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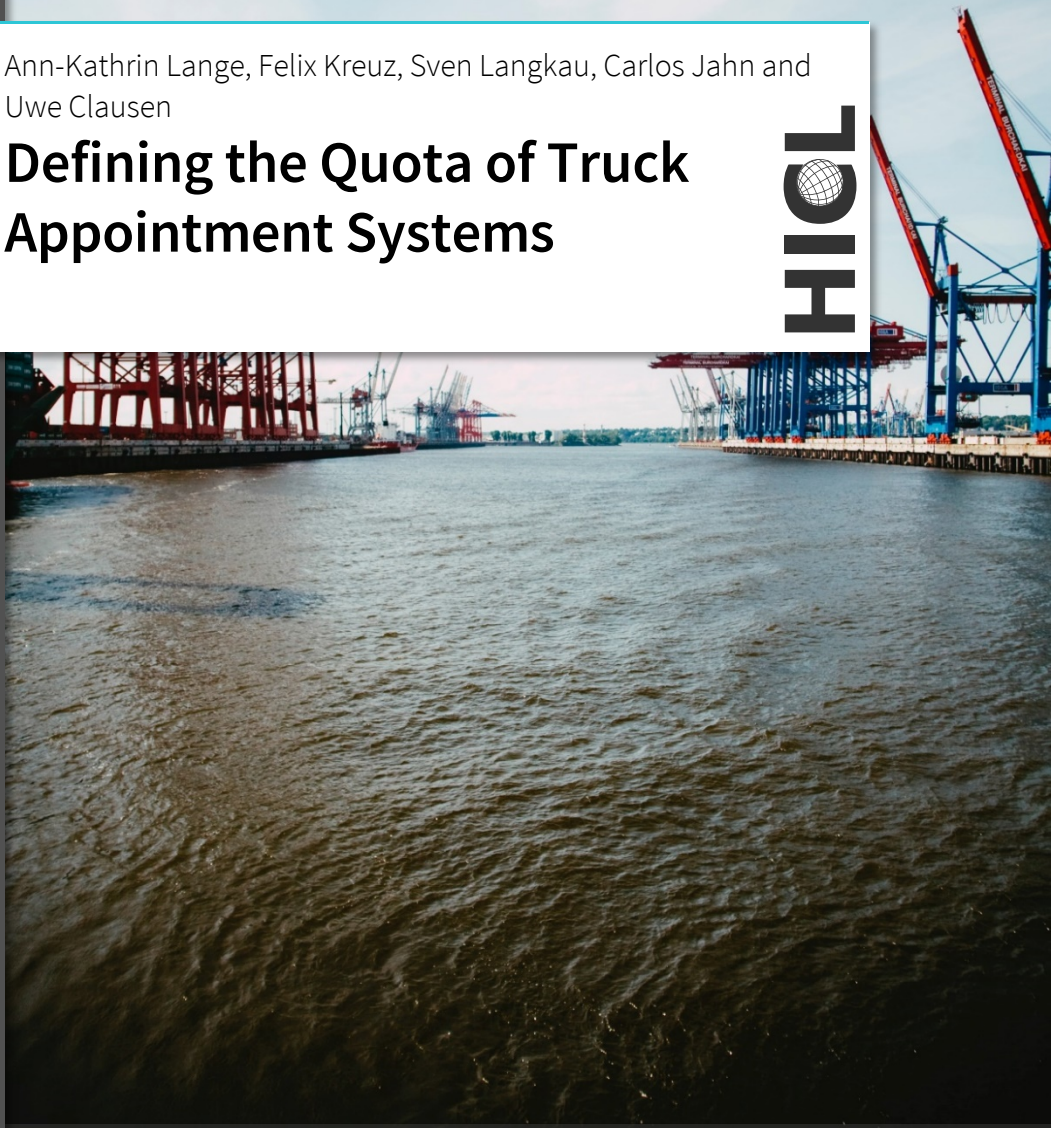

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Defining the Quota of Truck Appointment Systems

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Purpose: Truck appointment systems (TAS) are a widely used method to alleviate peaks in truck arrivals at container terminals in seaports and in the hinterland. One big advantage is the opportunity to reduce operation costs for the terminals and the truck queue length in front of the terminal gate. This study aims to analyze and classify different approaches used in science and industry to determine the quota of allowed trucks per time window.

Methodology: A comprehensive systematic literature analysis is applied to identify the different approaches to determine the quota of time windows in science and in industry.

Findings: The results of the study show that many approaches have been based on experience and are mostly used to improve individual terminals rather than the port as a whole. Methods used to improve and analyze interrelationships are mainly methods of mathematical optimization and simulation.

Originality: The question under consideration was mostly only marginally considered in existing investigations, even though it has a major impact on the success of a TAS. Furthermore, only individual solutions have been examined so far and not the suitability of the approaches compared.

