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MASTER THESIS

Logistical improvements of the arrival process at CSI Twente

A process-wide analysis providing improvement options at three ambition levels using a timeslot allocation system

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"All things come to those who wait,

they come, but often come too late"

Lady M. Marie Currie: *Tout vient a qui sait attendre (1980)*

Preface

This report is the result of my graduation project to acquire my master's degree in Industrial Engineering and Management, with the specialization Production and Logistics Management.

First of all, I would like to thank Rob Maathuis for the opportunity to do my thesis at CSI Twente. It was a pleasure to make my hobby and sports my graduation project. I would also like to thank all the riders and grooms for supplying me with information and their honest opinion about the event.

Furthermore, I would like to thank my first supervisor Peter Schuur for his critical view on the project and useful feedback and support. But even more so for his enthusiasm and positivity, which gave me an extra boost after every conversation. For this reason, I would also like to thank my external expert, Henk Kroon. Another **very** positive person, who shares the love for horses with me. The conversations with these men were, besides the 10 serious minutes, 50 minutes very pleasant.

In addition, I would like to thank my fellow student Laura Nieuwmeijer. I studied my entire bachelor's and most of my master's with her and we carried out all the projects together. Without her, my studies would have been a lot less enjoyable. I wish her all the success for her upcoming two graduation studies.

Finally, I would like to thank my family and friends for the support and motivation during my entire master's program. I am a lucky person with these beautiful people around me. I especially want to thank my dear parents, Franc and Esther, for the love and warmth they give me every day.

Although a nice and instructive period of studying has come to an end, a new period with new challenges and adventures will come soon.

It always seems impossible until it's done - Nelson Mandela

Ellemijn Ensink

Rossum, June 2019

Management samenvatting

Het hoofddoel van dit onderzoek is het verbeteren van de logistiek van het aankomstproces van CSI Twente door de wachttijden te verkorten en de veiligheid en tevredenheid te verhogen. Op basis van deze onderzoeksdoelstelling en de probleemidentificatie geeft deze studie een antwoord op de volgende onderzoeksvraag:

Hoe kunnen we de logistiek van het aankomstproces bij CSI Twente verbeteren, om wachttijden te verkorten en de veiligheid en tevredenheid te verhogen?

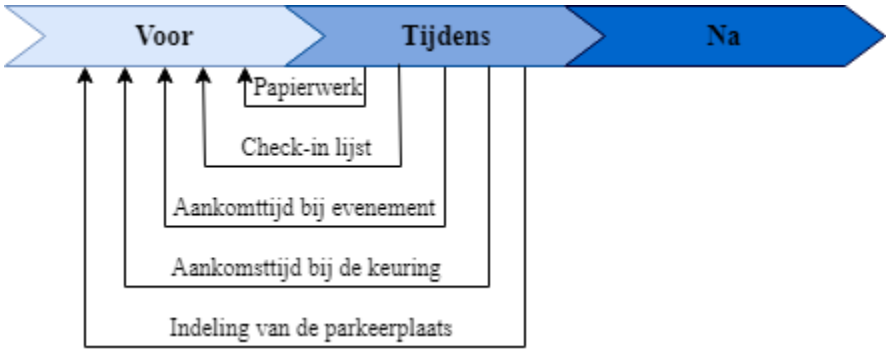
CSI Twente is een internationaal paardenevenement georganiseerd op het privéterrein Erve Maathuis, gevestigd in Geesteren, Overijssel (OV). Het is uitgegroeid tot een toonaangevend evenement in het internationale circuit, met de promotie naar een CSI5* status voor de komende editie in 2019. Echter, elk jaar ervaart het Organiserend Comité (OC) terugkerende problemen in het aankomstproces. De aankomsttijden van de paardenvrachtwagens bij aankomst en van de paarden bij de keuring zijn onzeker, wat leidt tot lange wachtrijen en wachttijden. Daarnaast leidt het gebrek aan toezicht op de parkeerplaats van de vrachtwagens tot onveilig en inefficiënt parkeren. Deze problemen leiden op hun beurt tot ontevreden belanghebbenden. Om een beeld te krijgen van het aankomstproces is de huidige situatie geanalyseerd. Hiervoor is het aankomstproces van de 2018 editie van CSI Twente gebruikt, inclusief de middelen die in het proces zijn ingezet en de aantallen van de vorige editie. Deze analyse heeft geleid tot constateringen en aannames die bruikbaar zijn in dit onderzoek en waarmee rekening wordt gehouden om de knelpunten van dit onderzoek te identificeren.

Na de analyse van de huidige situatie is de literatuur geraadpleegd over de wachtrijtheorie. In de literatuur blijkt dat de ervaring in de wachtrij van invloed is op de algemene perceptie van het evenement. Daarnaast kan de variatie in service- en aankomsttijden deze wachtrijen veroorzaken. Door deze service- en aankomsttijden constanter te maken, worden de wachtrijen verminderd. Volgens de literatuur kan het aankomstproces van deze studie in een theoretisch kader geplaatst worden gebaseerd op het M/M/1 model van Kendall en de basisstructuur van het wachtrijmodel. In dit kader wordt het proces weergegeven door twee opeenvolgende M/M/1 modellen, die de aankomst en de keuring weergeven. Geschikte prestatiemaatstaven van het systeem in deze studie zijn de verdeling van de wacht- en verblijftijd (de totale verwachte tijd van het gehele aankomstproces) en het aantal paardenvrachtwagens en paarden in de wachtrij.

Na het literatuuronderzoek heeft de knelpuntenanalyse de visie van de stakeholders geanalyseerd. Daarvoor werden de wensen en eisen van de OC, de stalbeheerder en de ruiters en grooms in kaart gebracht. Daarnaast is de tijdsduur van de activiteiten in het aankomstproces berekend aan de hand van de Three Times Estimates in PERT. Deze schattingen zijn bewezen op hun nauwkeurigheid. Op basis van de informatie uit dit hoofdstuk samen met de probleemkluwen en de huidige situatie analyse zijn de volgende vijf knelpunten van het aankomstproces in kaart gebracht:

- De onbekende aankomsttijden van de paardenvrachtwagens
- Het zoeken naar de naam en bijbehorende stallen bij het inchecken
- Naar het secretariaat gaan en het papierwerk invullen
- De onbekende aankomsttijden van de paarden bij de keuring
- Afwezigheid van toezicht op de parkeerplaats

Om deze vijf knelpunten aan te pakken, zijn er drie verbetermogelijkheden met verschillende ambitieniveaus vastgesteld, die gebruik maken van een tijdslot systeem. De optie met ambitieniveau I gebruikt e-mail en telefoon, de optie met ambitieniveau II gebruikt de inschrijfpagina van de Koninklijke Nederlandse Hippische Sport (KNHS) en de optie met ambitieniveau III gebruikt een applicatie voor mobiele apparaten. Afhankelijk van de ambitie van het OC kan één van de drie opties worden geïmplementeerd. Andere opties werden ook overwogen, maar waren voor deze studie niet haalbaar.



De verbetermogelijkheden zetten vijf informatiepunten naar voren, van 'tijdens het aankomstproces' naar 'voor het aankomstproces'. Door gebruik te maken van één van deze verbetermogelijkheden kunnen de ruiters/grooms een tijdslot kiezen voor zowel de aankomst op het evenement als bij de keuring. Door dit tijdslotsysteem weet de stalbeheerder welke vrachtwagens hij op welk moment kan verwachten. Zo kan hij van tevoren weten naar welke stallen hij de arriverende vrachtwagens moet doorsturen. Bovendien kan de stalbeheerder beter inschatten waar elke vrachtwagen ongeveer moet uitladen, waardoor de afstand die de grooms van de vrachtwagen naar de stallen moeten lopen wordt verkleind. De grooms hoeven het papierwerk niet meer in te vullen op het secretariaat om aan te geven of ze elektriciteit nodig hebben en of ze in het bezit zijn van gezondheidspapieren. Deze informatie wordt in de nieuwe situatie vooraf aan het evenement verkregen. Daarnaast zal er een georganiseerde parkeerplaats komen. In de huidige situatie werden grooms gedwongen om zelf een parkeerplaats te kiezen, vaak in onenigheid over de elektriciteitspalen. Deze waren vaak allemaal bezet, of ontoegankelijk door chaotisch parkeren. In de nieuwe situatie kan het OC vooraf weten hoeveel vrachtwagens elektriciteit nodig hebben en dus hoeveel elektriciteitspalen er nodig zijn. Voor de complexere opties (met ambitieniveau II en III) weten ze zelfs welke vervoersmiddelen worden

gebruikt en de bijbehorende hoeveelheden. Dit maakt het mogelijk om het parkeerterrein voorafgaand aan het evenement volledig in te delen en ervoor te zorgen dat er voldoende elektriciteitspalen beschikbaar zijn. Dit zal ook leiden tot een veiligere positionering van de paardenvrachtwagens op het parkeerterrein. Daarbij wordt ervan uitgegaan dat het OC het toezicht op het parkeerterrein regelt. Ook de wachtrij bij de keuring wordt aanzienlijk verbeterd door het gebruik van het tijdslot systeem. De dierenarts weet welke paarden hij op welk tijdstip kan verwachten. Net als de wachtrij van paardenvrachtwagens wordt ook deze wachtrij verkort door het gebruik van een verbetermogelijkheid.

Optie	**Verblijftijd in het aankomstproces**	**Verbetering (ten opzichte van de huidige situatie)**
Ambitie Niveau I	69.26 minuten	44.85%
Ambitie Niveau II	60.42 minuten	51.89%
Ambitie Niveau III	47.76 minuten	61.97%

Rekening houdend met de duur van het gehele aankomstproces zal de optie met ambitieniveau I de huidige situatie verbeteren met 44,85% en de optie met ambitieniveau II met 51,89%. De grootste verbetering wordt bereikt door gebruik te maken van de optie met ambitieniveau III. Deze optie heeft een verbetering van 61,97% ten opzichte van de huidige situatie. Naast de tijdsduur van het gehele proces zijn het aantal wachtenden in de rij bij aankomst (L_q^A) en bij de keuring (L_q^{HI}) berekend, net zoals de wachttijd bij aankomst (W_q^A) en bij de keuring (W_q^{HI}).

KPI	**Huidige situatie**	**Ambitie Niveau I**	**Ambitie Niveau II**	**Ambitie Niveau III**
$\boldsymbol{L_q^A}$	Exploderende wachtrij	0.911 vrachtwagens	0.619 vrachtwagens	0.324 vrachtwagens
$\boldsymbol{W_q^A}$	Exploderende wachtrij	2.655 minuten	1.824 minuten	0.955 minuten
$\boldsymbol{L_q^{HI}}$	Exploderende wachtrij	12.992 paarden	12.992 paarden	12.992 paarden
$\boldsymbol{W_q^{HI}}$	Exploderende wachtrij	7.099 minuten	7.099 minuten	7.099 minuten

Door de verbeteroptie met ambitieniveau III te implementeren zal de wachtrij bij aankomst reduceren tot een gemiddelde van 0,324 paardenwagens en een gemiddelde wachttijd van 0,955 minuten. Voor de wachtrij bij de keuring reduceert het de gemiddelde wachttijd tot 7,099 minuten met een gemiddelde van 12,992 paarden in de rij. Het gemiddelde aantal paarden in de rij bij de keuring en de bijbehorende gemiddelde wachttijd zijn hetzelfde voor de opties met ambitieniveau I en II. Het gemiddelde aantal paardenvrachtwagens in de wachtrij bij aankomst en de bijbehorende gemiddelde wachttijden in deze wachtrij zijn hoger, wanneer het ambitieniveau lager is.

Desalniettemin zal het gebruik van elke optie leiden tot een verbetering van de huidige situatie, waarbij de wachtrijen exploderen en het hele aankomstproces een hoge verblijftijd kent. De verbetermogelijkheden resulteren uiteindelijk in meer tevreden brandweer en politie na de inspectie en meer tevreden ruiters, grooms en paarden, omdat de logistiek van het gehele aankomstproces wordt verbeterd. Het antwoord op de onderzoeksvraag is dan ook om één van de drie mogelijke verbetermogelijkheden met verschillende ambitieniveaus te implementeren. Deze verbeteropties maken, door het gebruik van een tijdslot allocatiesysteem, de service- en aankomsttijden constanter, wat resulteert in een vermindering van de wachttijden en een verhoging van de veiligheid en tevredenheid.

Voor een optimale werking van de verbeteropties worden de volgende aanbevelingen gedaan voor het OC:

- Wijzig de tijd voor het openen van de stallen
- Gebruik tijdsloten van 1 uur bij aankomst
- Gebruik tijdsloten van 30 minuten voor de keuring
- Gebruik een limiet van 25 paardenvrachtwagens voor elk tijdslot voor aankomst
- Gebruik een limiet van 58 paarden voor elk tijdslot voor de keuring
- Wijs iemand aan die begeleidt op het parkeerterrein
- Wijzig de dag van de keuring
- Optioneel: Verander de plaats van de keuring

Naast het gebruik van een van de genoemde verbeteropties zijn er aanbevelingen gedaan voor andere internationale paardenevenementen, omdat er nog geen wetenschappelijk onderzoek is gedaan naar de logistiek van een dergelijk evenement. Dit betreft de volgende aanbevelingen:

- Houd veel ruimte over voor het uitladen rond het stallencomplex
- Laat de grooms eerst uitladen en dan het papierwerk regelen
- Gebruik een potlood voor de stalindeling
- Vrijwilligers zijn altijd een goed idee
- Houd de gemeente tevreden

Management summary

The main goal of this study is to improve the logistics of the arrival process of CSI Twente by reducing waiting times and increasing safety and satisfaction. Based on this research objective and the problem identification this study gives an answer on the following research question:

How can we improve the logistics of the arrival process at CSI Twente, in order to reduce waiting times and increase safety and satisfaction?

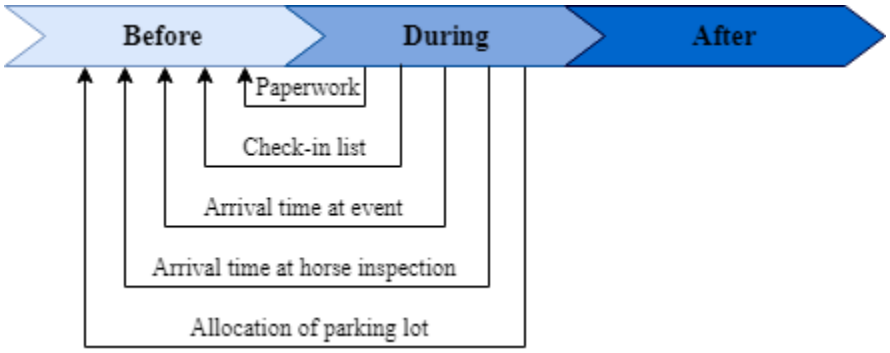
CSI Twente is an international horse show organized at a private property called Erve Maathuis, based in Geesteren, Overijssel (OV). It has grown into a leading show jumping event in the international circuit, with the promotion to a CSI5* status for the coming edition in 2019. However, every year the Organizing Committee (OC) obtains recurring problems in the arrival process. There is a high uncertainty on the arrival times of the horse trucks at arrival and of the horses at the horse inspection, which leads to queues and long waiting times. In addition, the lack of supervision of arriving trucks leads to unsafe and inefficient parking. These problems, in turn, lead to unsatisfied stakeholders. To get a view on the arrival process, the current situation is analyzed. The arrival process of the 2018 edition of CSI Twente was used for this purpose, including the resources used in the process and the numbers of the last edition. This analysis has led to observations and assumptions that are useful and taken into account to identify the bottlenecks of this study.

After the current situation analysis, the literature is consulted about the queuing theory. In the literature it is found that the experience in the waiting line affects the overall perception of the event. In addition, the variation in service and arrival rates can cause these waiting lines. By making these service and arrival rates more constant, queues will be reduced. According to the literature, the process of this study can be placed in a theoretical framework based on the basic M/M/1 model from Kendall and the basic structure of the queueing model. In this framework, the arrival process is represented by two consecutive M/M/1 models, representing the arrival and the inspection. Suitable performance measures of the system in this study are the distribution of the waiting time and sojourn time (the total expected time of the entire arrival process) and the number of customers in the waiting line.

After the literature review, the bottleneck analysis determined the stakeholders' view. Therefore, the wishes and requirements of the OC, the stable manager, and the riders and grooms are mapped out. In addition, the duration of the activities in the arrival process is calculated, using the Three Times Estimates in PERT. These estimates have been proven to be accurate. Combining the information in this chapter with the problem cluster and the current situation analysis, the following five bottlenecks of the arrival process were identified:

- The unknown arrival times of the horse trucks
- Search for name and stables at check-in
- Going to the show office and fill in paperwork
- The unknown arrival times of the horses at the horse inspection
- Absence of an allocation at the parking lot

To tackle these five bottlenecks, we established three improvement options with different ambition levels, all using a timeslot allocation system. The option with ambition level I uses e-mail and telephone, the option with ambition level II uses the KNHS subscription page and the option with ambition level III uses an application for mobile devices. Depending on the ambition of the OC, one of the three options can be implemented. Other options were also considered, but were not feasible for this study.



All three improvement options put five information points forward, from 'during the arrival process' to 'before the arrival process'. With the use of one of these improvement options, riders/grooms can choose a timeslot they prefer to or expect to arrive for both the arrival at the event and the horse inspection. By using this timeslot allocation system implemented in the options, the stable manager knows which trucks he can expect at what time. This enables him to find out in advance which stables belong to the arriving trucks and send them in one line to the right stables. In addition, the stable manager can estimate better where to put each truck, which reduces the distance that the grooms have to walk from the truck to their stables. The grooms no longer need to fill in the papers at the show office to indicate whether they need electricity and if they are in possession of health papers, as this information is all obtained through using an option. In addition, there will be a more organized parking lot. In the current situation, grooms were forced to choose a parking space themselves, often in disagreement over the electricity poles. These were frequently all occupied, or inaccessible due to chaotic parking. In the new situation, the OC can obtain how many trucks need electricity and therefore the amount of electricity poles needed. For the more complex options (with ambition level II and III), they even know what modes of transport will be used and the corresponding quantities. This makes it possible to allocate the parking lot in advance of the event and to ensure that there are enough electricity poles available. This will also result in safer

positioning of the horse trucks at the parking lot. Thereby, it is assumed that the OC arrange supervision at the parking lot. The queue at the horse inspection is also improved considerably with the use of the timeslot allocation system. The VET knows which horses he can expect at what time. Like the queue of horse trucks, this queue has been reduced. The improvement options allow the entire process, from arrival at the event to the inspection of the horses, to run without many interruptions.

