MODELLING AND ANALYSIS OF MECHANICAL STEEL HANDLING PROCESSES IN SEAPORTS

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ABSTRACT

Despite the actual financial crisis the quantities shipped in international seaports are assumed to increase during the next years. Due to spatial and capacity restrictions many modern seaports have limited possibilities for expanding their current infrastructure. Hence, seaports need to use their particular resources in a more effective manner, in order to fulfil the demand. In this context novel approaches and processes for material handling may help to increase the effectiveness of the entire maritime logistic chain. This paper will focus in particular on the handling of steel sheets, which are determined for the export, in an exemplary case at a German seaport. It focuses on modelling the underlying business processes by event-driven process chains (EPC). These EPCs are analysed in order to identify major weak points and improvement potentials. On the basis of these potentials an innovative magnetic handling process will be discussed. It will be shown how this magnetic device may help to use the identified potentials and to overcome the weak points.

Keywords: maritime logistics, handling processes, magnet technology, event-driven process chains

1. INTRODUCTION

During the last years an intensive growth of cargo traffic in seaports world-wide was recorded. Especially, the world-wide maritime traffic profited from this development strongly (Stopford 2009, Amerini 2007). However, on the one hand there is a need to serve these increasing cargo quantities. On the other hand, efficient handling and warehousing processes have to be offered to customers, in order to stay competitive (Zondaga et al. 2010). Additionally, the actual financial crisis has intensified this competitive pressure. In this context technological process innovations are promising. Especially, with regard to the limiting factors, e.g. spatial restrictions, which reduce possibilities to upgrade existing infrastructure and capacities, the implementation of new technologies is necessary. The development of such novel technologies increases the competitive advantage of enterprises in the maritime business. But also, these innovations may affect the whole sector (Metcalfe and Ramlogan 2008, Roper et al. 2008). Regarding steel handling in seaports this means, that the whole industry sector may be affected positively by the implementation of new efficient handling technologies and unified processes.

The handling of steel products is a classical load handling process with a low degree of automation. It is characterized by mechanical load handling devices like hooks, chains, ropes and belts. Usually, these devices are attached manually to the steel sheets. Therefore, this process offers potential for technological improvements.

This paper will present a detailed analysis of a steel handling process in an exemplary business case, which mainly focuses on the handling of steel sheets at BLG Cargo Logistics GmbH & Co. KG. in Bremen, Germany. Based on an event-driven process chain model of the entire process its weak points will be identified and classified. These weak points will be investigated with regard to aspects of process quality, process stability, economic potentials and safety of workers. Furthermore, a magnetic traverse for steel sheet handling will be discussed as a possible solution for the identified weak points.

Therefore, this paper is structured as follows: section 2 presents the perspective of modelling maritime processes with event-driven process chains. Subsequently, section 3 presents the detailed model of all process steps involved in the whole handling process. The corresponding weak points are discussed in section 4. In section 5 a possible solution for this process by using a magnetic handling device is discussed. Finally, section 6 gives a summary and provides an outlook with further research directions.

2. MODELLING BUSINESS PROCESSES USING EPC

The analysis of material handling processes should not be limited to a pure analysis of single handling functions. Rather the entire logistic process should be investigated, in order not to breach interdependencies between logistic target measures (Arora and Shinde 2007).

The event-driven process chain is a commonly used method for business process modelling (BPM) (Rosemann and van der Aalst 2007). It is a graphical representation of processes, which divides the total process into sequences of functions and events. These elements (functions and events) are modelled as nodes, which are connected by arrows. Logical distinctions of processes can be modelled by applying logical connectors. Functions in an EPC are denoted by rounded rectangles. These functions describe tasks, which have to be performed by an organisational unit. In this context functions are time-consuming procedures. In contrast, events do not consume any time. They are passive elements, which occur as a result of one or more functions at a particular point in time. In the graphical EPC-representation events are denoted as hexagons. Logical connectors can be used to model different kinds of distinctions in the process. These different types are 'AND', 'OR' and 'XOR' connectors. They denote when a function leads to two or more events, when two or more functions start one event and both vice versa (Scheer 1999).