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1 Introduction

The volume of goods transported by sea, especially in container traffic, has risen continuously over the past 10 years (UNCTAD, 2019). This also applies to the competition among shipping companies resulting in declining margins. Therefore, shipping companies are increasingly trying to use economies of scale and thus reduce the costs per TEU (twenty-foot equivalent unit). Due to the associated growth in ship size, ports are facing increasing peak loads. In addition to the loading and unloading of ships on the seaside of the container terminals, this also applies to the handling of containers in the yard and the handling on land by truck. A widespread solution to distribute truck arrivals evenly throughout the day is the introduction of a truck appointment system (TAS). This requires trucking companies to book time slots in advance for the delivery or collection of containers at terminals. These time slots are binding for them. If they fail to comply, the trucks are usually not dispatched. The quota is the central element of the TAS, with which the terminals can control the number of arrivals. The quota determines how many trucks are allowed per time slot. Despite the central importance of the quota, its determination, however, is only marginally considered in most scientific publications, is by-product of research or is carried out with very simple means such as empirical values or simple rules of thumb. It can be assumed that many terminal parameters, from the land side as well as from the yard and seaside, have to be considered in order to adjust the quota to all relevant processes. It should also be considered whether external factors, such as demand, load on the port infrastructure and weather, should be taken into account when determining the quota. In order to provide a basis for such an assessment, this study will conduct a

comprehensive literature analysis of the procedures for quota determination. In particular, answers to the following research question are to be found:

Which methods are currently used in science and practice to set the quota?

This research question set the research objective to descriptively analyze the state of the art in determining the quota for TAS. Within this analysis a secondary focus is set on how the current practice effects terminals, trucking companies and the entire port. Depending on the outcomes of the analysis, implications on how to improve the determination of the quota are given. Chapter 2 first gives an overview of the state of research on TAS in ports. Chapter 3 presents and explains the methodological approach of the analysis. Chapter 4 presents the developed classification scheme. Furthermore, chapter 4 presents the findings of the literature analysis and answers the research questions as the relevant factors are analyzed individually and in relation to each other. Chapter 5 gives a summary and an outlook on future research.

2 State of Research on Truck Appointment Systems

Seaport container terminals form the nodes in maritime transport chains. They are mostly trimodally connected, i. e. containers can be transported to and from them by water (both ocean-going vessels and inland waterway vessels), rail and road. They are divided into three areas: seaside, container yard and landside (see Figure 1). Seaside handling is usually carried out with specialized ship-to-shore cranes (STS), which guarantee a high productivity of 30 moves per hour on average compared to other types of seaside cranes. From the seaside, the import containers are transported to the container yard with terminal internal transport equipment. Depending on the type of terminal, the equipment either stores the containers in the yard itself (e. g. straddle carriers (SC)) or transfers them for storage (e. g. tractor trailers (TT), automated guided vehicles (AGV)) to storage cranes (usually rubber-tired gantry cranes (RTG) or rail-mounted gantry cranes (RMG)). Similar transfer to the collecting means of transport, usually rail or road, is carried out. It may be necessary to transport containers with internal vehicles from the yard to the rail handling (usually executed by RMG). The delivery of export containers takes place vice versa. For a more detailed overview of structures and processes at container terminals, refer to Brinkmann (2011), Stahlbock and Voß (2007) and Carlo, Vis and Roodbergen (2014).

Container terminals are closely linked to many other companies in the seaport. Empty container depots store containers for longer periods of time in order to save space at the terminals. They also provide additional services such as cleaning, repair and classification. If containers are loaded with

goods from more than one customer, the containers will usually be packed in so-called packing stations. Customs and the veterinary office carry out prescribed inspections. Transportation in the port is usually carried out by trucking companies.

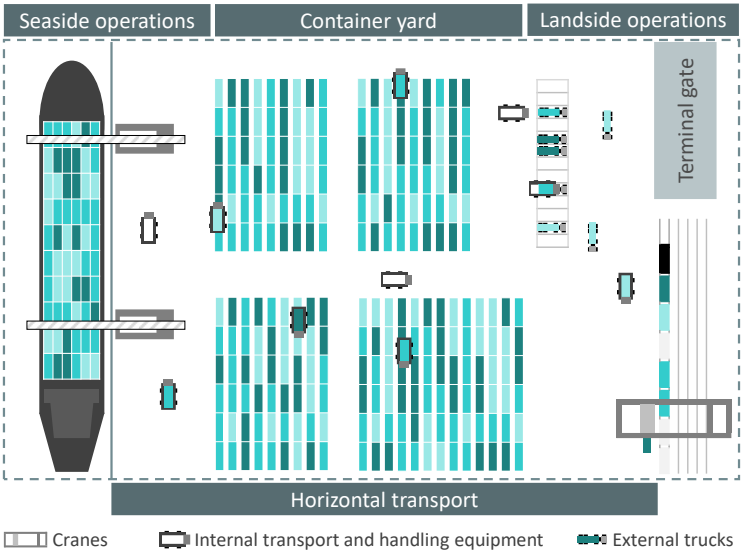

Figure 1: Exemplary container terminal layout

The continuing growth in the size of ships and the restrictive opening hours of other companies in the port and the surrounding area, especially for the recipients of the goods, but also for empty depots and packing stations, result in peaks in truck arrivals during the course of the day. If a terminal does not influence truck arrivals and does not receive advance information on when which containers will be delivered or collected, the planned terminal resources often do not match the demand. As a result, these peaks lead to