Option	Sojourn time	Improvement (compared to current situation)
Ambition Level I	69.26 minutes	44.85%
Ambition Level II	60.42 minutes	51.89%
Ambition Level III	47.76 minutes	61.97%

In means of the duration of the entire arrival process, the option with ambition level I will improve the current situation with 44.85% and using the option with ambition level II with 51.89%. The greatest improvement is gained by using the option with ambition level III. This option has an improvement of 61.97% on to the current situation. In addition to the sojourn time, the number of horse trucks waiting in the queue at arrival (L_q^A) and horses at the horse inspection (L_q^{HI}) are calculated, as well as the waiting time at arrival (W_q^A) and at the horse inspection (W_q^A).

KPI	Current situation	Ambition level I	Ambition level II	Ambition level III
L_q^A	Exploding queue	0.911 horse trucks	0.619 horse trucks	0.324 horse trucks
W_q^A	Exploding queue	2.655 minutes	1.824 minutes	0.955 minutes
L_q^{HI}	Exploding queue	12.992 horses	12.992 horses	12.992 horses
W_q^{HI}	Exploding queue	7.099 minutes	7.099 minutes	7.099 minutes

Implementing the option with ambition level III will reduce the queue at arrival to an average of 0.324 horse trucks and an average waiting time of 0.955 minutes. For the queue at the horse inspection, it reduces the average waiting time to 7.099 minutes with an average of 12.992 horses in the queue. The average number of horses in the queue at the horse inspection and the corresponding average waiting time are the same for the options with ambition level I and II. However, the average number of horse trucks in the queue at arrival and the corresponding average waiting times in this queue are higher, where the ambition levels are lower. Nevertheless, the use of each option will result in an improvement of the current situation, which experiences exploding queues and a long sojourn time of the entire arrival process. The improvement options ultimately result in more satisfied fire brigade and police after the inspection, and more satisfied riders, grooms, and horses as the logistics

of the entire arrival process are improved. Therefore, the answer on the research question is to implement one of the three possible improvement options with different ambition levels using a timeslot allocation system. These improvement options make the service and arrival rates more constant, which results in a reduction of waiting times and an increase in safety and satisfaction.
For an optimal functioning of the improvement options the following recommendations are made for the OC:

- Change the time for the opening of the stables
- Use timeslots of 1 hour for arrival
- Use timeslots of 30 minutes for the horse inspection
- Use limits of 25 horse trucks for each timeslot for arrival
- Use limits of 58 horses for each timeslot for the horse inspection
- Appoint someone to provide guidance at the parking lot
- Change the day of the horse inspection
- Optional: Change the location of the horse inspection

In addition to using one of the improvement options given, recommendations have been made for other international horse shows, because no scientific research has yet been carried out into the logistics of a similar event. These are the following:

- Keep a lot of space for unloading around the stable complex
- Let the grooms first unload and then arrange the paperwork
- Use a pencil for the stable plan
- Volunteers are always a good idea
- Keep municipality satisfied

Logistical improvements of the arrival process at CSI Twente

A process-wide analysis providing improvement options at three ambition levels using a timeslot allocation system

Content

List of abbreviations

Abbreviation	Definition	Introduced on page
App	Application (for mobile devices)	55
CHIO	Concours Hippique International Officiel	3
CSI	Concours de Saut International	1
FCFS	First Come First Serve	26
FIFO	First In First Out	29
FEI	Fédération Equestre Internationale	3
GP	Grand Prix	2
KNHS	Koninklijke Nederlandse Hippische Sport	52
OC	Organising Committee	3
OV	Overijssel	2
VET	Veterinarian	7

List of figures

List of tables

List of symbols

Symbol	Definition
$\boldsymbol{\lambda}$	Average arrival rate
$\boldsymbol{\mu}$	Average service rate
$\boldsymbol{\frac{1}{\mu}}$	Mean service time
$\boldsymbol{\rho}$	Occupation rate
$\boldsymbol{L}$	Average number of customers in the system
$\boldsymbol{L_q}$	Average number of customers in the queue
$\boldsymbol{W}$	Average time a customer spends in the system
$\boldsymbol{W_q}$	Average time a customer spends in the queue

1. Introduction

In the framework of completing the Master of Industrial Engineering and Management, a study is performed on the board of Concours de Saut International (CSI) Twente. In this study, the focus lies on the general and layout logistics of the arrival process at the international horse show. The project resulted in providing three improvement options with different ambition levels using a timeslot allocation system and recommendations that improve the logistics of the arrival process at the international horse show, while considering the trade-offs involved. This study is completely innovative, since - to the best of our knowledge - no scientific research has ever been done into the logistics at an (international) horse show. Therefore, this study will also provide recommendations to other international horse shows, based on the experiences and information gained during the graduation period at CSI Twente.

For the external readers, the context of the research is given in Section 1.1. Subsequently, in Section 1.2, information about the event is provided. Section 1.3 contains the problem description and the problem cluster, where the relevance and motivation of the research are highlighted, followed by the research goal and research questions in respectively Section 1.4 and Section 1.5. Section 1.6 describes the data gathering methods and Section 1.7 indicates the stakeholders of the event. Finally, Section 1.8 defines the scope of the research and Section 1.9 the deliverables.

1.1 Context of this research

"No hour of life is wasted that is spent in the saddle." – Winston S. Churchill. Many people will agree with this quote of Churchill, while horse riding is a popular sport that is done all over the world. But the area called 'Euregio' is unique in Europe. Nowhere else is the equestrian sector so broad and so large. It is an area with an above-average high horse density (13 horses per square km), core competencies in equestrian sports, an above average high proportion of active equestrian sports (wo)men, birth and habitat of top riders and top horses, and lots of infrastructure for keeping horses and for equestrian sports. In addition, it is an area known for its top breeding, with no less than four leading studbooks (Horse Competence Center Germany; Hippisch Platform Twente, 2014). Part of Euregio is Twente, which is a region in The Netherlands known as the land of horse lovers. This regional characteristic also can be found in the prominent symbol of the area in which the so-called 'Twentse Ros' is processed (Appendix I). The fascination for the harmonious and unique relationship between (wo)man and horse is high and finds its origin in the traditionally strong agricultural character of this region, that is surrounded by the German equestrian bastion of Lower Saxony and North Rhine-Westphalia (CSI Twente, 2018). This cultural historical background clarifies the enormous enthusiasm and the love for this animal in general and the equestrian sport in particular.

1.2 About the event

Thanks to the passionate devotion to horses and the equestrian sport in this region as stated above, CSI Twente has grown into a leading show jumping event in the international circuit (CSI Twente, 2018). CSI Twente is an international horse show organized at a private property called Erve Maathuis, based in Geesteren, Overijssel (OV). To get a picture of the mentioned regions, Figure 1 shows the maps of Euregio, Twente and Geesteren.

The event started after the Second World War as a small national show. Since 1975, it got an international status. Riders from all over the world come to Geesteren to participate in the competition. The annual highlight of the event is the battle for the Grand Prix (GP) of Twente. A GP is the highest level of show jumping, where rider and horse jump a course from 10 to 16 fences up to a height of 1.60 meters and a width up to 2 meters. This classic at CSI Twente is won by big names in equestrian sports, such as Hugo Simon, Jos Lansink, Meredith Michaels-Beerbaum, and Patrice Delaveau. Appendix II contains a list of the winners of the Grand Prix of Twente from 1975 to the present.

The event is divided in four main branches, namely; Sports, Business, Culture, and Entertainment. Besides the competitions with the world's greatest riders, there is a VIP-Hospitality for companies and their (business) relations, a fair with vendor spaces, and multiple entertainment activities. To go short, CSI Twente has all the ingredients to create a wonderful mix of top class sport and emotion (CSI Twente, 2017).

Figure 1 - Euregio, Twente, and Geesteren on the map

1.3 Problem description

In 2019, the European Championships jumping, dressage, and para-dressage are held at Concours Hippique International Officiel (CHIO) Rotterdam. For this reason, CSI Twente is asked to take over the Nations Cup for jumping and dressage, which normally takes place in Rotterdam. This means that the 2019 edition of CSI Twente is a special one with the promotion to a CSI5*. Therefore, the event must be error-free to gain a high satisfaction of the riders, grooms (the persons who take care of the horses), visitors, and other stakeholders. However, every year there are some recurring problems in the arrival process. This process starts at the arrival of the horse trucks at the event and ends with the horse inspection (see Section 2.2). In the document 'Fédération Equestre Internationale (FEI) Approved Schedule' there are times given for the opening of the stables, the horse inspection, and the horse re-inspection (see Table 3). With this as the only given, riders and grooms are able to decide themselves what time they arrive at the show. This uncertainty of arrival times is till now uncontrolled by the Organization Committee (OC). As a result, trucks arrive at the most diverse times. This makes it impossible to continuously monitor the process of arrival, which lead to several problems. One of the problems is the queue of trucks. Most trucks arrive on Wednesday, from the moment that the stables are opened. Because everyone is free to determine their own time of arrival and the stables are opened in the middle of the day, there is often a long queue. The lead to long waiting times and unsatisfied grooms and riders.

Besides the queue of horse trucks, a recurring problem is the parking of the horse trucks and the need of electricity poles. Because of the lack of supervision, grooms can often decide for themselves where they park their trucks on the parking lot. As a result, the horse trucks are often parked too close to each other. When the fire brigade and police, together with the OC, carry out the inspection just before the start of the event, they are not satisfied. The trucks parked closely to each other do not meet the safety plan, in situations such as an outbreak of fire. In addition, there is often a shortage of electricity poles. This is also due to the inefficient parking and the fact that grooms only can indicate on the day itself that they need electricity.

Another problem can be found in the procedure of the horse inspection. Also in this procedure the grooms mostly experience a queue, because the arrival times are uncertain. This leads to long waiting times and mostly even a delay, which is absolutely not to be welcomed. All the problems mentioned lead to unsatisfied stakeholders of the event. The complete problem cluster can be found in Figure 2. This problem cluster structures the possible causes of the research problem and demarcation of the problem. As can be seen in the figure, the whole process of arrival needs to be improved with a critical look at the uncertainty in arrival times, in order to gain more satisfaction and safety.

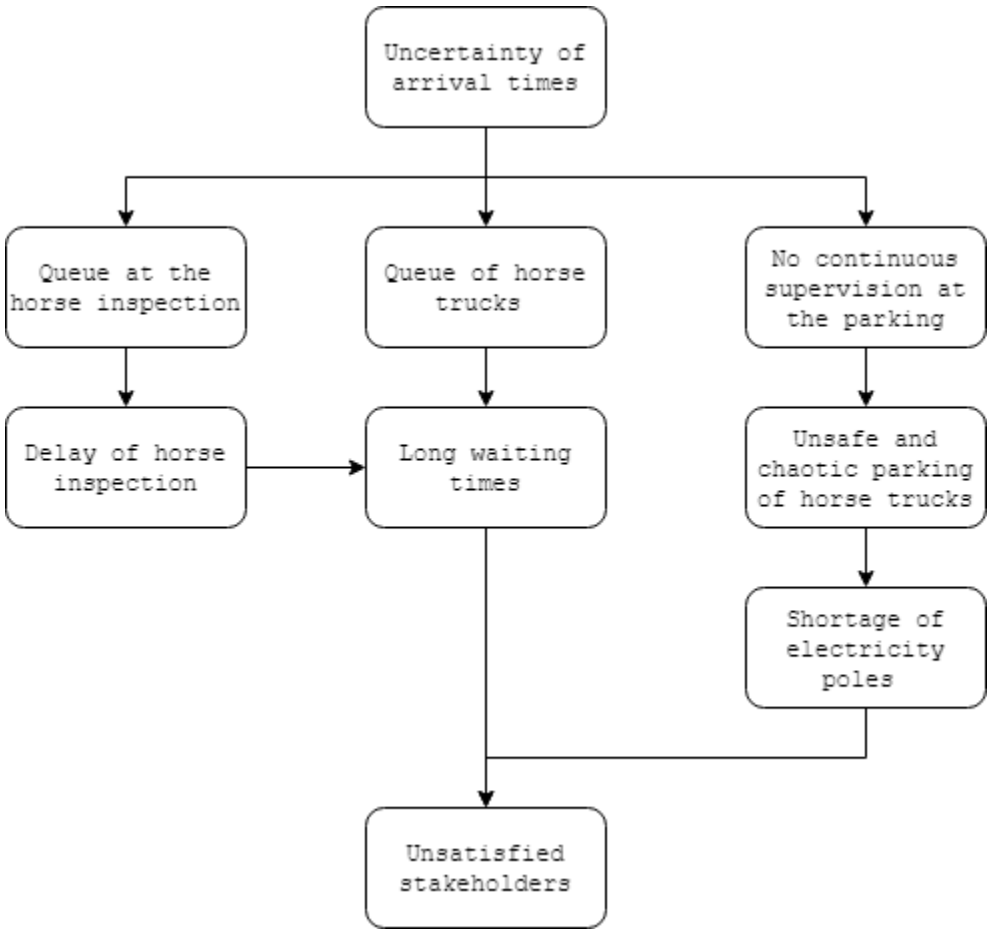


Figure 2 - Problem cluster

1.4 Research objective

The problem identification leads to the following objective of this research, which is formulated in accordance with the internal supervisor:

To improve the logistics of the arrival process at CSI Twente by reducing waiting times and increasing safety and satisfaction.

1.5 Research questions

In order to solve the aforementioned key problems, a main research question must be drawn up. Based on the problem identification and the research objective, the main research question is as follows:

How can we improve the logistics of the arrival process at CSI Twente, in order to reduce waiting times and increase safety and satisfaction?

In order to answer this question, other questions arise that need to be answered. The following sub-questions are formulated to answer the main research question:

1. *How is the current situation at CSI Twente with regard to the arrival process?*
   a) *What do the different event categories mean?*
   b) *Which processes can be identified?*
   c) *What resources are used?*
   d) *Which route do trucks and horses take?*
   e) *What were the numbers of last year?*

   In Chapter 2 the current situation is described. The current procedure refers to the working method of the 2018 edition of CSI Twente. To describe the current situation it is necessary to answer the sub-questions (a) till (e) in chronological order. These questions can be answered by collecting historical data. Besides, it is useful to interview the OC. With numbers in question (e) we mean the amount of trucks, riders, and grooms.

2. *What can be found in the literature about arrival processes and queuing?*
   The literature review can be found in Chapter 3. In this chapter information from books, internet, and other scientific sources will be used in order to find information about the research subject. To answer this question meetings are planned with teachers from University Twente, who are specialized in this field, to ask questions.

3. *What are the bottlenecks in the arrival process?*
   a) *How is the stakeholders' view?*
   b) *What are the wishes and requirements of the upcoming edition?*
   c) *What is the duration of the process activities?*

   Chapter 4 identifies the bottlenecks in the process. Therefore, the stakeholders' view is analyzed, including their wishes and requirements. This section makes use of interview techniques with several stakeholders. After that, the duration of the process activities is estimated, because this data is not available. The sub-questions (a) till (c) will be answered in the corresponding sections. Taken this into account, together with the problem cluster and the current situation, the bottlenecks of the process are identified.

4. *What are improvement options for CSI Twente?*
   a) *What is a timeslot allocation system?*
   b) *Which key performance indicators are used to measure the performances?*
   c) *How much improvement will the options provide?*

Chapter 5 describes three possible options with different ambition levels that will improve the arrival process of CSI Twente. All the options make use of a timeslot allocation system, which is explained first. After that, the key performance indicators will be highlighted, that are calculated for each option and compared with the current situation. Also other options that are considered in this research will be described.

The research questions need to be answered in chronological order to eventually propose a solution to the research problem and recommendations to the OC.

1.6 Data gathering

The method that will be used in the research to collect data is a combination of quantitative and qualitative. The quantitative data is the historical data from the event. How long were the waiting times last times? How many trucks were present at the show? And how many riders? These questions are examples to collect the quantitative data (see Section 1.5). It is chosen to use the data from last year, from June 12th till 17th. The data is exact and objective, making the research scientific. In addition to the quantitative data, qualitative data will also be collected. For example, multiple interviews will be held with riders and grooms from the different countries about their experience of the current situation of the event and their wishes and requirements for the desired situation (see Section 1.5). There may be clear differences between the different nationalities. In addition, several interviews will be held with the supervisor, the OC, the stable manager and with people from the company V2-Facility. The information from these interviews is qualitative. In order to use a combination of a quantitative and qualitative method, valuable data will be collected which will contribute to the research.

1.7 Identification of the stakeholders

There are multiple stakeholders at CSI Twente, the OC is dealing with before and during the event. These general stakeholders are all named and shortly explained in the following list.

- *Riders*: The persons riding the horses (Collins , 2018) and competing against each other in the show. This stakeholder can be seen as the most important one.
- *Grooms*: The persons employed to take care of the horses and all thing around them.
- *Visitors*: The persons visiting the event. For example, horse people, business people, or interested parties.
- *Owners of the horses*: Many horses are not owned by the riders themselves, but by people who pay the rider to compete with his/her horse.
- *Show office*: The department where administrative tasks are performed and riders can go for questions and/or comments.

- *Stable manager*: This person is responsible for the stable complex and all related matters.
- *Sponsors*: A person or organization that pays for or contributes to the costs involved in staging a sporting or artistic event, mostly in return for advertising.
- *FEI Officials*: For the discipline jumping the FEI Officials consist of the judge, course designer, technical delegate, steward, and official veterinarian (VET).
- *V2-Facility:* The facility services. This company takes care of the Facility Event Management from A to Z, better said from AutoCad drawing to VIP Box and from meadow to event area (v2-facility, 2018).
- *Municipality*: Responsible for issuing the license of the event and approving the safety and traffic plan.
- *Boomkamp security*: The organization that takes care of the security at the event.
- *First aid*: The emergency services who must be present throughout the event in case of accidents.
- *Volunteers*: The persons who do work without being paid for it, because they want to do it (Collins , 2018).

