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Potential of Non-port Slot Booking Systems for TAS

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Purpose: Truck appointment systems (TAS) are a reliable method for seaport container terminals to reduce peaks in truck arrivals. Thereby, the operation costs for terminals and the waiting times for trucking companies are reduced. The focus of this study is to optimize TAS by analyzing and transferring the components of non-port time slot booking systems.

Methodology: A comprehensive systematic literature analysis is applied to identify the potential of non-port time slot booking systems. Three industries are identified whose time slot booking systems are well transferable to TAS. The most promising industry, the health care sector, and specific approaches are selected for a benchmark.

Findings: The results show that in particular the time window booking systems from the health care sector have a good transferability to TAS in ports. Of the approaches examined, the overbooking of appointments in fixed time windows was rated most positively in the benefit analysis.

Originality: Past studies usually treat TAS in ports as a completely new subject area. Findings from other industries are rarely taken into account. A systemic study on the transferability of selected approaches from other sectors has not yet been carried out for TAS.

Keywords: Truck Appointment System, Container Terminal, Benchmark Analysis, Health Care

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1 Introduction

Seaports have always played a special historical role in trade. Container terminals in particular have developed into the backbone of the national and regional economy. The introduction of Ultra Large Container Vessels in recent years resulted in a strong increase in the demands placed on container handling. Terminals are faced with the challenge of loading and unloading more containers in less time. One way to meet this challenge is to introduce management strategies aimed at avoiding bottlenecks (Ambrosino and Peirano, 2016). Furthermore, considerable traffic loads with increasing truck waiting and handling times and therefore reduced productivity of container terminals can be observed. Bottlenecks, producing truck congestion inside and outside the terminal, can lead to serious local environmental problems such as noise and harmful emissions, but also to major inefficiencies in various operations. The main cause of truck congestion is the fluctuating arrival pattern of trucks. This results in a situation where demand significantly exceeds supply or vice versa (Huynh and Walton, 2011). A well-established solution to mitigate the problems described is to implement a truck appointment system (TAS). With this, it is possible to increase the gate capacity without expanding the area. The terminal operator determines time windows when containers may be delivered and collected. The truck operators can then choose between the time windows. This enables optimum use of the terminal's capacities and prompt operation of the trucks (Li, et al., 2016). Various approaches can be observed as to how TAS can be designed to counteract truck congestion and the associated stresses. Nevertheless, so far no structured analysis on the different parameters of TAS and their effect on the efficiency exists. Furthermore, many

studies focus on TAS in ports as an isolated problem and do not use all the potential knowledge about time slot booking systems generated in years of research in other industries. This aspect has so far only been illuminated to a limited extent in literature on TAS.
The explicit aim of the present work is to answer the two following research questions:

1. Which systemic properties of non-port time slot booking systems in other industries are relevant for TAS in ports?
2. To what extent can the highlighted properties be transferred to TAS?

In order to answer the first research question, a systematic literature search is carried out to identify the potential of non-port time slot booking systems. The second research question implies the examination of the highlighted components for their transferability in the TAS under consideration. First, in Section 2 the background is illuminated to introduce the topic of container terminals in general and TAS especially. The current state of research is presented as well. Section 3 shows the results of a systematic literature review and shows possible approaches to optimize TAS from other industries. Section 4 presents a benchmark analysis for one chosen industry and evaluates the utility for the presented solutions for implementation in TAS. Subsequently, in Section 5 a conclusion and an outlook are given.

2 Truck Appointment Systems at Container Terminals

In the following section, the overall structure and current developments of container terminals are presented. Afterwards, the functionalities of TAS and their interference influences are shown. Lastly, the state of research for TAS' characteristics is determined as a basis for this study.

2.1 Container Terminals: Recent Developments

International trade increases steadily since 2010, with maritime transport representing around 90 % of the global trade volume. Seaports support globalized production processes and their integration into the world economy. In line with this development, the container handling volume increased from 560 million Twenty Foot Equivalent Units (TEU) in 2010 to 752 million TEU in 2017 (UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT, 2019).

Economies of scale in transport are increasingly used to cope with rising competition and transport volumes. Today's container vessels have a capacity of over 21,000 Twenty-foot equivalent unit (TEU). Since the introduction of Post-Panamax container vessels in 1992, ship sizes quadrupled, whereas construction costs do not differ significantly from those of a Panamax class ship from the 1990s (Haralambides, 2017). As a consequence, the number of containers to be unloaded per port is increasing, thus increasing load peaks for container terminals and their hinterland.

