trailer has markers with standard alpha-numeric codes. To handle rearrangements of loadings in the seaport terminal or move loadings without defined shipping company roll-trailers, the seaport operators use their own roll-trailers called service roll-trailers. These roll-trailers always remain on the seaport terminal. They just bridge the relocation distance between the ship and the terminal, until a forklift unloads the loadings.

2.1. Roll-trailer operations cycle

The project relevant section of the roll-trailer cycle can be differentiated to the import and export processes. The import processes begins with the arrival of the vessel, which are loaded on shipping company roll-trailers, in which import means the import to Germany. After the vessels unloading and the cargo´s registration, the loaded roll-trailers come into stock. Following the delivery of the loadings, the empty roll-trailer comes back into the stock. To reduce the area by occupied empty roll-trailer, forklifts stratify empty load carriers to so called ‘stacks’. These stacks can reach a high up to four roll-trailers.

The export process includes the roll-trailer activities to load the goods to the ship for their transportation from Germany to abroad. During the delivery the customer, a shipping company for example, brings the cargo to the terminal. If the shipping company has already allocated a specific roll-trailer to this order, a seaport operator employee searches for the roll-trailer, loads it and puts it into stock. If there is no direct allocation of a roll-trailer to a loading, the good is stored temporarily on a service roll-trailer. After the arrival of the Ro-Ro vessel the settling activity starts, where the employees remove the loadings from the stock. If the good is loaded on a roll-trailer of a shipping company, the roll-trailer is set onto the vessel directly. If the good is temporarily stored on a service roll-trailer, the good itself is set onto the vessel and the service roll-trailer leaves the ship. Figure 1 depicts the relevant activities of the import and export processes.

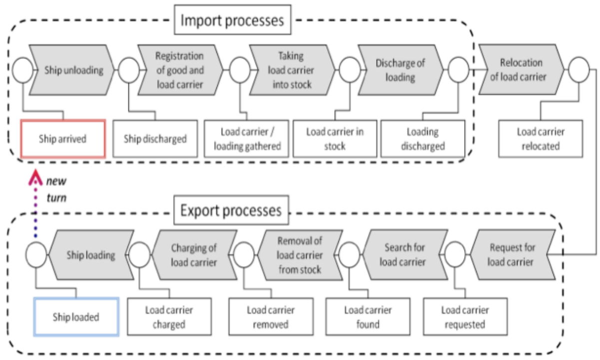

Figure 1: Current roll-trailer operations cycle (based on Scholz-Reiter et al. 2008)

3. CRITICAL POINTS

A detailed examination of the relevant roll-trailer processes has identified several critical points within the terminal operations. These critical points decrease the efficiency in a significant manner. Following points can be divided:

Lack of knowledge about the position and status of a roll-trailer

The storage of loaded and empty roll-trailers is documented in lists of identification codes and storing positions. Due to the strong increase of the cargo volume over the last years and more extensive land use, the assignment situations became more complex and this manual type of documentation has reached its limit. The storage capacity of the terminal is almost utilised, so that stored or parked roll-trailers increasingly constrict the terminal operations. Within such a situation, the paper based documentation causes information gaps. Relocations of roll-trailers, reorganisation of storage areas under time pressure and temporary use of roll-trailers are undocumented, so that accurate information about storing positions and status to roll-trailer are lost. To detect such position and status errors, the seaport operator performs manual stocktaking of the roll-trailers in regular intervals. The rental of roll-trailers to other seaport areas causes additional undocumented roll-trailer movements. The transfers are made over land and sometimes they are carelessly documented.

Due to the allocation of an order to a specific roll-trailer by the shipping company, the undocumented roll-trailer position and status cause a significantly higher effort and costs for searching and handling of roll-trailers. The search time takes in exceptional cases up to two hours. Besides the inefficient use of working time there is increased fuel consumption, due to the use of tug-masters for search operations.