To identify and analyze the stakeholders of CSI Twente a stakeholder matrix is developed. There are multiple versions of the stakeholder matrix or quadrant. It is a simple but very effective tool for analyzing stakeholders. A common way to plot stakeholder is by power on the y-axis and interest on the x-axis. The power/interest grid focusses on those who have an interest and the power to affect the 'strategic future' (Eden & Ackermann, 1998). Figure 3 shows the power/interest matrix including the general stakeholders of CSI Twente.

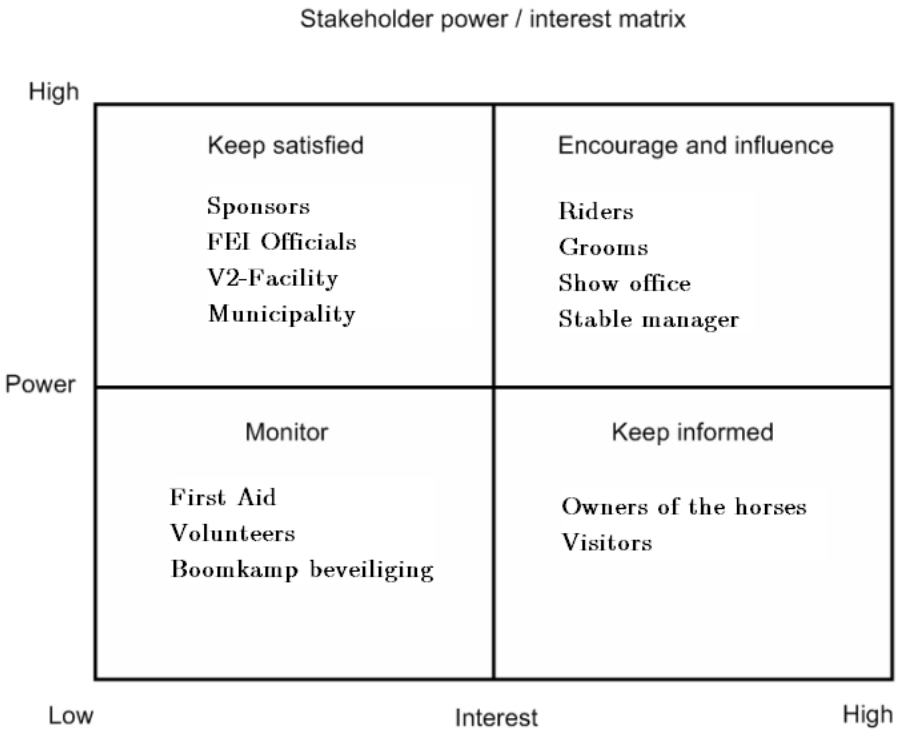


Figure 3 - Stakeholder power/interest matrix

However, not all of these general stakeholders are included in this study. Only the stakeholders who have a role in the arrival process will be included. Table 1 shows the stakeholders involved and their role in the process.

Stakeholder	Role in the arrival process
Riders	The riders control their grooms and in some cases help them in the arrival process.
Grooms	The grooms drive the truck, unload it, prepare the stables, and go with the horses to the VET. They undergo the whole arrival process.
Show office	Takes care of the paperwork that each groom/rider has to fill in at arrival.
Organizing committee	They make the choices within the arrival process, determine the times, and course of activities.
Stable manager	This person receives the horse trucks at arrival, makes the stables layout, and refers the grooms to their tents and stables.
Official veterinarian (FEI Official)	This person assesses the health of the horses at the horse inspection.

Table 1 - The stakeholders and their role in the arrival process

1.8 Scope of the research

This research will take place in Geesteren for the event CSI Twente. The national competitors are active in the first days of the event and mostly finished when the international part of the show starts. In addition, they experience no queues. For this reason, the national competitors and their trucks/trailers are outside the scope of this research. The infrastructure remains the same compared to last year. In this research, we focus on the horse trucks from the international competitors and the corresponding parking lot. Besides, the research is limited to the showjumping part of the event. The dressage part is much smaller and therefore not taken into account.

1.9 Deliverables

The final deliverables of this study are three improvement options with different ambition levels to improve the logistics of the arrival process at CSI Twente, including recommendations for the OC, and recommendations for other international horse shows. These recommendations can be useful, because the logistics of such an event have never been researched before. To provide these final deliverables, each chapter will contribute through the deliverables described in Table 2.

Chapter	Deliverable
2. Current situation	Observations and assumptions by the current situation analysis
3. Literature study	A theoretical model based on the queuing theory
4. Bottleneck analysis	The stakeholder's view and the activity times estimation of the current situation, and the identification of bottlenecks
5. Improvement options	Three improvement options with different ambition levels using a timeslot allocation system
6. Conclusions and recommendations	The conclusions and recommendations for the OC and other international horse shows, and proposals for further research

Table 2 - Deliverables per chapter

2. Current situation

This chapter describes the current situation of CSI Twente, meaning the 2018 edition. Before the description of the arrival process and the process flowchart in Section 2.2, the event categories will be explained in Section 2.1, so that a layman understands what the different categories mean. Section 2.3 highlights the main resources used in the process. This section also contains a technical drawing that clarifies the current situation. In Section 2.4 the route that the trucks take and the route of the horse inspection are drawn and explained. Section 2.5 contains the historical data from the 2018 edition and Section 2.6 closes this chapter with the conclusions of the current situation.

2.1 Event categories

An international horse show can have different numbers of stars. A CSI5* is the highest level achievable in equestrian sports. It is not possible to just enroll for this level, but a rider must be invited by the OC or designated from one's own country. Riders at this level are usually high on the world ranking list. The height of the fences and the height of the prize money also depends on the number of stars. CSI1* goes up to a height of 1.30 meters and CSI5* up to a height of 1.60 meters. An international horseshow can offer multiple event categories, so riders at a high level can also start younger and inexperienced horses in lower classes or amateur riders can compete. In the current situation CSI Twente is a CSI1*, CSI2*, and CSI4* horseshow. In the 2019 edition, CSI Twente is promoted to a CSI5*, while still maintaining the CSI1* and CSI2* categories.

2.2 The process description

The details of this process description will be further explained in the next sections. This description shows the main lines of the process. In the current situation, the stables are opened on Wednesday at 1:00 pm. Most of the competitors arrive on this day, because the horse inspection starts already at 8:00 am on Thursday before the classes. However, there is no information in advance about the arrival times of the horse trucks of the competitors. In addition, it is not known how many trucks are coming. The trucks arrive from one direction on the Denekamperweg, where the event is located. The Betonweg is the main entrance, and has a width for a maximum of one truck. For that reason, this road becomes a one-way street during the whole event. When cars and/or horse trucks leave the event, they will be directed to the Denekamperweg via side roads. Figure 4 shows the main entrance and the Betonweg. The horse trucks form a single row towards the stables. When they arrive at the stable complex, the stable manager is waiting for them to do the check-in. He manages the plan of which horses are in which tents and boxes. He fills in this plan with pencil, so that he can make changes on the spot. He has to find the name of the rider from the arrived truck on his list and then indicate in which tent and stables the horses are standing. The detailed process of the check-in can be seen in Figure 6 which will be explained later. If the weather is good, the trucks can unload between the tents. There is space for 25 horse trucks to unload. However, if the weather is

bad, the trucks will damage the field. In this situation the grooms are forced to drive to the parking lot and unload everything from there. The rightmost image in Figure 4 shows the lawn where the tents with the stables are located during the event. As can be seen, this is where the paving turns into grass. Because the event takes place in the middle of the summer (June), we assume in this study that the weather is good and the unloading can be done between the tents at the stable complex.

Figure 4 - Main entrance, Betonweg, and arrival stable complex

The unloading part consist of several steps, this detailed process can be seen in Figure 7 which will be explained later. After the unloading, the grooms need to park the truck. The parking lot is located on the right side of the stables (see Figure 9). Every groom need to indicate at the show office whether they use electricity at the parking lot or not and if they are in possession of health papers. Some grooms undertake this action before parking the truck, during the unloading, others do it afterwards (see Figure 7). There are only a few electricity poles in the parking lot. The trucks that actually need this electricity must be parked around these poles. Trucks that do not use electricity, for example because riders/grooms do not sleep in it during the event, will be parked elsewhere on the parking lot. There is no guidance for parking the truck at the parking lot. Grooms can decide themselves where to park the truck, which leads to unsafe and inefficient parking. If the horses are all stabled, the stuff is unloaded and the truck is parked, it is time for the grooms to have the horses inspected at the horse inspection that takes place at the stable complex. At many horse shows, the horse inspection is at the same day as the opening of the stables. On the contrary, CSI Twente holds the inspection on the day after the opening of the stables. However, because this activity is always performed before the start of the classes, it is included in the arrival process. The horse inspection takes place on Thursday between tents D and E at the stable complex. The OC has allocated time slots per event category. The horse inspection itself consist of several steps, this detailed process can be seen in Figure 8 and will be explained later. Figure 5 contains a flowchart of the arrival process. Lane 1 represents the roads, lane 2 the stable complex, and lane 3 the parking lot. These 3 main resources are used during the arrival process and further explained in Section 2.3.

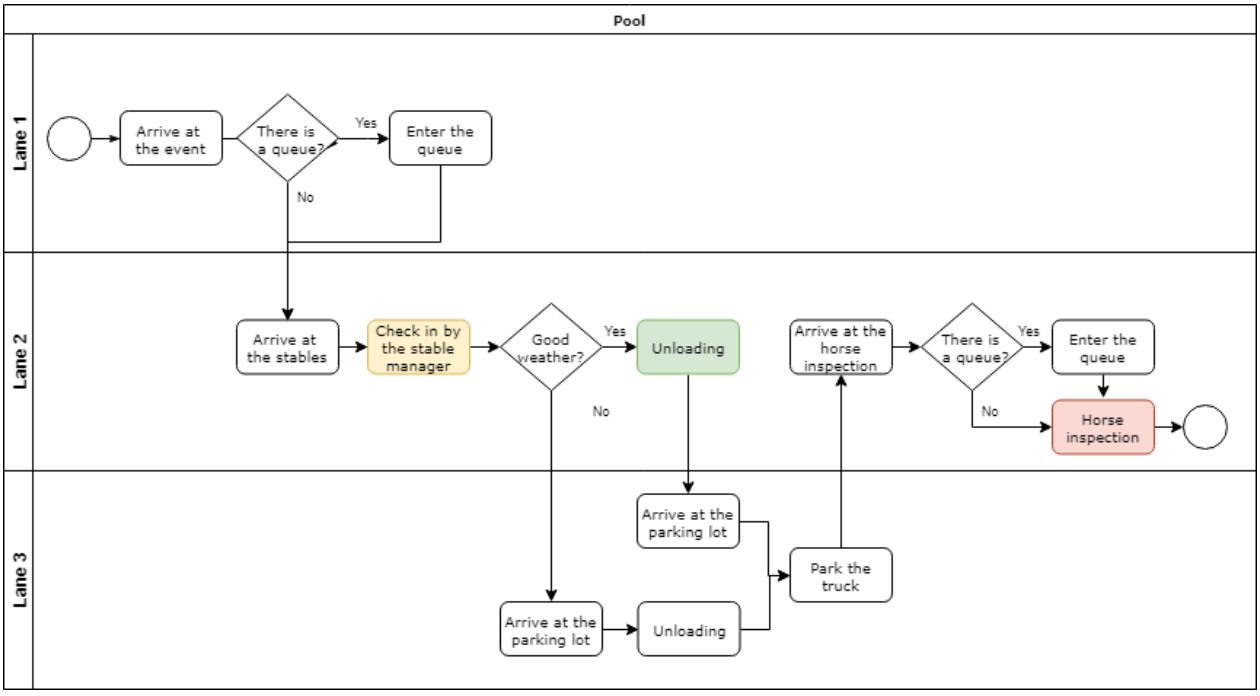


Figure 5 - Flowchart of the arrival process

As can be seen in Figure 5, at two moments in the process there exist the possibility of a queue. This is the case at arrival at the event and at arrival at the stables for the horse inspection. In addition, the process steps 'Check-in by the stable manager', 'Unloading', and 'Horse inspection' are marked. These process steps in turn consist of several steps and are elaborated in separate flowcharts to avoid complexity and illegibility. These flowcharts can be found in Figure 6, Figure 7, and Figure 8 respectively.

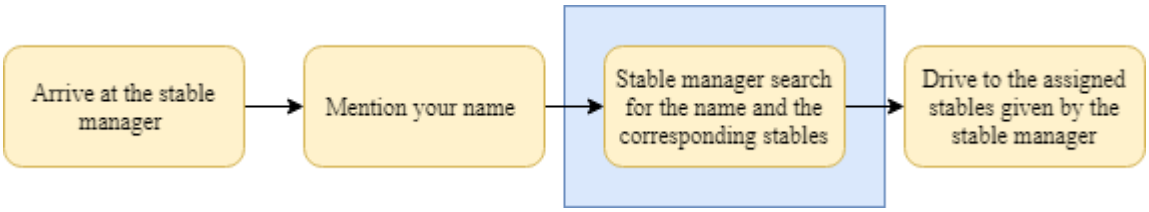


Figure 6 - Flowchart of the process step 'Check-in by the stable manager' as in 2018

The analysis of the current situation showed that CSI Twente has a lot of space around the stables to unload. However, the stable manager has no idea how late which trucks and how many trucks will arrive. Because there are 241 riders, 549 horses, and around 165 horse trucks (See Section 2.6), it takes a while to find the stables of the horse truck in front of him. In Figure 6 this inefficient part of the check-in is marked blue.

As Figure 6 shows a flowchart of the check-in by the stable manager, Figure 7 shows the flowchart of the unloading process step. This process step is the same in both situations of the weather (good or bad). The only difference is the place where the unloading takes place. In case of bad weather, unloading will take place on the parking lot and in case of good weather around the tents in the stable complex. This means that when the weather is bad, the distance to move the horses and stuff will be longer than with good weather. As stated before, it is assumed in this study that the weather is good.

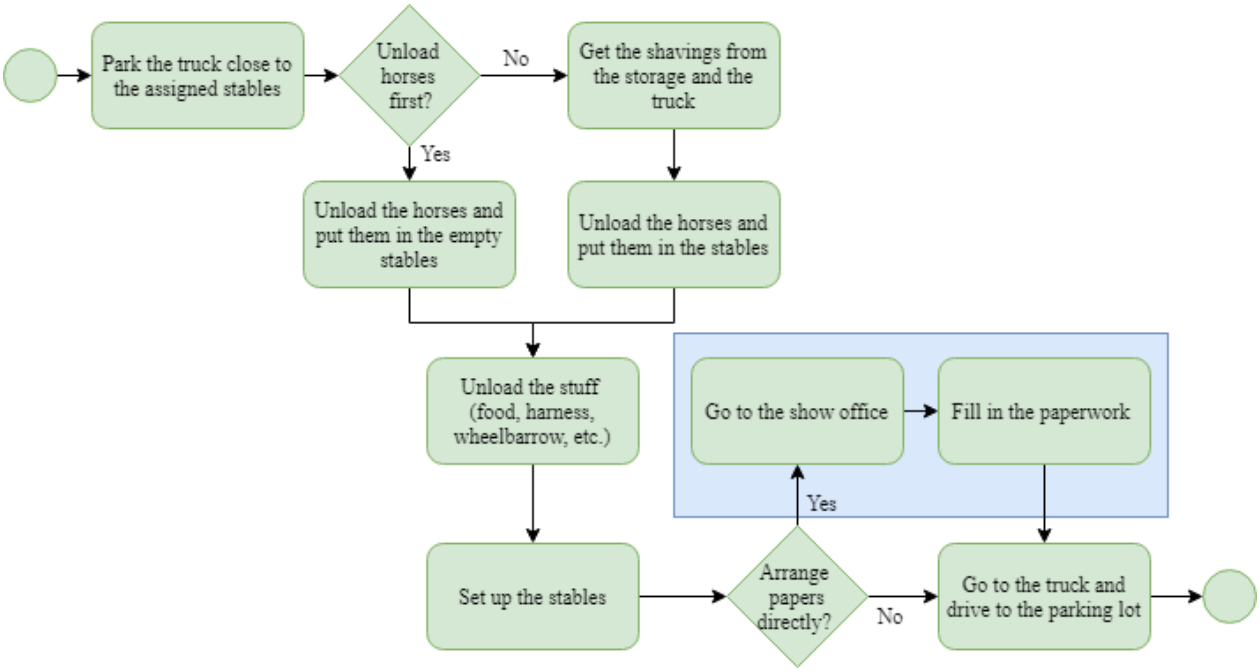


Figure 7 - Flowchart of the process step 'Unloading' as in 2018

As can be seen in Figure 7, there are two choices to take during the unloading. Some grooms prepare the stables first with shavings, so that the horses does not have to stand in the grass. Other ones prefer to stable the horses directly, so that they no longer have to stand on the truck and they can eat the grass in the stables. The latter they do because otherwise some horses will dig in the shavings for the grass. This choice will not make much difference in terms of time, as the same work will have to be done in both cases. On the other hand, the second choice is very decisive in terms of the length of time. If a groom decides to go first to the show office to take care for the paperwork before parking the truck, this will result in extra waiting time for the trucks waiting. In the time the groom is at the show office, his/her truck is still parked at the stables without anything happening to it. In addition, it is in many cases crowded at the show office which also results in waiting times. This sequence of actions is by far unnecessary. In Figure 7 this unnecessary part is marked blue and can be seen as a detour. If a groom does not arrange the papers directly, he/she can park the truck at the parking lot and will go afterwards to the show office. In this situation, the person does not let anyone wait for him/her, which will speed up the process. Appendix III contains the paper that needs to be filled in at the show office for every rider.

The last marked process step in the arrival process is the horse inspection. The horse inspection, sometimes called the VET check, must be carried out at all FEI events. For jumping, the horse inspection has to be within 24 hours of the start of first competition. The intention of this horse inspection is to check the horses' eligibility to compete, including a check of the horse's passport. The inspection panel consist of three members and the horses are presented by the athlete, driver, or groom (the "handler") who must be suitably dressed for handling horses. The process of the horse inspection is shown in Figure 8.