congestion at the terminal gate and the terminal site. This increases the transport time for the trucking companies and thus endangers their profitability. It is also possible that urgent containers do not reach the terminal in time. Due to the bottleneck at the gate, congestion can build up throughout the port area. This also leads to increased emissions from waiting vehicles. In order to smooth the arrival of trucks, the implementation of a TAS has proved particularly effective. The terminal sets a quota per time window (usually one to two hours). This quota corresponds to the number of trucks that can be handled in this time window. It should be set in such a way that the terminal's resources are used as efficiently as possible without causing congestion. The trucking companies book time slots for each delivery or collection of a container at the terminal, which fits as well as possible into their route planning and whose quota has not yet been reached. Depending on the design of the TAS, the truck is only granted access to the terminal site during the assigned time window. Furthermore, it may be denied access to the terminal if it arrives late. In this case, a new time window needs to be booked, which usually results in waiting times as the following time window are booked up and no longer available.

TAS are very advantageous for terminals, as in addition to smoothing truck arrivals, they are able to provide extensive information about the arriving trucks and their cargo. If this data is evaluated, the terminal processes can be adapted to the arrival times and, if necessary, even the sequence of the trucks. In this way, equipment can be used more efficiently and unnecessary container restacking processes can be avoided. For the trucking companies, the waiting time in front of the gate and at the terminal can be sig-

nificantly reduced, provided that the quota is suitably defined. The handling times are thus more predictable. At the same time, the trucking companies lose some of their freedom of action, as they have further constraints to take into account when planning the routes.

Since the introduction of the first TAS around 2004, many scientific studies have looked at its design and impact. Overviews of the related publications can be found in Davies and Kieran (2015), Huiyun, et al. (2018) and Lange, Schwientek and Jahn (2017). The focus is often on the consideration of the effects on container terminals (e. g. Chen, Govindan and Golias (2013), Zhao and Goodchild (2013)). Some publications deal with trucking companies. There, for example, dispatching strategies (e. g. Namboothiri and Erera (2008), Fan, et al. (2019)) or cooperation possibilities between different trucking companies (e. g. Gharehgozli, Koster and Jansen (2017), Schulte, et al. (2017)) are examined. Significantly fewer publications consider the effects of TAS on several participants. The most common type is the combined consideration of container terminals and trucking companies (e. g. Phan and Kim (2016), Yi, et al. (2019)). To the authors' knowledge, interactions with other stakeholders in the port or with the road infrastructure are not considered.

TAS can have very different structures. Possible distinctions are, for example, the length and allocation (e. g. in the case of export containers to the ship) of the time window, the booking rules (how many hours/days in advance, possibilities and time limits for rebooking, cancellation and re-booking), the binding nature of the booking (voluntary/binding TAS for all arriving trucks, penalties for non-compliance with the specifications, grace periods before and after the actual time window) and the definition of the

quota. The specification of TAS affects not only the gate and yard, but also, reciprocally, the areas in advance and those beyond in the processes, such as the port infrastructure and seaside handling. Due to the high interdependencies of the terminal processes and the poor predictability of demand and the traffic situation in the port, the determination of the quota is a major challenge that has not been extensively investigated either in practice or in research.

The research usually aims to determine how the performance (measured in trucks or containers) of the terminal can be improved. Usually not a quota is calculated, but a maximum performance that can be achieved under the constraints of the respective research. To what extent these findings can be used to determine a quota at all or to what extent this quota is meaningful (possibly practical) remains unsaid. In order to close this research gap, a classification scheme is developed, in which the different approaches to determining the quota are compared with relevant factors such as the aim of the research, the focus of consideration and the methods used. With this a new perspective on current approaches is given, which might lead to additional research approaches on the determination of the quota.

3 Research Methodology

According to Cooper's taxonomy (Cooper 1988) this literature review focuses on research outcomes and practices and applications. The focus on research is derived directly form the research question. The research question also has a strong practical relevance. We therefore also identify a focus on practices and applications. The analysis of the relevant publications accordingly includes an investigation how the results of publications give insight in and can be transferred into practice. The literature review is based on the guidelines for literature reviews by vom Brocke et al. (2009), especially by selecting sources and databases and coverage, identifying key terms and developing the search string and conducting an additional backward search. The way of screening and analyzing the found publications is based on Liberati's et al. (2009) PRIMSA statement and adapted as follows:

The initial literature search was based on English publications. In order not to falsify the results, the authors have refrained from translating papers in languages they do not speak. An initial, comprehensive screening showed, that English publications on the topic are considerably more numerous than the German publications, so that the focus was placed on the English publications. Since English is also the language of science, publications can be recorded worldwide. The search was based on electronic databases for scientific publications. A total of eight electronic databases were searched: The database of Springer Nature Switzerland AG (link.springer.com), Google's search engine for scientific publications with the German interface (scholar.google.de), Elsevier's Scopus database (scopus.com), ITHAKA's

JSTOR database (www.jstor.org), the EBSCOhost database (search.ebscohost.com), Elsevier's ScienceDirect database (sciencedirect.com), Clarivate Analytics' Web of Science database (webofknowledge.com) and IEEE's Xplore database (ieeexplore.ieee.org).

