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Truck Congestion at and in the Terminal – A Simulation Study

By

Dennis Vlugt
302463

Supervisor:
Prof. dr. Ir. R. Dekker

Co-reader:
Dr. A.F. Gabor

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Acknowledgements

Several numbers and figures are used in this thesis. It was supposed that these numbers and figures came from the ECT terminal in Rotterdam, so that we could represent all the data correctly. Unfortunately, the ECT terminal could not provide us those figures in time. Therefore, all numbers and figures in this thesis are based on assumptions. We tried, based on what we did know from ECT, to choose the data as realistic as possible. But we have no doubt that parts of the data are incorrect. The data is only used to analyze and construct model, which could also be used with real data later on.

The simulation model for this thesis is partly derived from the model developed for the seminar of the major Econometrics in Logistics. One of the models we used there to analyse a call centre, forms the foundation for the model we use in this thesis.

Then, I would like to thank professor Rommert Dekker who supported and guided me with this thesis. He helped a lot in pushing things in the right direction. I also would like to thank my co-reader dr. Adriana Gabor. Finally, I would like to thank Sietske for her support and her help with the final version.

Executive Summary

Truck congestion is a serious problem in many terminals around the world. During peak hours truckers have to wait long, the workload for the terminal is high and the environment is affected by the polluting truckers. One option to spread the arrivals and the workload more equally over the day is by making use of a Truck Appointment System (TAS). The main idea of a TAS is to use timeslots for planning truck arrivals. According to the literature, the best way to analyze appointment systems is to make use of simulations. Especially for the ECT terminal in Rotterdam a simulation model is designed, based on several assumptions. Queuing theory is used in order to determine the number of appointments. The results of the simulation model indicate that a TAS manage to spread the arrivals more equally. There is also a large reduction in waiting times for truckers with an appointment. Because the waiting time for truckers without an appointment went up compared the original situation, there is no reduction in the total waiting time. On average a quarter of the truckers have to choose a different timeslot than the one they prefer. This could be a problem for truckers and trucker companies. Implementing the model in reality will not be an easy thing to do, as there are several problems that could occur and the behavior of truckers cannot be predicted. Even though, several recommendations for the terminal are given in order to make a TAS as successful as possible.

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1. Introduction

1.1 Problem background

Queues at the terminal

A great part of the hinterland container movements is done by truck. Therefore, container terminals in the port where truckers load containers that arrived by ship and unload containers for shipping, is a busy place. Especially during peak hours in the afternoon, truckers face the problem of long waiting times at or mostly in those terminals.

Truck congestion at and in terminals is a problem seen among ports all over the world. The long waiting times are not only a problem for the truckers who have to wait. Transport companies are less certain about the time of arrival of their goods; they have to take an uncertainty factor into account for the delivery of goods. Also their costs are higher, since the time that a trucker has to wait could be spend on driving to another destination.

Besides that, there is the environmental issue. While waiting, truckers leave the engines of their trucks running in order to not lose a spot when the queue moves. So the longer the truckers have to wait, the more emission there will be.

Solving the problem of waiting times could also be in favour of the port authorities. Usually they do not mind if the truckers have to wait; the containers will still be there. But if the port authorities have environmental goals to achieve and/or they want to have a port that is better accessible, reduction in waiting time could be a good way to reach that.

1.2 Possible Solutions

Probably the first idea that occurs in solving the problem is to increase the capacity of the terminal, so that more trucks can be served at the same time. For port authorities this is not an option, since they have to invest in capacity and need to hire extra personnel for the peak hours.

Another option is to introduce an truck or terminal appointment system (TAS). With an appointment system, the port authority can better control the number of trucks on each moment of the week. In that way, the peaks that occur during a day can be smoothed down, so the arrivals of trucks will be more equally spread over time.

A different possible solution is to move some activities to an area close to the terminal. In that area, truckers can change their chassis. Then, during the night, the containers are moved to/from the terminal. In that way, the workload at the terminal will also be more equally spread over time. This idea, where the new area is called a chassis park, is currently developed for terminals in the port of Rotterdam by a company for green solutions in logistics.

1.3 Research questions and goals

The main goal of this thesis is to give a good analysis of ways of reducing waiting times at the terminal. The main focus will be on appointment systems. Therefore, the main research question is *"What is the effect of implementing a TAS?"*. In order to bound the answers on this rather wide question, the following sub-questions are introduced:

- *What are the bottlenecks in the current situation?*
- *What is an trucker appointment system?*
- *What are advantages/disadvantages of a TAS?*
- *What will be the improvement of a TAS compared to the current situation?*
- *How to design a TAS?*
    - *How will the new process look like?*
    - *What are the assumptions?*
        - *How large should the window be for truckers to arrive?*
        - *And what if trucks arrive outside that window?*
        - *Do they have to make a new appointment?*
        - *Or how to deal with trucks that arrive without an appointment?*
    - *What are the business rules and how do they look like in the case of ECT?*
- *How to simulate the current situation and a TAS?*
    - *What are the assumptions?*
    - *How can both situations be approached?*
    - *What is the data?*
    - *What is the effect of different arrival patterns?*
- *How does a TAS affect the outcomes?*
    - *What does it mean for the terminal?*
    - *What does it mean for the truckers?*
- *How can a TAS be implemented by terminals?*
    - *What is necessary to make a TAS work?*
    - *What could go wrong?*
    - *What are the limitations of a TAS?*
- *Are Truck Appointment Systems already implemented in some ports?*
    - *How is it implemented?*
    - *Is it a success?*
- *What are difficulties for implementing a TAS?*
- *What are the alternatives to a TAS?*
    - *What are their advantages/disadvantages?*

1.4 Methodology

In order to find answers to the research questions a literature review will be done. Besides a literature review, an important part of this research is the use of simulation models. Before we are going to use the models, we need to make a design of how we want the Truck Appointment System to look like. Then we will implement the design by creating a simulation model in the mathematical program Matlab. Matlab is used because it is a software package that can do calculations fast and the program is chosen because of our experience with it. It is necessary to build a model that can approach the current situation well. After that we are going to extend the model to model the situation where a TAS is implemented. In order to do so, we will use queuing theory to calculate the number of appointments that will be available for truckers.

1.5 Thesis outline

The structure of this thesis can be divided into four main parts. In section 1 and 2 there is the introduction and a more detailed description of the problem and process. Furthermore a TAS and its main features will be defined.

The second part of the thesis is the review of the literature. Section 3 gives an overview of existent literature about (truck or terminal) appointment systems and other relevant literature on appointment systems. Besides that in the section is described how the literature has been found.

In section 4, the design of the TAS for this thesis is discussed. First the new process is introduced and there is the discussion of the business rules and assumptions regarding those business rules.

In section 5, the simulation models will be explained. There is the discussion of the data. The first model approaches the current situation, while the second model models the situation where an appointment system is implemented. The results of both models will be compared. Also, different effects of using different inputs and/or appointment rules will be discussed in the third part of this thesis.

The final part of this thesis, section 6, discusses how a TAS could be implemented in reality. To do so, possible barriers for the implementation of a TAS, problems that could occur after the implementation of a TAS, limitations of a TAS and real world examples of implementations of a TAS will be discussed. Finally, two alternatives to Truck Appointment Systems are presented.

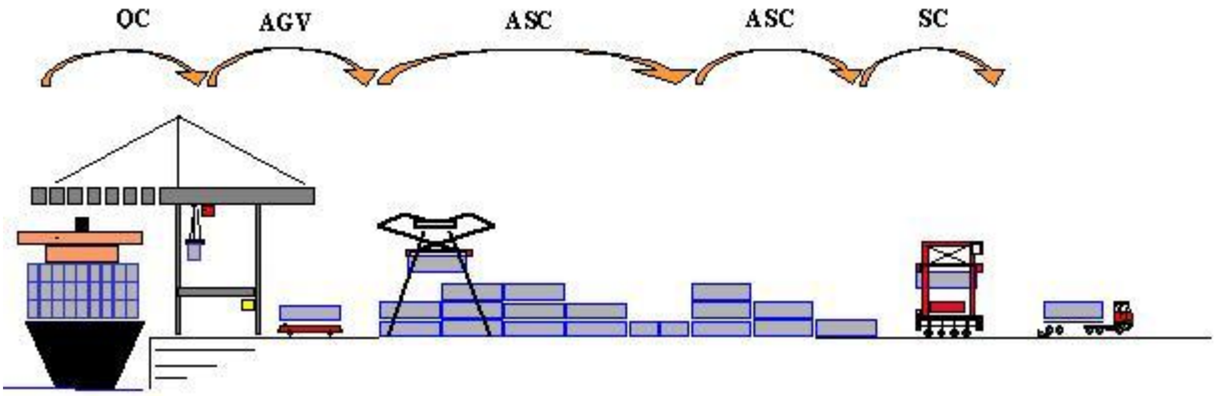
2. Congestion at the gate – The ECT terminal

In this section there will be a closer look at the problem. It is clear that congestion is a problem, but in order to correctly analyze the problem, a full description of the situation at the terminal is needed. Section 2.1 will take a look at the process and its bottlenecks. In section 2.2, TAS is introduced by discussing its definition and its properties.

2.1 The handling process

When truckers want to load and/or unload the container their truck is carrying at the terminal, they need to go through a certain process. The process between the arrival and the departure of trucks is as follows.

When trucks arrive, they have to pass a gate where there is an administrative check. Then they drive to a place where trucks are parked for loading and/or unloading. In case of loading, Straddle Carriers (SC's) pick containers from the ground and put those containers on the trucks. In case of unloading, SC's pick the container from a truck and put it on the ground. Automated Stacking Cranes (ASC's) get all the containers destined for the trucks from the stacks and put them on the ground and the containers delivered by trucks are taken from the ground and moved. When the truckers received their (new) load, they drive from their 'parking spot' to the gate and there the container is checked. When everything is all right, the truck leaves the terminal and goes to its destination.



Source: www.ect.nl

The ECT terminal in Rotterdam has lanes with only one ASC. Having only one ASC is the biggest bottleneck in the ECT terminal. Especially when there are ships at the seaside that have to be handled, the landside has no priority. The ASC's are focussed on moving the containers from and to the seaside and since there are no or few containers moved to the landside, the truckers have to wait.

Besides the high workload for the ASC's there is also the problem of the time of arrival of truckers. When looking at figure 1.1, a clear pattern can be detected. During working days, most truckers arrive in the afternoon. Also in the morning there seems to be a peak on the working days, but they are not as high as the late afternoon peaks. In combination with a busy ASC, the waiting times during the peaks can be very high.

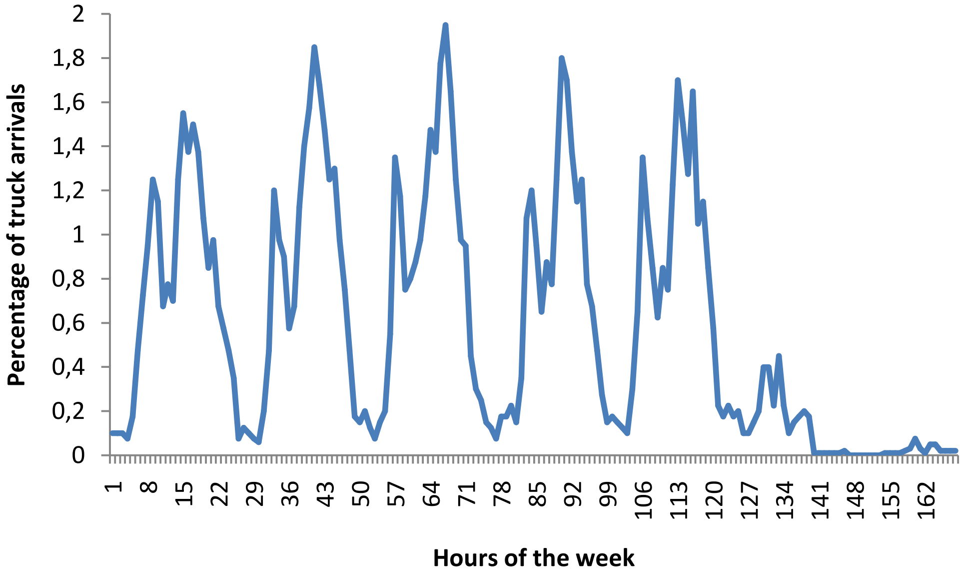


Figure 2.1: Arrival percentages of trucks per hour.
This figure is partly based on a figure published in 2000. At that time there were no morning peaks while, based on information from ECT, nowadays there are peaks in the morning.

In order to analyze the capacity, one can calculate peak factors. Peak factors are used to evaluate the performance of capacity in the most critical periods. The Peak Hourly Factor formula is given by (University of Idaho, 2009)

$$PHF = \frac{Hourly\ volume}{Peak\ rate\ of\ flow\ within\ the\ hour}.$$

If we would use the formula like this, we would get that the lower the PHF, the higher the peaks. That is a bit counter intuitive and therefore we will substitute the numerator term with the denominator term. Besides that, the above formula is based on several observations in one hour; we have only observations on a hourly scale. So instead of hourly volume, we will look at weekly volume and the Peak Factor will be given by

$$PF = \frac{Peak\ rate\ of\ flow\ within\ the\ week}{Weekly\ volume}.$$

To give an example, we will show the calculation of the Peak Factor for the peak on Monday morning. The weekly volume of percentage truck arrivals equals 95,485%. In this volume the weekend is not taken into account, because the weekend is less important in this analysis. Also, taking the weekend into account would give a wrong image of the Peak Factors, as the values are much lower compared to the working days and there are no capacity problems in the weekends. In the busiest hour on Monday morning, 1,25 percent of the total weekly truckers arrive. By multiplying this value by 120 (because 1,25% is per hour and we take five working days into account), the peak rate of flow is obtained to be 150%. Then the PF value equals 1.57. Table 1.1 displays the PF's for all the peaks of the week.

Tabel 1.1: PF values

Day	Part	Peak Factor
Monday	Morning	1,570927
	Afternoon	1,94795
Tuesday	Morning	1,50809
	Afternoon	2,324973
Wednesday	Morning	1,696602
	Afternoon	2,450647
Thursday	Morning	1,50809
	Afternoon	2,262135
Friday	Morning	1,696602
	Afternoon	2,136461

Table 1.1 shows that on working days the afternoon peaks are the highest. In the morning the peaks are somewhat lower, but still those peak factors are quite high as they are between 1.5 and 2 times the average amount. A highest peak is on Wednesday afternoon. This is consistent with the pattern seen in figure 1.1.