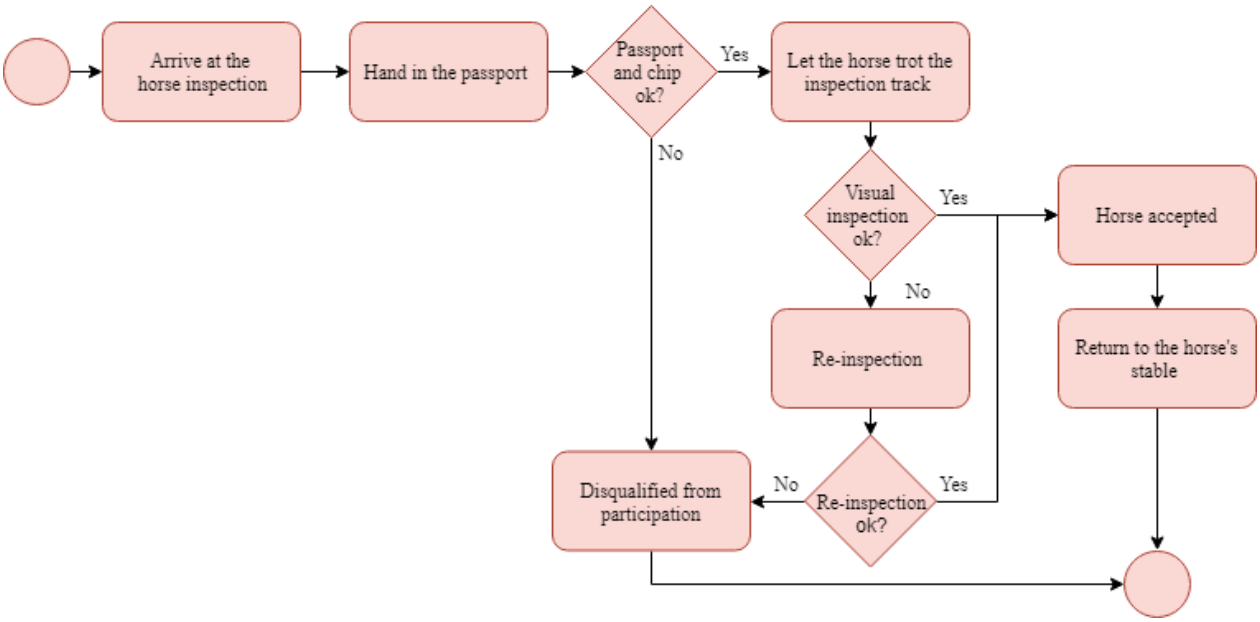


Figure 8 - Flowchart of the process step 'Horse inspection' as in 2018

The horse inspection goes as follows: If the handler arrive with the horse at the horse inspection, the passport must be handed in. The VET or a designated assistant will first identify the horse from its passport and microchip where applicable. He/she also checks whether the horse has the right vaccinations. Handlers must stand the horse in front of the inspection panel facing the end of the inspection track. The VET walks around the horse and makes a brief visual inspection. Any other examinations (e.g. palpation or limb flexion) may not be performed. Handlers must lead the horse from the horse's left hand side on a loose rein (Dutch = teugel) while the VET watches the horse's gait (Dutch = de gangen van het paard) from the center of the inspection track. On the inspection track, the handlers first walk the horse for a short distance, then trot the horse to the end of the track, subsequently walk the horse and turn in a clockwise direction at the end of the inspection track, and trot the horse back to the starting point (Fédération Equestre Internationale, 2019). Due to this process, the inspection panel will assess the horses' fitness to compete, and decide whether horses are accepted or not accepted (if horses are unfit to compete). If a horse is not accepted, the horse will be referred to the re-inspection that takes place after a few hours. If a horse is still not accepted at the re-inspection, this horse is not allowed to participate in the event and will be

disqualified. After the inspection the passport will not be returned, but kept by the OC, who is responsible for the safe and orderly keeping of passports during the event and for returning the passports to the competitors at the completion of the event. The inspection panel may decide not to accept horses that cannot be presented within the time period of the horse inspection, for this reason it is desirable that all horses are inspected within the allocated time (see Table 3).

2.3 The main resources

CSI Twente uses multiple resources before, during, and after the event. However, the arrival process uses only three resources and takes full place on the locations of them (see Figure 5). In addition, these resources are in possession of fixed characteristics that cannot be changed during this study. For these reasons they are called the main resources in this study. These resources are the roads, the stable complex, and the parking lot, which are briefly explained below.

- The roads: In the process two roads are used. These are the Denekamperweg and the Betonweg. The Denekamperweg is a provincial road, where a maximum speed of 80 km/h applies. During the event, this maximum speed will be adjusted to 50 km/h for safety by means of temporary traffic signs. The Betonweg is a private road of Erve Maathuis, and is used during the event as a one-way road. This road has a width for a maximum of one truck (see Figure 4).
- The stable complex: The stable complex consist of 598 boxes, for both dressage and showjumping horses. The boxes are divided into 13 tents (numbered by A to M), each consisting of 46 boxes. The size of each box is 3x3 meter and the size of each tent is 70x10 meters. A tent can be entered from both sides. The stable complex has an area of 88x195 meters and has therefore access to a lot of space.
- The parking lot: There is space for 165 horse trucks. The trucks can't be parked in the area of the stables, because grooms and riders sleep in the trucks and are not allowed to be in the stables in the middle of the night. This is to prevent robberies and to establish the safety of the horses. The parking lot has an area of 103x226 meters.

Figure 9 shows a technical drawing of the stables and the parking lot. Figure 10 shows photographs to clarify how the tents and stables look. The technical drawing of the roads can be seen in Figure 11, which is further explained in Section 2.4.

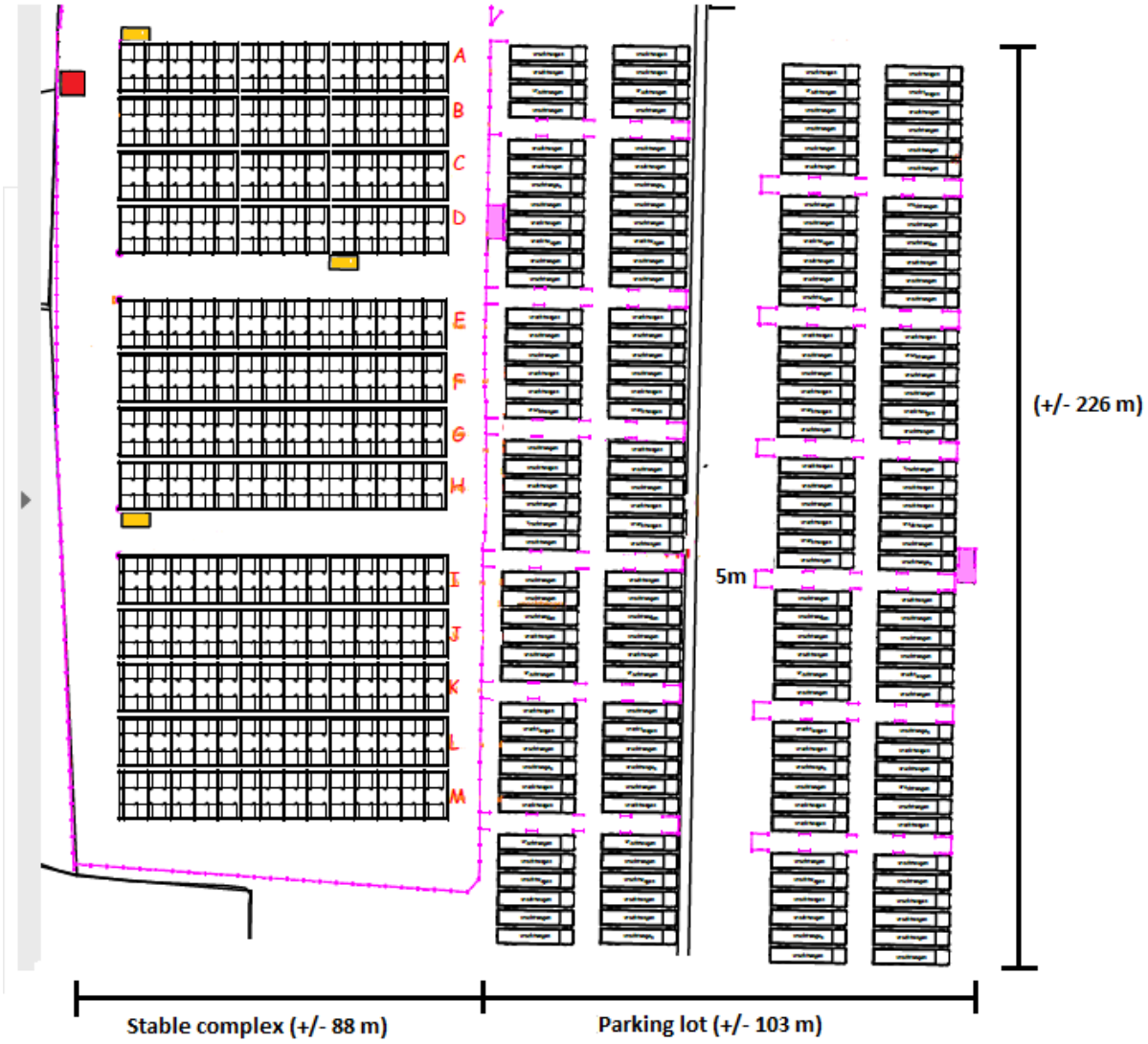


Figure 9 - Technical drawing of the stable complex and the parking lot

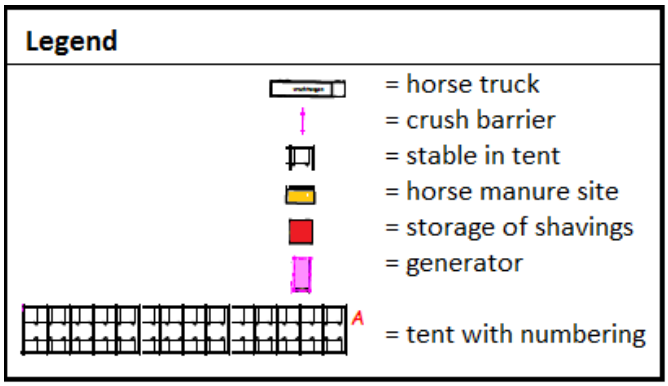


Figure 10 - Photographs of the tent and stables

2.4 The routes

In Figure 11, the route that trucks take is drawn. In the right top corner you can see the Denekamperweg, where the trucks only come from the right direction. The trucks turn into the Betonweg and drive towards the stable complex. The stable manager will indicate which tent and stables the horses are in, by naming the tent number and stable location. There are no fixed unload spots and times assigned. The tents can be entered from both short sides and the layout of the stables is not arranged according to the arrival of the trucks. As a result, the trucks drive in all directions to their own tents and also leave the stables after unloading via different routes. As a result, there are no arrows in the green route in the drawing. The same goes for the parking lot. For the parking lot, the stable manager gives no instructions at all on how and where to park the truck after the unloading. After unloading, the grooms drive the trucks to the parking lot to park at a random place. Most trucks need the electricity poles and grooms will drive across the parking lot in search of another spot near a pole. This results in driving in all directions and chaotic parking. The red line in Figure 11 indicates the route where the queue is created, this can be seen as the proactive part of the route. The red route is taken by every truck in the same direction. The green route runs along the servers, where continuous action takes place. There is no fixed route within the stables complex and the parking lot. Therefore, the trucks drive on the green route in all directions.

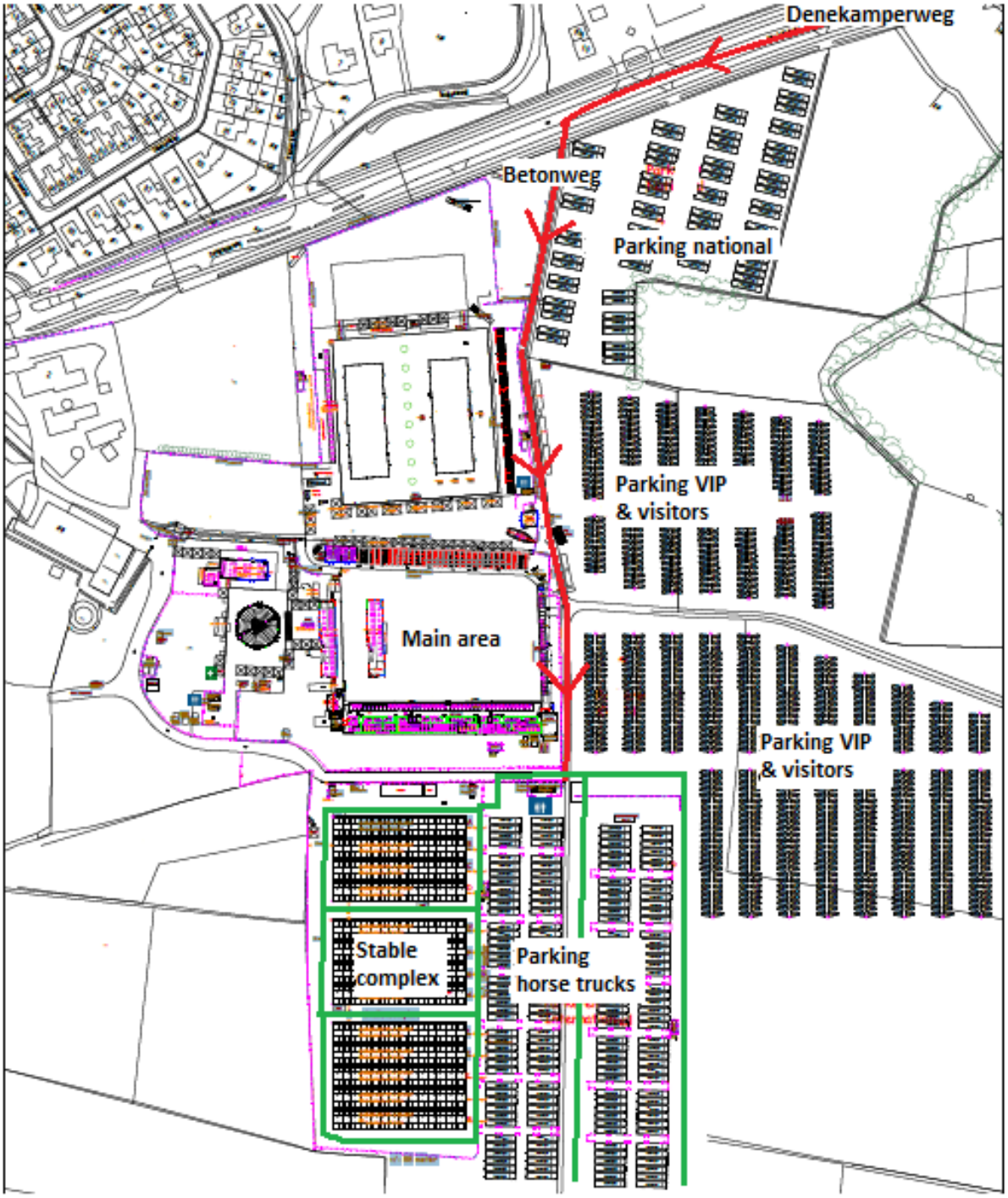


Figure 11 - Technical drawing of the route

In addition of the route that trucks take, Figure 12 shows the route of the horse inspection for grooms and their horses. As stated before, the horse inspection takes place between tents D and E at the stable complex. The black square represents the VET, the green line is the area where one horse at a time trots up and down, and the red line represents the queue of horses still to go. When the groom ran with the horse up and down, they return to the stable of the corresponding horse. For this reason, the green line in the drawing stops by the VET.

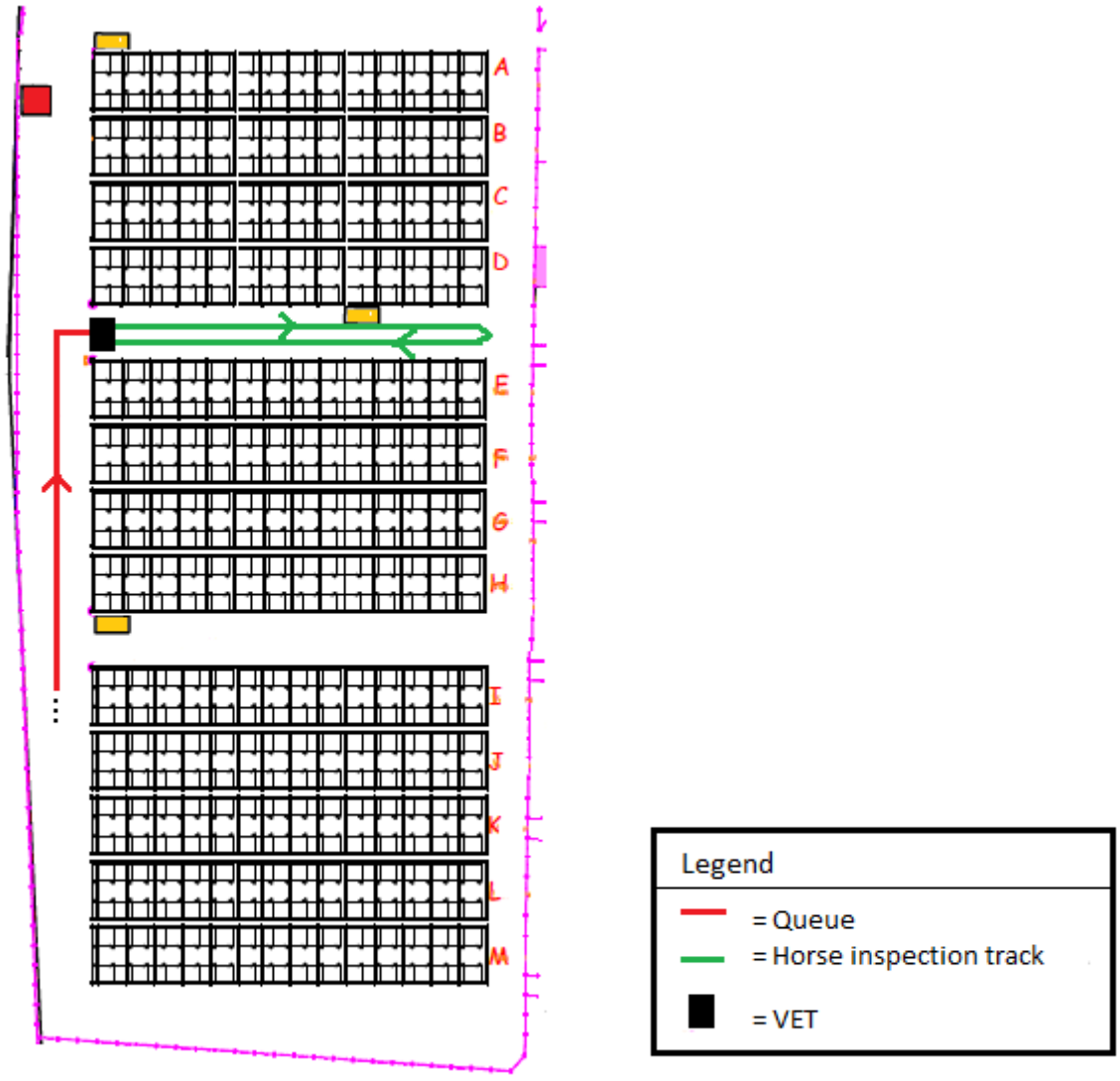


Figure 12 - Horse inspection and queue

2.5 Data from the 2018 edition

To analyze the current situation, there is some quantitative data gained from the FEI Approved Schedule 2018 and the Excel file with the competitors in 2018 handed out by the OC. With this data insight is given into the current times, the number of riders, horses, and horse trucks, and the different participating countries. These numbers are useful for designing a solution in this research. First of all, research was carried out into the times given by the OC to the participants. The only times that the FEI Approved Schedule provides are from the opening of the stables and the horse inspections per event category, which can be found in Table 3.