The initially defined search terms were derived directly from the research question: 'container terminal', 'truck appointment system' and 'quota'. These search terms were then extended by similar or possibly synonymously used search terms to obtain additional hits. Each database was searched with the following search string (see Figure 2):

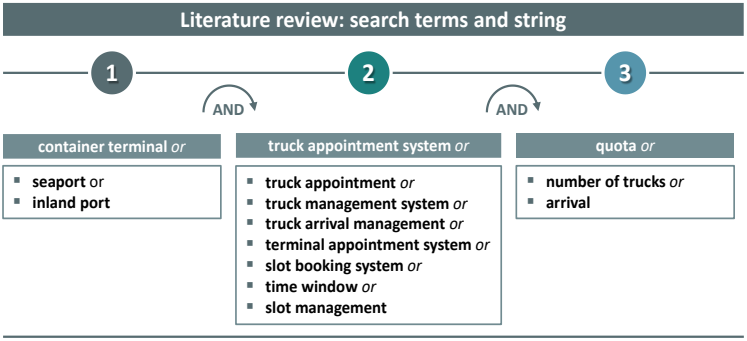

Figure 2: Search terms and string

The search returned 7,525 results, so that it was additionally restricted to publications from 2015 to the time of the search in April 2020. With this restriction, the search still returned 1,984 results. To review these publications, a methodological procedure was established (see Figure 3). In order to handle the vast number of publications efficiently, firstly the search results were viewed by title only. Two general selection criteria were defined, after which it was decided to examine the paper more detailed or to exclude

it at this stage. It was also determined that the title had to indicate clearly that the publication referred to container terminals or seaports. In addition, the title did not necessarily have to contain one of the other search terms, but it had to clearly indicate the search term of the category 'truck appointments system' or 'quota'. All papers whose title could not clearly establish this reference were sorted out. With this procedure, a total of 59 publications were identified, which were classified as relevant and used for further analysis. In the next step the abstracts and keywords of the papers were read and examined. It was determined that the abstracts must refer to at least one of the topics: ‘defining the quota of TAS’, ‘slot or truck management and queuing’, ‘enhancing performance or reducing negative impacts at container terminals’ and doing either of the before mentioned by an explicitly named method. If one of these topics was clearly mentioned in the abstract, the paper has been read in full.

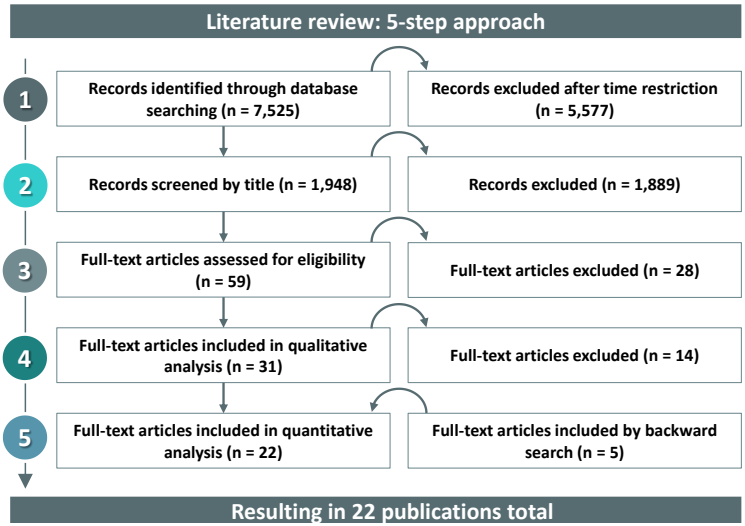

Figure 3: Five-step approach of literature review based on Liberati et al. (2009)

Altogether 31 of the 59 papers could be identified which were to be investigated in depth. In step three, the papers were read fully and examined using a previously defined classification scheme (see Figure 3). For this purpose, the papers had to meet at least one criterion in each of the categories "type of quota definition" and "factors in quota definition" of the classification scheme. If none of the criteria was met, the papers were classified as not relevant. Thus, 17 papers were identified that made statements on the research question. Based on these 17 papers, a backward search was conducted (Webster and Watson, 2002; vom Brocke, et al., 2009). This backward search was carried out on the basis of the bibliography of the papers already classified as relevant. Accordingly, this backward search focused on

the period prior to 2015, which brought to light five additional publications. The five-step approach resulted in 22 publications total relevant for analysis.

The classification scheme is central element for the analysis of the 22 relevant publications. In addition to bibliographic information (authors, year, title, keywords etc.), the classification scheme comprises seven content-related categories. These categories were defined before analyzing the papers. The seven categories can in turn be divided into three groups. 'Aim' and 'method' are categories that describe the paper methodologically. The category 'aim' was chosen to determine whether the primary objective of the paper is to determine the quota or whether this is a by-product. The category 'method' was chosen to establish a reference to the way quotas are set. This is to check the extent to which there are interdependencies between the general method and the method used to set the quota. The categories 'TAS', 'quota definition' and 'relevant factors' are categories that directly examine the results of the papers in terms of their contribution to the research question. Thus, these categories constitute the core of this literature review. 'Focus' and 'application' are categories that classify the relevant papers in terms of their practical approach. These two categories allow a more detailed examination with regard to the transfer or transferability into practice. Thus, it is assumed that papers whose point of view is not the terminal, hardly provide any practice-relevant information on the determination of the quota (by the terminal). Similarly, it is assumed that papers with explicit practical relevance apply a practical determination of the quota or have already been applied in practice. The respective characteristics of each category were developed during the analysis and not before the

analysis. Therefore, it must be noted that possible values that do not occur in the papers examined must also be identified. Furthermore, this procedure means that each proficiency has occurred at least once in the relevant publications.

