DECISIVE INCREASE OF CAPACITY AND THROUGHPUT BY USING ADVANCED PLANNING AND REAL-TIME OPTIMIZATION ALGORITHMS

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ABSTRACT

Automation of terminals with integrated optimization approaches is a big topic. But at most only a few companies worldwide really have the knowledge to base their approaches on highly sophisticated mathematical algorithms and heuristics to improve equipment and yard utilization. INFORM combines in unique manner the advantages of *planning* ahead by assigning slots and equipment over a *longer time period* and the necessities of making *optimized decisions* in *real time*. Based upon this knowledge as well as the consulting experience of HPC the new brand TERMINALSTAR was established in 2006. In cooperation INFORM and HPC are offering a TOS for sea ports and various standardized and customized optimization packages. The challenging CTB project proves the expectations to be justified.

Keywords: advanced-optimization, CTB, TERMINALSTAR, planning-and-control-combination

1. INTRODUCTION

Sea ports are the engines of our economy. Their possibility to cope with the continuously increasing maritime trade is essential for the health of our economies. Innovative technologies help to increase capacities and throughput of new and already existing terminals (Niessen 2007, Niessen 2008a, 2008b). Especially advanced IT technologies prevent those economical junctions from becoming fatal logistic bottlenecks (Savelsberg 2008).

What are the main challenges for ports which can be supported by innovative IT applications?

Generally, the main objective at a container terminal is to minimize vessel turnaround times, corresponding to the maximization of quay crane throughput. Furthermore, the demand for increasing density by stacking higher leads to the necessity to implement optimization tools to avoid extensive reshuffling. And last but not least all involved employees have to be and -even more ambitious- have to feel themselves supported by a new IT-system during their daily business.

For almost 10 years, INFORM has developed a modular terminal logistics operating and optimization system that is today used for handling tens of thousands of containers at maritime and inland ports as well as road/rail terminals. Together with HPC the new brand TERMINALSTAR was established in 2006 offering a TOS for sea ports and various standardized and customized state of the art optimization packages (Niessen 2007, Niessen 2008a, 2008b). These packages build upon the extensive research results on optimizing container terminals with the help of advanced mathematical models and methods developed in the field of Operations Research. A recent survey (Stahlbock and Voß 2008) lists over 200 references for these topics.

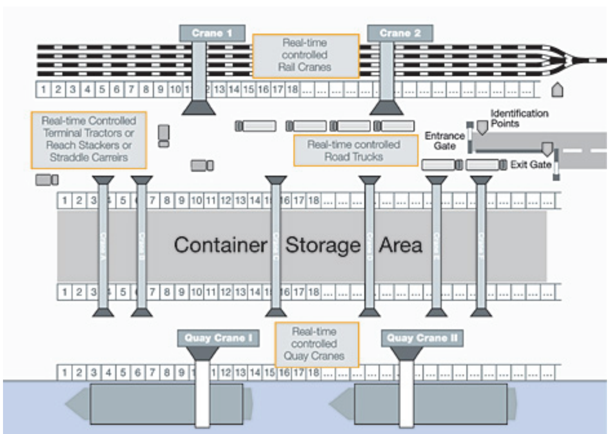

Figure 1: General Transportation flow through a port container terminal. Source: INFORM

2. THE CONTAINER TERMINAL BURCHARDKAI (CTB)

2.1. The “Implementation-Framework”

The CTB project is a good example for the challenges today’s software and software design have to face.

Regarding this terminal the overall goal is to almost double the throughput over the next couple of years (2.6 Million TEU to 5.2 Million TEU). A combination of new and already existing transport technologies (fully automated RMG, conventional VC, rail cranes …) and storage facilities shall be in use (RMG-Blocks, VC-Blocks, Empty Facilities). Software from different companies for different purposes will be implemented and parts of the old software system will be kept.

TERMINALSTAR is in charge of the storage and stacking logistics, the transport optimization, the loading and unloading of vessels as well as the information management and the GUIs for the control centre. Since CTB operates at its capacity limits, down times for implementation have to be reduced to some minutes. Time for testing has to be used very efficiently.