Activity	Day	Time
Opening of stables	Wednesday	01:00 pm
Horse inspection CSI1* and CSI2*	Thursday	08:00 am till 10:30 am
Horse re-inspection CSI1* and CSI2*	Thursday	11:30 am
Horse inspection CSI4*	Thursday	02:30 pm till 03:00 pm
Horse re-inspection CSI4*	Friday	09:00 am

Table 3 - Timetable opening stables and horse inspections

Beside this information, the FEI Approved Schedule also contains the following extra information regarding to the entries: Riders who are competing in the CSI2* are not allowed to compete in the CSI4*. Riders who are competing in the CSI4* are not allowed to compete in de CSI2*. Riders who are competing in the CSI1* are allowed to compete in the CSI2* or in the CSI4* (Fédération Equestre Internationale, 2018). The deadline for the entries is 2 weeks before the event takes place. A rider is allowed to compete with a maximum of 3 horses per event category and to take a maximum of 6 horses. In 2018 there were 282 entries of riders, of which 41 eventually unsubscribed themselves. Besides, there were 683 horses subscribed, of which 134 horses were also unsubscribed again. Horses can only compete in one event category. In Table 4 and Table 5 the amount of riders and horses are shown respectively per event category.

Event category	Amount of riders
Only CSI4*	48
Only CSI2*	64
Only CSI1*	48
CSI4* & CSI1*	26
CSI2* & CSI1*	55
Total	**241**

Table 4 - Amount of riders per event category

Event category	Amount of horses
CSI4*	189
CSI2*	205
CSI1*	155
Total	**549**

Table 5 - Amount of horses per event category

The division of the countries competed at CSI Twente 2018 can be found in Figure 13. There were 37 different countries present at the show. As stated before, the total amount of riders was 241 in the 2018 edition. As you can see in the figure, 50% of the total amount of riders comes from The Netherlands. America, Belgium, Germany, and Italy are the only countries that are present with a number of over 10 riders. In addition, there are many countries where only one rider competes.

There is no historical data available about the exact number of horse trucks. However, the estimate from the stable manager and the OC is around 165 trucks. This number will be assumed in this study. There is also no historical data available about the waiting and activity times in 2018. To get insight in these times, there is spoken with riders and grooms after which the times are estimated. This will be further described in Chapter 4.

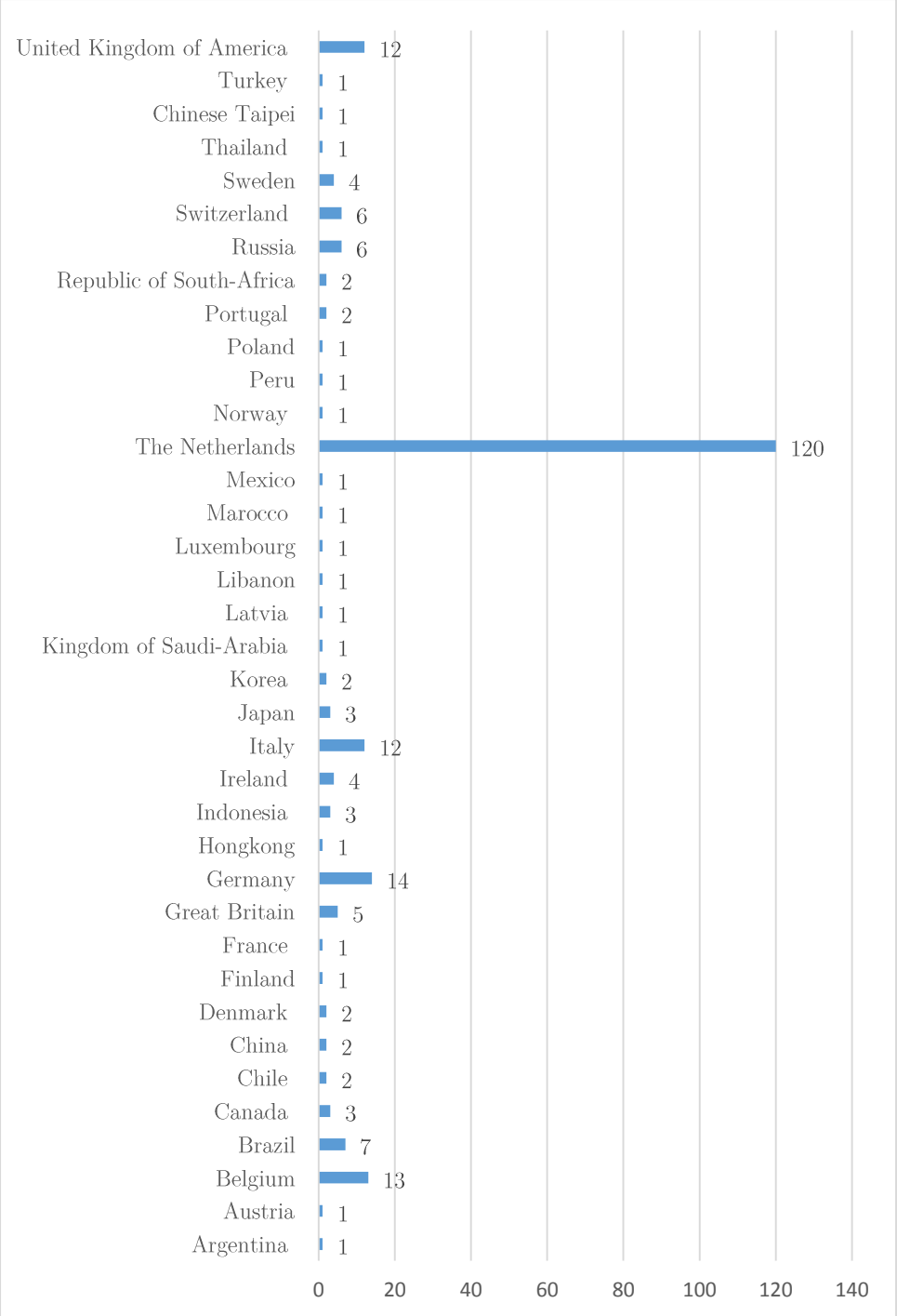


Figure 13 - Division of countries

2.6 Conclusion

This chapter gives an answer on the research question '*How is the current situation at CSI Twente with regard to the arrival process?*'

To answer this question, the current situation is analyzed to get a view on the process steps, the resources used in the process, and the numbers of the last edition. The arrival process can be divided into three main resources namely; the roads, the stable complex, and the parking lot. Only these resources are used within the arrival process and the routes also run along these three. The analysis of the current situation has led to observations and assumptions that are useful and taken into account at the bottleneck analysis (Chapter 4) of this study. Table 6 shows the observations and assumptions of the current situation.

The roads	
1	No arrival times known of the horse trucks
2	The roads are fixed resources and cannot be changed
3	241 riders and 549 horses arrived, coming from 37 different countries of which half from the Netherlands. The number of arriving horse trucks is assumed to be 165.
The stable complex	
3	Opening of the stables is at 1:00 pm
4	The horse inspection is on Thursday
5	Assumed that the weather is good and unloading takes place in the stable complex
6	The search for the name and the stables by the stable manger during the check-in is an inefficient process step
7	There is a lot of space available to unload
8	Going to the show office and fill in the paperwork are inefficient process steps
9	Hardly any arrival times known of the horses at the horse inspection
10	There are no fixed unloading spots and times
11	The layout of the stables are not arranged according to the arrival times
12	No fixed route, so driving in multiple directions
13	The horse inspection is divided into time slots per event category
The parking lot	
14	There is no supervision at the parking lot
15	There is no parking plan and/or map
16	The parking around the electricity poles is chaotic and unsafe
17	No fixed route, so driving in multiple directions

Table 6 - Observations and assumptions of the current situation analysis

3. Literature study

The literature study of this research is used to get information about queuing systems and the theory behind it. In addition, the process of this research is placed in a conceptual framework, using the information obtained. This chapter starts with the relevance of the research in Section 3.1. Section 3.2 describes the queuing theory, including the general characteristics, the input process, and the output process. The theoretical model is highlighted in Section 3.3, where the M/M/1 model is explained with the corresponding performance measures. Using the aforementioned sections, Section 3.4 presents the conceptual framework. This chapter ends with the conclusions in Section 3.5.

3.1 Relevance of the research

Every person knows that waiting can cause negative experiences. This can be agreed by Federal Express (a courier service), who noted in one of their advertisements that "Waiting is frustrating, demoralizing, agonizing, aggravating, annoying, time consuming and incredibly expensive. Moreover, the waiting-line experience in a service facility significantly affects our overall perceptions of the quality of service provided (Maister, 1984). Maister (1984) also states that once we are being served, our transaction with the service organization may be efficient, courteous and complete: but the bitter taste of how long it took to get attention pollutes the overall judgments that we make about the quality of service. This quality of service can be translated to an event, where the experience in the waiting line affects the overall perception of the event. Variation in service and arrival rates can cause queues (Maister, 1984). By making this service and arrival rates more constant, queues will be reduced.

3.2 Queuing theory

Queuing theory deals with one of the most unpleasant experiences of life; waiting. Queuing is quite common in many fields, for example, in telephone exchange, in a hospital, at computer systems, etc. Agner Erlang was the first who treated congestion problems in the beginning of 20th century. His works inspired engineers and mathematicians to deal with queuing problems using probabilistic methods (Sztrik, 2012). Queueing theory became a field of applied probability and many of its results have been used in, for example, operations research, computer science, and traffic engineering. This section starts with describing the general characteristics of the model of this study in Section 3.2.1. Beside the general characteristics, a queuing model consist of an input and output process. The input process is usually called the arrival process. In Section 3.2.2 the input process is modelled. The output process is often referred to as the service process. Section 3.2.3 describes this process.

3.2.1 General characteristics

First of all, the model of this research has servers in series, which means that a customer (e.g. groom) must pass through more than one server before completing service. Thereby, at the arrival and at the horse inspection there can only be one customer served at the same time by the stable manager

and the VET. Another characteristic of the model is the queue discipline. This describes the method used to determine the order in which customers are served (Winston & Goldberg, 2004). The queue discipline of the queuing model in this research is the first come first served (FCFS) discipline, which means that customers are served in the order of their arrival. The system in this research has an unlimited waiting room (on the roads and in the stable complex). Finally, the queuing model in this research has a single line to join for arrivals. So there is no possibility of jockeying. In addition, there is also no possibility of balking. Customers will not leave the waiting line, because they subscribed for the show and have to stable the horses and park the trucks. Finally, all the customers will be served, even if this will mean a delay in time. The server (stable manager/VET) will not stop before completing the work.

3.2.2 The input process

The arrival process is unaffected by the number of customers present and arrivals are independent. The arrival process of the horse trucks at the event can be modelled as a Poisson process. In each small time interval of length Δt the occurrence of an arrival is equally likely. In other words, Poisson arrivals occur completely random in time (Adan & Resing, 2015).The Poisson process is extremely useful in modelling the arrival of practical applications. Figure 14, obtained from Adan & Resin (2015), shows a realization of Poisson arrivals with rate 1.

Figure 14 - A realization of Poisson arrivals

Let $N(t)$ be the number of arrivals in [0, t] for a Poisson process with rate λ. Then $N(t)$ has a Poisson distribution with parameter $\boldsymbol{\lambda}$, so

$$P(N(t = k) = \frac{(\lambda)^k}{k!} e^{-\mu}, \qquad k = 0,1,2, \dots$$

The mean, variance and coefficient of variation of $N(t)$ are equal to

$$E\big(N(t)\big) = \lambda, \qquad \sigma^2\big(N(t)\big) = \lambda, \qquad c^2_{N(t)} = \frac{1}{\lambda}$$

It is easily verified that for small Δt,

$$P(arrival\ in\ (t, t\ +\ \Delta t]) \ \approx\ \lambda \Delta t$$

3.2.3 The output process

To describe the service process of a queuing system, we usually specify a probability distribution—the service time distribution—which governs a customer's service time (Winston & Goldberg, 2004). It is assumed that this distribution is independent of the interarrival times. In this research, the service times are exponential distributed. The density of an exponential distribution with parameter μ is given by

$$f(t) = \mu e^{-\mu t}, \qquad t > 0$$

The distribution function equals

$$F(t) = 1 - e^{-\mu t}, \qquad t \geq 0$$

For this distribution we have

$$E(N(t)) = \frac{1}{\mu}, \qquad \sigma^2(N(t)) = \frac{1}{\mu^2}, \qquad c_{N(t)} = 1$$

3.3 The theoretical model

This section starts with describing the model used in this research in subsection 3.3.1. In subsection 3.3.2 the corresponding performance measures of the model are identified. These performance measures are used in Chapter 5 to measure the performances of the current situation and the three options.

3.3.1 M/M/1 model

The theoretical model used in this research is the basic queuing model 'the M/M/1 model', introduced by David George Kendall. This shorthand so-called Kendall's notation is to characterize a range of queueing models. It is a three-part code a/b/c. The first letter specifies the interarrival time distribution, the second one the service time distribution, and the third one the number of servers (Adan & Resing, 2015). As stated above, the model of this research has exponential interarrival times with mean $1/\lambda$, exponential service times with mean $1/\mu$ and one server. The letter M is used for the exponential distribution (M stands for Memoryless). Customers are served in order of arrival. Figure 15 shows the flow diagram of the M/M/1 model. The arrows indicate possible transitions. The rate at which a transition occurs is λ for a transition from n to n+1 (an arrival) and μ for a transition from n+1 to n (a departure). The number of transitions per unit time from n to n + 1, which is also called the flow from n to n + 1, is equal to pn, the fraction of time the system is in state n, times λ, the rate at which arrivals occur while the system is in state n (Adan & Resing, 2015).

Figure 15 - The flow diagram of the M/M/1 model

3.3.2 Performance measures

To analyze the M/M/1 model in this study, some performance measurements can be done. Relevant performance measures are:

- The distribution of the waiting time and the sojourn time of a customer. The sojourn time is the waiting time plus the service time
- The number of customers in the waiting line

In particular, we are interested in mean performance measures, such as the mean waiting time and the mean sojourn time (Adan & Resing, 2015). To calculate these performances we need to specify the symbols used. These symbols are summarized in Table 7.

Symbol	Definition
$\boldsymbol{\lambda}$	Average arrival rate
$\boldsymbol{\mu}$	Average service rate
$\boldsymbol{\frac{1}{\mu}}$	Mean service time
$\boldsymbol{\rho}$	Occupation rate
$\boldsymbol{L}$	Average number of customers in the system
$\boldsymbol{L_q}$	Average number of customers in the queue
$\boldsymbol{W}$	Average time a customer spends in the system
$\boldsymbol{W_q}$	Average time a customer spends in the queue

Table 7 - Symbols used in queuing theory

In a single-server system M/M/1 with arrival rate λ and mean service time $\frac{1}{\mu}$ the occupation rate is the fraction of time that the service is working and equals $\frac{\lambda}{\mu}$. The server can handle 1 unit work per unit time. To avoid that the queue eventually grows to infinity, the M/M/1 model requires the following:

$$\rho = \frac{\lambda}{\mu} < 1$$

In addition, Little's law gives an important relation between L, the average number of customers in the system, W, the average time a customer spend in the system and λ, the average number of customers entering the system. Little's law states that (Adan & Resing, 2015):

$$L = \lambda W$$

Applying Little's law to the queue (excluding the server) yields a relation between the number of customers in the queue L_q and the waiting time in the queue W_q, namely;

$$L_q = \lambda W_q$$

Where L_q and W_q can be calculated as follows:

$$L_q = \frac{(\lambda/\mu)^2}{1 - \lambda/\mu} = \frac{\rho^2}{1 - \rho}$$

$$W_q = \frac{L_q}{\lambda} = \frac{\lambda/\mu}{\mu - \lambda} = \frac{\rho}{\mu - \lambda}$$

With these formulas the performance of the current situation and the three improvement options described in Chapter 5 can be measured.

3.4 The conceptual framework

Because the M/M/1 model of Kendall is a basic queuing model, the conceptual framework used in this research is based on the basic structure of the queuing model. This basic model has an input source that arrives through a First In First Out (FIFO, also referred to as FCFS) queue discipline. It enters the queuing system where it first joins the queue, then arrives at the service and 'undergoes' it, and then leaves this service again. In this study, the first queue arises at arrival at the event. The first service in the process is the check-in at the stable manager. After this, there are a few steps in the process that do not have a queue (such as parking). The second queue takes place at the horse inspection. The service that the horses undergo here is the horse inspection itself. Evaluating the literature and the process description leads to the conceptual framework that is shown in Figure 16. Hereby, the activities in between are left out, because they do not have a queue. As can be seen in the figure, the queuing system of this research consist of two successive M/M/1 models. The arrival rate is displayed with λ and the service rate with μ.