The core task of a terminal is to handle containers between different means of transport. It can be stated for all terminals that they consist of at least three elementary subsystems (Kim and Günther, 2007):

1. sea-side (handling area between terminal and ship and vice versa)
2. container yard (container stacking area)
3. land-side (handling area between terminal and means of land transport).

The sea-side functional area is usually equipped with ship to shore cranes to load or unload the sea container vessels, feeder ships or inland waterway vessels. The container yard offers storage capacities for import, export and transshipment containers. The landside superstructure consists of truck and train handling areas in conjunction with the physical entrances, the gates. The hinterland handling operations are designed to efficiently control access to and from the terminal (Steenken, Voß and Stahlbock, 2004).
The gate represents a bottleneck whose efficient operation is important to the terminal operator. Due to the close connection of all three functional areas, the gate processes also have an effect on the other functional areas (Dekker, et al., 2013). According to Abe and Wilson (2009), if traffic congestion in ports increases by 10 %, maritime transport costs will rise by 0.7 %. Furthermore, during the waiting times in queues in front of the gate, the truck aggregates are idling and continuously emit exhaust gases that are harmful to health and the environment.
Possible measures to reduce the congestion in front of the gate are:

- Enhance the physical capacity of the existing gate complex by increasing the number of gates and truck access lanes.
- Increase gate capacity by accelerating gate service time by using management solutions and information technologies, e. g. automated truck registration and container identification systems and

cameras to check the physical condition of the container (Bentolila, et al., 2016).

- Extend gate opening combined with a differentiated pricing system to reduce peak times at the gate and shift to less busy times of the day (Bentolila, et al., 2016).
- Construct a pre-storage area or marshalling yard (Gracia, González-Ramírez and Mar-Ortiz, 2016).
- Diversify truck arrivals by introducing a TAS to regulate the number of trucks that can enter the terminal (Bentolila, et al., 2016).

However, extending gate opening hours is not always possible and purposeful, since driving bans exist for trucking companies. Infrastructural measures represent long-term solutions that can have a strongly limiting effect due to the sometimes tense space situation in the port area and the associated high infrastructure and maintenance costs.

In contrast, TAS are implemented more easily. The aim is to achieve a more even distribution of arrivals over the available time by better planning and scheduling of the arrival patterns of the trucks in order to reduce peak loads. The concrete implementation strategy of a TAS varies from case to case. The design and implementation of these technical instruments must always be adapted to the individual circumstances of each terminal in order to play to its full potential (Ambrosino and Peirano, 2016).

2.2 Functionalities of Truck Appointment Systems

In literature, there are various terms used to describe the optimal flow control of trucks at terminals. Examples are the terms "terminal appointment system" (Morais and Lord (2006)), "gate appointment system" (Giuliano and O’Brien (2007)), "vehicle booking system" (Davies (2009)), and "truck

appointment system" (Huynh, Smith and Harder (2016)). Since the terms are largely used with the same meaning, the term truck appointment system is chosen, which is most frequently used in literature and practice. Gracia, González-Ramírez and Mar-Ortiz (2016, p. 405) define TAS as follows:
" […] technological platforms designed to coordinate and balance truck flows at ports, supporting planning and scheduling truck arrivals, such that truck arrival patterns may be more evenly distributed by reducing peak hour arrival patterns. The general idea is that port terminals may receive advanced information for better planning of the operations at the yard and this may reduce truck turnaround times as well as waiting times of trucks at the gate.“
Despite deviations due to specific local conditions, the following functionalities of TAS can be recorded according to Chen, Govindan and Yang (2013):

1. determining the quota
2. booking a time window
3. registering containers and trucks
4. checking the specific data at the gate
5. administration

By determining the quota, the respective TAS can limit the number of container inputs and outputs to be booked during the operating time of the gate. Depending on the requirements of the terminal, the operating time of the gate can be divided into hourly or daily shift segments or days (Huynh and Walton, 2008). Based on the defined quota, the trucks book a time window (Geweke and Busse, 2011). Registration and verification are usually

carried out in the gate area of the terminal. The registration of the delivering truck serves to compare internal system data for security purposes and prevents trucks from gaining access to the terminal without prior notification. The administration includes the functions of security and controlling. The identity of container owner, trucking company and truck driver must be determined and recorded to avoid legal problems.
Furthermore, various interference influences on TAS need to be considered (Figure 1)