Unknown owners of empty roll-trailers

Although roll-trailers have identification codes, it is possible that the seaport operator cannot assign a roll-trailer to a responsible shipping company. That follows from the fact that roll-trailers are not only used by their owners, they can also be rent or leased – this also occurs during the storage stage of the terminal. Because empty roll-trailers have often not been allocated to orders or vessel departures, the responsible shipping companies cannot be identified. The lack of information about roll-trailers owners complicates concrete measures against an overload of the terminal with roll-trailers. Queries of shipping companies show, that even they do not have a complete overview about the distribution of their roll-trailer inventory. Occasionally this circumstance leads to a roll-trailer allocation, which is not realisable, because the roll-trailer has left the terminal over land for use in another seaport (as a truckload) or for repair. It is assumed, that the incomplete information as well as the lack of control and availability of roll-trailer increased the number of roll-trailers within the roll-trailer cycle.

Process delays due to the paper based information flows

The majority of the procedural information flows on the RoRo terminal occur in the form of paper documents. This delays especially those processes, which are waiting on a document as a basis for a decision or the process continuation. The main reason for this delay is the physical distance, which has to cover between the decision maker and the operator. This problem gets worse with the increasing traffic density, which is caused by the increase of the handling goods. A common characteristic of the critical points is a general lack of timely, complete and accurate information.

3. TECHNOLOGIES

To handle the identified critical points in the roll-trailer operations cycle, an adoption of innovative information and communication technologies for identification, communication and localisation tasks can be used. In this context, localisation systems as well as automated identification technologies are of particular importance.

In this chapter, the technologies, which offer a wide range of opportunities for tracking and tracing positions and status of roll-trailers in the seaport terminal, are described.

3.1. Satellite positioning system

To realize the location objective of the project, a technology is needed which can afford the most exact positioning data of the tug-masters as possible.

Via satellite positioning systems such as Global Positioning System (GPS) or the upcoming European Galileo system any object can be localised with an accuracy of several meters. This means that the exact position of an object can be determined in an appropriate frame of reference, e.g. in a geodetic graticule. However, GPS for example has some limitations. There must be a relatively clear "line of sight" between the GPS antenna and four or more satellites. Objects, such as buildings, overpasses, and other obstructions, that shield the antenna from a satellite can potentially weaken a satellite's signal such that it becomes too difficult to ensure reliable positioning. These difficulties are particularly prevalent in urban areas. The GPS signal may bounce off nearby objects causing another problem called multipath interference. Also single GPS receiver from any manufacturer can achieve accuracies of approximately only 10 meters. However, 10 meters are too inaccurate for utilization in an area of application like a seaport terminal. (Mansfeld 1998)

To achieve the accuracies needed for quality Geoinformation Systems (GIS) records from one to two meters up to a few centimetres in the seaport terminal requires differential correction of the data. The majority of data collected using GPS for GIS is differentially corrected to improve accuracy. The underlying premise of differential GPS (DGPS) is that any two receivers that are relatively close together will experience similar atmospheric errors. DGPS requires that a GPS receiver be set up on a precisely known location. This GPS receiver is the base or reference station. The base station receiver calculates its position based on satellite signals and compares this location to the known location. The difference is applied to the GPS data recorded by the second GPS receiver, which is known as the roving receiver. The corrected information can be applied to data from the roving receiver in real time in the field using radio signals or through post processing after data capture using special processing software. (Chivers 2003)

3.2. Identification system

To identify of each roll-trailer in the high & heavy area it is necessary to use a reliable and robust identification technology. To avoid identification failure based on manual and human mistakes it is equally important to make use of automated identification systems. The main purpose of automated identification systems is the fast and reliable identification of several objects. In addition to identification technologies such as barcode and OCR (Optical Character Recognition), especially the Radio Frequency Identification (RFID) technology gains in significance.

A RFID system consists of at least one storage medium (RFID transponder) fixed to the corresponding object and a reading/writing device (RFID reader), which communicates with each other via radio signals. Figure 2 illustrates the functional principle of an RFID system.