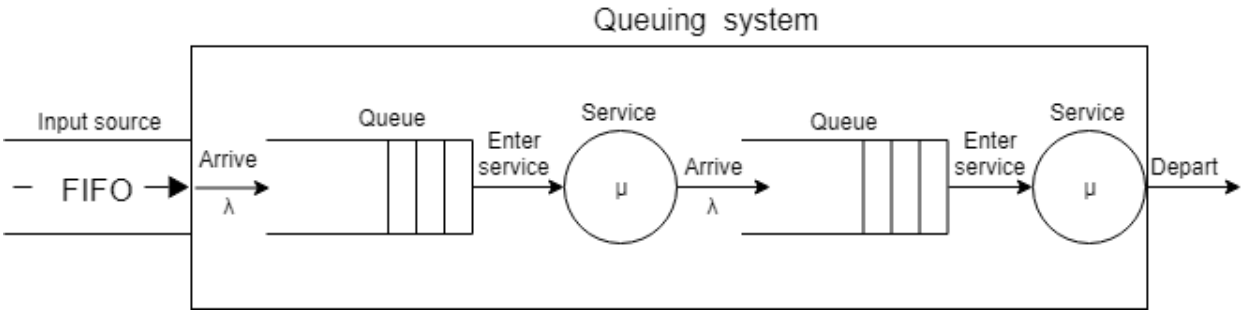


Figure 16 - The conceptual framework of the queuing system of the arrival process at CSI Twente

3.4 Conclusion

The aim of this section is to answer the research question '*What can be found in the literature about arrival processes and queuing?*'

From the literature it can be concluded that the experience in the waiting line affects the overall perception of the event. It is also stated that the variation in service and arrival rates can cause these waiting lines. By making this service and arrival rates more constant, queues will be reduced. Therefore, the queuing theory is introduced, where the general characteristics, the input process, and the output process are described. About the system of this study the following can be concluded:

- The system has servers in series
- One customer is served at the same time by stable manager and VET
- The queue discipline is FCFS
- At both servers there is an unlimited waiting room and a single line to join
- Customers do not leave the waiting line and will all be served
- The arrivals follow a Poisson process with rate λ
- The servers follow an exponential distribution with rate μ

It follows from the literature that the performance measures of the system in this study are the distribution of the waiting time and sojourn time and the number of customers in the waiting line. Therefore, Little's Law can be used. With all the information obtained from the literature, the system of this study can be placed in a theoretical framework that is based on the basic M/M/1 model from Kendall and the basic structure of the queuing model, where the queuing system of this research consist of two successive M/M/1 models.

4. Bottleneck analysis

Identifying bottlenecks is crucial for efficiency and finding applicable alternatives to the problem. In this chapter the bottlenecks of the arrival process will emerge. However, in order to find these bottlenecks, we first need to get insight in the stakeholders' view. Therefore, this chapter starts with the stakeholder's view by describing the current experience and the wishes and requirements for the upcoming edition of the riders, grooms, OC, and stable manager in Section 4.1. Section 4.2 estimates the activity times and corresponding variances per activity of the process. Section 4.3 takes all previously obtained information together and identifies the bottlenecks of this study, after which Section 4.4 concludes Chapter 4.

4.1 The stakeholders' view

To find the bottlenecks and applicable alternatives to solve these it is important to get a view of the opinions and experiences of the riders, grooms, OC, and stable manager. This also includes the wishes and requirements for the upcoming edition. Twenty-three people were interviewed, divided into ten riders, ten grooms, two persons from the OC, and the stable manager. In order to maintain the same proportions, half of the riders and grooms are Dutch nationals, as 50% of the participants come from the Netherlands (see Section 2.5). In addition, the different event categories were taken into account. Appendix IV contains a list of the riders and grooms interviewed. In addition, Appendix V shows the corresponding key questions of the interviews. The persons from the organization and the stable manager were asked more specific questions focused on their tasks in the arrival process. Based on the questions we asked through and gain information from multiple views. This section is divided in the three main resources (the roads, the stable complex, and the parking lot) in Section 4.1.1 to 4.1.3.

4.1.1 The roads

All the respondents agreed that the problem of waiting horse trucks on the roads need to be solved. Most grooms indicated that they have been in the queue at arrival on the Denekamperweg and Betonweg for about 30 minutes, which is unsatisfying. One respondent gave CSI3* Tubbergen as an example. On the day of arrival there was a row of trucks of +/- 3 kilometers, until the middle of the village. That same day it was 38 degrees, so the horses were wet with sweat in the trucks. He said that everyone complained and was worried about the horses' welfare. This was just an example of many other experiences in the waiting lines at international horse shows. Another respondent did not experienced a queue in 2018. However, he arrived already at 9:30 am, before the opening of the stables at 1:00 pm. This did not cause any problems and they could unload and park quietly without any waiting times. The stable manager did not like this. He indicated that in this way he loses the overview of which riders and horses have already arrived. If something has to be changed on the spot, this will be counterproductive. The OC does not benefit from this either. They are not prepared for this situation, which can lead to possible problems, such as the facilities not being ready yet.

However, the groom reacted as follows: “My rider would like to train her horses on the show arena the day before the competition starts, so that they can get used to the environment. This is not possible at CSI Twente when we can only arrive in the afternoon”. At CSI Twente it is only possible to train the horses at home on Wednesday morning and then leave to the show. However, this means that everybody arrives on this part of the day which causes a queue.

4.1.2 The stable complex

As mentioned above, the opening of the stables is at 1:00 pm. However, the OC mentioned that they have no valid reason for the choice of this time. For that reason it is asked to all the riders and grooms if they prefer to change the opening of the stables from 1:00 pm to 9:00 am. All respondents responded positively to this idea. For example, one groom gave the following feedback: "I think this is a good idea, because it makes the time longer for riders and grooms to bring their horses, which also means fewer people come at the same time. When the stables open at 1:00 pm many riders/grooms would also arrive around this time, because everyone prefers to finish their work around 5 to 6 o'clock". As mentioned before, one groom arrived in 2018 before 1:00 pm and this did not cause any problems. For these reasons, the idea of changing the opening of the stables from 1:00 pm to 9:00 am can be feasible. It even resulted in no waiting times for that specific groom. Finally, a foreign respondent said it would be better if the stables are opened earlier, because then they have the ability to train the horses on Wednesday in the show arena(s). In the current situation this is almost impossible due to time pressure. If the grooms arrive at the stable complex they have to check-in, which cost a lot of time. Besides, they indicate that is always a bit chaotic to find your stables and to know where to unload. This is acknowledged by the stable manager, who indicates that he has no idea in what order and at what time the approximately 165 trucks arrive. In addition, he indicated in the interview that he mentions to the grooms to unload and park the trucks before they have to do the necessary paperwork. However, he also mentioned that not everybody listen to this and the arrival process is always chaotic. There were indeed several of the interviewed grooms who went to the show office during unloading to take care of the paperwork. They also indicated that it is always busy here. A positive thing mentioned about the stable complex is the large amount of space that CSI Twente offers for the unloading.

After unloading and parking the truck, it is time for the horse inspection. This activity takes place at the stable complex. According to the riders and grooms, this must change immediately. The current situation analysis indicated that the horse inspection takes place between the tents, making it chaotic in the stables complex. One respondent even called it a ‘drama last year’. Besides the location, the day of the horse inspection is not according to the wishes and requirements of the riders. Many riders want to have the ability to ride or lunge their horses before the inspection, to warm-up the muscles. Other riders simply don't like having the horse inspection and the first class on the same day. This can be accomplished by replacing the horse inspection from Thursday morning to Wednesday afternoon/evening. “They should do the horse inspection one day earlier, so that this

does not have to be done in such a hurry", according to one respondent. Another respondent completed this by saying: "I would prefer to do the horse inspection Wednesday at the end of the day. I like it that when you arrive at the event you can prepare everything in the stables for the whole weekend and you can go to the VET check with the horses immediately, so you don't have to worry about that the next day. Because if your class would start in the morning, this would be quite a rush and if your class starts in the evening you still have to go to the show to do the horse inspection". Another point that came up regarding the horse inspection is the distribution. In the current situation it is divided in time slots per event category, as can be seen in Table 3. However, this is not really taken into account by the grooms and riders. Riders who compete in the 1* and in the 4* have to wait, in theory, at least 3 hours between the horse inspection of their 1* and 4* horses. In practice, of course, this does not happen and they will let the VET check their horses one after the other. One groom who has been practicing her profession for 25 years said that the inspection used to be divided into the different countries. She claimed that there were no queues at that time. The rider of this groom reacted positively and thought this could be a good solution for the queue. Like one respondent said: "I always go to the VET check when the queue is gone, even if this means that I arrive outside the allowed time. I did stick to the given time slots before, but I was always waiting for half an hour". The riders and grooms indicated that this problems with the horse inspection were not only the case at CSI Twente, but at many other international horse shows. This illogical distribution and the fact that everyone is able to go at the same time creates an annual queue. All the riders and groom experienced a queue and long waiting times at the horse inspection. When asking the OC why they chose this day, location, and distribution, it soon became clear that they had no reason to do so. They've been doing it like this for years. The stable manager also sees no problem in changing these data.

4.1.3 The parking lot

As was pointed out in the problem description (Section 1.3), a recurring problem is the parking of the horse trucks and the need of electricity poles at the parking lot. During the interviews it became clear that there is no guidance regarding parking. The grooms can largely decide for themselves where to put their horse truck. This results in an often unsafe set-up, in which trucks stand close to each other to be able to use the electricity poles. The OC mentioned that this lead to unsatisfied police and fire brigade after the required inspection they have to carry out. It do not meet the safety plan, in situations such as an outbreak of fire. The stable manager indicated that the parking of the trucks is not his task. In addition to this unsafe and chaotic parking, there is often a shortage of electricity poles. Some riders and grooms said that it is an annual challenge to be able to park close to a pole. Especially when the trucks that do not need electricity are also parked close to a pole. One respondent said the following about this: "I find it very inconvenient that on the day itself you have to indicate whether you need electricity or not." Because of this remark, all respondents were asked if they already knew a few weeks before the event whether they needed electricity or not. To

this question they all had the same answer, namely that they know this well in advance. This seems to be an important point to take into account in this research.

4.2 Activity times estimation

To identify the bottlenecks of the process it is important to get an insight in the activity times and the variances. However, as mentioned in Section 2.5, there is no historical data available of the waiting and activity times of 2018. Therefore, it is necessary to estimate these times which can be done by indicating the different activities in the process and using the Three Times Estimates in PERT. Each activity is assigned a letter, where A stands for the first activity of the process and F for the last. As can be seen in Figure 17, the process and its flowchart of Figure 5 can be divided in the following activities:

A - Arrival at the event till service at the stables
B - Check-in at the stable manager
C - Unloading
D - Parking of the horse truck
E - Arrival at the horse inspection
F - Horse inspection

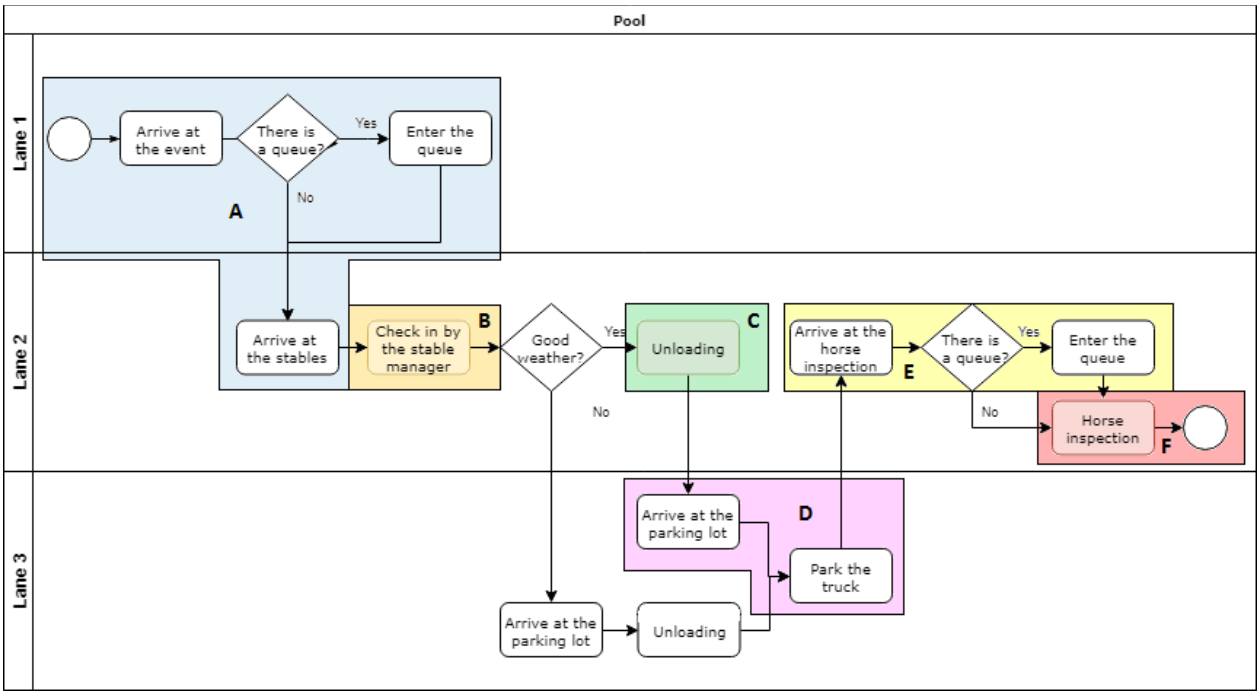


Figure 17 - Arrival process divided in activities

Some of these activities, in turn, consist of several sub-activities. However, the order of these sub-activities is not fixed for the different riders/grooms, as is shown in the flowcharts in Chapter 2. For this reason, A through F consists of the main activities that are performed by everyone in the same order. Because it is assumed that the weather is good and the unloading takes place at the stable complex, this choice and path in the process is out of scope of this study. Therefore, these process steps are not marked, but remain white.

For estimating the activity times and variances the Three Time Estimates in PERT is used. Hereby, the probability distribution is based on three time estimates for each activity. The three time estimates are the following:

- **Optimistic time (a)** = time an activity will take if everything goes as planned. In estimating this value, there should be only a small probability (say, 1/100) that the activity time will be $< a$.
- **Pessimistic time (b)** = time an activity will take assuming very unfavorable conditions. In estimating this value, there should also be only a small probability (also, 1/100) that the activity time will be $> b$.
- **Most likely time (m)** = most realistic estimate of the time required to complete an activity.

When using PERT, it is often assumed that activity time estimates follow the beta probability distribution that is shown in Figure 18. This continuous distribution is often appropriate for determining the expected value and variance for activity completion times (Heizer & Render, 2008). To calculate the expected activity time t for each activity i, the following formula is used:

$$t_{exp}^{i} = (a + 4m + b)/6$$

The beta distribution gives the most likely time *(m)* four times the weight as the optimistic time *(a)* and the pessimistic time *(b)*. To compute the dispersion or variance of activity i completion time, PERT uses the following formula:

$$\sigma_i^2 = (\frac{b - a}{6})^2$$

This formula is based on the statistical concept that from one end of the beta distribution to the other is 6 standard deviations (+/- 3 standard deviations from the mean). Since *(b-a)* is 6 standard deviations, the variance is *[(b-a)/6]^2* (Heizer & Render, 2008).

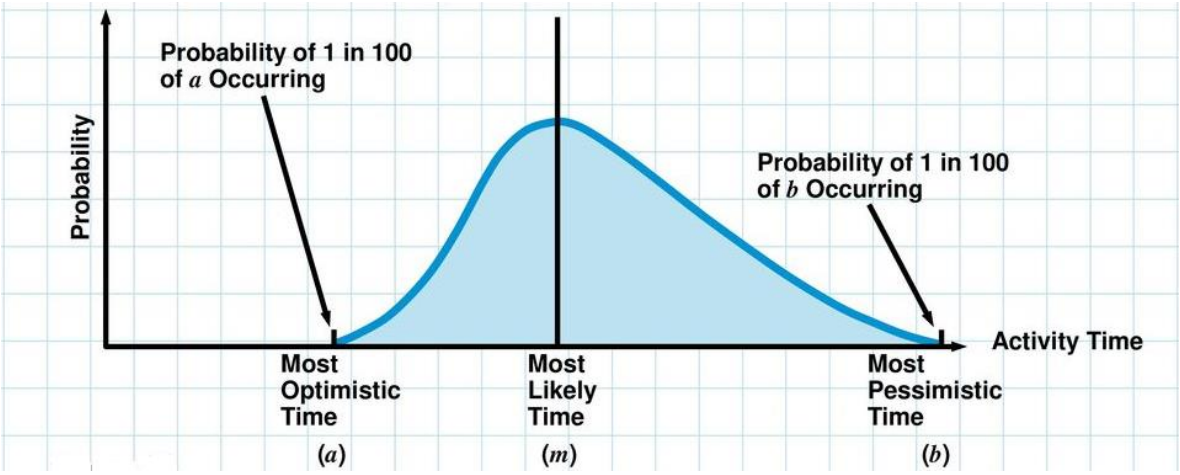


Figure 18 - The Beta Probability Distribution

The three activity time estimates are based on the information gained from the riders and grooms. A distinction is made between optimistic, pessimistic, and realistic persons, who are all asked to estimate the duration of the three scenario times. The experience of 20 minutes waiting time can be described by positive people as 'about 10 minutes', while negative people can experience this as 'at least half an hour'. This is compared to the estimation of the duration per activity under optimum conditions and under worst conditions. In addition to the estimations of the respondents and the duration at optimum and worst conditions, the activity time of the horse inspection is measured at CSI Tubbergen. This show was organized during the graduation period of this study and could therefore serve as a contribution the estimation of the horse inspection. This activity has exactly the same procedure as at CSI Twente. Appendix VI shows the results of the fieldwork at CSI Tubbergen. The expected times can be found in Table 8. The times given in the table are in minutes.