The high peaks on the working days lead to a major implication for the terminal. To deal with workload during the peaks, the terminal can increase its capacity during those hours. The problem is that the extra personnel and equipment is only needed for one to three hours a day. For those hours, the terminal cannot use fulltime personnel, since full-time personnel work on average seven to eight hours a day. Using a lot of full-timers in peak hours means overcapacity in other hours.

The use of part-timers is also not very likely. The distance between a port and living areas is usually quite large. So letting a worker travel for at least one hour to work one hour is not an serious option. Besides, with those long distances it is even questionable that a terminal has part-time personnel at all. It is more likely that the personnel of a terminal consists mainly of full-timers.

Another problem is that the morning peak and the afternoon peak lay several hours out of each other. This gap is too big to plan for example breaks for workers that worked during the morning peak, such that they can also work during the afternoon peak. The planning of personnel is a deterministic problem and will be not considered anymore in this thesis.

Since using extra personnel is not an option, a terminal can choose to smooth down the peaks. One way to do that is making use of a Trucker Appointment System.

2.2 Trucker Appointment Systems

First, we will define a TAS. Van de Heide and van Vliet (2009) presented in their work a definition to work with. The definition we will work with is an adjustment of their definition. We define a TAS as a system using timeslots for appointments, which is not a notification but a two-sided confirmed agreement, for planning the arrival of a trucker at the terminal. Truckers or transport companies can contact the terminal in order to make an appointment for the pick-up and/or drop off of containers. This appointment concerns a certain amount of time (timeslot) in which the trucker may come. If he/she arrives outside that window, he/she cannot be served.

The main idea of a TAS is to spread the workload more equally over the day by making use of appointments. By using appointments, a terminal can set a maximum to the number of arrivals in each hour. In that way, when all timeslots are full in a certain hour, truckers are forced to choose a different time of arrival.

Besides spreading the workload, a TAS is mentioned to reduce the waiting times. When waiting time reduces, the emission of trucks in the terminal also reduces and so a TAS has a positive effect on achieving environmental goals.

2.4 Conclusions

This section described the problem in detail. It described the process that truckers go through when picking up and/or dropping off containers. Furthermore, the bottlenecks in this process are discussed and there is a general description of what a TAS exactly is. In order to analyze the performance of a TAS a model can be constructed. Therefore, the best method to model a TAS has to be determined. This will be done in the next section.

3. Literature review

This section describes the search to relevant literature for this research. A literature study can be useful in order to find more information on appointment systems and to find out what the best method is to analyze such a system. In section 3.1 there is a description of the search strategy. 3.2 discusses literature on appointment systems in health services, while in section 3.3 port-related literature is discussed.

3.1 Search strategy

The first thing that we did in our search was to get access to literature on Truck Appointment Systems written by other students from the Erasmus University. With those papers we could directly find more relevant literature by looking at the references.

The second thing we did in searching for relevant literature was making use of the search engine Google Scholar. The most obvious terms to fill in there are 'Truck Appointment System(s)' and 'Terminal Appointment System(s)'. Unfortunately, these search terms delivered very little relevant results.

Search terms like 'timeslots', 'simulating timeslots' and variants of those terms did not lead to any relevant literature. The next terms we used were terms like 'Appointment system(s)' , 'Simulating appointment system(s)', 'Simulation appointment system(s)' and 'Truck congestion terminal'. These terms also delivered little relevant material. The most material is on outpatient appointment systems.

Therefore we decided to try to find some more literature on outpatient appointment systems. Using 'Outpatient appointment system(s)' as search term, I found some articles in that field of research.

The last articles we tried to search for on Google Scholar were articles with respect to bookings and booking systems. Unfortunately, also in this case we could not find relevant articles for this thesis.

Finally, we checked all the articles on possible relevant references. This led to the finding of some relevant articles we could not find on Google Scholar before.

3.2 Appointment systems in the health services

The most articles available with respect to appointment systems, are articles on appointment systems in health care services. Most of them take into account outpatient appointment systems. An outpatient is a patient attending a hospital for treatment without staying overnight. It differs from inpatients in the sense that inpatients stay one or multiple nights at the hospital or clinic before getting treatment.

(Out)patients however, cannot be completely compared with truckers. Patients can arrive at any time, while truckers have limitations. They have the problem of traffic congestion and they have to take into account the consignee, who need to receive the goods in time and mostly cannot receive goods during the night. Therefore, most truckers need to load and/or unload containers at the terminal during daytime.

The first article in a range of articles on reducing patient waiting times is the article of Bailey (1952). He used mathematical models to analyze different appointment systems in hospital outpatient departments. He shows that patient waiting times can be reduced by using a suitable appointment system.

Vissers and Wijngaard (1979) build upon the work of Baley. They discuss the design of a simulation study with respect to outpatient appointment systems. They describe the (main) characteristics of general appointment systems and then discuss the variables present in outpatient appointment systems. Vissers and Wijngaard give a description of a reduction in the number of variables used, and validate the reduction by giving a proof. Unfortunately this paper is too focused on appointment systems in clinics and the simulation procedure is not described, so for this thesis the article is not very useful.

Another article where simulation is used for finding an appointment system that reduces patient waiting time is the article of Harper and Gamlin (2003). They take into account the variable needs of patients in finding a way to improve appointment scheduling. Although they pay much attention to their simulation model it is not directly useful for the simulation models in this thesis, as their model is based on a complex Ear, Nose and Throat clinic and was built in a software program with which we are not familiar.

Also Brahmi and Worthington (1991) build upon the work of Baley. They do that by using queuing theory. In their article a case study on queuing models for out-patient appointment systems is described. They are not discussing in detail the queuing model they use, but they describe how an existing appointment system easily can be revised.

The authors discuss the revision by comparing appointment systems with various numbers of patients at the start of the clinic and various patterns of appointments. They succeed in bringing down patients waiting time and the probability that a doctor is busy in both the situation where all patients attend and the situation where 10% do not attend. In the situation with patients that do not attend they plan extra patients at the beginning of a day.

With a TAS there is also the problem of truckers that do not attend. Only in the case of truckers it cannot easily be solved by planning some extra truckers at the beginning of the day. Replacing truckers can cause problems for truckers and operators, since most truckers and operators want to make multiple trips a day and they are subjected to the times when consignees can receive goods. Therefore, replacements should be minimized.

Cayirli, Veral and Rosen (2006) wrote an article on the design of appointment scheduling systems for ambulatory care services. They make a distinction between sequencing rules and appointment rules. To analyze the effects of the different decision rules they created an overall applicable simulation model. Cayirli, Veral and Rosen came to the conclusion that sequencing rules have a greater effect on performance than appointment rules.

In the article six sequencing rules are tested. Sequencing rules consider the planning of new and return patients. New patients are patients who have never been in the clinic before, while return patients are former patients who arrive with new problems or for follow up for an old problem. This distinction has been made, because new patients usually have higher service times. For example, one sequencing rule is to schedule new and return in a alternating pattern, while another rule is to schedule new patients in the beginning and return patients in the remaining part of the session.

Appointment rules are rules concerning the appointment intervals. An appointment interval is the time between two appointments. In the article seven rules are compared. For example, each appointment can be made with fixed intervals between them. Another rule is to increase the appointment intervals gradually to the middle of the session and then decrease slightly at the end of the session.

Unfortunately, sequencing rules are rules for planning new and return patients; in truck appointment systems there is no distinction between new and return truckers. On the other hand, appointment rules could be more interesting to investigate. But like said before, the writers conclude that sequencing rules have a larger impact than appointment rules. Besides that, they also conclude that the best choice regarding appointment rules depends upon the combination with a particular sequencing rule.

The simulation model in this article could be useful for this research, but the authors discuss their model very briefly. An interesting result in the paper is that a first-call, first-appointment (FCFA) system performs always worse than a system based on sequencing. So it is better to implement a sequence rule compared to planning every entry instantaneously.

3.3 Literature on TAS

Like said before, there is little literature on TAS. Two students from the Erasmus University Rotterdam wrote a thesis on truck congestion in ports. Plata (2008) and Mallidis (2008) wrote their theses on truck congestion in the port of Valencia and Thessaloniki respectively.

Mallidis recommends the use of an appointment system in the port of Thessaloniki for spreading truck arrivals more over the day. The author uses queuing theory to calculate some operating characteristics, like for each truck the average waiting time and average time in the system. Unfortunately, Mallidis does not discuss in his thesis how the appointment system should look like.

Plata is discussing Truck Appointment Systems more deeply in his thesis. He discusses advantages and disadvantages of such a system, several types of appointment systems and where and how appointment systems are already implemented. The thesis contains a computer science and economic based view on TAS. For example, in the article Terminal Operating Systems, Truck Appointment Management Systems and hardware technologies are discussed.

Plata also applies queuing theory in his thesis. He analyzes what the optimal capacity should be in order to reduce waiting times. Besides queuing theory, the author applies simulation. Both approaches are not considering appointment systems, but are used to find the optimal capacity.

The author finally represents the economic evaluation of the reduction in waiting time by increasing capacity and the economic evaluation of implementing a TAS. Plata concludes that using a TAS can have many positive effects and the costs of implementing a TAS can be recovered quickly, but that the implementation of a TAS will be very hard to achieve, since there is a lack of willing by different parties.

The Erasmus University students van de Heijde and van Vliet (2009) wrote their Economics & ICT seminar on Truck Appointment Systems. In their research, they discuss all aspects of TAS. Therefore, it is a very useful report to gain insight in TAS. Later on in this thesis, in section 6, we will discuss some subjects that are also discussed in their paper. But also in their research, a mathematical model for analyzing the implementation of a TAS is missing.

Morais and Lord (2006) did a study on Terminal Appointment Systems. In their study they analyzed the impact of Terminal Appointment Systems, automation technologies, extended gate hours and other strategies for improving cargo velocity at ports and gates in order to reduce congestion, delays and emission.

The researchers stated that an arrival management has to be able to:
- handle cancellations;
- re-assign reserved time that has been cancelled or re-assign reserved time for no shows;
- introduce fines for missed reservations;
- allow one hour window for trucks to show up;
- make appointments based on container appointments (instead of truck appointments);
- allow telephone reservations

These are the most important abilities that Morais and Lord name, but they name more abilities in their paper. The authors also discuss the implementation of a TAS in the port of Vancouver, but this will be discussed in section 5.

Besides Vancouver, there are some other examples of ports where a TAS is implemented. Guiliano and O'Brien (2007 & 2008) described and evaluated the Terminal Gate Appointment System at the port of Los Angeles and the port of Long Beach. The appointment systems in both areas where implemented after the California State legislations imposed a reduction in vehicle emissions and highway congestion by reducing truck queuing at marine terminal gates and distributing truck traffic over a greater period of time throughout the day.

Based on interviews, field observations, company surveys and data provided by terminals, Guiliano and O'Brien's most important conclusion is that the appointment systems have no effect on the queues at terminal gates. So in this example, implementation of appointment systems is no success. In section 5 more attention will be paid on these articles.

Also in the port of Hong Kong an appointment system is implemented. Murty et al. (2005) describe the situation where the terminal operator decided to implement a policy of a quota system for import containers for trucks arriving between 8 and 17 hours, letting the rest of working hours be available to serve those truck drivers that have arrived without an appointment.

This could be an important decision in forcing truckers to make an appointment. However, in this thesis such a situation is not analyzed, but for decision makers who want to implement a TAS, this could be a serious option to consider. The Hong Kong example will return in section 5 of this thesis.

3.4 Conclusions

From the literature on appointment systems in health care service can be concluded that the best method to describe and analyze (different forms of) appointment systems is making use of a simulation model. Furthermore the literature impose some ideas on appointment rules and sequencing rules, which might be considered for designing a TAS.

From the available literature on TAS, it becomes clear that a TAS is not simulated before. Besides that, examples show that a TAS can have different effects depending on the way it is implemented. For the successful implementation of a TAS, the literature provides different views on how to achieve that.

Since a TAS is not simulated before, while from the literature it becomes clear that simulation is a good way to analyze appointment systems, it seems a good attribution to the research area of TAS to provide a simulation model. Before implementing such a simulation model the appointment system has to be designed.

4. TAS design

Section 3 concluded that according to the literature simulation is the way to analyze appointment systems. Before modelling a TAS, there are some choices that have to be made regarding the design of a TAS for this specific case concerning the ECT terminal in Rotterdam. Business rules have to be set and some assumptions with respect to the behaviour of truckers have to be made. In 4.1 the process as it will be is described. Section 4.2 contains the business rules and some assumptions regarding the business rules.

4.1 The new process

When making use of a TAS, the process at the gate will be somewhat different. Instead of treating all truckers the same at the gate, there will now be difference in truckers with an appointment and truckers without an appointment.

Truckers with an appointment will be assigned to a different queue than truckers without an appointment. Since the terminal knows in which hour which container will be picked-up, the handling of truckers with an appointment will be more fluent. Truckers without an appointment will be assigned to a queue for which the handling process is exactly the same as explained in section 2.

Creating two different queues means that the capacity also will be divided into two. The largest part of the capacity will be assigned to the truckers who have an appointment. The reason for not assigning all capacity to truckers with an appointment is to make the system more flexible. When only truckers with an appointment are handled, a significant part of the truckers cannot be served.

4.2 Business rules and assumptions

When designing a TAS, some business rules concerning the operation of a TAS have to be set. There have be decisions taken with respect to:

- The length of the slot.
- The number of appointments.
- When the appointment has to be made (how long in advance).
- What will happen if a trucker arrives outside the slot.
- The guarantee on service time when arriving in the slot.
- Rules for changing an appointment.
- Rules for cancelling an appointment.

These rules are likely to vary from terminal to terminal. Since it is not known how these rules will look like in case of the ECT terminal in Rotterdam, we will make assumptions about them.

An important aspect of timeslots is the length. It is not clear what the optimal length is for both the terminal and the truckers, but when looking at Truck Appointment Systems implemented by other terminals, the most common length seems to be one hour. Besides that, one hour seems a logical choice since it very easy to implement.

Besides length, a terminal has to choose how many appointments there will be available for each timeslot. This can be determined by using queuing theory. In the next section we will get back on that.

When a trucker has to both deliver and pick-up a container, he/she only has to make one appointment. So the trucker does not have to make two appointments; one for delivering and one for picking up a container. We do not deal with the case that a trucker for example has to deliver a container at one terminal and pick-up a container at another terminal. We will limit ourselves to the case of one terminal only and neglect pick-up and delivery at two terminals.