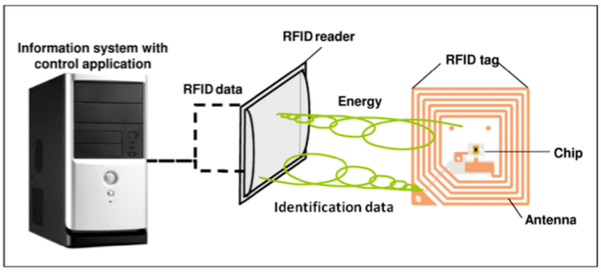

Figure 2: Function principle of a RFID system

The RFID reader generates an electromagnetic frequency field that provides power and data to the RFID transponder. These data stored onto the transponder is transmitted to the reading device as a response to a request impulse. Both the transponder as well as the reading device has an integrated transmitting and receiving antenna. Thus is it possible to write and read a RFID transponder with the same device. The RFID transponder, which contains a unique identification number, uses its antenna to take energy from the frequency field of the RFID reader. This energy is used from the RFID transponder to send the stored identification data to the RFID reader via its antenna. The RFID reader transfers the identification data to a computer unit. RFID transponders which use the signal energy from the RFID reader to transfer their data are called passive transponders. In contrast to passive transponders, active transponders have their own source of energy in form of a battery, so they are independent of the frequency field of a RFID reader. However, compared with passive RFID transponders active ones are more expensive and need much more maintenance. (Shepard 2005)

Additionally to their energy supply, RFID tags can also be differed concerning to their transmission frequency. This high frequency (HF) and ultra high frequency (UHF) transponder have enforced. During HF transponder with a frequency field of 3-30 MHz and a range up to 10 cm are mainly used for access control, UHF transponder with a field frequency of 850-950 MHz and a range of up to six meter as passive and up to 100 meters as active ones can be used for object identifications where a wide range identification is necessary.

The main advantage of RFID technologies as against optical identification technologies is that RFID readers do not need a direct view to RFID transponders for data exchange. Rather, the data exchange is independent from RFID transponder positions in the reading area of the RFID reader. Thereby, it is possible to read multiple RFID tags at once. The so called "bunch processing" has positive emergences by the identification of stacks in the high & heavy area. Furthermore, their exist many design solutions of RFID transponder which do not lose their reliable functionality on metallic surfaces, for example on a roll-trailer, and which are robust against mechanical stress and wet weather conditions.

3.3. Communication system

If the position and status data of roll-trailers are generated and used by spatially distributed and asynchronous operating employees, for collecting and providing up-to-date data, the project solution requires a centralised server (i.e. a data base). For the communication between mobile data terminals and a centralised server, the project uses a Wireless Local Area Network (WLAN), which already exists on nearly all Ro-Ro terminals.

WLAN is a well accepted technology for data transmission. It includes encryption and authentication mechanisms and operates on different frequencies, data transfer rates and ranges – depending on the used standard. WLAN can be operated in two modes: the infrastructure mode and the ad-hoc mode. While the ad-hoc mode is designed to enable spontaneous connections of coequal end devices, the infrastructure mode are less dynamically and more stationary: there are fixed installed base stations (access points). They provide access to the basic network (centralised server) and coordinate the devices within their work area (Netgear 2009). So, even if the WLAN on the Ro-Ro terminal operates in the infrastructure mode, it is possible to work real-time on the centralised server. But there is a special challenge for the WLAN: the so called handoff. A handoff is necessary when a device leaves the cell of a base station and enters the cell of another base station. The movement is detected by regularly measuring the received transmitting power of the surrounding base stations. If the received transmitting power of another base station exceeds those of the current one, it is assumed that the device moves into this direction, so that a connection change is advisable. To ensure an uninterrupted data stream, the connection change has to occur simultaneously on the centralised server as well as on the end device (Zhang et al. 2007).

3.3. Technical Implementation

The technical implementation of the designed system for tracking and tracing roll-trailers on seaport terminals is based on the described technologies RFID for identification, GPS, especially DGPS technology, for positioning and WLAN for communication as illustrated in figure 3.

The focus of the technical implementation is directed to stationary and mobile detection of position and status information of roll-trailer on seaport terminals. For this purpose, roll-trailers are fitted with passive UHF transponder. Tug-masters are equipped with combined data terminals, which contain an UHF reader to identify the related roll-trailers, a positioning component for locating the current position as well as a communication component for transmitting transport orders, positioning and status data. The position of the roll-trailer determined by DGPS, or Galileo in the near future is assigned to the roll-trailer identified by its RFID tag.