Modelling business processes by EPCs is widely spread among researchers and practitioners. Nevertheless, this method has besides its several advantages certain disadvantages. Kesari et al. (2003) point out in their survey on BPM some of them, which mainly concern the possibility of over-analysis, developer-biasedness and misinterpretations. An over-analysis means that the modeller sets the wrong focus. Highly detailed models which do not focus the main aspects of the processes are a possible consequence. Moreover, this kind of over-analysis leads on the other hand to possible misinterpretations of third parties. Some authors identified another reason for possible misinterpretations. They argue, that the semantics and syntax of the EPC are not well defined (van der Aalst 1999, Kindler 2004). But due to their simple notation and their intuitive interpretability (Ko et al. 2009, Scheer et al. 2005) EPC models are used in this paper.

3. PROCESS MODEL

3.1. General process description

In the presented case a particular handling process of steel sheets at BLG Cargo Logistics GmbH & Co. KG. in Bremen, Germany is investigated. Usually the steel sheets are delivered by rail to the seaport and are stored for further export shipment. Starting from this point, the investigation focuses physical handling processes concerning the loading procedure of ships for export. Hence, port internal storage and handling processes are included in this study.

The complete steel handling process in the case at hand can be divided into three parallel running sub processes:

1. Pick-up from storage
2. Transfer to ship
3. Placing timber

In the first sub process a reach stacker or a fork lifter takes out material from stock in the 'storage area' and places it on a trailer. Notice that multiple steel sheets are moved as a ply to the trailer. The amount of sheets per ply depends mainly on the weight of the steel sheets and varies between two to four. After pick-up from the 'storage area', the trailer drives directly to the 'adjustment area', where a second fork lifter adjusts the steel sheets interlocking by pushing them in a predefined position. This is necessary because the crane can only pick up steel plies with a plain geometry. Afterwards the trailer transports the steel sheets to the 'crane area'. It has to wait in this area until the crane picks up the steel sheets. In this moment the trailer starts driving and completes its round course with arriving at the storage area again. Meanwhile, the crane turns and releases the steel sheets into the ship. After this, workers inside the ship have to place timber beams on the top of the latest ply of sheets. This step is indispensable for the unloading procedure in the port of destination. Without placing the dunnage there is no jacking point for the steel handling device in this port. In this particular case the mechanical load handling device consists of four claws mounted on chains, which are connected to a traverse at the crane. The claws have to be fixated on predefined positions at the steel ply to ensure a correct transportation.

The amount of trailers circulating between storage and crane area depends mainly on the distance between mooring place of the ship and storage area. Usually it varies between two and five trailers. The particular number of trailers is determined by a task-dispatcher case-by-case. Further resources involved are two fork lifters, four manual workers on the land side and four manual workers on the water side. These resources are schematically depicted in figure 1.

The following provides a detailed model of this steel handling process in terms of event-driven process chains.

3.2. Detailed EPC-Model

The overall EPC model in figure 2 depicts the total process and the dynamic interplay between all involved sub processes. For the focus of this paper the general EPC model is aggregated to the form of the model in figure 2. In particular the functions 'pick up of steel sheets' and 'crane turns load into the ship' are aggregated representations of sub processes.

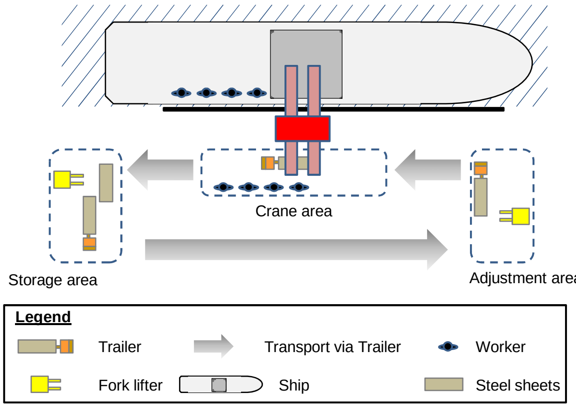

Figure 1: Schematic view of the handling process

In order to investigate the mechanical handling process, this paper presents only the underlying process of the first sub process ‘pick up of steel sheets’ in figure 3.