When the number of appointments are determined, truck companies can give their preference for an appointment. We can assume that those preferences are the same as the arrivals as they are now (so with the peaks in the afternoon). This means that each trucker has one preference for a certain timeslot and therefore a trucker cannot have multiple preferences. Figure 4.1 displays the preferences of the truckers and the number of available appointments per timeslot.

In the figure we can see that in some cases there are more preferences for a timeslot than there is capacity. When a trucker cannot make the appointment he/she prefers, it is assumed that the trucker will take the timeslot which is closest to trucker's preference. This means that a trucker deviates forward or backward in time, depending on the slot which is closest.

For example, if a trucker wants an appointment corresponding to the timeslot 10:00 hrs to 11:00 hrs, but there are no appointments left for this slot. Also, there are no appointments left in the slots 9:00 hrs to 10:00 hrs, 11:00 hrs to 12:00 hrs and 12:00 hrs to 13:00 hrs. This automatically means that the trucker will choose the appointment in the slot 8:00 hrs to 9:00 hrs and not the appointment in the slot 13:00 hrs to 14:00 hrs, since a deviation of 2 hours is smaller than a deviation of 3 hours.

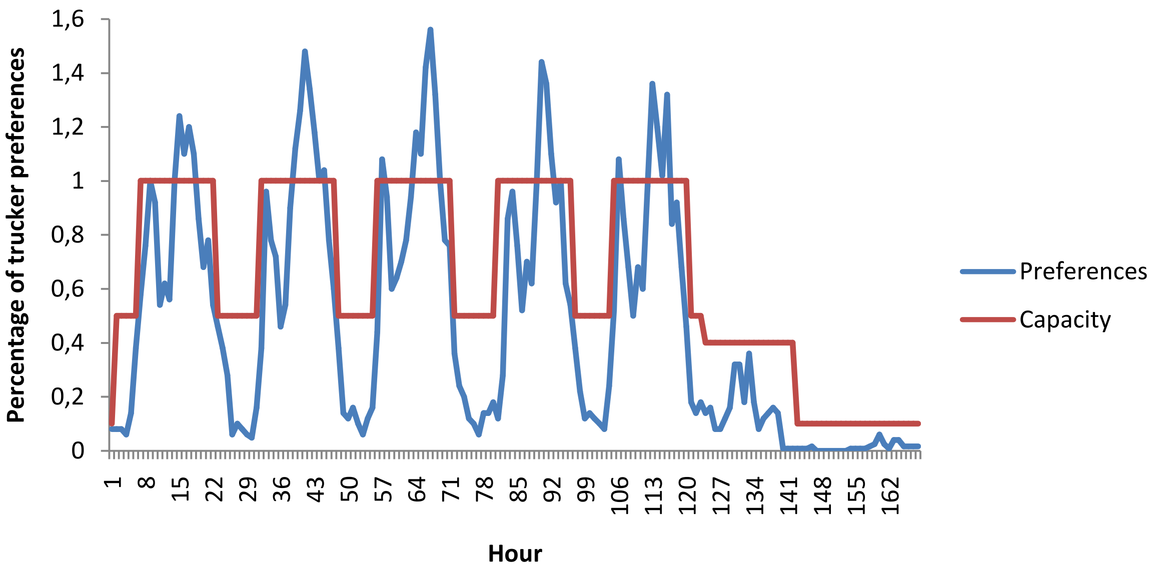


Figure 4.1: Trucker preferences versus capacity

If there are no appointments left for the trucker to choose, we assume that the trucker joins at the time of his preference the queue of truckers with no appointment.

Furthermore, when a trucker has made an appointment, it is not automatically assumed that trucker arrives in the corresponding window. When truckers arrive too early, it is assumed that they wait until the start of their slot. When truckers arrive too late, we assume that they are not making a new appointment, but that they will join the queue for truckers without an appointment.

The issues of when an appointment has to be made and how an appointment can be changed or cancelled are not interesting for the model we will later on use. The only thing that is important, is that the appointments are made in advance. When that is, is for this research less important. Also decisions about changing appointments will have no influence on the analysis.

4.3 Conclusions

In this section the design of the TAS, which will be implemented in the next section, is described. It became clear how the new process will look like and there are assumptions made with respect to the business rules that have to be set. Now we know what has to be simulated, we can proceed with the actual modelling of a TAS.

5. The modelling of a TAS

The conclusion in section 3 was that simulation is a good way to analyze the implementation of a TAS. In section 4, the design of the appointment system is discussed. That, the introduction of the data in section 5.1 and the calculation of the number of appointments for each timeslot in 5.2 is enough to make it possible to create a simulation model. In section 5.3, the simulation model to model the current situation and the extension of that model to model the situation where an appointment system is implemented are discussed. Then, in 5.4, the results of the experiments are compared and discussed.

5.1. The data

If we assume that the arrivals happen according to a Poisson process, we can conclude from figure 2.1 that the process is a non-homogeneous Poisson process. To find the parameters for this process, we need to know the number of truckers that arrive during one week, because then we can use the percentages in figure 2.1 to calculate the arrival rates.

We assume that during a standard busy week there are 8196 leaving containers, and that there is an equal amount of incoming containers. As will be discussed later on, 60% of the truckers both drop off and pick up a container and the remaining 40% of the truckers only needs to drop off or pick up a container. When, for simplicity, assuming that each truck can carry one container, the number of truckers that arrive during one week equals 10245 (as the total flow of 16392 containers is equal to 160% of truckers, because of the double counting of in and outgoing containers). With that number and the percentages in figure 2.1, the calculation of the arrival rates is easy. For example, the total arriving truckers on Wednesday is equal to 2108 truckers.

The arrivals can also be approached differently, namely by generating arrivals on a fixed interval. This means that the arrivals will happen every amount of minutes. By using the arrival rates found above, one can easily determine after which amount of minutes the next trucker will arrive.

Then, for each arrival there is uncertainty taken into account, because the arrivals will most of the time not be after precisely each amount of minutes. This uncertainty effect is assumed to be approached with the Normal distribution with a mean of 0 minutes and a standard deviation 2 minutes. This standard deviation of 2 minutes is arbitrarily assumed. We will call these type of arrivals *uniform arrivals*.

In the handling process there is a distinction between three types of truckers. The first type of trucker only needs to deliver a container. The average time for a trucker to drop his/her container is assumed to be 20 minutes, which from now on will be called service time. The second type of trucker is a trucker that needs to both deliver and pick-up a container. The average service time for this type is assumed to be somewhat longer, namely 40 minutes. The third type of trucker only needs to pick-up a container. The average service time in this case is assumed to equal 30 minutes. These service times are based on the whole process of 'check at the gate – handling – check at the gate'.

The distribution of the service times is assumed to be Exponential, with rates 0.33, 0.67 and 0.5 (for type one, two and three respectively). These rates are derived from the service times 20, 40 and 30 minutes. The percentage of truckers that are said to be type one truckers is assumed to be 20%. The percentage of type two truckers is assumed to equal 60% and type three truckers are assumed to account for 20% of the arrivals.

Then, figure 5.2 gives the available capacity of the ECT terminal. This capacity equals the hourly number of truckers the terminal can handle, based on an average service time of 34 minutes. This is a compound of the above three mentioned service times. Figure 5.2 also shows the divided capacity. 80% of the capacity will be assigned to truckers with an appointment, while the remaining 20% is reserved for truckers without an appointment.

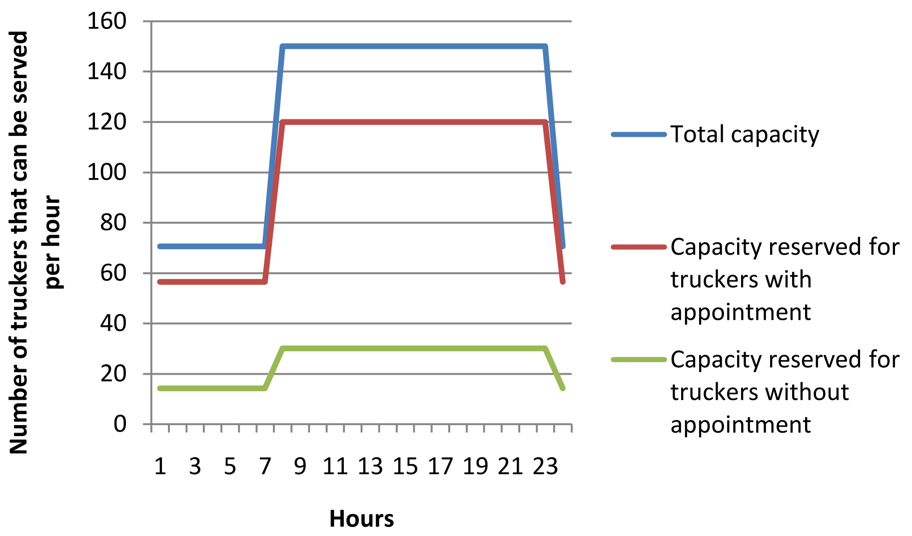


Figure 5.2: Capacity of the ECT terminal

For truckers with an appointment, also an uncertainty factor has to be taken into account. They can deviate from the time of their appointment. We assume that this uncertainty factor can be approached with the Normal distribution with mean 0 and a standard deviation of 5 minutes. Again the standard deviation of 5 minutes is arbitrarily assumed.

At first thought it sounds a bit strange to use the Normal distribution, as the arrivals will not be Poisson anymore. But in fact, it is not a problem, since after the scheduling of the preferences, the arrivals are anyhow not anymore Poisson distributed. This is due to the replacements that are made when a trucker cannot get the appointment corresponding to his/her preference. Like said before, when a trucker is moved to another timeslot, the time of arrival is set to the half of that timeslot.

The use of the uncertainty factor can cause that the actual arrival of the trucker is on the day before or on the day after. In order to not 'loose' these arrivals, we decided to still measure them. So if a trucker has an early appointment and arrives before the start of the day, we will store the time the he/she had to wait before the start of the time window. If a trucker has a late appointment and arrives on the next day, we will store that he missed his appointment and had to join the queue for truckers without an appointment.

If we assume the process of 'check at the gate – handling – check at the gate' to be one process, this situation can be approached with an M/M/s queuing model. In this model, the first 'M' stands for Poisson distributed arrival times, just like described above. The second 'M' stands for Exponential distributed service times and the 's' stands for the number of servers.

Since it is hard to determine the number of servers for a process consisting of three parts, with each part having its own measure of capacity, we assume that the capacity is given by a little bit less than one half of the capacity presented in figure 5.2 (since each server can handle on average slightly less than two truckers per hour).

5.2 Determining the number of available appointments

Before getting to the simulation models, the number of appointments for each timeslot has to be determined. The length of the timeslots is assumed to be one hour. Since it is known that 80% of the capacity is available for appointments, the maximum number of appointments can be determined using queuing theory. This means that by putting conditions on the waiting times we will determine the number of appointments that will be available for truckers, that correspond to those conditions.

The long-run fraction of customers whose delay in the queue is no more than x, is given by (Tijms, 2003 p.192)

$$W_q(x) = 1 - \frac{\rho}{\rho - 1} p_{s-1} e^{s\mu(1-\rho)x} \ , \qquad x \geq 0 \qquad (1)$$

with

$$\frac{\rho}{\rho - 1} p_{s-1} = \frac{(s\rho)^s/s!}{[(s\rho)^s/s! + (1-\rho)\sum_{k=0}^{s-1}(s\rho)^k/k!]} \qquad (2)$$

the long run fraction of customers who are delayed (Tijms, 2003 p.191-192), and

$$\rho = \frac{\lambda}{s\mu} \qquad (3)$$

where λ is the arrival rate, μ the mean service level which is a compounded exponential distribution based on the three types of truckers and s the number of servers. Also it is assumed that $\rho < 1$, so $\lambda/\mu < s$, which states that the average amount of work offered to the servers per time unit is less than the total service capacity (Tijms, 2003 p.188). If this condition is not satisfied, the system is said to explode.

The next step is to determine λ. Since the number of servers and the service times are known, and taking values for x and $W_q(x)$, for every hour λ can be found by numerical solving equation (1) after substituting (2) and (3).

x will be set to 8 minutes, so it means that x equals 0.1333. $W_q(x)$ has to be set by the decision maker. For now we will allow $W_q(x)$ to take different values between 0 and 1. By using different values for $W_q(x)$, we will find different values for λ. Later on we will decide what value for $W_q(x)$ we will take. Figure 5.3 displays the number of appointments for some different values of $W_q(x)$.

The figure displays a logical result, namely that the higher the number of appointments, the lower the fraction of truckers with no delay longer than 8 minutes. When the fraction is getting lower, the number of appointments tend to move closer to the capacity displayed in figure 5.2.

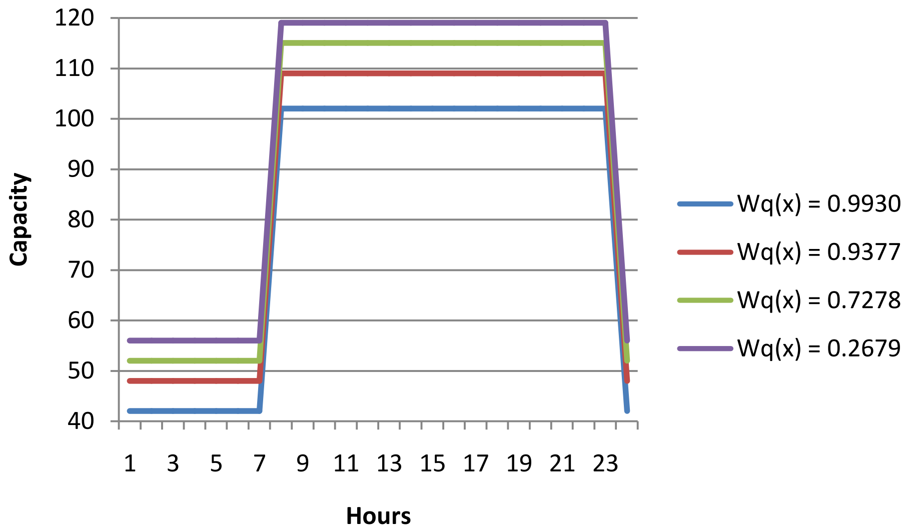


Figure 5.3: Available appointments for one working day

5.3 Simulation model

5.3.1 Modelling the current situation

The current situation at the ECT terminal can be modelled by using discrete event simulations. Such simulation models contain a central clock. It is assumed that this clock always starts at time zero. Furthermore, it is assumed that at that time no truckers are in system, so no servers are occupied and the queue is empty.