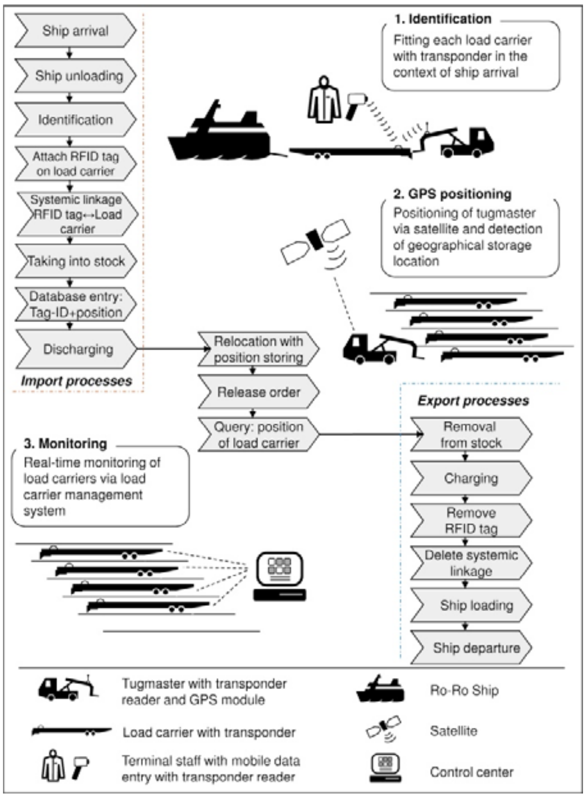

Figure 3: Technical implementation of the composed IC-Technologies (based on Scholz-Reiter et al. 2008)

A detection of the specific position of the roll-trailer can be achieved while moving the roll-trailer with a tug-master from one location to another. An appropriate combination of the described technical components allows a continuous monitoring of position and status of the roll-trailers (loading status, current allocation of roll-trailer to tug-master, movement status etc.) on the huge terminal area. As a result, the main stock keeping processes of roll-trailers such as taking into stock, removing from stock and relocation can be tracked. For each process step (ship loading / unloading, taking into stock / removal from stock / relocation of roll-trailers, unloading of roll-trailers etc.) a timestamp as well a location stamp is documented. The identification number of the roll-trailers and loadings as well as the voyage numbers are documented in the corresponding software system and are assigned to the related ships and shipping companies in their function as invoice recipient for storage charge. At neuralgic points of the seaport terminal area (ship ramps, storage gates etc.) additional stationary reader devices are implemented, which complete the monitoring of roll-trailer movements by identifying passing roll-trailers fitted with passive transponders.

By means of the IT-based roll-trailer management system described above, the process chain in the field High & Heavy (ship unloading, taking into stock, relocation of roll-trailer, removal from stock to ship loading) can be permanently observed and therefore significantly improved. Further sub processes are primary data collection and receiving inspection in the context of the ship arrival process. On the seaport terminal, the RFID system represents a temporary closed loop solution with main focus on the time periods, during which the roll-trailers are staying on the terminal area. Transponders, which are tagged to the roll-trailers in the context of the ship unloading process, are read by stationary or mobile RFID reader devices at the ship ramp. When a roll-trailer leaves the seaport terminal area, the transponder is read again by the RFID reader at the ship ramp and after that removed from the roll-trailer. Another field of application of the described system is the inventory of roll-trailers, which can be significantly, accelerated using a mobile data entry device (MDE) with integrated RFID reader and GPS component. (Scholz-Reiter et al. 2008)

4. TECHNICAL AND ECONOMICAL EXAMINATION

In a first one year technical examination, 20 RFID transponders from two different producers were tagged on the front side of different roll-trailers in an early project stage. The intention was to get some knowledge about the reliability of the transponders under the influence of metallic environment, wet weather conditions and mechanical stress. During the examination, the roll-trailers were normally used, a part of them even travelled to another seaport harbour abroad. The results of the survival test for the RFID transponder were surprisingly good. Even though the rough handling on the high & heavy section and the associated use without carefulness, the RFID transponders were not damaged even after one year of use. Quite the contrary, even during the winter with cold, snowy and rainy weather, reliable reading ranges up to 4 meters could be measured. Even the metallic surface of the roll-trailer, which mostly can be a problem for the reliability of RFID transponder, had only, if any, an insignificantly influence on the reading distance. First tests of WLAN connectivity and DGPS accuracy were convincingly. Detailed tests will be conducted over several months in the next stage of the project.