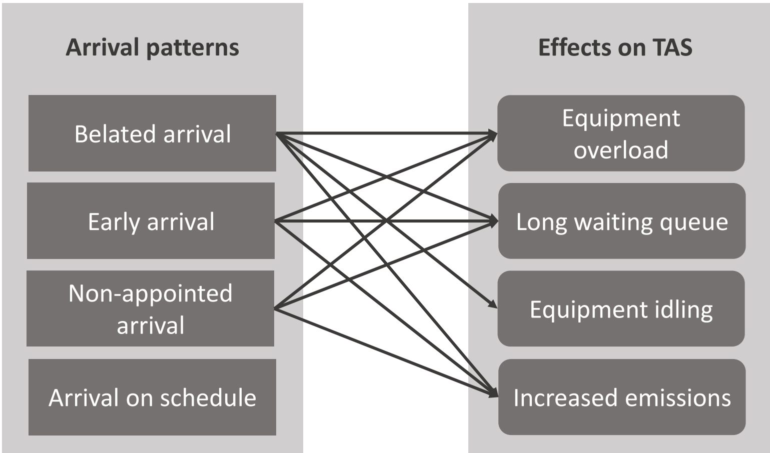

Figure 1: Interference influences on TAS (based on Li, et al. (2016))

If the trucks reach the terminal late or prematurely, the terminal equipments' capacity might either be not sufficient or too high. This leads to long queues in front of the gate or hinder planned maintenance or restacking operations. This disruption can become even more serious if additional arrivals are not agreed. If these types of arrivals accumulate, the terminal will be confronted with additional burdens in the handling of trucks, which can have serious consequences for the punctual handling of other trucks and lead to problems in terminal operations (Li, et al., 2016).

2.3 State of Research

TAS at container terminals have been increasingly investigated since 2004. The focus is mostly on the benefits generated for container terminals. Furthermore, it is noticeable that mostly only individual terminals were considered and different characteristics were examined there. A systematic investigation of various TAS parameters across terminals has not yet taken place (Lange, Schwientek and Jahn, 2017). A good overview of existing TAS worldwide can be found in Huynh, Smith and Harder (2016). Huiyun, et al. (2018) show examples of important focal points in TAS research. Innovative approaches that consider other actors, such as trucking companies, in addition to container terminals can be found in Caballini, Sacone and Saeednia (2016); Namboothiri and Erera (2008) or Rajamanickam and Ramadurai (2015). Here, too, the focus is on individual ports or individual parameters, which are examined in more detail.

Furthermore, TAS are mostly treated as completely new innovations or at most compared with other, already existing solutions in other ports (Lange, Schwientek and Jahn, 2017). The insights gained in other industries for comparable applications are very rarely taken into account. The only study known to the authors in this respect is by Huynh and Walton (2011), in which the similarities and differences between time window booking systems in the health system and in ports are compared briefly. This area has been chosen because it has the greatest similarities to TAS in ports. These similarities include the randomly fluctuating demand figures, changing processing times, a high no-show quota and a high importance of punctuality.

It can be stated that TAS differ greatly and that there is no reproducible template for a successful TAS. Furthermore, little experience from other industries has so far been transferred to TAS in ports. It can be assumed that valuable insights are possible by this broader approach.

3 Systematic Literature Analysis

In order to investigate the potentials of non-port time slot booking systems for TAS in ports, a systematic literature analysis is carried out. The literature databases Scopus and Web of Science are used, which contain the research output from the fields of natural sciences, technology, medicine, social sciences and the humanities. In order to obtain as broad a spectrum of results and topics as possible, synonyms and extensions of the term 'Appointment System' are used. The search query in the two databases Scopus and Web of Science therefore looks as follows: ((„Appointment“ AND „System“) OR („Time Slot“) AND („Management“ OR „Booking“ OR „Scheduling“)).

3.1 General Results

Due to the high hit rate of 9,566 publications, the search result must be further restricted to enable evaluation (Figure 2).