Another element of a simulation that has to be determined is the simulation window. We chose to model one day of the week, namely the Wednesday, since this is the busiest day of the week (see figure 2.1). The reason to only simulate one day is that using a larger simulation window would increase the calculation time a lot. Besides that, the simulation of one day will be enough to reach the goals of this thesis.

A consequence of simulating only one day and starting each day at zero is that there will be no changeover effects between different days. If we would simulate the whole week at once, there would for example be truckers who arrive on one day and are handled on the next day and thereby affecting the system at the first hours of the new day. As only the Wednesday is simulated, it seems not realistic to let the truckers that arrive late in the evening on Wednesday affect the system at the beginning of the next simulated Wednesday, because the beginning of the Wednesday should be affected by the end of the Tuesday and the end of the Wednesday should affect the beginning of the Thursday. Therefore, the changeover effects will not be taken into account in this thesis. If truckers are still in the system at the end of the day, we will only determine after what amount of time a trucker leaves the system. In that way we can determine the waiting times without affecting the system at the next Wednesday, because the trucker or not kept in the system.

When everything is determined, the simulation model can be built. The main setup of the model is displayed in figure 5.4. In this global overview of the simulation setup, the time interval T is not the same as the central clock. T is ranged from 1 to 24. For example, if T equals 3, it means that the model is in the interval 02:00 hrs. to 03:00 hrs. The central clock can take more specific values than just an interval.

Every step displayed in the overview is implemented in the mathematical software package Matlab. The exact codes depend on the way of programming of the user, but when steps in the overview are followed, the results should be similar.

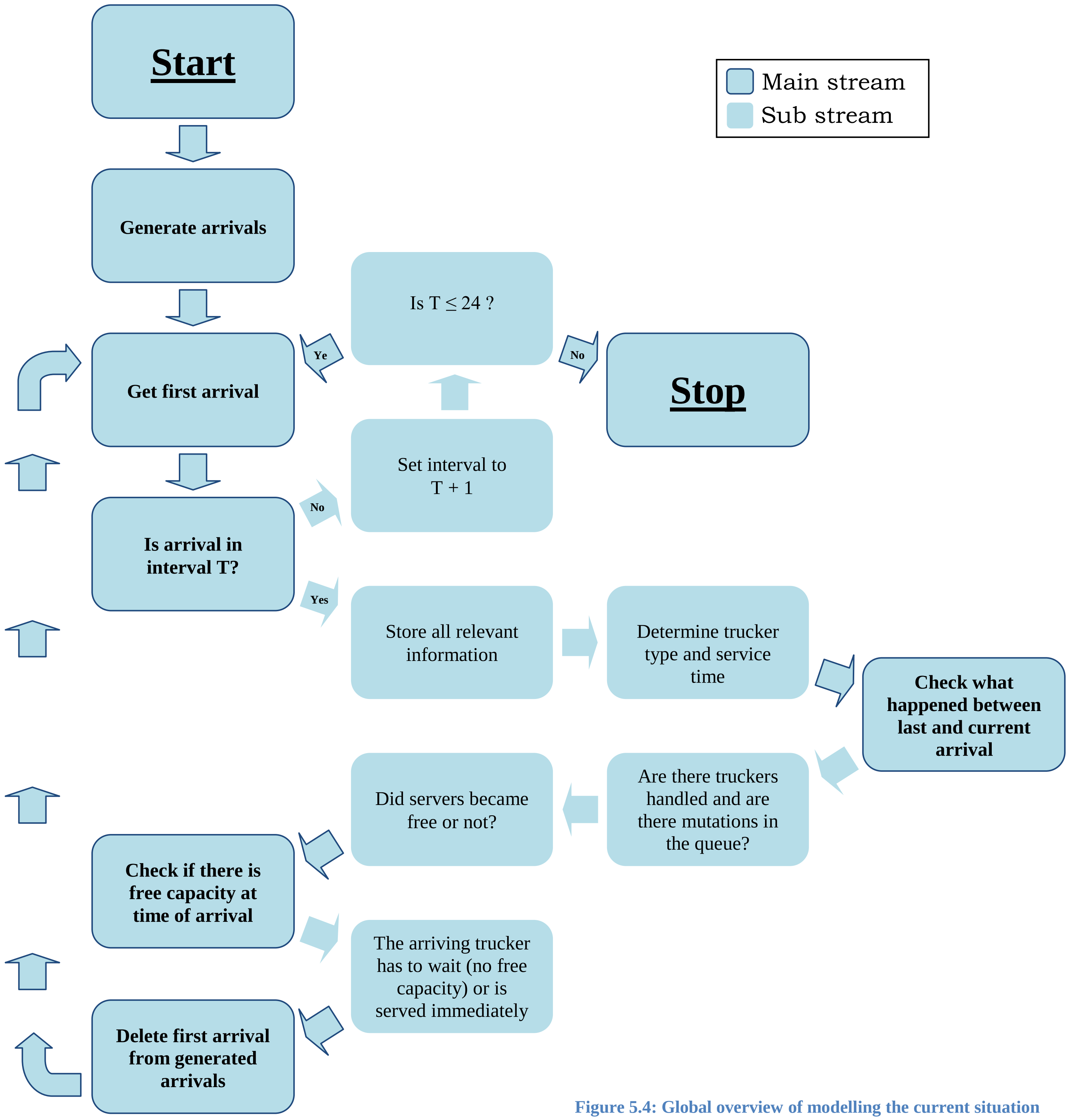


Figure 5.4: Global overview of modelling the current situation

5.3.2 Modelling an appointment system

For the situation where an appointment system is implemented an extension of the above model can be used. Now a part of the arrivals has an appointment and a part of the arrivals has no appointment. Since there is a split up in the arrivals, the simulation model is not consisting of one function anymore; now several functions are working together. Figure 5.5 displays the hierarchy of the different parts of the appointment system.

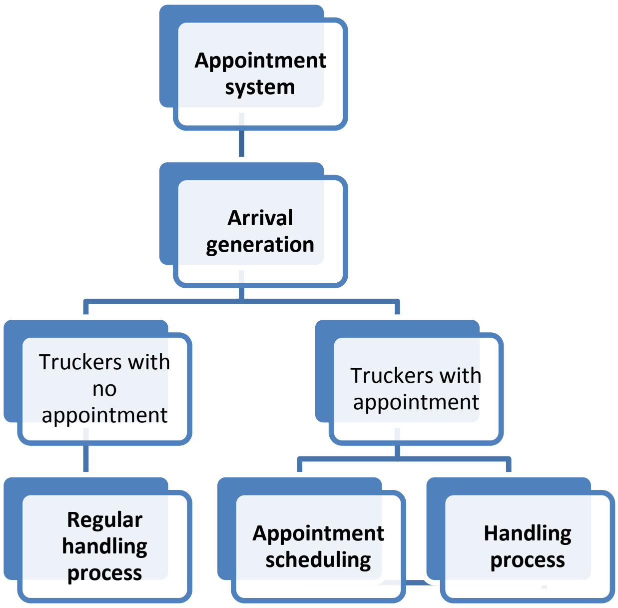


Figure 5.5: Structure different parts appointment system simulation model

As can be derived from the figure, there is one main part named *appointment system*. In this main function, several other functions are called. First the *arrival generation* function is called, where all arrivals for the truckers that have no appointment are generated. Also the preferences for the appointments are generated in the *arrival generation* part. 10% of the generated arrivals will be arrival times of truckers without an appointment and 90% of the arrivals will be the preferences of the truckers who want to make an appointment.

These percentages might seem to be inconsistent with the earlier mentioned division of the capacity, where 80% of the total capacity is reserved for truckers with an appointment and 20% for truckers without an appointment. But due to the fact that about 12% of the truckers with an appointment arrive too late, the division of the truckers who are handled by capacity for appointments and for no appointments will be about 80% and 20% respectively.

In the next part of the appointment system, the preferences are scheduled in the *appointment scheduling* function. This is done by drawing randomly an arrival from the preferences and assigning it to the according timeslot. The drawings are random, because in that way the first-come-first-served principle can be approached. If there are no timeslots available anymore, the arrival is moved to the closest available timeslot. Figure 5.6 gives an overview of how this part of the model looks like.

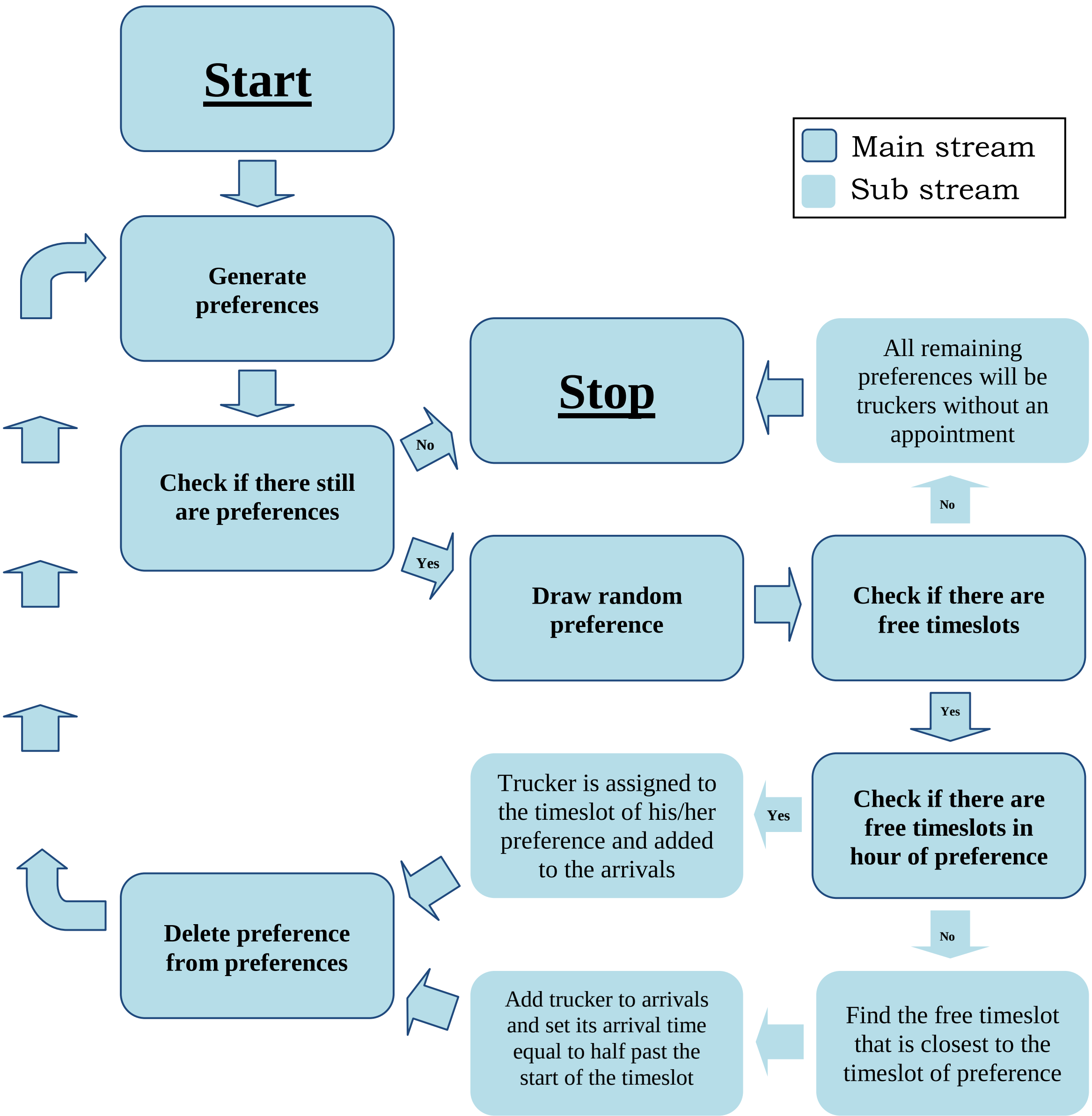


Figure 5.6: Overview appointment scheduling function

Then, the schedule is executed in the *handling process* function. This is quite similar to the *regular handling process* part, which is the same model as in figure 5.4. The only difference is that there is a deviation taken into account on the time of appointment. If truckers are too early, they wait until the beginning of their slot. If they are too late, they are added to regular arrivals. These two conditions are only valid at the beginning and the end of the hour. As we did not implemented flexible capacity, we will do nothing in case of idle capacity. Those servers wait until they can serve a trucker.

5.3.3 Validating the simulation model

Now that the simulation model is built, we need to validate the model. Validation is necessary in order to verify the correctness of the results. In the development we have made several runs and inspected the outcomes. Initially there were a number of striking differences between experiments. These all turned out to be programming errors. Although we cannot give a 100% guarantee, we are strongly convinced that the at present results are correct.

5.4 Results

5.4.1 Results current situation

Every simulation simulates 500 (Wednes)days. This number is chosen as a tradeoff between calculation time and still having a significant number of runs. The simulation of 500 days takes about 15 minutes of time. As input the capacity per hour, the arrival rates per hour (lambdas), the service rates for the different types (mu's), the number of appointments per hour and an indicator for the time units (in this case hourly) is used.

Table 5.1 represents the daily results of the simulation that models the current situation for both Poisson arrivals and uniform arrivals. The 95% confidence interval is given between brackets.

Table 5.1: Results model current situation

	Average daily number of waiters (rounded)	*Average daily waiting time per trucker (in minutes)*	*Average total daily arriving truckers*
Poisson arrivals	921 [908 – 934]	11,14 [10,68 – 11,70]	2102 [2098 – 2106]
Uniform arrivals	912 [903 – 921]	10,36 [10,05 – 10,67]	2095 [2095 – 2095]

When we compare the total daily number of arriving truckers with the number presented in section 5.1, we see that these numbers lie quite close to the 2108 arriving truckers. That there a couple of truckers less is caused by the fact that in the model some truckers are lost due to the changes in the arrival rates as a new hour starts.

The table shows a small difference between Poisson and uniform arrivals in the average waiting time per trucker. On average, there are 10 truckers more in the system and 18 truckers more waiting in case of Poisson arrivals compared to uniform arrivals. Also the waiting time per trucker is somewhat larger, on average 47 seconds.

Besides these general figures, it is interesting to take look at the hourly figures. In figures 5.7 we can see that the number of arriving truckers per hour is almost equal in both the case of Poisson arrivals and uniform arrivals. When looking at the average waiting time per trucker we see that in each hour (instead of the first 15 hours when there is no waiting time) the waiting time is slightly lower in case of uniform arrivals.