Figure 2: Progress in terminal operations: The Burchardkai, Hamburg, in 1968; straddle carrier based operation in 2005; and the future layout in 2014 with automated six-high storage blocks served by triple rail mounted gantry cranes (in red). Source: INFORM

2.2. Software modules of TERMINALSTAR implemented at the Burchardkai Hamburg

The following modules of TERMINALSTAR will be implemented in Hamburg.

The first module, called *Yard Contro,l* includes algorithms taking care of smart stacking which will be explained in more detail in the next chapter, the preplanning of Empties and the possibilities to exchange same empty containers against each other. Furthermore it helps to avoid idle times of equipment by smart Housekeeping rules. Finally it takes care of the whole IMO and Reefer management.

The module *Process Control* optimizes all workflows. This module is a kind of centre module since all manual and automated transport demands are governed here. Furthermore the Process Control takes care of the truck schedule. Hence, according to specific rules the most favorable order to load and unload container at certain areas of the terminal is determined within this module.

Most of the decision intelligence is located in the *Equipment Control* module. Optimization tools offer a medium term planning, e.g. scheduling of the upcoming transport demands, as well as an online control optimization, e.g. when a container has to be moved on short notice and hence all orders close to this point in time have to be rescheduled – again in a smart way keeping in mind directions and distances which have to be covered. All different kinds of equipment can be organized. The software is partly customized according to the special conditions which have to be kept in mind for each specific terminal.

The *Vessel Manager* takes care of the sequences in which the containers arrive beneath the quay cranes.

The *Hinterland Manager* is in charge of the loading and unloading procedures and all optimization aspects regarding the rail interface.

Figure 3: Softwaremoduls of TERMINALSTAR implemented at the Burchardkai Hamburg

The final module to be presented here is the *Control Center*. GUIs to supply information and to give support for decisions have to be developed closely according to the mental models of the users. Hence, a thorough procedure of development including regular user reviews and adjustments to their needs was carried out during this project.

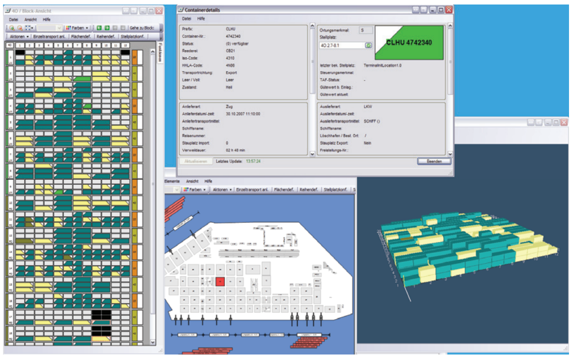

Figure 4: Examples of GUIs developed during the CTB project

This year in summer the first modules of TERMINALSTAR will be implemented at the Burchardkai Hamburg.

2.3. TERMINALSTAR´s contribution to meet the overall goal

The overall goal of the CTB project is to increase capacity, to push the throughput, reduce the costs per box while using the same space. Hence, this demands higher and smarter stacking as well as faster and more efficient handling.

In the following some examples will be pointed out to explain the input advanced optimization can offer regarding this challenges (Dorndorf et al. 2007).

Two of the main differences regarding *planning and control* applications at terminals are that uncertainty is higher in planning than in control, and that reaction time is much shorter in control, which generally has to be done "online." Hence, computation in planning is not a very strict constraint and uncertainty models and calculi can be used. By contrast, in control computations have to be very fast, which can either be achieved by very fast algorithms or by only modifying planning results according to realizations (wait-and-see approach).

To maximize the throughput of the system, unproductive moves should be avoided by using advanced storage and stacking approaches.

The *stacking problem* consists of finding an optimal location for each incoming container. The container is characterized by a set of attributes (geometrical, operational and logistical). It is good practice to place containers with similar attributes one on top of the other. In this way, each container in a stack can be considered equivalent, avoiding rehandles. One of the most used stacking strategies involves placing export containers with the same departing ship and same destination on top of each other. Alternatively, it is possible to stack according to the estimated time of departure so that containers with an earlier departure time will be placed on top of others that will be picked up later.

In automated storage blocks, automatic re-stacking during times where the handling equipment would otherwise be idle, can be used to re-optimize the storage area, resulting in a reduction of one-tenth of container loading operations.