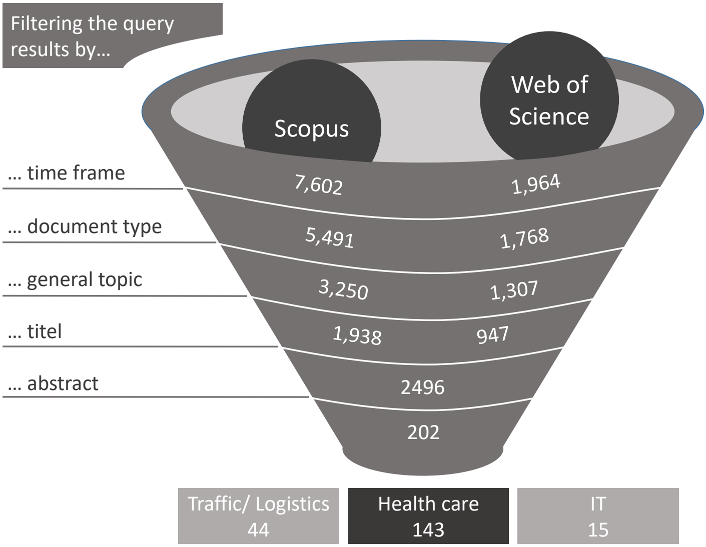

Figure 2: Number of publications in different filtering stages

The time frame of the search query is set to the period 2005 - 2018. Subsequently, the available literature is restricted exclusively to journal articles. Furthermore, all publications are excluded from the search results which focus differ greatly from time window booking systems that are used, discussed, or evaluated in relevant subject areas. Finally, the remaining publications can be categorized to the main subject areas. Articles that cannot be assigned to any of these main areas will not be considered any further. The subject areas can therefore be divided as follows:

- Healthcare: 143 publications
- Computer Science: 15 Publications

- Transport/Logistics: 44 Publications

As a result of the systematic literature analysis, the following aspects can be summarized: In science, time window booking systems are considered for numerous areas. However, these were quantitatively most frequently examined in health care. The number of scientific publications in this area is significantly higher than in the other two areas examined. The complex of topics of the health care system can be further subdivided into strategic, tactical and operative levels, which is borrowed from the entrepreneurial planning horizon. From the literature analysis carried out, a continued discussion of other benchmarking potentials with the topics of information technology and logistics/transport is not considered to be effective. The reasons are the low or even non-existent systemic similarities, such as the demand volatility of system-specific capacities, service times of different durations and the sudden loss of demand due to non-appearance. Furthermore, against this background, a continuous focus on the operative health care system is not appropriate either. The short time horizon of the operative planning horizon, by definition, cannot be taken into account for benchmarking because it is characterized by a fast and flexible handling of different patient classes on the demand side.

3.2 Health Care Sector

In this subsection the most promising three approaches to optimize time windows in the health care sector are presented. All of this approaches have a tactical/ strategic planning horizon.

Open Access

It is customary for patients to arrange appointments several weeks or even months in advance.

The so-called Open Access approach represents a compromise between a physician's break time and the patient waiting time by arranging appointments for patients with urgent needs, which are not urgent enough for the emergency department (same-day patients). The number of routine patients can be determined in advance, but the number of same-day patients varies. The appointment planner will assign appointments to patients. The treatment time cannot be specified in advance. In addition, it is not certain that same-day patients will actually appear at their appointment. However, Chen and Robinson (2014) and Robinson and Chen (2010) demonstrate that the Open Access approach qualitatively exceeds traditional scheduling in the vast majority of cases. Their articles focus on the optimal combination of routine and same-day patients. They also show how these two groups can be planned throughout the day and how the same-day patients' treatment outlook affects the appointment times of routine patients (Robinson and Chen, 2010; Chen and Robinson, 2014).

Defragmentation

The standard procedure for scheduling appointments is to divide the opening hours of a clinic into a finite number of non-overlapping time windows. Each time window is defined by a fixed duration. After an appointment request, the appointment planner first estimates the number of required standardized consecutive time windows. In the subsequent step, the system searches within the schedule for possibilities to book these time windows. If appointments are available, an offer of different appointments is made to the patient. According to Lian, et al. (2010), the conventional procedure for creating appointment plans systematically leads to inefficiencies. Their research therefore focuses on controlling the scheduling process through schedule defragmentation. Consequently, a procedure is recommended that displays all available appointment proposals when a patient requests an appointment. The proposed appointments are listed with regard to their defragmentation effect on the overall system. It turns out that the fragmentation of the time schedule can be effectively reduced by the increased cooperation of the patients with the doctor's practices or clinics. As a result, the capacity utilization of the practices or clinics will be higher (Lian, et al., 2010).