The general process shown in figure 2 can be divided into three strands, which represent the three sub processes described before. The process starts with an initial event, which indicates that all necessary resources (e.g. cranes, fork lifters or trailers) are in the right set-up state to start the process. Then, the first strand describes the transfer of the steel sheets to the ship. The interdependency between this sub process and the sub process ‘placing timber’ can clearly be seen in figure 2. There is a loop for the ‘placing timber’ process, which starts after the crane placed the steel sheets in the hatchway. On the other hand the next ply of steel sheets can be transferred, if all timber beams are in the right place. This interplay of both processes is indicated by the multiple ‘AND’ connectors between these process steps. In the same way the interdependency between the sub processes ‘transfer to the ship’ and ‘pick-up from storage’ is modelled. As indicated in the verbal description, the trailer drives directly after ‘pick-up’ back to the storage area. In the EPC model this is represented by an ‘AND’ connector. Similar to ‘placing timber’ this sub process has a loop back to the ‘transfer to ship’ process. The loops determine the temporal interdependency of all three sub processes. In occurrence of an unforeseen disturbance in one of these processes the total process stops. In this context, the manual handling process in the crane area is the temporal bottleneck of this process. Thus, a detailed EPC diagram is given in figure 3. It represents the activities in the aggregated function ‘Pick-up of steel sheets’ in figure 2.

Almost all activities in figure 3 can be modelled as a linear sequence of functions and events. The crane turns the chains to the workers, who finally attaches the chains and the claws to the ply of steel sheets. Subsequently, the workers have to press manually against the claws until the crane lifts the sheets slightly.