Furthermore a first economic estimation, which based on the current and target process models was calculated. Therefore the process cost accounting method was compiled with the use of total costs of ownership. A comparison of estimated cost reductions through the use of the composed technologies and the estimated investigation costs for software and hardware came to the mentioned amortisation of 1.5 years. A full comprehensive economic analysis about the cost effectiveness of the technical implementation will be made after implementing a prototypical system and generating real data.

5. CONCLUSION AND OUTLOOK

This paper presents an implementation concept of IC-technologies that captures position and status of roll trailers in Ro-Ro traffic on sea harbour terminals. The described analysis points out weaknesses in the roll trailer operations cycle and show how to handle these weaknesses by implementing of IC-Technologies. The paper also shows that an early economical examination comes to the result that an amortisation of the implementation concept can be generated in 1.5 years. The integration of the concept into the seaport warehouse management system includes the development of software for roll-trailer management and the selection of appropriate hardware components. Thus, further steps of work will be the implementation of software and hardware components according to the model.

A prototypical system based on the shown model and system concept will be implemented on a German Ro-Ro terminal and an extended testing will be carried out. With the expectation that sea harbours will be increasingly frequented in the future the implementation of IC-technologies into Ro-Ro traffic in sea harbours cannot be disregarded.

6. ACKNOWLEDGMENTS

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7. REFERENCES

Arnold, D.; H. Isermann, A. Kuhn, H. Tempelmeier (Hrsg.), 2002. *Handbuch Logistik*. Springer Verlag Berlin.

BMVBS, 2007; Seeverkehrsprognose 2025. http://www.bmvbs.de/-,1477/knoten.htm [Accessed 16 February 2010]

CHIVERS, M., 2010: Differantial GPS Explained, http://www.esri.com/news/arcuser/0103/differentiad1of2.html [Accessed: 12 July 2010]

DESTATIS, 2009a; Beförderungsmenge nach Hauptverkehrsrelationen. http://www.destatis.de/jetspeed/portal/cms/Sites/destatis/Internet/DE/Content/Statistiken/Zeitreihen/LangeReihen/Verkehr/Content100/lrvkr004a,templateId=renderPrint.psml [Accessed: 16 February 2010]

DESTATIS, 2009b; Güterverkehr 2009: Starker Rückgang des Transportaufkommens um 11,2%. http://www.destatis.de/jetspeed/portal/cms/Sites/destatis/Internet/DE/Presse/pm/2010/01/PD10__030__46,templateId=renderPrint.psml [Accessed: 16 February 2010]

Fleisch, E., F. Mattern (Hrsg.), 2005. *Das Internet der Dinge*. Springer Verlag Berlin.

Heimbrock, H., 2001. *Palettenlose Lager- und Transportsysteme als Alternative zu konventionellen Ladungsträgern.* Deutscher Fachverlag, Frankfurt am Main.

Mansfeld, W.; 1998; Satellitenortung und Navigation: Grundlagen, Wirkungsweise und Anwendung; Vieweg + Teubner – GWV Fachverlage GmbH; Wiesbaden

Netgear, 2009. Basiswissen - Wireless LAN Grundlagen.

Oppel, J.-A., 2008. *Der Seehafen als Engpass.* März 2007. Online source. Available from: http://www.dmkn-beta.de/downloads/51/De/FILE451/DerHafenalsEngpass.pdf/ [Accessed: 31 March 2008].

Scholz-Reiter, B.; Böse, F.; Teucke, M.; Virnich, A.; 2008; Load Carrier Management on Ro-Ro Terminals. Proceedings of the 11th International Workshop on Harbor, Maritime & Multimodal Logistics Modelling & Simulation. Campora San Giovanni, Italy, September, pp. 274-279.

Shepard, S.; 2005; RFID - Radio Frequency Identification, The McGraw-Hill Companies, New York.

Zhang, Y.; Yongquiang, L.; Xia, Y.; Huang, Q. (2007): LeapFrog: Fast, Timely WiFi Handoff. Proceedings of the IEEE Global Communications Conference 2007 (GOBCOM 2007), Washington, USA, November, pp. 5170-5174.

ZDS, 2007; Zentralverband der deutschen Seehafenbetriebe: Jahresbericht 2006/2007. September 2007. Online source. Available from: http://www.zds-seehaefen.de/pdf/jahresberichte/2007.pdf [Accessed: 31 March 2008].

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