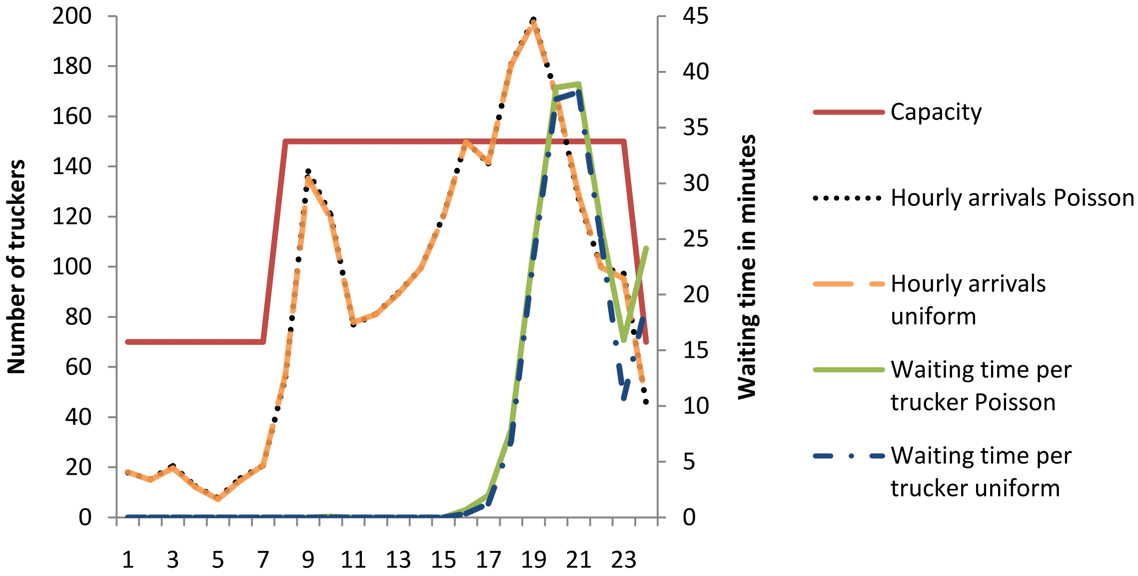


Figure 5.7: Capacity, number of arrivals and waiting time per hour in case of Poisson arrivals and in case of uniform arrivals

But the shape of the lines are in both cases the same. In the first 15 hours of the day there is no pressure on the capacity, so there is no waiting time. Around 15:00 hours there is a peak that approaches the available capacity and after a little decrease in arrivals there is a higher peak that exceeds the capacity. This results in a rise in the waiting time and while the number of arrivals is decreasing again, the congestion goes on until after midnight.

For truckers this pattern means that if they arrive before 15:00 hours, the chance they have to wait is very small as the average waiting per trucker equals zero. After that point, the average waiting time per trucker rises fast and tops at 38 and 39 minutes. This means that the truckers arriving in that period have to wait. After that peak the average waiting time reduces fast and increases again at around 23:00 hours. This is probably caused by less steep decline in arrivals at around 22:00 hours and a reduction in the capacity at the same time.

5.4.2 The use of different numbers of appointments

When considering the simulation model for the situation where an appointment system is implemented, it is interesting to see the effect of different numbers of appointments. Recall that we can change the number of appointments by taking different targets for $W_q(x)$. All requests above the allowed number will be called deviators. Remember that we take x equal to 8 minutes and that the total number of requests equals 80% of 2108. In order see what the effects are on a daily base, we will use the different numbers of appointments as input in the simulation model. First we will look at those effects when the arrivals are assumed to be Poisson.

Figure 5.8 and 5.9 show for different numbers of appointments the daily average number of truckers that deviate from their preference and the daily average size of the deviations, respectively. The different numbers of appointments are represented by different values for $W_q(x)$ as explained in previous paragraph.

As can be seen in the graphs, both figures show similar patterns. We can conclude that the higher the number of appointments, the lower the number of deviating truckers and also the lower the size of deviation. This is a quite straightforward result, since a higher number of available appointments in every hour means that more truckers can get the appointment of their preference.

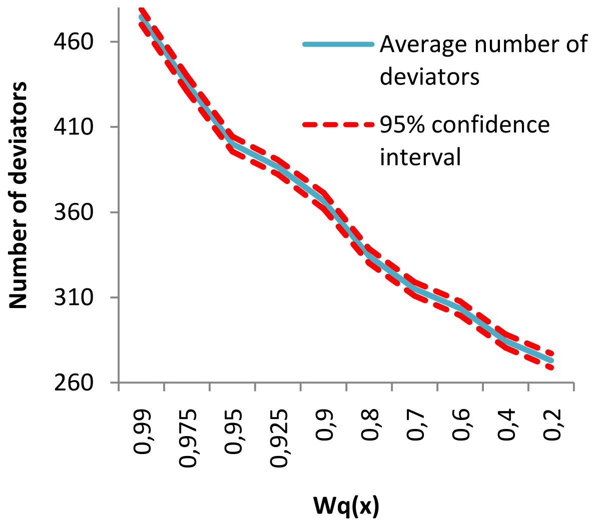


Figure 5.8: Average daily number of truckers who had to take an appointment different from what they preferred in case of Poisson arrivals

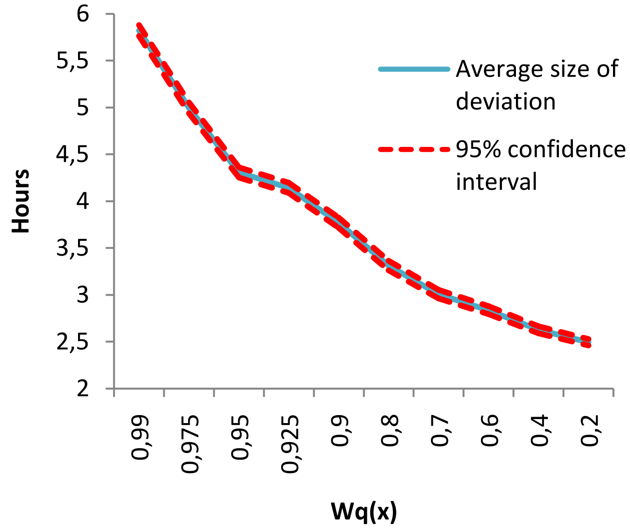


Figure 5.9: The average daily deviation in hours of truckers who had to take a different appointment than they preferred in case of Poisson arrivals

A higher capacity utilization leads to more satisfaction of the truckers' preferences, but will probably lead to higher waiting times. In order to analyze this, we will consider the average number of waiters and the average waiting times for different number of appointments. This is represented in figure 5.10 and 5.11 respectively.

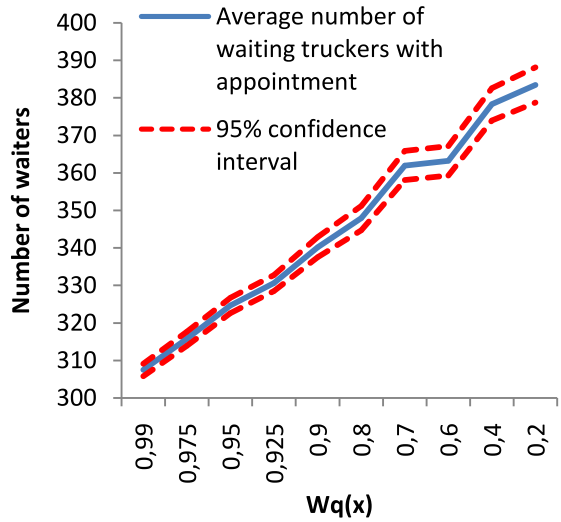


Figure 5.10: Average daily number of truckers with an appointment who have to wait in case of Poisson arrivals

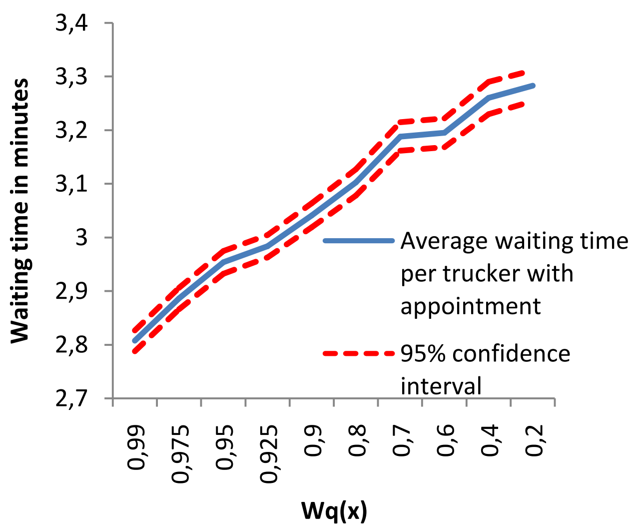


Figure 5.11: The average daily waiting time in minutes per truckers of all truckers with an appointment in case of Poisson arrivals

Figure 5.10 shows the expected pattern of more waiters by increasing numbers of timeslots. Because the higher the number of appointments, the lower the possibilities to use 'free' capacity to help waiting truckers. 'Free' capacity is the difference between available capacity and the number of appointments.

In figure 5.11 we see the same pattern, as expected. As more appointments are used, the higher the waiting time will be because of the higher pressure on the available capacity.

So a higher number of available appointments lead to more satisfaction of truckers who can get the appointment they want, but at the same time it leads also to dissatisfaction of truckers, since more truckers have to wait. For the waiting time the number of appointments should neither be low, nor high. It seems there has to be a trade-off between both factors. Figure 5.12 presents the number of deviations versus the number of waiters and figure 5.13 displays the size of deviations versus the waiting times.

In both figures it seems to be best, regarding the tradeoff, to choose a number of appointments corresponding to a $W_q(x)$ which lies on the middle of both lines. The first figure shows a not very smooth curve. Based on this curve it seems most fair to choose a $W_q(x)$ value between 0.90 and 0.70. In the second figure, the fairest choice lies between 0.90 and 0.95.

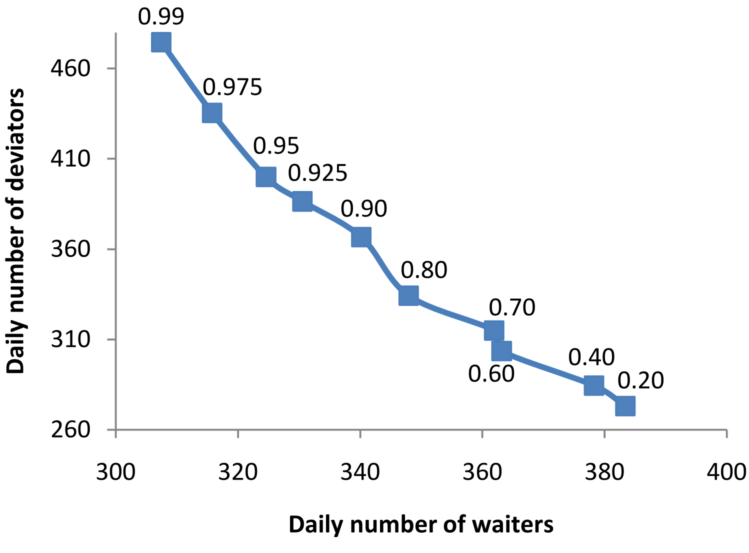


Figure 5.12: Number of deviating truckers against number of waiting truckers in case of Poisson arrivals

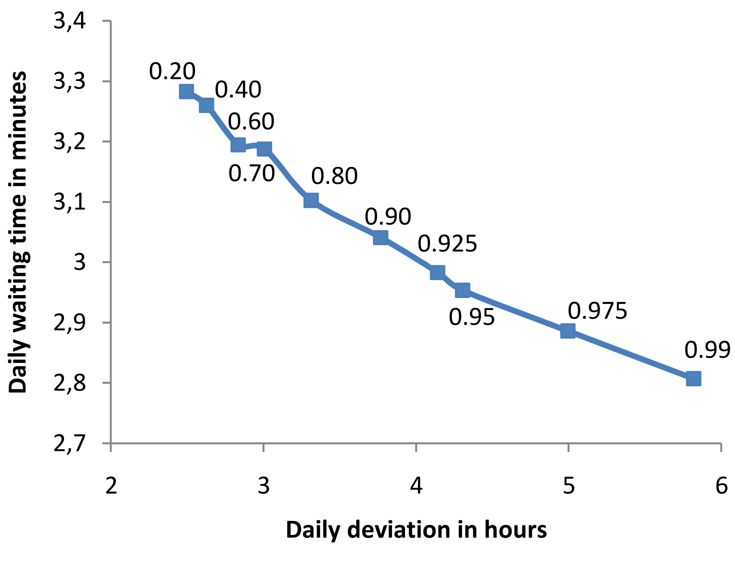


Figure 5.13: Size of deviations against waiting time in case of Poisson arrivals

Based on these criteria and eventually looking at capacity utilization, a terminal can decide which number of appointments will be available. For the results in this thesis, we will choose a $W_q(x)$ value of 0.90 with the corresponding rounded number of appointments as this seems to be the most 'fair' value in all tradeoffs.

But, that we choose a medium number of appointments does not mean that a tradeoff between waiters/waiting time, deviatiors/deviation size and waiting time appointments/waiting time no appointments is always preferred. It could also be the case that only waiters/waiting time determines the choice of the number of appointments. If that is true, it is more likely that the number of appointments corresponding to a high value of $W_q(x)$ is chosen.

When the goal is to have lowest possible deviation, to make sure that the total waiting time in the new situation is lower than the waiting time in the old situation or to have a highest as possible capacity utilization, then the highest number of available appointments should be chosen. But there can also be other goals which lead to other numbers of appointments.

For uniform arrivals, we can do the same analysis as we did for Poisson arrivals. Also for uniform arrivals we come to the conclusion, if we want to have a tradeoff between all factors, that it is best to have a medium number of appointments. The figures for this analysis are presented in the Appendix.

5.4.3 Results TAS

With the number of appointments corresponding to a $W_q(x)$ of 0.90, we obtain some general results. Figure 5.14 displays again the arrival rates for Poisson arrivals, but also for uniform arrivals. For visibility the confidence intervals are not displayed. The capacity line is the number of appointments corresponding to a $W_q(x)$ of 0.90. We can see clearly that the peaks are smoothed down. This automatically means that also the capacity utilization of the terminal is more equally spread.