4 Results of Literature Review

To answer the first research question the sources are classified on the basis of seven categories with their respective sub-items (see). In the following, the seven categories are presented with regard to their respective evaluation criteria and their mutual dependencies.

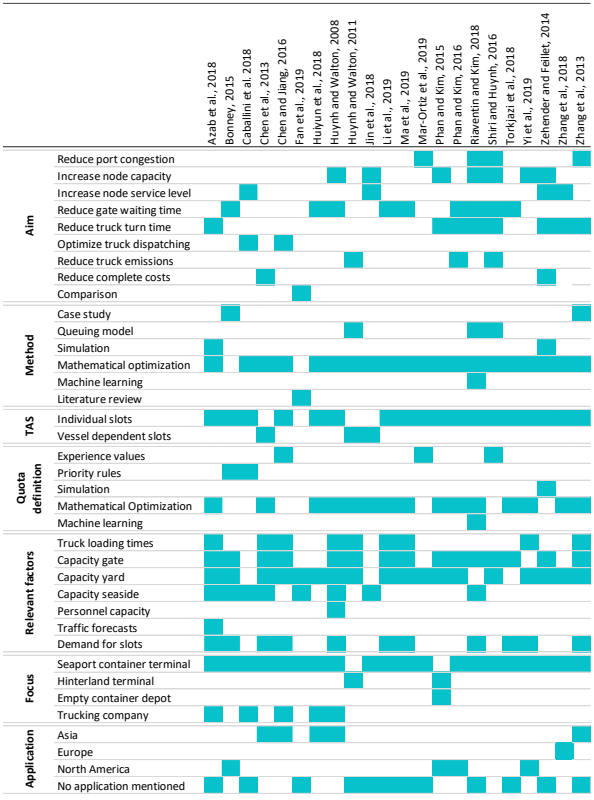

Figure 4: Classification scheme for defining the quota of TAS

4.1 Aim of the Analyzed Publications

The category *aim* comprises the motivation or focus of the scientific publication under consideration. The allocation of the publications examined to the various research objectives and the corresponding development over time is shown in Figure 5.

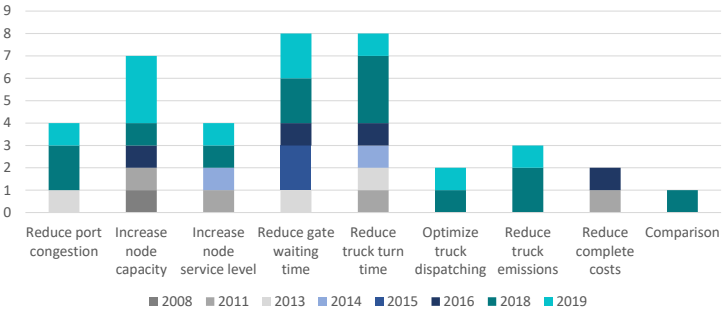

Figure 5: Allocation of publications to category aim

Two essential evaluation criteria are the *reduction of the gate waiting time* and the *truck turn time*. The gate waiting time focuses on the loss of time of the trucking companies due to a delayed access to the site. Truck turn time comprises the time required by the trucking companies from registration, loading and unloading, to leaving the premises. With eight mentions each, both criteria are the most frequent target of the publications considered. These two criteria are also the focus of port authorities, trucking companies and terminal operators. With seven mentions, the criterion *increase node capacity* is almost as often in focus. Linked to this is the aim to increase the efficiency of the node by ensuring that the water and land resources and interfaces of the terminal and those of the carriers are well matched to the

incoming and outgoing transport volumes. The resulting challenges also motivate the relatively high number of related publications. Although a *traffic jam in the port* has a significant impact on gate waiting time and truck turn time, this criterion is only in focus in four of the 22 publications analyzed and therefore just as often as increase node service level. The remaining four criteria are *optimize truck dispatching* (2), *reduce truck emission* (3), *reduce complete costs* (2) and *comparison* (1). Until 2015, all publications essentially deal with only one of the first five criteria. In all subsequent scientific work, several of the criteria mentioned are usually examined in combination. In addition, the criterion 'reduce truck emissions' is gaining in importance as a result of social change and the associated political discussion.

4.2 Used Research Method in the Analyzed Publications

The category *research method* describes how the aforementioned criteria of the category *aim* were examined. Figure 5 shows an overview of the used research methods and their time of publication.