Activity i	Optimistic a	Most likely m	Pessimistic b	Expected time $t^i_{exp} = (a + 4m + b)/6$	Variance $\sigma_i^2 = [(b\text{-}a)/6]\hat{}2$
A: Arrival at the event	1	30	60	30.17	96.69
B: Check-in	0.5	2	4	2.08	0.34
C: Unloading	30	60	75	57.5	56.25
D: Parking of the truck	2	5	20	7	9
E: Arrival at the horse inspection	5	30	45	28.33	44.44
F: Horse inspection	0.25	0.45	1	0.51	0.02
Total	38.75	127.45	204	125.59	206.74

Table 8 - The expected times and corresponding variances

As can be seen in Table 8, the expected times and variances of activities A, C, and E are marked yellow. These activities have the longest expected times and corresponding high variances, which mean that these activities can fluctuate greatly in terms of duration. For activity C this can be explained, because this activity depends on the workload and productivity of the groom. In the case of activities A and E, this high variance is due to the queue created by the uncertain arrival times, which is usually experienced at both activities. As can be seen in Table 8, the total expected time of the whole process is 125.59 minutes. However, there is a chance that in reality this time is exceeded. Because all times are estimated it is good to get an insight into the probability that these times deviate from the expectation. To calculate this chance, we first need to determine the standard deviation of the total expected time, which can be calculated as follows:

$$\sigma_{exp} = \sqrt{\sum_{i=A}^{F}(\sigma_i^2)} = \sqrt{206.74} = 14.38$$

In order to calculate the probability that the time duration of the whole process is longer than the expected time duration of 125.59 minutes, the z-distribution is used. We define the variable t_s as the specified time. This refers to the time for which we want to calculate the probability that the expected time will exceed this time.

$$z = \frac{t_s - \sum_{i=A}^{F}(t_{exp}^i)}{\sigma_{exp}}$$

These z values take on meaning by using the Standard Normal Table (see Appendix VII). The table entries are the area under the standard normal curve to the left of z ($P(Z \leq z)$). This is shown in Figure 19. However, in this study we want to know how likely it is that the expected time will be exceeded, which is the area under the standard normal curve to the right of z. This can be calculated using the following formula:

$$P(Z > z) = 1 - P(Z \leq z)$$

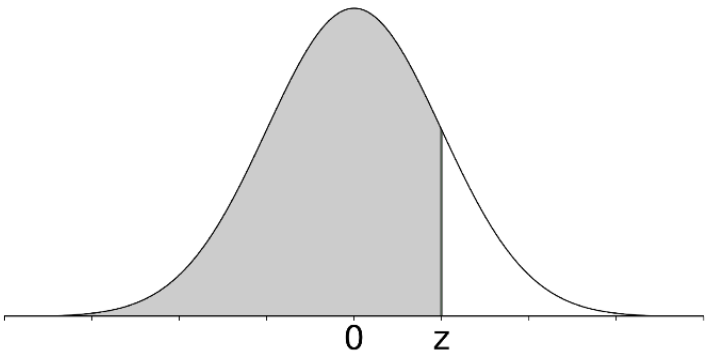


Figure 19 - The area of the entries in Standard Normal Table (Galarnyk, 2018)

Table 9 shows the probabilities that a certain specified time exceeds the expected time, with t_s rising from 130 to 180 minutes.

t_s(*in minutes*)	z	$1 - P(Z \leq z)$	Probability (in %)
130	0.31	0.3783	37.83
140	1.00	0.1587	15.87
150	1.70	0.0446	4.46
160	2.39	0.0084	0.84
170	3.08	0.0010	0.10
180	3.78	0.0001	0.01

Table 9 - The probabilities that a certain specified time exceeds the expected time

In order to get a picture of the probabilities, Figure 20 is added. On the x-axis the specified times in minutes are placed and on the y-axis the percentages of the probabilities that the specified time exceeds the expected time of 125.59 minutes. As can be seen, the graphical representation follows an exponential distribution. The exponential distribution (also known as the negative exponential distribution) is the probability distribution that describes the time between events in a Poisson process. The probabilities decrease regressively and eventually approach zero.

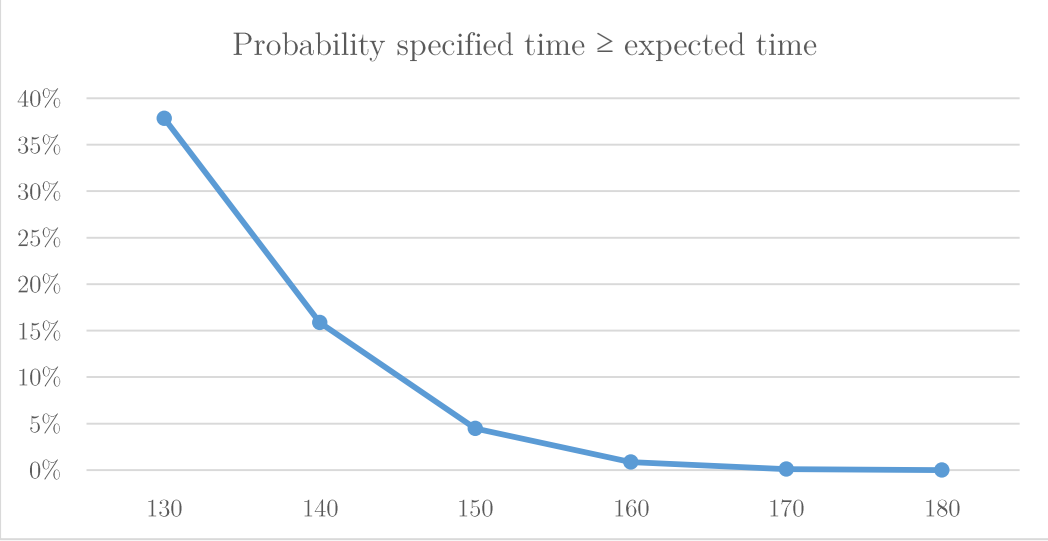


Figure 20 - Graphical representation of the probabilities

4.3 Identification of bottlenecks

After constructing the problem cluster, analyzing the current situation, interviewing the stakeholders, and estimating the activity times and variances, we can identify the bottlenecks of the process. Table 10 is created to aggregate all the information obtained in this study and to determine the bottlenecks. Again, this is divided into the three main resources (the roads, the stable complex, and the parking lot) in order to maintain an overview. The columns in the table have the following purpose:

- **Resource**: The main resource, described in Section 2.3, and the location where the bottleneck emerges.
- **Problem cluster**: The problems in the problem cluster, described in Section 1.3 and shown in Figure 2, that occur at this resource.
- **Stakeholders' view**: The stakeholders' view of the problems that occur at each resource, obtained through the interviews and elaborated in Section 4.1.
- **Fixed conditions**: The fixed conditions within the problems, which cannot be influenced or changed and therefore are outside the scope of this study. These conditions are obtained from the analysis of the current situation.
- **Unfixed conditions / Possibilities**: The unfixed conditions that can be influenced or changed and therefore can be seen as an opportunity to solve the problems. These conditions are obtained from the analysis of the current situation.
- **Corresponding activities**: The activities of the process, shown in Figure 17, in which the bottlenecks occur. The activity time and variance for each activity are estimated in Section 4.2.
- **Bottleneck**: The identified bottlenecks for each resource, using the information in the other columns of the table.

As can be seen in Table 10, there are five bottlenecks identified, three of which belong to the resource the stable complex. These bottlenecks can be linked to the different activities of the process, for which the expected activity times and variances are calculated in Section 4.2. In the next chapter, improvement options at three ambitions levels are proposed to tackle these bottlenecks.

Resource	Problem cluster	Stakeholders' view	Fixed conditions	Unfixed conditions / Possibilities	Corresponding activities	Bottleneck
The roads	- Uncertainty of arrival times - Queue of horse trucks - Long waiting times - Unsatisfied stakeholders	- Waiting time around 30 minutes in queue - Good experience for grooms with arriving before opening of stables, but not for stable manager and OC	- # of arriving trucks - Road dimensions - Day of arrival - # of servers	- Time of arrival - Opening of the stables	A: Arrival at event till stables	**The unknown arrival times of the horse trucks**
The stable complex	- Uncertainty of arrival times - Queue at the horse inspection - Delay of the horse inspection - Long waiting times - Unsatisfied stakeholders	- No time for training at the show on Wednesday - Unsatisfied about check-in duration - Chaotic to find stables and good unloading place - Experience crowded show office	- Location of stable complex - Dimensions of stable complex - # of servers - Unloading takes place at stable complex - Location of stable manager	- Unloading times - Opening of the stables	B: Check-in C: Unloading	**Search for name and stables at check-in** **Going to the show office and fill in paperwork**
		- Unsatisfied about day, place, and distribution of horse inspection - Waiting time around 30 minutes in queue	- # of horses - # of VETs - Route of inspection - Procedure	- Day of inspection - Location - Distribution of inspection	E: Arrival at horse inspection F: Horse inspection	**The unknown arrival times at the horse inspection**
The parking lot	- Uncertainty of arrival times - No continuous supervision at the parking lot - Unsafe and chaotic parking of horse trucks - Shortage of electricity poles - Unsatisfied stakeholders	- Chaotic to park at electricity pole - Experienced shortage of electricity poles -	- Location of parking lot - # electricity poles - Place of electricity poles - Parking lot dimensions	- Modes of transport - Supervision availability	D: Parking of horse truck	**Absence of an allocation**

Table 10 - Identification of the bottlenecks

4.4 Conclusion

This chapter gives answer on the research question '*What are the bottlenecks in the arrival process?*'

To answer this question the stakeholders' view, which is important in this respect, is analyzed. Currently, riders and grooms are not satisfied about the arrival process. Most of the time, they experience a queue when they arrive. Also the unloading at the stables is always chaotic and takes a lot of time. There is no guidance at the parking lot and the use of electricity poles still has to be arranged on site, which lead to chaotic parking and a shortage of electricity poles. The horse inspection is not at all satisfactory. The place, the time, and the distribution should be changed according to the riders and grooms. But most important, they indicate that the queue and corresponding waiting time should be reduced.

Also important to identify the bottlenecks are the activity times and variances. Therefore, the activity times are calculated for each activity of the process, using the Three Times Estimates in PERT. This resulted in the total expected time of the whole process of 125.59 minutes. Besides, we calculated the probability distribution of the change that this total expected time is exceeded in reality. This resulted in an exponential distribution, where the probabilities decrease regressively and eventually approach zero. What is striking in this Section are the activity times and variances of activities A, C, and E. These activities have long expected times and corresponding high variances, which mean that they fluctuate in duration.

Taken this info in account, together with the problem cluster in Section 1.3 and the current situation analysis of Chapter 2, we can identify the following five bottlenecks:

- The unknown arrival times of the horse trucks
- Search for name and stables at check-in
- Going to the show office and fill in paperwork
- The unknown arrival times of the horses at the horse inspection
- Absence of an allocation at the parking lot

Taking the information from Table 10 together with the expected activity times and variances per activity, we can conclude the following: The arrival at the event till the stables and the arrival at the horse inspection need improvement the most. These activities have long expected times and high variances. The bottlenecks linked to these activities are the unknown arrival times and the fact that the grooms fill in the papers at the show office during the unloading.

5. Improvement options

This chapter outlines three improvement options at different ambition levels, to tackle the five bottlenecks identified in Chapter 4. For each option, it is assumed that all possible users actually use the option. The improvement options are all based on time slot allocation. Section 5.1 describes the use of a timeslot allocation system in this process. Section 5.2 indicates the Key Performance Indicators (KPI) and calculate them for the current situation. Section 5.3 till 5.5 describes the three improvement options with different ambition levels. For each improvement option the KPIs are calculated and compared to the current situation. Section 5.6 describes the other options considered, while Section 5.7 presents the conclusions.

5.1 Timeslot allocation system

According to the literature review, by making service and arrival rates more constant, queues will be reduced. The research problem of this study can be compared to the problem that restaurants own. Restaurants and other capacity-constrained services, such as spas, hotels, golf courses, hair salons, and dental offices face variable demand that makes it difficult to optimize perishable inventory (Kimes & Chase, The strategic levers of yield management, 1998). One way service firms try to manage this uncertainty is with reservations, which represent a normative and often explicit contract describing the rights and obligations of customers and service providers (Wilson, 2007). This is acknowledged by Thompson and Kwortnik Jr (2008) who stated the following: "Permitting customers to "lock in" service with a reservation reduces uncertainty for both parties to the exchange". Restaurants want to maximize their efficiency, which explains the surge in the usage of point of sales (POS) software that tracks the arrival time, size, and order of each customer (Bertsimas & Shioda, 2003). However, usually they follow a simple FCFS policy, like the trucks and horses in the current process of this study. From the literature and the information obtained in this research, the idea arose of using a system with timeslots for the arrival process. In this system, riders and/or grooms are able to choose two timeslots. First of all to indicate what time they expect to or prefer to arrive at the event. Then to indicate what time they expect to or prefer to arrive at the horse inspection. Therefore, the use of timeslots can be implemented for both arrival and horse inspection, where the interval of each time slot is smaller for the horse inspection than for arrival. This is because the horse inspection is carried out over a shorter period of time and has a shorter activity time. For the more complex systems (Options with ambition levels II and III), an automatic limit can be set on the number of arriving trucks and horses in a given time slot. Each time slot will indicate their current status of bookings, by changing the color. A green color represents quiet timeslots, orange nearly full timeslots, and a red color full timeslots with the risk for a queue. With the use of this colors the OC can manipulate the choice of time slots by, for example, making a time slot red, where crowdedness is undesirable. This also gives extra information to the riders/grooms about the current situation of the timeslots. The system of allocating time slots can be implemented at three ambition levels, which are explained in the next sections. The complexity in which this implementation is

done differs per option. In order to get the maximum result with the time slot allocation system, the following requirements should be met:

- Everybody uses the options provided when possible
- The opening of the stables is at 9:00 am till 05.00 pm
- The procedure of the horse inspection does not change
- The distribution of the horse inspection is no longer in event categories
- The timetable of the horse inspection is no longer in use
- There is supervision at the parking lot

As stated before, the improvement options need to tackle the five bottlenecks. With the use of timeslots, arrival times are known. This tackles the bottlenecks 'The unknown arrival times of the horse trucks' and 'The unknown arrival times at the horse inspection'. In addition, the use of a timeslot system provides a list with the arrivals at each timeslot. With this list, the OC and stable manager can predict which trucks and horses and how many at which time arrive. This tackles the bottleneck 'Search for the name and stables at check-in' and improves the step of the check-in procedure marked blue in Figure 6. Finally, for each option, the system includes the completion of the paperwork in addition to choosing a timeslot. This is not a complex functionality, as it only consists of indicating whether you need electricity and whether you are in possession of health papers (see Appendix III). This tackles the bottleneck 'Going to the show office and fill in the paperwork'. As stated in Chapter 4, the riders know the information of the paperwork already before the event starts. This means that the number of horse trucks requiring electricity is known in advance and the number of poles can be adjusted accordingly. This provides a list of the trucks that have to be parked next to the electricity poles and tackles the bottleneck 'Absence of an allocation at the parking lot'. With the use of a timeslot system, a total of five information points are put forward in the process, as can be seen in Figure 21. This information is in the current situation obtained during the event, but in the new situation gained before the start of the event.

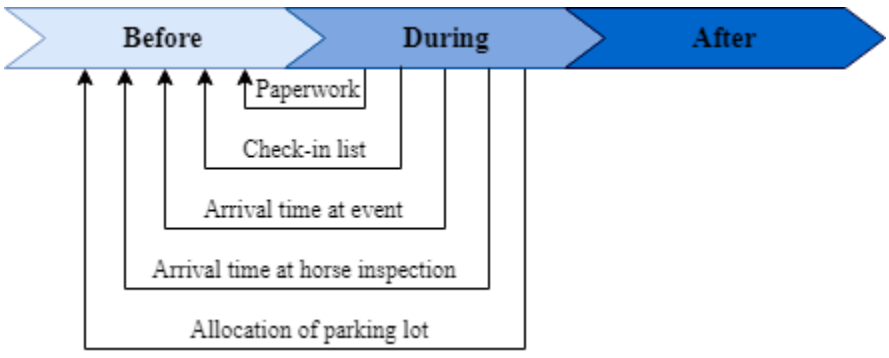


Figure 21 - The five information points that are put forward in the process

5.2 Key performance indicators

In order to compare the improvement options with the current situation and to be able to quantify the improvement, five key performance indicators (KPI) have been drawn up. These KPIs are based on the performance measures of the M/M/1 model in Section 3.3.2 gained in the literature study. The following KPIs are used for this study:

1. $Sojourn\ time$ = The total expected time of activity A till F
2. L_q^A = Expected number of horse trucks in the queue at arrival
3. L_q^{HI} = Expected number of horses in the queue at the horse inspection
4. W_q^A = Expected time a horse truck spends in the queue at arrival
5. W_q^{HI} = Expected time a horse spends in the queue at the horse inspection

The choice of the KPIs can be explained. The sojourn time is the total expected time of the whole process. Because the logistics of the entire arrival process is examined in this study, this KPI is suitable to analyze the improved situation. The other KPIs measure the details of the queues of this process, which occur at the arrival and during the horse inspection, and ensure long activity times and high variances. The main goal of this research is to reduce the waiting times and therefore the queues. In order to calculate KPI 2 till 5, some input need to be determined. This input, calculated by the data obtained in this study, is shown in Table 11. The data in this table is more accurate than the estimated activity times in Table 8 and therefore used to calculate the KPIs.

Queue at	Data obtained in this study	Input (units per hour)
Arrival	- 165 trucks arrive - Arrival between 1:00 am - 6:00 pm - Check-in activity time of 2.08 min	$\lambda = \frac{165\ trucks}{5\ hours} = 33$
		$\mu = \frac{60\ min}{2.08\ min} = 28.85$
Horse inspection	- 549 horses arrive - Arrival between 8:00 - 10:30 am and 2:30 - 3:00 pm - Horse inspection activity time of 0.51 min	$\lambda = \frac{549\ horses}{3\ hours} = 183$
		$\mu = \frac{60\ min}{0.51\ min} = 117.65$

Table 11 - Input for KPIs of current situation

The results of the KPIs for the current situation are shown in Table 12. For this calculation, the information the performance measures from Section 3.2.4 and the activity times estimation of Section 4.2 are used.