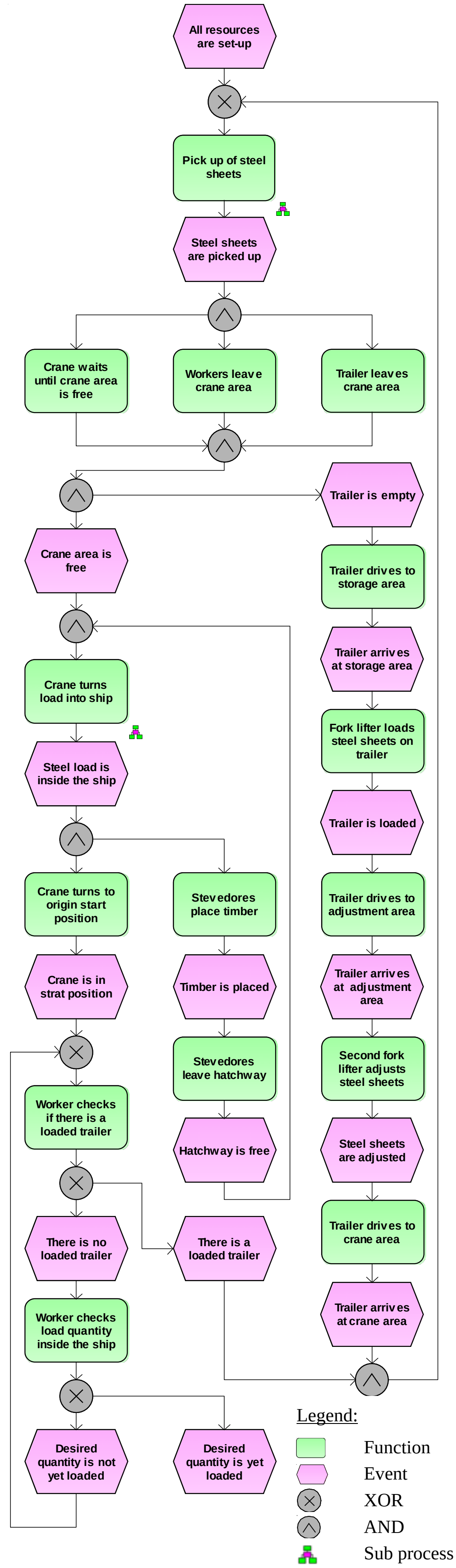

Figure 2: EPC Model of the steel handling process

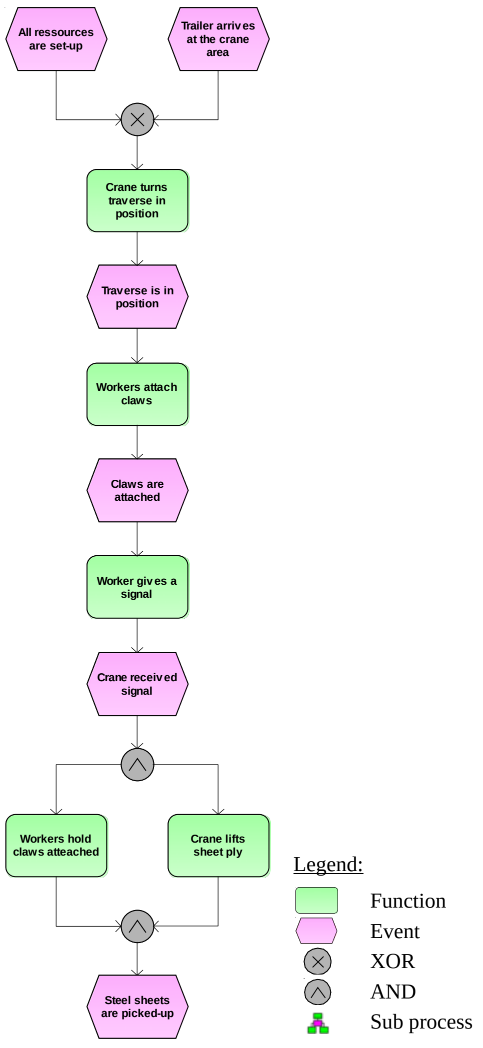

Figure 3: EPC sub model crane turns load into the ship

Only after this slight lifting of the steel ply the correct mechanical force transmission can be guaranteed. Finally, after these steps the process continues at the first 'AND' connector in figure 2. In the next process step all workers have to leave the crane area for safety reasons. Thus, as indicated in figure 2, the process interrupts until the crane area is free. Due to the modelled loop in figure 2 the total process is repeated until the pre-defined quantity of steel sheets is loaded into the ship.

4. WEAK POINT ANALYSIS

A detailed analysis of the handling process led to four major weak points regarding the safety, quality, stability and efficiency of the process. They appear especially in the sub-process of mounting the handling device to the steel sheets.

4.1. Safety

As shown in figure 3, workers have to attach claws to the steel sheets manually. Afterwards, they have to hold them in the right position while the crane is lifting the handling device until all chains are tight. This is necessary to ensure the correct fixing of the claws at the steel sheets. It is obvious that during this process workers can easily bruise fingers or a hand by accident. In general bruises are besides fractures a common type of injuries in the maritime sector (Ellis et al. 2010). Due to the weight of the claws and the occurring forces during the lift process, this may lead to serious injuries.

Furthermore, the claws need to be mounted at predefined positions at the steel sheets. If they are located at a wrong place, e.g. in the border area or in the middle of the sheets, the steel sheets will bend. Thus, they cannot be handled and transported correctly. In the worst case scenario, the claws can loosen and the steel sheets would fall down. Due to the physics of such sheets, they would not fall down straightly but float down like a sheet of paper. This may lead to damage of surrounding infrastructure or to serious or lethal injuries of workers.

4.2. Quality

Generally, the use of claws in the handling process leads to the danger of damaging the steel sheets. While the claws are put on, there is a risk of scratching the sheets. This causes a reduction of the product quality. Also, like described above, the incorrect mounting of claws leads to a bending of the steel sheets. This also reduces product quality. In the worst case scenario, when the steel sheets fall down, they are generally completely damaged.