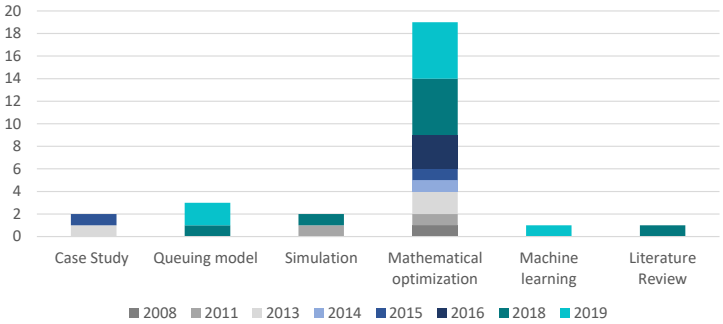

Figure 6: Allocation of publications to category method

Essentially, the *mathematical optimization*, which is used as a method in 19 publications, should be mentioned here. With the aim of maximizing truck utilization and thus reducing costs, the aim function assumes, for example, costs for missed or postponed time slots or waiting at the gate. At the same time, restrictions such as the average loading time, the number of containers to be loaded and the maximum number of available time slots for a TAS are taken into account. In recent years, the mathematical optimization models have increasingly (3) been combined with *queuing models*, for example, in order to map the operation of external and internal vehicles as well as the yard cranes used and to be able to determine a better basis for the mathematical optimization. In a few cases (2) the mathematical optimization is used in combination with *simulation*. Here the focus of the simulation is on the trips and activities around the terminals and less on the traffic that goes beyond. Until 2015, (2) *case studies* and very rarely (1) *literature reviews* were also used as a method, which were only in one case combined with the mathematical optimization method. In summary, it can be said

that the use of mathematical optimization as a method predominates and new possibilities such as *machine learning* are not yet frequently (1) used.

4.3 Type of TAS in the Analyzed Publications

In the category *TAS*, a basic distinction is made between two different types. The first type allocates an *individual time window* for each truck and each container to be delivered or collected. Depending on the capacity of the TAS and the availability of import containers, the trucking company is free to choose this. The second type are the so-called *vessel-dependent time windows* (VDTW). Here, containers may only be delivered and picked up in specific time periods that are assigned to the handling of a ship. These time windows are usually considerably longer than the individual time windows, but cannot be freely selected. 18 of the publications considered examine individual time windows and only three VDTW. In a publication on the state of the art in research and technology both types are compared. This distribution can have several reasons: In principle VDTW are more likely to be found in the Asian region. In the rest of the world rather individual time windows are used. Furthermore, the quota considered in this study is particularly relevant for individual time windows. For this reason, the selection of search terms tended to find publications on individual TAS.

4.4 Used Approaches to Define the Quota in TAS

The category *quota definition* is the core of the literature review. This is where the quota of the applied TAS is defined in the examined papers. A

total of five different approaches were identified that were used in the papers (see Figure 7).

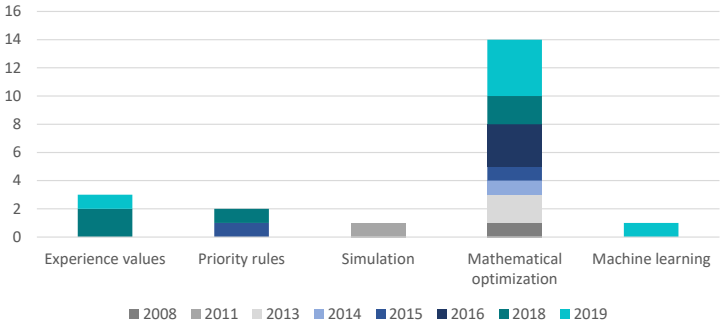

Figure 7: Allocation of publications to category quota definition

Mathematical optimization (15) is mainly used to determine the quota. The quota is usually not the decision variable, but a parameter or variable that is determined as a by-product during the solution of the problem. Other ways of determining the quota are *experience values* (3) and *priority rules* (2). Experience values are based on experience or expert knowledge. Priority rules are also often based on knowledge. This knowledge is formalized and stored as rules. Two methods are only used once for defining the quota: *simulation* (1) and *machine learning* (1). The fact that only little work was done with machine learning can probably be explained by the fact that this method is only used for a relatively short time in in research. Also, it is noticeable that simulation has rarely been used in the recent past. It was assumed that TAS, as an interface between two systems is heavily shaped by

unplanned and poorly predictable influences, which as stochastic elements are more likely to be represented by simulation.

4.5 Relevant Factors for Defining the Quota in TAS

The category *relevant factors* summarizes all key figures and parameters used in the publications which are used to determine the quota. A distinction is made between two types of factors. Some publications list factors that can be used to calculate or define the quota, but they are not used in any of the papers. These factors are either actually not used in practice for the definition of quota or they are not used in scientific papers. Here it should be clarified which of the assumptions is correct and why the described discrepancy arises. The factors that are mentioned but not used are not considered in this category. Only factors that were actually used in the definition of the quota have been included.

In total, the category comprises seven relevant factors: *truck loading times* (9), *capacity yard* (18), *capacity gate* (15), *capacity seaside* (8), *personnel capacity* (1), *traffic forecasts* (1) and *demand for slots* (11) (see Figure 8).