Overbooking

No-shows usually result in performance losses in capacity utilization and productivity for health service providers. To reduce no-show effects, appointments are often overbooked. However, this strategy inevitably leads to overcrowding, more overtime and longer waiting times. A variation of the time window length allows greater flexibility in when treatments can be started. The flexible handling of the start of treatment is particularly suitable in an environment where patients can be informed of exact appointment times via mobile phone applications. Chen, et al. (2018) study the impact of three types of time window structures on the efficiency of healthcare systems: Time windows with fixed length, with dome patterns and with flexible appointment start times. The aim is to determine the optimal overbooking allocation and slot interval structure in response to the uncertainties that may arise from the different treatment times of patients and their possible no-show behaviour (Chen, et al., 2018).

4 Benchmarking Analysis

In this section, a systematic benchmark process is presented using selected TAS processes. Industry-external benchmarking is used to answer the research questions. Compared to industry- and competition-related benchmarking, industry-independent benchmarking offers new perspectives and more innovation potential. Non-monetary parameters are used for the evaluation, for which a utility value analysis is subsequently carried out. This ultimately results in a weighted number of measures that can be used as recommendations for further improvement of TAS.

4.1 Selection of the Processes to be Examined

Several processes offer potential for optimization when implementing a TAS. In the further course of the work, two of these processes will be taken into focus, namely 'booking a time window' and 'setting the quota'.

The process 'booking a time window' is selected because the handling of no-shows can be improved. Influencing factors such as traffic congestion, full closures of motorways, construction sites or accidents can lead to short-term failure of booked time windows. Moreover, authors such as Huynh and Walton (2008) take walk-ins into account in their approaches. In the context of TAS, these are trucks that gain access to the terminal without an appointment. The productivity of the terminal can only be maintained at a high level if the failures are countered accordingly. To achieve this, TAS often use the 'Open Access' concept (Ambrosino and Peirano, 2016). However, little is known about the practical design of the approach from literature. In addition, the time frame in which the trucks are to be dispatched on

the terminal premises in front of the container storage facilities must be examined more closely in this context. The time frame can range from half an hour to 24 hours (Huynh, Smith and Harder, 2016).
Furthermore, another focus is on the process of 'determining the quota'. In this process it is possible to use the given terminal capacities more efficiently in order to further increase productivity and thus the quota. The time window lengths and the handling of individual time windows are dealt with. The present benchmark process focuses on the approach of Huynh and Walton (2008), how time windows for the arrival of trucks are divided. This approach divides the operating time of the terminal into evenly distributed time windows. The time window size is then used as the basic unit.

4.2 Determination of Optimization Potential

This subsection deals with the analysis of the two critical processes of time window booking and quota setting. The performance gaps of the selected processes are determined in comparison to the health care system and examined with regard to their causes.
The practices of short-term removal of booked appointment windows or exchange of agreed appointment windows create gaps in the terminal's schedule. In particular, by taking into account the needs of the haulage companies, a minimum degree of flexibility can be guaranteed. This flexibility, however, entails the risk of productivity losses due to the fact that time windows can no longer be filled.
The time frame within which the container is to be collected or brought can vary from half an hour to 24 hours with a certain tolerance (e. g. half an hour). However, when setting up large time frames, the procedure leads to exactly the type of behavior that the TAS should prevent. In the case of TAS,

there is no exactly determined arrival time compared to the health care system. Accordingly, there is no precise control of demand over the existing supply in the form of handling equipment. A system with an exact arrival time has not yet been implemented, as traffic jams, accidents etc. would lead to strong fluctuations.

The approach of Open Access is mentioned to a minor extent in specialist literature. Due to the lack of detail in the publications, this offers great potential for improvement, especially in comparison to the health care system. One explanation for the predominant failure to comply with the Open Access approach may be a lack of interfaces between online platforms for booking time windows and the staff for manually entering same-day trucks. This only applies under the condition that personnel is made available for the appointment entry process or that manual interventions of this kind are possible.

The time windows often have a standard size per terminal. It is assumed that the truck arrivals deviate from the set time window value by a small standard deviation. As a safety factor, a buffer is inserted between individual truck handling operations, which can vary from terminal to terminal. As a result, time gaps between trucks are not used (Huynh and Walton, 2008).

4.3 Improvement Measures

In the following, suggestions are made for solutions which should serve to remedy the previously identified performance gaps. The proposed solutions are based on the presented approaches of time window booking systems in health care. In addition, these solutions are examined with regard to their adaptation and impact on TAS. Subsequently, an evaluation of the different solution proposals takes place.