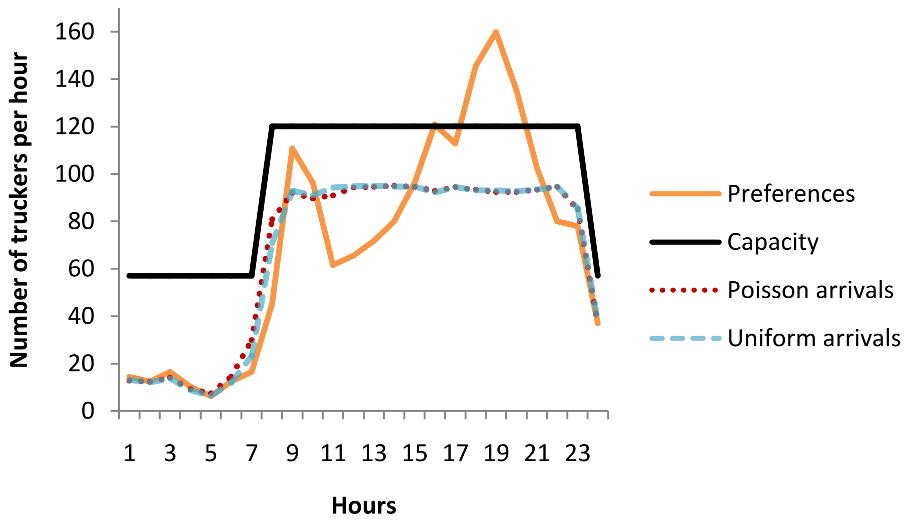


Figure 5.14: Preference, capacity, Poisson arrivals and uniform arrivals per hour

We will take a look at some general results, which are represented in table 5.2. The 95% confidence interval is given between brackets.

Table 5.2: Simulation results TAS

	Av. # of waiters with app. (rounded)	*Av. # of waiters without app. (rounded)*	*Total av. # of waiters (rounded)*	*Av. waiting time p. trucker with app. (in minutes)*	*Av. waiting time p. trucker without app. (in minutes)*	*Total av. waiting time p. trucker (in minutes)*
Poisson arrivals	340 [337 – 343]	351 [346 – 357]	691 [683 – 699]	3,04 [3,02 – 3,06]	48,66 [46,57 – 50,73]	13,98 [13,45 - 14,52]
Uniform arrivals	338 [336 – 341]	351 [346 – 356]	689 [682 – 697]	3,05 [3,03 – 3,08]	48,02 [45,93 – 50,11]	13,83 [13,27 – 14,40]

	Av. # of deviating truckers (rounded)	*A. size of deviation (in minutes, rounded)*	*Av. total arriving truckers (rounded)*
Poisson arrivals	360 [356– 364]	221 [218 – 224]	2110 [2106 – 2114]
Uniform arrivals	343 [341 – 345]	219 [218 – 220]	2095 [2095 – 2095]

First of all, we see that total number of arriving truckers corresponds with the numbers presented in table 5.1. In case of uniform arrivals, the total numbers are exactly the same, as expected. And for the Poisson arrivals the number deviates a bit from the number presented in table 5.1, but in case of Poisson arrivals that is allowed. If we look at the number presented in section 5.1, we can say that also 2110 arriving truckers is a good approach.

The results for both Poisson arrivals and uniform arrivals are similar. Overall, we can say that the uniform results are slightly better compared to results with Poisson arrivals. It is unknown which of the two would model the reality better, so we will analyze both.

Comparing the results generated with Poisson arrivals and uniform arrivals with the results in table 5.1, truckers with an appointment have on average almost 73% lower waiting times in both cases than if they arrive in the current situation. And this waiting time of truckers with an appointment, contains also the waiting time of truckers that arrive too early. If we do not consider the time early truckers have to wait until the start of their timeslot, the reduction would even be higher. For truckers who do not make an appointment or arrive too late (and therefore are truckers without an appointment), the situation gets worse. Those truckers have to wait more than 4 times longer compared to the old situation. Because the waiting times are that high for truckers without an appointment, the total average waiting time in the new situation is worse than the waiting time in the old situation.

In the old situation almost 44% of the truckers had to wait. For truckers with an appointment only about 22% of the truckers have to wait. 60% - 70% (depending on Poisson or uniform generated arrivals) of the truckers without an appointment have to wait in the new situation. Although this percentage is worse, the total average number of waiters is lower. In the new situation about 33% has to wait, which is a decrease of about 11%. This means that in the new situation less truckers have to wait, but the average time those truckers have to wait went up.

From the truckers with an appointment, between 20% and 25% (depending on Poisson or uniform generated arrivals) of the truckers could not get the appointment they preferred. In case of Poisson arrivals, the 24% deviating truckers deviate on average 226 minutes, that is, almost 4 hours. For example, if a trucker would like to make an appointment for the timeslot from 14:00 hrs to 15:00 hrs, he/she has a 24% chance of not getting that appointment and must deviate from their preference by taking on average an appointment in the timeslot from 10:00 hrs to 11:00 hrs or from 18:00 hrs to 19:00 hrs.

In case of uniform arrivals, the 22% deviating truckers deviate on average 219 minutes, that is, a little bit more than 3,5 hours. So, on average, in case of uniform arrivals truckers have a smaller chance in not getting the appointment they preferred and if they cannot get the appointment of their preference, the size of the deviation is smaller.

Also, in this new situation we can look at some hourly figures. We already saw the arrival rates in figure 5.14. Figure 5.15 shows, for Poisson arrivals, the hourly capacity reserved for truckers with and without an appointment, the hourly arrival rates for both types of truckers, the hourly waiting times for both types of truckers and the total waiting time.

When truckers do not want to make an appointment, it is best for them to arrive before afternoon. After that, the waiting time increases fast. This is due to the high pressure on the capacity starting at 09:00 hours. The waiting time for truckers with an appointment never exceeds 10 minutes on the whole day. The total waiting time stays until about 15:00 hours floating around five minutes. Then it is increasing rapidly, caused by the massive increase in waiting time for truckers without an appointment.

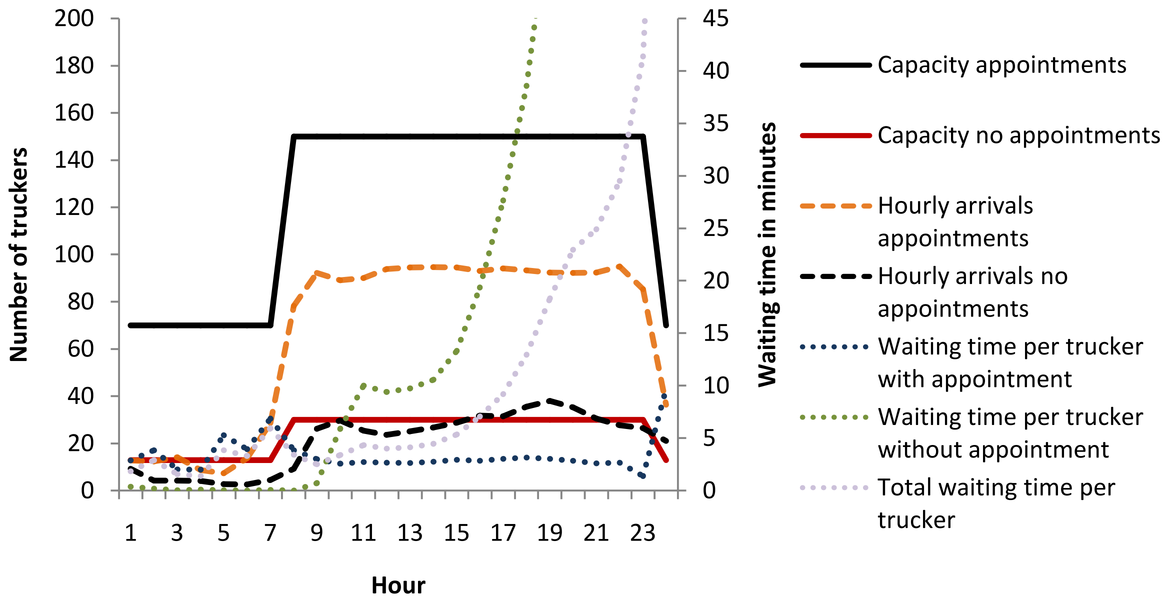


Figure 5.15: Capacity, arrivals and waiting time per hour of truckers with and without appointment in case of Poisson arrivals

The results for uniformly generated arrivals are similar to the above results. The figure corresponding to uniformly generated arrivals can be found in the Appendix.

Finally, we will look from which part of the day and to which part of the day the most deviations take place. The truckers that deviate from their preference, but have an appointment in the same part of the day as their preference, are not considered. In table 5.3, again for both Poisson arrivals and uniform arrivals, the deviations are represented. All values are rounded to their nearest integer and the 95% confidence interval is given between brackets.

In case of Poisson arrivals, most deviations are from the afternoon to the morning and from the evening to the morning. So, in case of larger deviations, most truckers are forced to have their appointment in the morning. This is not an entirely fair outcome, since the day that is simulated stops when the night of the new day begins. If we would have simulated the whole week there would probably more evening to night deviators than evening to morning deviators. In total about 35% of the 24% deviators have to deviate to another part of the day.

When the arrivals are uniformly generated, also most deviations are from the afternoon to the morning and from the evening to the morning. Now, about 33% of the 28% have to deviate to another part of the day and we can see that there are less deviations over two parts of the day compared to the Poisson arrivals.

Finally we notice that there are for example both shifts from the afternoon to the evening and shifts from the evening to the afternoon. This means that it can be the case that truckers who must deviate choose an appointment on a part of the day which also becomes full and therefore truckers who want an appointment on that part of the day have to deviate to another part of the day. This is caused by the first-come-first-served principle, which is one by one appointment scheduling method. A terminal could also choose to reschedule the preferences at once in order to achieve for example the least number of deviations. We did not choose that policy because in that case truckers cannot choose themselves anymore.

Table 5.3: From day part to day part deviations

	Poisson arrivals	Uniform arrivals
From night to morning	0 (0 - 0)	0 (0 – 0)
From night to afternoon	0 (0 - 0)	0 (0 – 0)
From night to evening	0 (0 - 0)	0 (0 – 0)
From morning to night	1 (0 - 1)	0 (0 – 0)
From morning to afternoon	0 (0 - 0)	0 (0 – 0)
From morning to evening	0 (0 - 0)	0 (0 – 0)
From afternoon to night	1 (0 - 1)	0 (0 – 0)
From afternoon to morning	55 (53 - 57)	51 (50 – 52)
From afternoon to evening	3 (2 - 4)	1 (0 – 1)
From evening to night	1 (0 - 1)	0 (0 – 0)
From evening to morning	44 (43 - 46)	45 (44 – 46)
From evening to afternoon	19 (18 - 20)	15 (14 – 16)
Total	124	112

5.5 Conclusions

In this section we described the data, the simulation models and discussed the outcomes. It seemed that the model approaches reality better when Poisson arrivals are used than when uniform arrivals are used, since the waiting times and the number of waiting truckers are more realistic when Poisson arrivals are used.

In the situation with a TAS, the terminal indeed succeeds to smooth down the peaks. With respect to the workload offered to the employees of the terminal and the capacity utilization, this is a quite important result. An advantage for the terminal could be that with appointments it is known when truckers arrive and thus the can be planned more efficiently. In that way, a terminal can eventually decrease the throughput time.

But the smoothing down of the peaks leads to a disadvantage for truckers. In around a quarter of the cases, truckers do not get the appointment they wished for. Those truckers have to choose an appointment which lies on average between three and five hours away from their preference.

But besides the disadvantage, truckers with an appointment also have a large advantage. There is a massive reduction in the waiting time per trucker and the probability that a trucker has to wait also decreased a lot. This means that transport companies can plan the delivery of their goods more accurately if they make use of the appointment system. Truckers that do not have an appointment or arrive too late have to wait in most of the cases and especially in the afternoon the waiting times are high. Because of those high waiting times in the afternoon, the system as presented in this thesis is not leading to a lower total average waiting time per trucker.

In the model, the system where a TAS is implemented works well. But a nice model does not mean that implementing a TAS in reality is easy. Things that the model is not taking into account, could be a problem in reality. This and more will be considered in the next section, were we will try to describe how to get from the model to the reality.

6. Implementation of a TAS

In this section we are going to see how the simulation model can be implemented. Therefore, this section will look at some problems that could occur which are not considered in the simulation models. Section 6.1 discusses barriers before the implementation of a TAS and section 6.2 discusses problems that could occur after the implementation. By considering examples in other ports around the world, we hope to see what are good things to do and where possible pitfalls lie. This is discussed in section 6.3. In section 6.4 we will give some recommendations concerning the implementation of a TAS, based on all the things we have discussed so far. Finally, in section 6.5 two alternatives to TAS are considered.

6.1 Barriers for the implementation of a TAS

A big issue is of course the question of who is going to pay for the system. It seems logical that the one who is going to implement the system is the one who invests, so that will be the terminal. But there could also be a situation where the port authorities or the government pays a part of the investment, since they are the ones that want ports to become more friendly for the environment.

It could even be the case that the terminal let the truckers and truck companies pay a part, by, for example, let them pay a fixed amount to become registered to the system. Although they will probably profit from the new system, it is not likely that they are willing to pay.

Of course, like discussed earlier, the design of a TAS is very important and must be well thought off. Especially business rules can have different effects on the success of the appointment system.

6.2 Problems that could occur after implementing a TAS

For example, truckers can react different on policies regarding fines on no shows. Since, in our system, truckers are not forced to make an appointment, high fines can lead to less appointments. Because when truckers are most of the time not arriving according to their appointment, they might choose to not make appointments anymore and join the queues for truckers without an appointment.

To prevent this, the terminal can also introduce an reward policy or a combination of reward and fine policies. We can think of a system where truckers that often stick to their appointment, will be favoured the next time when they need to make an appointment by letting them choose first from the available timeslots.

But even then the behaviour of truckers is not certain. This is especially due to the concept of two queues, which gives the system more flexibility, but at the same time leads to more uncertainty in the behaviour of truckers. A study among truckers and trucker companies might give a better view on this matter.

Another option is to test the system on a significant scale over a longer period. In case of a TAS testing is very important, since there are not many examples of a TAS around the world and it is very unlikely that the system will work well at once. Like said before, business rules can have different effects on behaviour of truckers and might therefore be changed over time when it has become clear that the rules are not having the wanted effect.

6.3 Examples of a TAS

We just said there are not many examples of a TAS around the world. This does not mean there are no examples at all. We could find four examples of ports where a TAS is implemented. By looking at the systems in those ports, we can learn from their failures and successes.