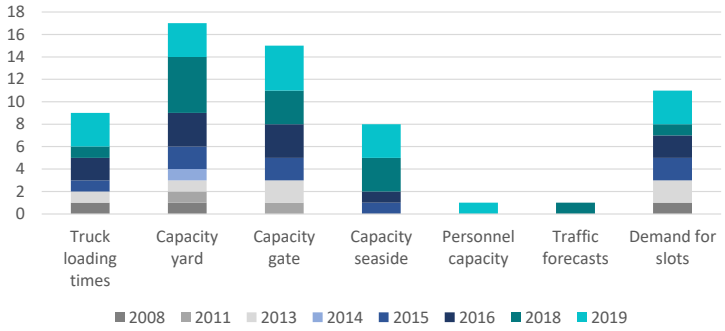

Figure 8: Allocation of publications to category relevant factors

The distribution of the relevant factors opens three perspectives. First, capacity yard and gate are the most commonly used to determine the quota. Therefore, the definition of quota is mainly derived from infrastructural capacities. Secondly, with *capacity yard* (18), *capacity gate* (15) and *capacity seaside* (8), the majority of papers refer to the terminal, which is consistent with the observation of the category focus. Thirdly, with *truck loading times* (9) and *demand for slots* (11) the framework conditions of landside freight transport are also considered. A possible interpretation of these results is that one research focus is to make the best possible use of existing (expensive and long-lasting) port infrastructure and that another focus is to adapt the port infrastructure to cope with the volume of landside transport. Furthermore, it is striking that usually several factors are relevant for the definition of quota. The 22 papers contain a total of 63 references to relevant factors, so that on average almost three factors per publication are used to

determine the quota. The number of factors used in a single paper varies between one and six.

4.6 Focus on Specific Stakeholders of the Publications

The category *focus* comprises characteristics that indicate from whose perspective the quota is determined or whose problem situation is addressed with the solution found. The characteristics are accordingly actors who cooperate in the TAS system. Basically, they are divided into actors of the transhipment node in question (i. e. hinterland or terminal) and actors of land-side transport. In particular, the focus of the publications under consideration is on: *seaport container terminals* (20), *hinterland terminals* (2), *empty container depots* (1) and *trucking companies* (5). The clear focus is not surprising, since the papers under consideration deal with a TAS or elements of a TAS that are used and owned by transshipment nodes. In particular, seaport container terminals have to face the problem described in the introduction and hope to be able to deal with it effectively with a TAS. In the future, this focus may be extended to hinterland terminals in particular, as they will face similar challenges as the capacity of seaport container terminals increases.

4.7 Application of the Research

In the context of the literature search, the category *application* covers the geographical areas where the truck appointment systems are used. In the majority of cases (12), the exact location is not specified. If the location is described, the terminals are usually located in Asia (5), North America (4) or Europe (1). This can be explained, firstly, by the fact that TAS are introduced

in particular when the terminals are under increased pressure due to the growth in the size of ships and the increasing volume of cargo handled, while at the same time there is little space available to expand the terminal. Secondly, this can lead to an accumulation of research, as they usually examine the same applications in different publications.

4.8 Analysis of the Mutual Dependencies

In the following the mutual dependencies between the categories *quota definition* and *relevant factors* with all other categories will be analyzed.
Independent of the time of publication, the research objectives focus on reducing the waiting time of trucks or the truck turn time and increasing efficiency. The second priority is to reduce congestion in the port and increase the service level. Irrespective of the focus of the research objectives, 80 percent of the methods used are mathematical optimization for defining the quota. The simulation would offer the advantage of being able to take more stochastic factors into account. Due to its complexity, however, it is rarely used. Machine learning may provide new approaches for this.
In order to reduce truck waiting time or truck turn time and to increase efficiency, the authors often focus on the capacity of the gates (17) and the yard (15). Both factors are usually considered in combination to determine the quota. The demand for slots (11), truck loading times (9) and capacity seaside (7) are also considered to a significant extent in order to determine a suitable quota for the above-mentioned goals. In all cases the focus is therefore on internal factors of the terminal. Influencing factors such as inbound and outbound traffic are not taken into account.

Due to the strong dependence between the quota definition and the method, the distribution is not conspicuous.

The distribution of the relevant factors and the method is not uniform. On the one hand, the *capacity yard and gate*, the *demand for slots* and the *truck loading times* are considered. On the side of the method the mathematical optimization dominates. With the help of mathematical optimization, three relevant factors are mostly considered at once to determine the quota.

In total, VDTW was only considered in three publications. For this reason, the figures are only of limited significance. Nevertheless, it is noticeable that in the three publications with VDTW, mathematical optimization was used to determine the quota. The remaining methods were all applied to individual time windows.

The factors that are taken into account when setting quotas are very similar for individual time windows and VDTW. There is a slight tendency for individual time windows to take a wider range of factors into account (including personnel and traffic forecasts). However, this may also be due to the larger number of publications on individual TAS considered.

The various methods of setting quotas take account of different and varying numbers of factors (see Figure 9).