4.3.1 Presentation of Measures

The performance gaps highlighted cannot be solved in isolation by the following proposed solutions. The elimination of a performance gap can at the same time lead to the reduction of further performance gaps. Subsequently, the three in section 3.2 presented approaches from the health care sector are transferred to TAS in ports.

Open Access

The Open Access is applied most easily in a hybrid form. This means that routine time window bookings can take place parallel to time window bookings made on the same day a few hours before container delivery or collection. In particular, smaller terminals that do not use a 24/7 working scheme are suitable for the Open Access approach. If, for example, a terminal is operated in a two-shift system, several time windows can be blocked proportionately for time-independent trucks. For larger terminals with a 24/7 working scheme, Open Access can be used in a modified form. Although there are no longer any extra blocked time windows, the approach is still suitable for closing unoccupied time windows. Trucks without appointments have the option of being assigned a corresponding time window on the same day. It is possible to make requests for free time slots throughout the day. With this procedure it is possible to fill free time windows caused by no-shows or rebookings.

Overbooking

Unnoticed time windows lead to a reduction in the performance potential of the terminals. The following solution for overbooking is first applied to fixed time windows and then to the assignment of time windows at flexible times.

The approach of fixed time window allocations can be further optimized for overbooking with a finer grid. This is done by overbooking the first available time slots of a day or a day segment. This counteracts the terminal resource idle caused by a missing queue or potential no-shows. In addition, the following time windows can be overbooked depending on the no-show probability. At the end of a day segment, no more overbooking of appointments should take place to avoid overtime of the workforce.

The enhancement provides for flexible assignment of time windows. Appointments or time windows can be assigned at any time. It is advisable to make overbookings without exception in the first time windows, as in the previous approach. For all other time windows, only one truck may be booked per time window. With regard to the length of check-in times, there will be a multiple coupling pattern resulting from the distribution of the actual check-in times of the trucks. The time windows that complete or end a day segment will be extended, as unexpected above-average handling times will be absorbed and overtime avoided.

Defragmentation

The current procedure is characterized by inefficiencies, as these tend to generate fragmentary time window sequences. Reasons for this are the allocation of time windows according to the preferences of trucking companies and/or the cancellation or change of previously allocated time windows. In the following, adaptations or modifications of the TAS management software are recommended. The goal is a minimal fragmentation in the sequence of all booked time windows. Each possible option of the time window selection is quantitatively evaluated with regard to the fragmentation effect. These evaluated time windows shall be proposed to the companies booking according to their possible impact on the status of the date fragmentation. A list of all available time windows contain date proposals that are found in the immediate vicinity of the desired date of the trucking company, but are sorted according to the effect on a defragmentation of the time window sequence. The first time window suggestions have the greatest effect on the defragmentation, while the last time window suggestions have the least effect. Trucking companies are encouraged, but not obliged, to accept the slots preferred by the terminal. The available time windows could be presented consecutively. Thus, the best time window from the terminal operator's point of view would be offered first. Only in case of rejection would the subsequent time window be shown.

4.3.2 Evaluation of Presented Measures

The presented measures are evaluated regarding the following criteria: Effort of introduction, impact on terminal productivity, influence on traffic jams in the port, effect on truck throughput time and influence on customer satisfaction. A multi-dimensional assessment of non-monetary variables is a good way of obtaining a multilayered and summarizing overall assessment. The evaluation of individual criteria is subsequently carried out with dimensionless evaluation numbers, which are then added up to a total evaluation number. The total valuation number ultimately represents the utility value. A ranking of the measures presented is created in Table 1 on the basis of the total valuation number. Four integer gradations from 0-3 are available for the valuation of these measures. These correspond to the scores 'poor', 'medium', 'good' and 'very good'. In order to enable the evaluation, the measures were compared on the basis of the publications found for each individual criterion. In particular, it was determined whether a measure was better or worse suited than the other measures to positively influence this criterion.

Table 1: Evaluation of selected measures

Criteria	**Open Access**	**Over-booking (1)**	**Over-booking (2)**	**Defrag-men-tation**
Implementation costs	2	2	0	1
Impact on terminal productivity	1	2	3	2
Influence on port conges-tion	1	1	1	1
Influence on truck turn time	1	1	1	1
Influence on customer satisfaction	2	1	1	1
Overall evaluation	**7**	**8**	**6**	**6**

According to the evaluation, the following picture emerges: The measure of overbooking dates (1) occupies first place with eight points. Second place went to the Open Access approach with seven points. In third place were the measures for overbooking appointments (2) and defragmentation, each with six points. However, it can be seen from the evaluation that the best-rated measure of overbooking appointments (1) does not represent the best possible solution in all individual parameters.