In the vast majority of cases, information is uncertain at the moment of the decision. Often it changes over time (for example, time of departure). The fast turnover of containers implies that the available time window for each decision is usually very limited (order of seconds). For these reasons, the stacking problem can be classified as a real-time optimization problem. This means that, in practical applications, one of the most employed optimization techniques are heuristics, mainly rule-based systems or ranking systems.

Other alternative approaches are based on the use of the "soft computing" area of research. A key element of the system is an inference engine formed by a set of rules "if... then..." that operates on fuzzy variables. The use of fuzzy technology allows to model uncertain and qualitative data through the use of linguistic variables, simplifying the mathematical model and reducing the number of variables. The resulting inferential engine uses its tolerance towards imprecision and uncertainty to represent adequately the complex relationships between the variables of the system, making it more understandable and transparent to the user.

In many cases, different algorithms or mathematical models are evaluated and validated through simulation tools.

Transport optimization deals with the horizontal transportation of containers. An import container is initially transported from the quay side to the storage area, most frequently by straddle carriers or internal trucks and on some modern facilities by automated guided vehicles. This leads to challenging online vehicle routing optimization problems. At CTB, for example, 104 straddle carriers are controlled. Compared to current practice, the efficiency can often be improved by pooling vehicles. Similar vehicle routing problems arise on the land side, where containers are transported between the storage blocks and the railhead and where external trucks must be scheduled and routed through the terminal.

The intermediate storage area is organized in rectangular blocks that are either served directly by the straddle carriers, which can stack containers up to three or sometimes four high, or by rubber tired or rail mounted gantry cranes (RTMG and RMG) that can typically stack up to five or six high. For example, an RMG block at the CTB can hold more than 2,000 standard containers. At newer facilities the operation of the RMG cranes is fully automatic with two or even three cranes per storage block. Crane scheduling is concerned with the online optimization of the stacking cranes. The objective is to minimize the travel times of the cranes and delays and waiting times at the interfaces of the storage blocks. Online crane scheduling is also needed at the rail interface to unload and load rail cars.

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AUTHORS BIOGRAPHY

Udo Niessen After completing his studies in engineering and economy Mr. Udo Niessen worked as sales engineer at the wagon factory Talbot in Aachen, Germany. Here he learned about rail technology and companies involved. The majority of Mr. Niessen's experience has been built up during a 16-years employment with INFORM GmbH (Institute for Operations Research and Management), Aachen. From 1992 to 1993 he was employed as System Consultant and Customer Adviser. In 1994 he became head of the sales department and in 1997 Director of the Logistics Systems Division. Since 2000, Mr. Niessen has been Vice-President of INFORM GmbH. During the last years, he and his team have been involved in the planning and installation of various implementations of the Logistics Optimisation System SyncroTESS in different application areas. He was member of the central logistics planning team for the new Container Terminal in Altenwerder (CTA) for one and a half years. After the design phase SyncroTESS was installed at CTA for the rail connection and the truck dispatch within the terminal. Currently Mr. Niessen is heading the Inform team delivering the new control software for the CTB project.

Mr Niessen was also involved as the general project manager for the implementation of the Logistics Optimisation System SyncroTESS in the three new parcel centres of the Swiss Post. Each parcel centre is connected to the national railways.

Since 2003, Mr Niessen has been one of the four shareholders of INFORM GmbH.

For several years, **Eva Savelsberg** was head of a research group on national and international large-scale logistics projects at the RWTH Aachen University in Germany. During this time, she also received her PhD in Mechanical Engineering (2002) and was subsequently awarded the title of "Privatdozentin" at the same university in 2007.

Since 2006 she has been working for the Logistics Systems Division of INFORM GmbH in Aachen. Here she is presently involved in research and development on complex automated systems, specifically the automation of large container terminals.

Her most recent book "Innovation in European Freight Transportation" will be published in May 2008.

Ulrich Dorndorf is the Chief Technical Officer of INFORM. After receiving his Master in Engineering from the Technical University of Darmstadt, he joined INFORM in 1992. As project manager and head of software development he has been involved in the development and introduction of large scale decision support systems mainly for transport, terminal and airport logistics. As Chief Technical officer, he now manages the company's Research and Development efforts with focus on optimization, decision support and simulation technologies. He holds a PhD in Economics and Operations Research from the University of Darmstadt and has published more than 40 papers on optimization models and methods.