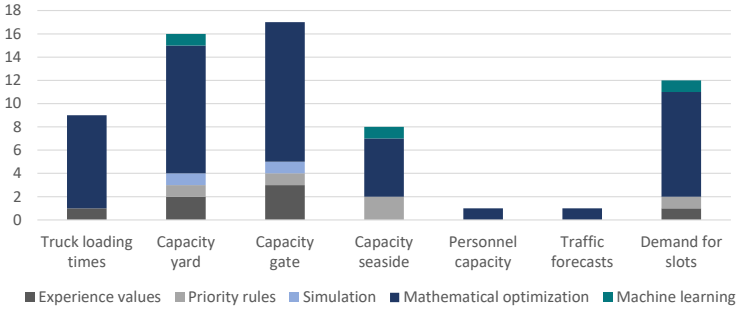

Figure 9: Dependencies of quota definition and relevant factors

Only in mathematical optimization are all factors taken into account, although not always. In the priority control methods, the second most factors are considered. Both simulation and machine learning would have the potential to consider more factors and to investigate these and their influence in more detail.

The way the analyzed publications define the quota as well as the focus of the publications is distributed unequally. Both categories show a clear accumulation for one characteristic. The quota definition is mainly done by means of mathematical optimization. The focus of the publications is clearly on seaport container terminals. It is therefore not surprising that the tuple *mathematical optimization* & *seaport container terminal* with 13 combinations clearly stands out in the comparison of the two categories. In addition, the seaport container terminal is also the focus of the methods *machine learning* and *simulation*. One conclusion could be that a larger amount of research has already been carried out in the focus seaport container terminals, so that new methods, especially machine learning, are

based on past experience. The relative accumulation of the *methods experience values* and *priority rules* with focus to *trucking companies* is also striking. Out of a total of only five projects focusing on trucking companies, experience values and priority rules for quota definition are both used once. This may be due to the fact, that a quota definition, which is based more on experience values and practical knowledge, corresponds more to the operational practice of trucking companies.

For the predominant focus *seaport container terminal*, the distribution of relevant factors is very similar to the distribution of relevant factors without considering the focus pf the publications. However, the specification of the relevant factors in relation to the focus *trucking company* is striking. Contrary to previous assumptions, the relevant factors used to determine the quota are not primarily oriented towards demand for slots or traffic forecasts that are more closely related to trucking companies. Instead, the relevant factors with focus on trucking companies are distributed almost equally over *truck loading times* (3), *capacity yard* (4), *capacity gate* (3), *capacity seaside* (3) and *demand for slots* (3). One possible interpretation is that the set up models have a comprehensive character, so that the entire port system with its interfaces to both land and sea side are considered. Therefore, despite the focus on trucking companies, factors such as *capacity seaside* would be considered relevant.

It was generally expected, that more practical methods, especially the definition of quotas by experience, would have a more specific application. The same applies to methods that are more data-based, such as machine learning in particular, since data from practice are usually required as in-

put. For the method 'mathematical optimization', however, this connection cannot be recognized. Due to the rarer occurance of the other characteristics, no statement can be made either.
The distribution of the relevant factors over the application areas does show any specific or distinctive feature. It was also not expected, that the factors used to calculate or derive the quota would differ from region to region.

4.9 Discussion

Based on the approaches described above to determine the TAS quota, the question arises why no uniform approach exists or has been developed so far. This may be due, among other things, to the individual framework conditions of the individual container terminals and the availability of the relevant information: Depending on the requirements, the equipment used and its quantity varies. The processes, such as receiving and issuing containers, are just as different as the control of the associated interfaces. For this reason, individual terminal operators usually concentrate on improving their own operations, such as improving the performance of individual areas, rather than supporting a holistic approach.
In the best case, a standardized approach to a solution involves all the players involved. However, they pursue different goals: While terminal operators and forwarders usually focus on high equipment utilization and efficient processes, the surrounding municipalities tend to pursue the political will and the associated transport policy goals. Against the background of the resulting complexity and conflicts of interest, it seems plausible that in the past only partial aspects were considered and improved.

Furthermore, it can be stated that methods such as mathematical optimization are already being used in operations to solve partial problems. However, due to the complexity and the associated time expenditure, the entire system is not considered. The challenge is therefore to identify the best method for the individual sub-areas in order to enable an overall view of the system in a relatively short time by networking them.

5 Conclusions and Outlook

The analysis focusing on the effect on terminals, trucking companies and the entire port does not provide clear results. The mainly used research method *mathematical optimization* might lead to the situation that stochastic influences cannot be represented comprehensively and that simplifying assumptions have to be made. Especially when considering and investigating several stakeholders, this can lead to a rather abstract representation of port reality. On the other hand, the various relevant factors are used to determine the quota. The relevant factors include both the perspective of the container terminals and the shipping and trucking companies. This points to a comprehensive, systemic approach that takes into account the interests of the different stakeholders. The comprehensive use of the different relevant factors seems to be one of the major strengths of the papers examined. However, the analysis has shown that the use does not necessarily lead to a result that takes the interests of the different stakeholders into account.

Although the factors are described as relevant, they are not taken into account. Their qualitative analysis is also not carried out. This is associated with the risk of considering factors that can be neglected in practice when determining the TAS quota. It would therefore be desirable for future scientific work to also examine and assess the interdependencies between the factors. Furthermore, a key finding of the present study is that only the node and its actors have been considered so far in determining the TAS quota. Their effects on the immediate (urban) surroundings and the connected road network are not taken into account. In addition, different

methods, such as simulation and machine learning, should be integrated in the already existing approached for detail questions.

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