The characteristics of TAS differ due to a multitude of individual approaches and solutions in the implementation. For this reason and because of the insufficient literature situation, it is hardly possible to define starting points for which there is the possibility of connecting measures. It is recommended to first check the effectiveness of the measures by means of simulations and to adapt them to the existing system with the help of an iterative process.

5 Conclusions and Outlook

The aim of this study is to give a quantitative overview of a non-port time window booking system, to show their potentials and to examine the relevance of their systematic properties for TAS. Following a systematic literature research, the health care system turns out to be the best reference partner in terms of systemic characteristics. Subsequently, the benchmarking method is used to check the transferability of highlighted systemic characteristics of the health care system to TAS. In view of the task, an industry-independent process benchmarking is applied, which focuses on the TAS-critical processes of quota determination and time window booking. Subsequently, three measures from the health care sector are evaluated according to various criteria using a benefit analysis. The best overall result was achieved by overbooking appointments in fixed time windows, followed by Open Access, overbooking appointments in variable time windows and defragmentation.

The limiting factor to be taken into account in this study is that only one benchmark was carried out with the industry that had the most agreements with TAS in ports. Due to the high similarity of other areas, e.g. logistics, it is to be expected that potentially well transferable solutions can be generated there too, which were not examined here. Furthermore, the presented benefit analysis is based on a subjective evaluation. Other outcomes of the individual evaluations are therefore possible.

This study can be seen as a starting point for further research projects. In future, the improvement of TAS based on approaches of other industries should concentrate on further strategic and tactical aspects of the health care system. For an exact evaluation of the approaches, it might proof beneficial to use a simulation tailored to the terminal. This could help to eliminate individual weak points in the specific TAS.

References

Abe, K. and Wilson, J. S., 2009. Weathering The Storm: Investing In Port Infrastructure To Lower Trade Costs In East Asia: The World Bank.

Ambrosino, D. and Peirano, L., 2016. Truck Arrival Management at Maritime Container Terminals. In: T. Claus, F. Herrmann, M. Manitz, and O. Rose, eds. 2016. 30th European Conference on Modelling and Simulation (ECMS 2016). Regensburg, Germany, 31 May-3 June 2016. Red Hook, NY: Curran Associates, Inc.

Bentolila, D. J., Ziedenveber, R. K., Hayuth, Y. and Notteboom, T., 2016. Off-peak truck deliveries at container terminals: the ?Good Night? program in Israel. Maritime Business Review, [e-journal] 1(1), pp. 2–20. http://dx.doi.org/10.1108/MABR-03-2016-0005.

Caballini, C., Sacone, S. and Saeednia, M., 2016. Cooperation among truck carriers in seaport containerized transportation. Transportation Research Part E: Logistics and Transportation Review, [e-journal] 93, pp. 38–56. http://dx.doi.org/10.1016/j.tre.2016.05.007.

Chen, G., Govindan, K. and Yang, Z., 2013. Managing truck arrivals with time windows to alleviate gate congestion at container terminals. International Journal of Production Economics, [e-journal] 141(1), pp. 179–188. http://dx.doi.org/10.1016/j.ijpe.2012.03.033.

Chen, R. R. and Robinson, L. W., 2014. Sequencing and Scheduling Appointments with Potential Call-In Patients. Production and Operations Management, [e-journal] 23(9), pp. 1522–1538. http://dx.doi.org/10.1111/poms.12168.

Chen, Y., Kuo, Y.-H., Fan, P. and Balasubramanian, H., 2018. Appointment overbooking with different time slot structures. Computers & Industrial Engineering, [e-journal] 124, pp. 237–248. http://dx.doi.org/10.1016/j.cie.2018.07.021.

Davies, P., 2009. Container Terminal Reservation Systems. Paper presented at the 3rd Annual METRANS National Urban Freight Conference. Long Beach, USA.

Dekker, R., van der Heide, S., van Asperen, E. and Ypsilantis, P., 2013. A chassis exchange terminal to reduce truck congestion at container terminals. Flexible Services and Manufacturing Journal, [e-journal] 25(4), pp. 528–542. http://dx.doi.org/10.1007/s10696-012-9146-3.

Geweke, S. and Busse, F., 2011. Opportunities to Exploit Capacity Reserves of the Hinterland Connection to Road Transport. In: J. W. Böse, ed. 2011. Handbook of Terminal Planning. New York, NY: Springer New York, pp. 305–322.