6.3.1 Los Angeles and Long Beach

Guiliano and O'Brien (2007 & 2008) have written their articles on a TAS in the ports of Los Angeles and Long Beach. Since the legislations forced the terminals to reduce the waiting times, the terminals needed to adjust their policies. Most terminals in that area did not want to extend their gate hours, so they chose to incorporate a TAS.

The problem with the new legislation, which forced terminals to let truckers wait at most 30 minutes, was that it had no authority inside the gate. As a result of that, the waiting times of the truckers were not reduced, but the waiting truckers were shifted from outside the gate to inside the terminal.

Besides that, several terminals provided a special entry lane for truckers with an appointment and some other terminals picked truckers from the queue that neared 30 minutes of waiting. But terminals did not adjust their policy inside the terminal. First-come first-served policies were still active, so the waiting times could not be reduced.

Furthermore, the terminals did not implement any rules or fines subject to missing an appointment. In that way, truckers were not encouraged to stick to their appointment or even use the system at all.

All these factors contributed to the fact that the implementation of a TAS in Los Angeles and Long Beach is no success. The intended changes were not achieved.

6.3.2 Hong Kong

Murty et al. (2005) describe a more successful implementation of a TAS. At Hong Kong International Terminals a telephone based TAS is incorporated. By contacting the automated telephone system a trucker can choose an available time slot in which their container will be ready to be loaded. The system is based on the earliness of the caller; the earlier a trucker calls, the more slots are available. Truckers that arrive without a reservation have to go to the booking center and can choose a timeslot there.

The TAS used in Hong Kong reduced the average turnaround time from 60 to 40 minutes of the trucks and it reduced the amount of external trucks at the terminal during peak hours. In combination with other systems, the waiting time was halved. While the throughput was increasing, the congestion was decreasing.

These improvements automatically led to a reduction in pollution. Also, it led to an increased satisfaction of trucker companies about the handling of containers in the terminal.

6.3.3 Vancouver

A third example is Vancouver, discussed by Lord and Morais (2006). The port of Vancouver is very progressive subject to environmental issues. The environmental view in combination with the increasing number of legislations forced the terminals to reduce the waiting times of truckers.

In order to do so, different technologies are used and one of them is a TAS. Unfortunately, the TAS they implemented did not reduce the waiting times and congestion as expected. The most important reason for that is the lack of planning more trips on one day by truckers.

6.3.4 Felixstowe

Finally, there is the example of Felixstowe. The Trinity terminal in Felixstowe implemented a TAS and called it Vehicle Booking System (VBS). The example of Felixstowe is not discussed in any literature, but Port of Felixstowe (2009) provide enough information to gain some insight in the system they use.

VBS was introduced in early 2007. Before being able to make use of the system, truckers and trucker companies need to register by completing a mandate. After that a username and a password is needed to gain access to the system, which is solely web-based.

The Trinity terminal only accepts bookings, so every arriving trucker has to have an appointment. Only during the night, the policy of the terminal is less strict. Between 23:00 hrs and 07:00 hrs the booking conditions are relaxed. This means that vehicles can be in-gated at any time during this period, provided that the driver has a valid booking. The only condition is that bookings has to be processed by 07:00 hrs, otherwise a no show charge will be incurred.

Regarding the business rules, Trinity terminal implemented the following:

- Bookings cannot be cancelled, except during a 'Weather Affected Period' (In a 'Weather Affected Period' the terminal is shut down due to bad weather or high winds).
- Bookings can be changed any time up to the driver arrival. The bookings can only be moved to hours that have vacant bookings and they can only be moved within a six-hour timeframe from the original booking period.
- In order to prevent abuse of the system, no show fines are set to £21,-.

Unfortunately, an evaluation of the VBS could not be found, so it is not known to what extend the VBS is successful. We only know from the website that after the implementation of the VBS, changes has been made to the system almost every month until the fall of 2008. Changes like reducing the maximum number of hourly bookings were common. This indicates that a terminal should not expect the system to work flawless directly after implementation.

6.4 Recommendations

From the previous section it becomes clear that forcing a terminal to implement an appointment system will not be successful. Only if the terminal implements a system on its own initiative, like Hong Kong, Vancouver and Felixstowe, it could be a success.

But even then it is not sure. The TAS in Vancouver is not very successful due to the lack of planning more trips on a day by truckers. So the success of an appointment will also depend for a great part on truckers and truck/transport companies.

But, as explained earlier, there is lot of uncertainty in their behavior. A great part of this uncertainty is caused by the use of two different queues. But we think that the use of the different queues is important. On the one hand it provides the terminal more flexibility. On the other hand it could also be useful when truckers decide to not make an appointment. They experience long waiting time and might choose the next time to make an appointment. It is more likely that a TAS will be successful when truckers and trucker companies choose out of own interest for appointments than when they are forced to make appointments. Besides that, it should not be hard for the terminal to allocate a certain percentage of truckers without an appointment to a different queue.

The appointment making itself can be implemented depending on the choice of the terminal. ECT can choose to use system that telephone-based like in Hong Kong or web-based like the Trinity terminal in Felixstowe.

The decision for the length of the timeslots also depends on the preference of the terminal. An obvious choice is to take one hour as length, since it is a common used length and at is easy to implement. As for the number of appointments, different numbers have different implications. Depending on the goals of the terminal, a number of appointments has to be chosen. The allocation of personnel and equipment to the timeslots and the truckers without an appointment is a deterministic problem. This problem can be solved by the terminal.

An efficient way to use appointments is to put containers from the stack to the landside during less busy periods as much as possible. Since it is known when truckers arrive, containers can be put in place in advance. In that way, the workload on the ASC's can be spread more equally. When for example a ship arrives at the seaside there will be less concerns about the landside.

Also for the truckers with an appointment, putting containers in place in advance would be an advantage, since the service time will reduce as truckers do not have to wait until the ASC's are ready to unstack the containers.

The final thing we will discuss here is the use of penalties/rewards. We think a reward system where truckers who always stick to their timeslot get the first choice the next round will contribute to the success of a TAS. In that way, truckers that make use of the appointment system have high incentive to stick to their timeslots.

It could be that the reward system makes penalties unnecessary, but we can think of a situation where the terminal would like to have a compensation for the costs they make for an appointment. These fines should not be high, since truckers that are uncertain about their time of arrival will be probably not make an appointment. And besides that, a terminal should anyhow question the implementation of penalties, since waiting for a long time in the queue for truckers without an appointment can be already considered as a penalty.

Anyhow testing of the system will be needed and it is very likely that business rules have to adjusted over time.

6.5 Alternatives

Not only the implementation of a TAS is currently a serious item in the port of Rotterdam. To reduce congestion in the terminals and on the highway to the terminals, two other ideas besides a TAS are in development.

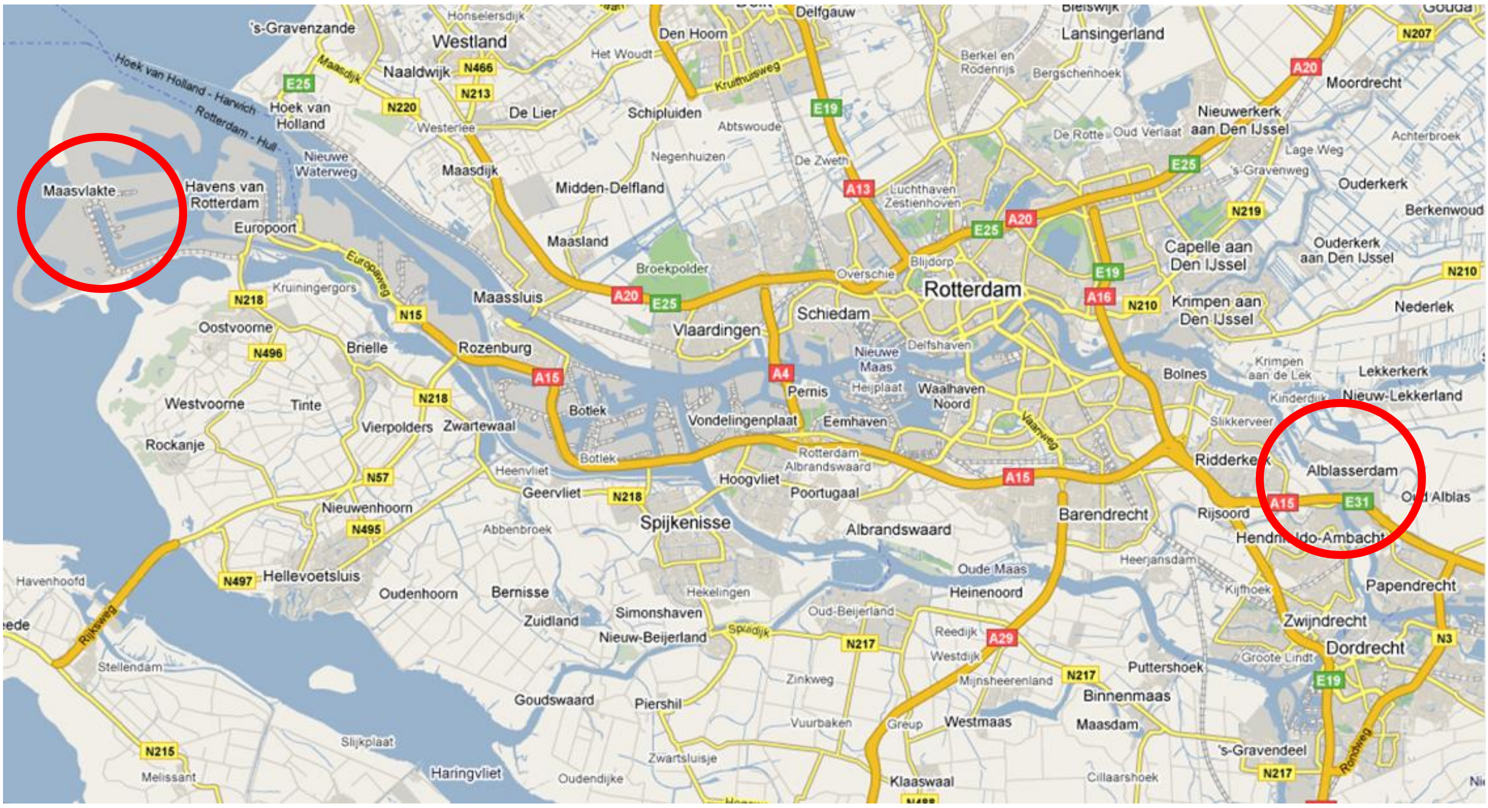
The first is a Dutch logistic company that currently is trying to realize a chassis park close to the ECT terminal in Rotterdam. The idea of the company is to turn some open space into a chassis park. This means that in that park chassis with containers on it, but without the trucks that pull the chassis, will be parked. Then trucks come in with the containers that have to be delivered in the port, park the chassis with the container they bring with them and take the new chassis with them. Of course, the truckers still have to pass the checks. The whole process will take about 20 minutes according to the company developing the plan.

The big advantage of this idea is that the chassis that are parked in the chassis park, can be transported by night to the terminals. This means that during the day there is less workload in the terminal and therefore the queues will become smaller.

There are also disadvantages of the chassis park. It needs for example a lot of space, since chassis cannot be stacked. And since the park will be close to the terminal, the congestion on the main road to the port will not be reduced.

The second plan is the creation of a satellite terminal. The main idea is to reduce congestion on the main roads to the port by moving activities to another terminal which lies deeper into the main land. Containers will be transported from the terminal in the port to the Transferium and vice versa making use of barges.

In the Netherlands, this Container Transferium will be in Alblasserdam. Alblasserdam lies about 45 km distance from the Maasvlakte, where the most important container terminals are located.



Source: Google Maps

The question is if such a short distance is profitable. The containers have to be transshipped twice, namely first in the port from a sea vessel to a barge and then in the satellite terminal from a barge to a truck. Besides that, Alblasserdam is connected to the same highway as the port, so it is questionable if the road will be less congested at all.

Yet, in the port of Rotterdam, these two examples are not really seen as alternatives, since just like an appointment system for the ECT terminal both options (as it looks like now) are going to be realized.

6.6 Conclusions

In this section the implementation of a TAS is considered. Some problems that could occur are discussed and by looking at other terminals with appointment systems things that lead to success and failure are discovered. Regarding the implementation of a TAS for ECT, we do some recommendations. Finally, there is short discussion of alternatives.

7. Conclusions, limitations and directions for further research

In this final section, it is time to come back to questions we asked ourselves in the introduction. This will be done in section 7.1. In section 7.2 we will discuss the limitations of this research. Finally, section 7.3 considers some directions for further research.

7.1 Conclusions

There is a lot of congestion at and in container terminals around the world and the ECT terminal in Rotterdam is no exception to that. Especially during peak hours the congestion is high, resulting in a high number of truckers that have to wait a long time. On every working day, there is a peak in the morning and a peak in the afternoon. During those peaks, the workload on ASC's is often too high. And because the seaside always has priority to the landside, the waiting times for truckers can be very high.

A terminal can use a Trucker Appointment System (TAS) in order to smooth down the peaks. The main idea of a TAS is to use timeslots for planning the arrival of a trucker at the terminal. For the implementation of a TAS, certain changes in the current situation have to be made. In order to design and analyze an appointment system, it was concluded from the literature that the best method is to use simulations.

An important factor in the design of a TAS are the business rules. There have to be choices made considering the length of the timeslots, the number of appointments, how long the appointments have to be made in advance, what will happen when a trucker arrives outside the slot and what the guarantee is on service time when arriving in a slot. Different choices of business rules will lead to different implications. For example the height of penalties can have effect on the number of appointments. Another example is that higher numbers of available appointments lead to higher waiting times.

The old situation and the new situation where a TAS is implemented are modelled by using two different approaches for the arrivals. On the one hand there is a simulation model where it is assumed that the arrivals happen according to a Poisson process, while on the other hand arrival process can be modelled by using uniform arrivals. There is not much difference in the results of using both types of arrivals. We can say that the model with uniform arrivals performs slightly better, but we cannot say that for example lower waiting times mean that the reality is modelled better.

From outcomes of the simulation models it can be concluded that a TAS succeeds in smoothing down the peaks and thereby spreading the workload in the terminal. In the new situation less truckers have to wait and also the waiting time is reduced massively if a trucker decides to use the appointment system. The reduction in waiting time is almost 73% in the new situation. For truckers without an appointment, the congestion problem is not reduced. Those truckers have to wait longer and in more cases compared to the original situation. Although the total number of waiters is reduced, the total average waiting time for both truckers with and without an appointment is higher than in the original situation. So making use of an appointment system where a part of the capacity is allocated to truckers without an appointment will not reduce the average waiting time, because of the congestion in the queue for truckers without an appointment.