4.3. Stability

The sub-process of mounting the claws at the steel sheets was described in section 3.2 in detail. An analysis of the process steps showed a certain instability of process times. The weight of the claws and the monotonous activity lead to rising fatigue of workers. Therefore, process times exhibit a higher mean value and a higher variance the longer this tiring activity is performed. The sub-process becomes more and more unstable. Since there is a strong interaction between all sub-processes the overall process times also increase and vary.

4.4. Efficiency

In the described handling process there are four workers needed on landside and on seaside, respectively. As detailed above, the workers at landside have the task to mount the handling device to the steel sheets. The remaining time within the process is waiting time for the next handling steps and can be used for recovery. Likewise, workers at seaside within the ship have a similar task. They loosen the claws from the steel sheets and place timber beams. In total, approximately only 20% of the whole process time is working time, whereas 80% is waiting time. This shows a low efficiency of this sub-process.

5. PROPOSED SOLUTION

The proposed solution to resolve the mentioned weak points within the handling process of steel sheets is the use of a magnetic traverse. Actually, there are three different possible magnet technologies which can be used here. These are an electromagnetic, an a-stable permanent magnetic and a bi-stable permanent magnetic system. The functionality as well as the advantages and disadvantages were shown by Scholz-Reiter et al. (2008).

Due to safety reasons an electromagnet system needs to be constructed redundantly. If one systems fails, the other one can take over the task. Thus, the weight of the whole traverse would be too large. Regarding the maximum load of the crane only one steel sheet could be moved per lift. Detailed calculations and simulations of the remaining two systems have shown that an a-stable permanent magnet system has the highest force/weight ratio. Furthermore, its capability to change the magnetic force continuously makes it the preferable choice.

At present, a magnetic traverse is being developed using this technology. Eight single magnet systems will be attached to a traverse and be equally distributed over the surface of the steel sheets. The solution has to be able to handle up to three stacked steel sheets with the dimensions 12m x 4,38m x 19mm each. Since there are air gaps between the single steel sheets, it is extremely challenging to develop this magnetic system, so that it complies with German safety standards in seaports.

The magnetic traverse will strongly change the here presented process of handling steel sheets in different points. Especially, the new process will exhibit the potential to resolve the presented weak point within the actual handling process.

Due to the process automation it will be possible to save labour. Depending on the final configuration and design of the traverse up to six workers might become free for further tasks in the seaport area. The automation also leads to a better stability of the process as a whole. The influence of tired workers on the process times can be reduced significantly. It can be estimated that the variance and the mean of the process times will decrease. Thus, the stability of this sub-process will positively influence the interaction of all three sub-processes.

With the substitution of the manual load handling attachments by a magnetic system many manual activities of workers become obsolete. Thus, possible injuries of workers when mounting the claws to the steel sheets can be avoided. Furthermore, the well defined position of the single magnet systems on the traverse ensures the correct and planar handling of the steel sheets. This prevents the sheets from being damaged or falling down.

6. SUMMARY AND OUTLOOK

Before the financial crisis, quantities shipped in international seaports increased and will in future again increase even more. Due to spatial restrictions in seaport areas, it is important to use the existing infrastructure effectively to stay competitive. Nowadays, the steel handling process in seaports is mostly performed with manual load handling devices.

To investigate the weak points of this handling process a detailed process analysis was performed in the seaport of BLG Cargo Logistics GmbH & Co. KG. in Bremen, Germany. A process model using EPCs was developed. Based on this, four major weak point could be identified regarding safety, quality, stability and efficiency of the process. The proposed solution to resolve these weak points is the use of a magnetic traverse. It can be estimated, that the four presented weak points can be optimized in this way. At present a model of the developed magnetic system is built to examine the real behavior of such a system. Based on the gathered results a magnet traverse will then be built.

To evaluate the impact of the solution a profitably analysis is being performed. It contains at present the actual situation of the process presented in this paper. Future work will contain a simulation study to approximate the benefits using a magnet traverse. To be later able to substitute the simulation data with real data, the developed magnet system will be installed to a crane in the port of the operator. Extensive field tests will then be performed to be able to finalize the profitably analysis.

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