Giuliano, G. and O'Brien, T., 2007. Reducing port-related truck emissions. The terminal gate appointment system at the Ports of Los Angeles and Long Beach. Transportation Research Part D: Transport and Environment, [e-journal] 12(7), pp. 460–473. http://dx.doi.org/10.1016/j.trd.2007.06.004.

Gracia, M. D., González-Ramírez, R. G. and Mar-Ortiz, J., 2016. The impact of lanes segmentation and booking levels on a container terminal gate congestion. Flexible Services and Manufacturing Journal, [e-journal] 244(3), p. 675–675. http://dx.doi.org/10.1007/s10696-016-9256-4.

Haralambides, H., 2017. Globalization, public sector reform, and the role of ports in international supply chains. Maritime Economics & Logistics, [e-journal] 19(1), pp. 1–51. http://dx.doi.org/10.1057/s41278-017-0068-6.

Huiyun, Y., Xin, L., Lixuan, X., Xiangjun, L., Zhihong, J. and Zhan, B., 2018. Truck appointment at container terminals: Status and perspectives. In: 2018 Chinese Control And Decision Conference (CCDC). 2018 Chinese Control And Decision Conference (CCDC). Shenyang, 09.06.2018 - 11.06.2018: IEEE, pp. 1954–1960.

Huynh, N., Smith, D. and Harder, F., 2016. Truck Appointment Systems. Where We Are and Where to Go from Here. Transportation Research Record: Journal of the Transportation Research Board, [e-journal] 2548, pp. 1–9. http://dx.doi.org/10.3141/2548-01.

Huynh, N. and Walton, C. M., 2008. Robust Scheduling of Truck Arrivals at Marine Container Terminals. Journal of Transportation Engineering, [e-journal] 134(8), pp. 347–353. http://dx.doi.org/10.1061/(ASCE)0733-947X(2008)134:8(347).

Huynh, N. and Walton, C. M., 2011. Improving Efficiency of Drayage Operations at Seaport Container Terminals Through the Use of an Appointment System. In: J. W. Böse, ed. 2011. Handbook of Terminal Planning. New York, NY: Springer New York, pp. 323–344.

Kim, K. H. and Günther, H. O., eds., 2007. Container terminals and cargo systems. Design, operations management, and logistics control issues. Berlin, New York: Springer.

Lange, A.-K., Schwientek, A. and Jahn, C., 2017. Reducing truck congestion at ports – classification and trends. In: C. Jahn, W. Kersten, and C. M. Ringle. Digitalization in maritime and sustainable logistics. City logistics, port logistics and sustainable supply chain management in the digital age: epubli, pp. 37–58.

Li, N., Chen, G., Govindan, K. and Jin, Z., 2016. Disruption management for truck appointment system at a container terminal: A green initiative. Transportation Research Part D: Transport and Environment. http://dx.doi.org/10.1016/j.trd.2015.12.014.

Lian, J., Distefano, K., Shields, S. D., Heinichen, C., Giampietri, M. and Wang, L., 2010. Clinical appointment process: improvement through schedule defragmentation. IEEE engineering in medicine and biology magazine : the quarterly magazine of the Engineering in Medicine & Biology Society, [e-journal] 29(2), pp. 127–134. http://dx.doi.org/10.1109/MEMB.2009.935718.

Morais, P. and Lord, E., 2006. Terminal Appointment System Study.

Namboothiri, R. and Erera, A. L., 2008. Planning local container drayage operations given a port access appointment system. Transportation Research Part E: Logistics and Transportation Review, [e-journal] 44(2), pp. 185–202. http://dx.doi.org/10.1016/j.tre.2007.07.004.

Rajamanickam, G. D. and Ramadurai, G., 2015. Simulation of truck congestion in Chennai port. In: 2015 Winter Simulation Conference (WSC). Huntington Beach, CA, USA, pp. 1904–1915.

Robinson, L. W. and Chen, R. R., 2010. A Comparison of Traditional and Open-Access Policies for Appointment Scheduling. Manufacturing & Service Operations Management, [e-journal] 12(2), pp. 330–346. http://dx.doi.org/10.1287/msom.1090.0270.

Steenken, D., Voß, S. and Stahlbock, R., 2004. Container terminal operation and operations research - a classification and literature review. OR Spectrum, [e-journal] 26(1), pp. 3–49. http://dx.doi.org/10.1007/s00291-003-0157-z.

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