A disadvantage for truckers of smoothing down the peaks is that a significant number of truckers have to deviate from their preferences of time of arrival, simply because there are not enough appointments in each hour to satisfy the demand in those specific hours. Roughly a quarter of the truckers with an appointment have to deviate from their original preference. About one third of these deviators have to choose an appointment on a different part of the day than the part of the day corresponding to their preference. This means that those truckers have to adjust their schedule quite drastically.

For the terminal the implementation of a TAS can have a positive effect. For example, a terminal could use the information of the appointments in order to put containers on the ground in advance. In that way, an arriving ship can be served without increasing the waiting times for truckers. And when containers are placed on the ground in advance, the handling time for truckers will go down. This will improve the image of the terminal. A clear positive effect is that the utilization of the capacity is spread more equally. This means that in all hours there is no shortage in capacity and in most hours there is no over capacity (in case of arriving truckers with appointment).

What the effect of the appointment system will be on truckers and trucker/transport companies is unclear. It is not clear whether the reduction in waiting time outweighs the adjustment some truckers have to made in their schedule, because they could not get the appointment they preferred.

It could be that truckers/transport companies prefer other solutions to the congestion problem, like the creation of a chassis park close to the terminal or the creation of a satellite terminal on a somewhat larger distance from the terminal for example. But also for these solutions the reaction of truckers and transport companies is unknown.

7.2 Limitations

The first limitation is the data. The results that are obtained come from assumed data. The arrival of truckers is partly based on figure that was published some time ago and it is questionable whether it represents the actual situation. But like explained in the Acknowledgements, the ECT terminal could not provide us recent data on time.

A second limitation is that we simply do not know how truckers and truck companies will respond to an appointment system, especially when the system is designed for two different queues like in our model. As the behavior of truckers is unknown, it is impossible to adjust the model for that behavior.

Besides behavior, there are some other issues that are not considered. For example, rewards/penalties are not considered in the model. Furthermore there are some assumptions that simplify the model, but a thesis of this size cannot handle all issues. In chapter 6 only some problems are named; it is not the goal of this thesis to consider all possible problems.

7.3 Directions for further research

The first thing to do in further research will be to validate the results in this thesis by using real data. The simulation model is build in such a way that it will give no problem when using different kinds and different sizes of data.

There is a lot of room left for exploring Truck Appointment Systems more deeply. This thesis considers one setup of a TAS, but there are a lot of different possibilities. It could be interesting to see what the results are in a situation where only truckers with an appointment are handled. Also, different percentages for the amount of truckers without an appointment and truckers with an appointment can be used if it turns out that the reality is different.

Besides that, one can also ‘play’ with different business rules. For example, the length of the timeslots can be changed. It could for example be interesting what the consequences are when the length of a timeslot will be two or three hours instead of one hour. In order to do so there should a modification be made in the simulation model, such that it can handle different sizes of timeslots. Also the decisions regarding what to do with too late truckers and too early truckers can affect the outcomes, both in the simulation model as in the reality.

A thing which the simulation model in this thesis is not taking into account is shared capacity. For example, when in a certain timeslot many truckers arrive early and are quickly finished, one could think of a situation where the free capacity in the remaining part is used to handle some truckers from the queue with truckers who have no appointment. Also, if the pressure on the capacity for truckers with an appointment is high the terminal could choose to use some capacity which was originally assigned to truckers without an appointment for truckers with an appointment.

The only indication we have in this research is that capacity of no shows could be used for truckers without an appointment. But the problem is that the terminal does not know a trucker is not showing up until the timeslot has ended. The only thing a terminal can do is to forecast the number of no shows, if it can be forecasted, and change capacity according to those forecasts.

If it is possible, there could be a research done among truckers in order to find out how they will respond to different settings. But to really give a good analysis of a TAS, it should be tested in reality.

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Appendix

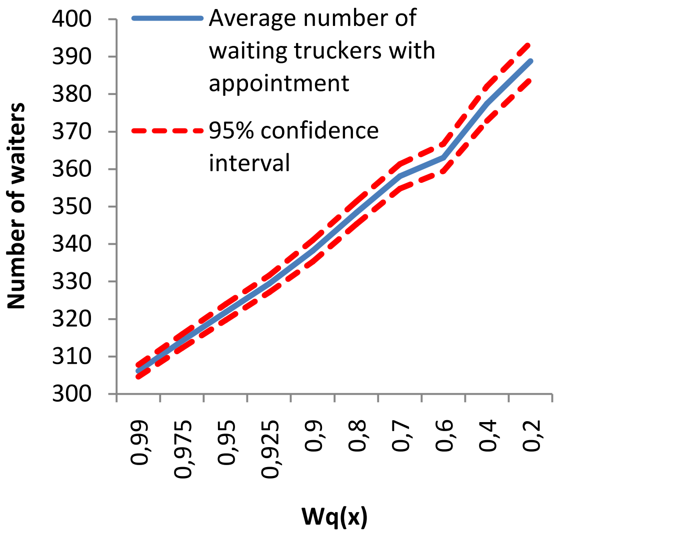

Figure A.1: Average number of truckers with an appointment who have to wait in case of uniform arrivals

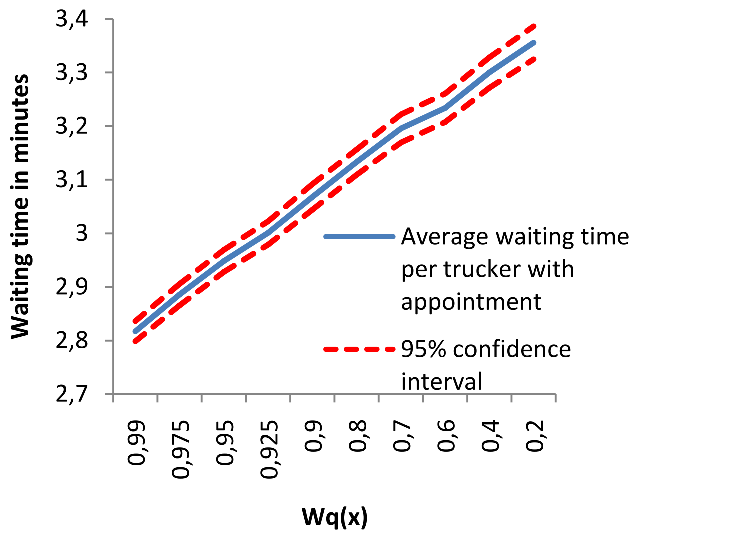

Figure A.2: The average waiting time in minutes per truckers of all truckers with an appointment in case of uniform arrivals

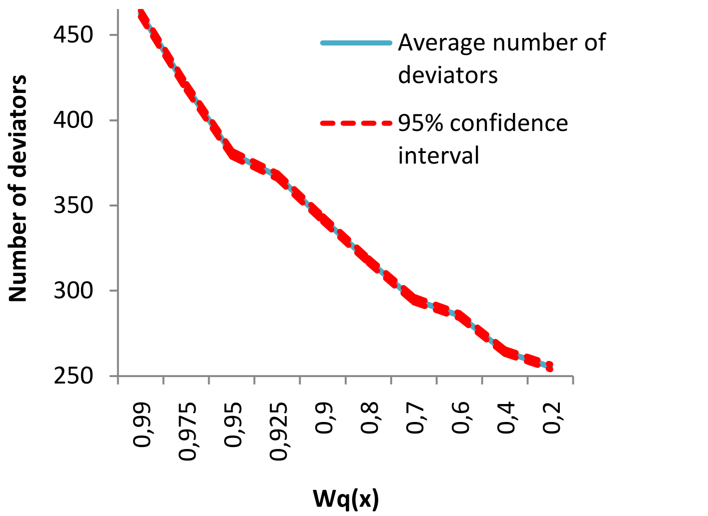

Figure A.3: Average number of truckers who had to take an appointment different from what they preferred in case of uniform arrivals

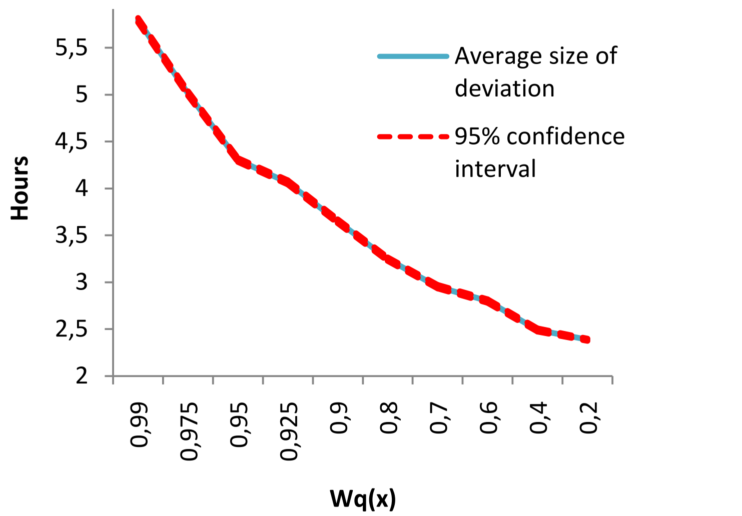

Figure A.4: The average deviation in hours of truckers who had to take a different appointment than they preferred in case of uniform arrivals

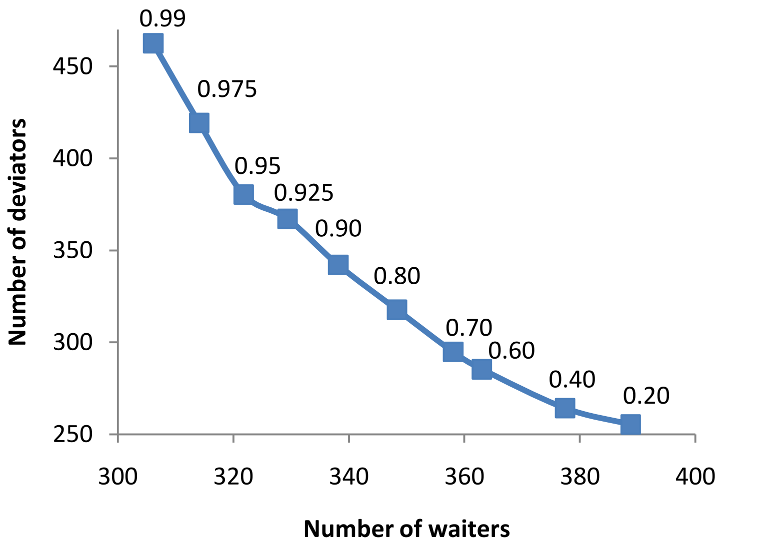

Figure A.5: Number of deviating truckers against number of waiting truckers in case of uniform arrivals

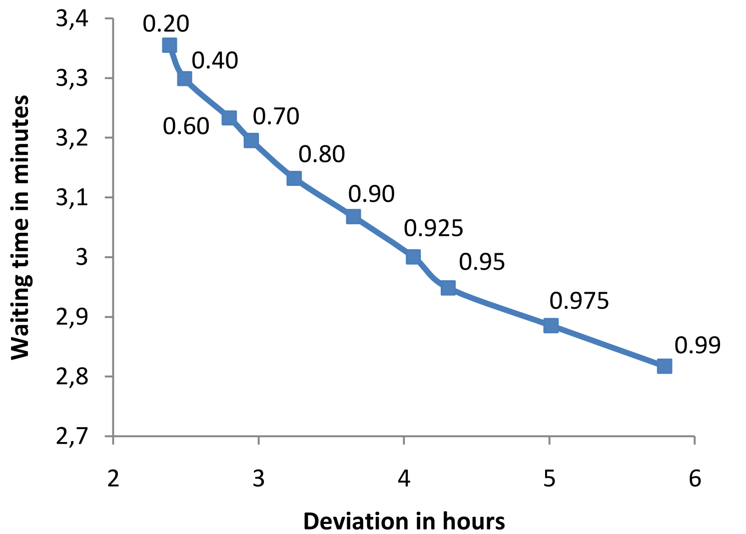

Figure A.6: Size of deviations against waiting time in case of uniform arrivals

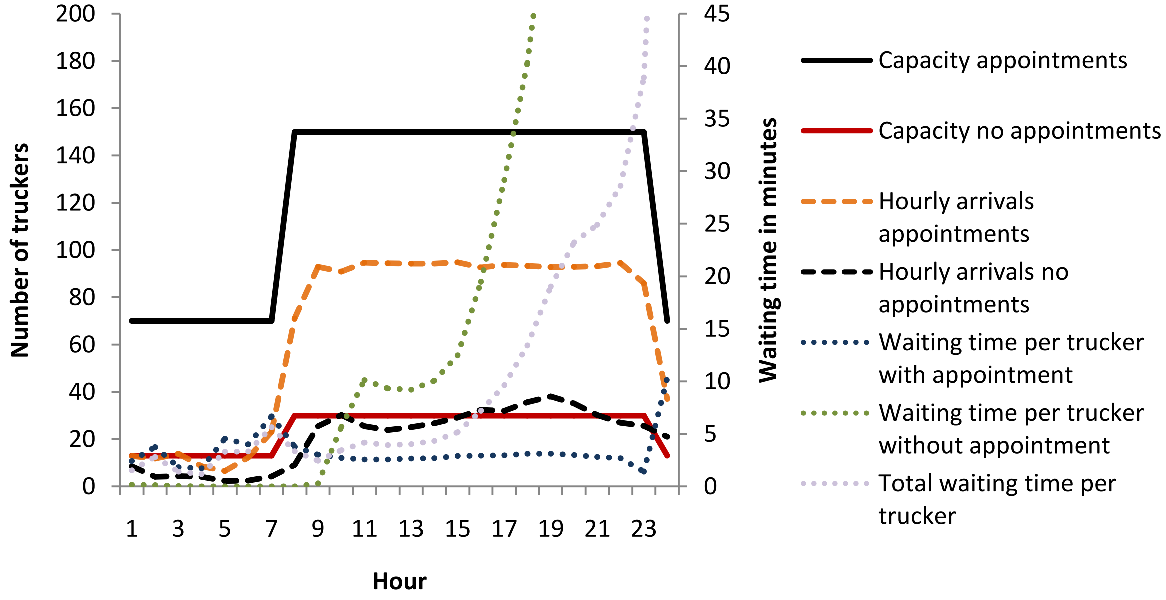

Figure A.7: Capacity, arrivals and waiting time per hour of truckers with and without appointment in case of uniform arrivals