KPI	Metrics	Calculation	Result
Sojourn time	see Table 8	see Table 8	125.59 minutes
L_q^A	$\lambda = 33$	$\rho = \frac{\lambda}{\mu} > 1$	Exploding queue
	$\mu = 28.85$		
W_q^A	$\lambda = 33$	$\rho = \frac{\lambda}{\mu} > 1$	Exploding queue
	$\mu = 28.85$		
L_q^{HI}	$\lambda = 183$	$\rho = \frac{\lambda}{\mu} > 1$	Exploding queue
	$\mu = 117.65$		
W_q^{HI}	$\lambda = 183$	$\rho = \frac{\lambda}{\mu} > 1$	Exploding queue
	$\mu = 117.65$		

Table 12 - KPI results of current situation

As can be seen in Table 12, the only KPI that can be calculated for the current situation is the sojourn time. For the other KPIs it is not possible to calculate them using the performance measures of the M/M/1 model. The reason for this is that the M/M/1 model requires that $\lambda < \mu$. As stated in Section 3.3.2, this is to avoid that the queue eventually grows to infinity. A simulation of a hospital, for example, often uses a long runtime (e.g. years), which leads to an exploding system when $\lambda > \mu$. In addition, the servers stop working after a specified period of time and the customers still in the queue will not be served. The difference between the M/M/1 model and the model at CSI Twente is that the queues of the model in this study will not grow to infinity as they have a maximum of horse trucks (165) and horses (549). In addition, the servers of this model will 'work overtime'. For example, trucks and horses that arrive too late will not be refused, but will be provided with a service. This will cause the times to run out, which is expensive. The length of time that both servers work overtime can be calculated. The overtime at arrival and at the horse inspection respectively are the following:

- $\frac{165\ horse\ trucks}{28.85\ trucks\ per\ hour} = 5.719\ hours \rightarrow 0.719\ hours\ overtime = 43.15\ minutes$
- $\frac{549\ horses}{117.65\ horses\ per\ hour} = 4.666\ hours \rightarrow 1.666\ hours\ overtime = 1\ hour\ and\ 39.98\ minutes$

This overtime working is not desirable. For this reason, and for the statements in the literature about the M/M/1 model, it can be concluded that the current situation needs improvement.

A possible cause of the fact that $\lambda > \mu$ in the current situation may be that the activity times are not well estimated. Contrary to the other data used for the input, these data are not accurate. However, we have reliable estimates of the most frequently mentioned waiting times by the riders and grooms (30 minutes) and λ. Now, let us use these to find μ and to exclude the fact that the activity times are not well estimated by performing the following calculations:

Queue at arrival

Given: 1.) $W_q = 30\ minutes = 0.5\ hour$

2.) $\lambda = 33\ horse\ trucks\ per\ hour$

Formulas: 1.) $W_q = \frac{\lambda/\mu}{\mu-\lambda}$

2.) $x = \frac{-b+\sqrt{b^2-4ac}}{2a}$ (abc-formula)

Calculation:

$$\frac{33/\mu}{\mu-33} = 0.5$$

$$\frac{33}{\mu} * \frac{1}{\mu-33} = 0.5$$

$$\frac{33}{\mu(\mu-33)} = 0.5$$

$$\frac{66}{\mu(\mu-33)} = 1$$

$$\mu(\mu-33) = 66$$

$$\mu^2 - 33\mu - 66 = 0$$

$$\mu = \frac{-(-33) + \sqrt{33^2 - 4(-66*1)}}{2*1}$$

$$\mu = \frac{33 + \sqrt{1353}}{2} = 34.89$$

Queue at horse inspection

Given: 1.) $W_q = 30\ minutes = 0.5\ hour$

2.) $\lambda = 183\ horses\ per\ hour$

Formulas: 1.) $W_q = \frac{\lambda/\mu}{\mu-\lambda}$

2.) $x = \frac{-b+\sqrt{b^2-4ac}}{2a}$ (abc-formula)

Calculation:

$$\frac{183/\mu}{\mu-183} = 0.5$$

$$\frac{183}{\mu} * \frac{1}{\mu-183} = 0.5$$

$$\frac{183}{\mu(\mu-183)} = 0.5$$

$$\frac{366}{\mu(\mu-183)} = 1$$

$$\mu(\mu-183) = 366$$

$$\mu^2 - 183\mu - 366 = 0$$

$$\mu = \frac{-(-183) + \sqrt{183^2 - 4(-366*1)}}{2*1}$$

$$\mu = \frac{183 + \sqrt{32025}}{2} = 180.97$$

As can be seen above, both service rates are not far from the used rates. In Table 13 this is converted to the number of seconds difference, where t is the activity time.

Queue at	Calculation method	μ	t	Difference
Arrival	Using activity times	28.85	60/28.85 = 2.08	**21.62 seconds**
	Using formulas	34.89	60/34.89 = 1.72	
Horse inspection	Using activity times	117.65	60/117.65 = 0.51	**10.71 seconds**
	Using formulas	180.97	60/180.97 = 0.33	

Table 13 - Difference in seconds of the two calculation methods

From the information in the table it can be concluded that the activity times are not wrongly estimated, and therefore this can be excluded. The deviation of a 21.62 and 10.71 seconds can be explained by the used waiting time of 30 minutes for both queues, which was also estimated by the riders and grooms. In reality, this can, for example, also be 29 or 31 minutes. The information above can be seen as a proof that the estimated activity times of the check-in and the horse inspection have been estimated fairly accurately.

5.3 Improvement option with ambition level I

This Section describes the improvement option with ambition level I. This option has level I, because the complexity level of implementation is low and the techniques used are simple. In Section 5.3.1, the option is introduced. Section 5.3.2 calculates the KPIs. These KPIs are compared with the current situation in Section 5.3.3.

5.3.1 Introduction

This option contains improvements that can easily be put into practice. The complexity level of implementation of this improvement is low, and therefore called 'level I'. The technique used for this option are simple means of communication such as telephone and e-mail. During this study, it became clear that the OC often communicates with the participants through these means. For this reason, this option has been developed. Table 14 shows the approaches for this option to improve the bottlenecks.

Bottleneck	Approach
The unknown arrival times of the horse trucks	Let the competitors choose timeslots and communicate them to the OC
Search for name and stables at check-in	Listing the time slot allocation
Going to the show office and fill in paperwork	Let the competitors mail the completed paperwork in advance
The unknown arrival times at the horse inspection	Let the competitors choose timeslots and communicate them to the OC
Absence of an allocation at the parking lot	Allocate the trucks that need electricity and determine number of electricity poles

Table 14 - Approaches for the option with ambition level I to improve the bottlenecks

With the use of telephone and e-mail the possible timeslots can be communicated to the riders and grooms. When they are aware of the possible time slots, they can indicate to the OC which time slot they prefer to arrive at the event and at the horse inspection. When all the competitors chose two timeslots, the OC or stable manager can make a list with the sequence of names that arrive at each timeslot. By using e-mail, the paperwork can be mailed to the competitors in advance, so that they can arrange it in advance of the event. With this list, the OC knows how many trucks need electricity and how many electricity poles are needed. In addition, they can sketch a basic allocation of the parking lot. With this personal method, t is even possible to call the competitors and ask them if they need electricity and if they are in possession of health papers. However, with this option it is not possible to put an automatic limit on the timeslots and to manipulate it. As a result, in practice it may happen that a majority chooses the same time slot. However, the change in time of the opening of the stables will lead to a smoother distribution of arrival, because there were many riders that indicated that they prefer to arrive in the morning which is not possible in the current situation. In addition, the OC is able to no longer offer a busy timeslot as a choice or they can negotiate with the competitors. As can be seen in Table 14, these approaches are not complex to implement. However, this option also contains some disadvantages. The option with ambition level I has the following pros and cons:

Pros

- Not complex to implement
- Personal method
- Negotiations possible
- All competitors can be reached

Cons

- Lists are not automatically generated
- Automatic limit and manipulation on timeslots not possible
- Possibility of no response
- Modes of transport and amounts unknown

In the next sections, the results of the KPIs are calculated and the comparative analysis is described.

5.3.2 KPI calculation

In this section the five KPIs, determined in Section 5.2, are calculated. To calculate the KPI 'Sojourn time', we first need to estimate the new activity times. As in Section 4.2, this is done using the Three Times Estimates in PERT. Table 15 shows the expected times and variances for the option with ambition level I. This table can be linked to Table 8, where the activity times for the current situation are estimated. However, these are mainly estimated on the basis of the experiences of the riders and grooms. We have estimated the times in Table 15 in consultation with the OC, as this situation has not yet occurred in practice. The activity times of Table 15 are compared with the times in Table 8 in the next section. All values in the table are in minutes.

Activity i	Optimistic a	Most likely m	Pessimistic b	Expected time $t_{exp}^{i} = (a + 4m + b)/6$	Variance $\sigma_i^2 = [(b\text{-}a)/6]\hat{}2$
A	1	2	8	2.83	1.36
B	0.5	1.5	4	1.75	0.34
C	25	50	70	50	44.44
D	1	5	15	6	5.44
E	1	7	20	8.17	10.02
F	0.25	0.45	1	0.51	0.02
Total	**28.75**	**65.95**	**118**	**69.26**	**61.62**

Table 15 - Expected times and variances for the option with ambition level I (in minutes)

As can be seen in Table 15, the expected activity times and variances are lower than in the current situation. The sojourn time is 69.26 minutes, which is also included in Table 16. In this table, the other KPIs are also included. These KPIs are calculated using the formulas of Section 3.3.2.

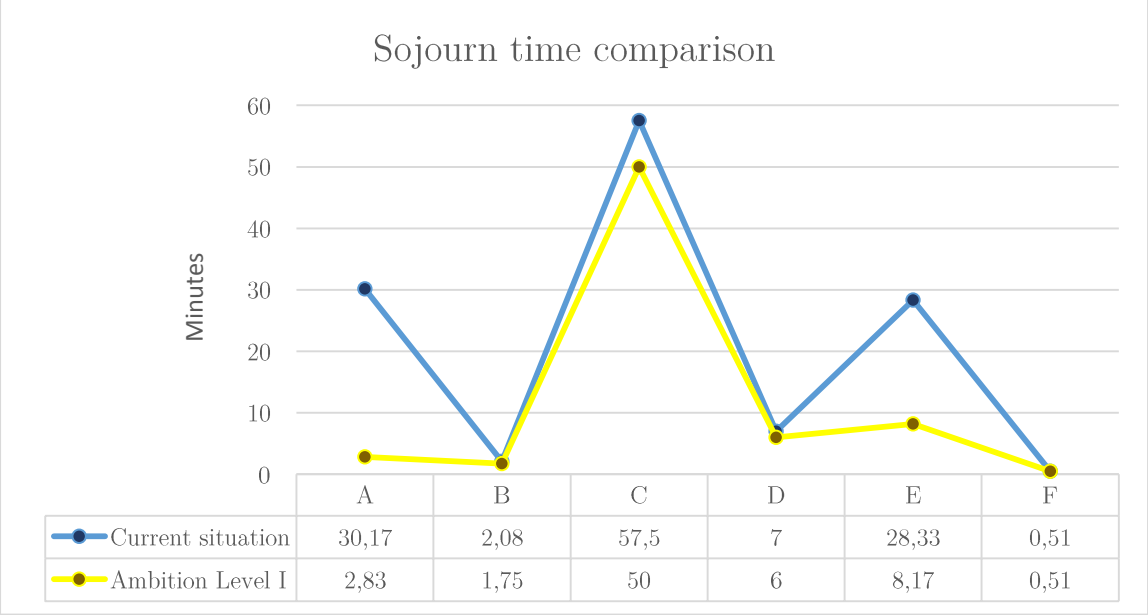
KPI	Input	Calculation	Result
Sojourn time	See Table 15	See Table 15	69.26 minutes
L_q^A	$\lambda = 165/8 = 20.63$	$\frac{0.602^2}{1-0.602}$	0.911 horse trucks
	$\mu = 60/1.75 = 34.29$		
W_q^A	$L_q^A = 0.911$	$\frac{0.991}{20.36} * 60\ minutes$	2.655 minutes
L_q^{HI}	$\lambda = 549/5 = 109.8$	$\frac{0.933^2}{1-0.933}$	12.992 horses
	$\mu = 60/0.51 = 117.65$		
W_q^{HI}	$L_q^{HI} = 12.992$	$\frac{12.992}{109.8} * 60\ minutes$	7.099 minutes

Table 16 - Results of the KPIs for the option with ambition level I

Table 16 shows that the queue at arrival is practically gone. The average number of trucks in the queue (L_q^A) is 0.911, which is on average less than one truck. The corresponding waiting time is only 2.655 minutes. The queue at the horse inspection is improved to 12.992 horses, with an average waiting time of 7.099 minutes. The waiting times in Table 16 can be compared to the waiting times in Table 15. Waiting at arrival at the event contains 2.66 minutes according to Table 16 and 1.75 minutes according to Table 15. For the waiting time at the horse inspection this is 7.10 minutes and 8.17 minutes respectively. Both waiting times have a difference of only +/- 1 minute, which leads to the conclusion that the estimates are reasonably reliable. In the next section the KPIs are compared to the current situation.

5.3.3 Comparative analysis

To measure the improvement of the option with ambition level I, we need to compare the current situation with the option. Because the sojourn time is the only KPI calculated for the current situation, only this KPI can be compared quantitatively. However, for the other KPIs it can be concluded that these have been improved compared with the current situation, as $\lambda < \mu$. Figure 22 shows the sojourn time comparison. As the sojourn time is the total expected time of activity A till F, the times of each activity of the process in the current situation and in the new situation are pointed out. It should be kept in mind, as calculated in Section 4.2, that there exist a chance that the sojourn time of the current situation will be exceeded. These probabilities can be found in Table 9 and Figure 20.



	A	B	C	D	E	F
Current situation	30,17	2,08	57,5	7	28,33	0,51
Ambition Level I	2,83	1,75	50	6	8,17	0,51

Figure 22 - Activity times comparison for the option with ambition level I

Figure 22 shows that the activity times of A and E have the biggest improvements, which are the queues at the arrival and at the horse inspection respectively. Activities B till D are also improved in means of duration. Activity F (the horse inspection) remains the same, because there are no changes to the current situation of this activity. The horse inspection itself is not a bottleneck. The sojourn time of the current situation, calculated in Section 5.2, is 125.59 minutes. The sojourn time of this option is 69.26 minutes, which is an improvement of 44.85%. Therefore, it can be concluded that the option with ambition level I already represents a major improvement on the current situation.

5.4 Improvement option with ambition level II

This Section describes the option with ambition level II. This option has level II, because the complexity level of implementation is medium. Also the technique used is not as simple as the techniques of improvement option with ambition level I. In Section 5.4.1, the option is introduced. Section 5.4.2 highlights the KPI calculation. The results of the KPIs are compared with the current situation in Section 5.4.3.

5.4.1 Introduction

The option with ambition level II contains improvements that are less easy to put into practice. The complexity level of these improvements is medium, and therefore called 'level II'. The technique used for this option is the subscription page of the Koninklijke Nederlandse Hippische Sport (KNHS). Through this page all Dutch riders register for international competitions in the current situation. Table 17 shows the approaches for this option to improve the bottlenecks.

Bottleneck	Approach
The unknown arrival times of the horse trucks	Let the competitors choose timeslots during subscription at KNHS page
Search for name and stables at check-in	KNHS page provides a list of the time slot allocation
Going to the show office and fill in paperwork	Let the competitors fill in the paperwork digital at KNHS page
The unknown arrival times at the horse inspection	Let the competitors choose timeslots during subscription at KNHS page
Absence of an allocation at the parking lot	Let the competitors indicate the mode of transport and the KNHS page will provide an allocation of the parking lot

Table 17 - Approaches for the option with ambition level II to improve the bottlenecks

It is possible to implement the timeslots on the subscription page of the KNHS and let the Dutch competitors choose the slots they prefer. When all the competitors chose two timeslots, the KNHS page can automatically provide a list with the sequence of names that arrive at each timeslot.

In addition, the paperwork can be filled in digital by indicating if you need electricity and if you are in possession of health papers. Finally, by letting the competitors indicating their mode of transport at the KNHS page, the page can provide an allocation of the parking lot. With this allocation, the OC knows how many electricity poles are needed and which trucks need to park where. However, the KNHS page is only for Dutch competitors. Therefore, only around 50% of the competitors is reached with this option. It is an idea to combine this option with the option with ambition level I and reach the non-Dutch competitors by e-mail or telephone. With this option, it is necessary for the KNHS and the OC to join forces and for the OC to convince the KNHS of the advantages of this cooperation. This option has the following pros and cons:

Pros

- Lists are automatically generated
- Automatic limit on timeslots and manipulation possible
- No possibility of no response
- Modes of transport and amounts known

Cons

- Medium complexity of implementation
- Only reaching Dutch competitors (around 50%)
- Necessity of convincing KNHS

In the next sections, the results of the KPIs are calculated and the comparative analysis is described.

5.4.2 KPI calculation

By implementing the timeslot allocation system at the KNHS subscription page, all Dutch riders are forced to use the system and provide the information needed. The results of this option will still not be optimal, because the competitors in Dutch horse shows often consist of 50% Dutchmen. The activity times for this option are obtained by using the Three Times Estimates in PERT. Table 18 shows the expected time for each activity and the corresponding variances. All values in the table are in minutes.

Activity i	Optimistic a	Most likely m	Pessimistic b	Expected time $t_{exp}^{i} = (a + 4m + b)/6$	Variance $\sigma_i^2 = [(b\text{-}a)/6]\hat{}2$
A	1	1.5	5	2	0.25
B	0.5	1.5	3	1.58	0.17
C	25	45	65	45	44.44
D	1	4	10	4.5	2.25
E	1	5	20	6.83	10.03
F	0.25	0.45	1	0.51	0.02
Total	28.75	57.45	104	60.42	57.16

Table 18 - Expected times and variances for the option with ambition level II

As can be seen in Table 18, the total expected time is 60.42 minutes. Which means that the expected activity times and variances are lower than for option I. The sojourn time is included in Table 19, which contains the results of all KPIs.

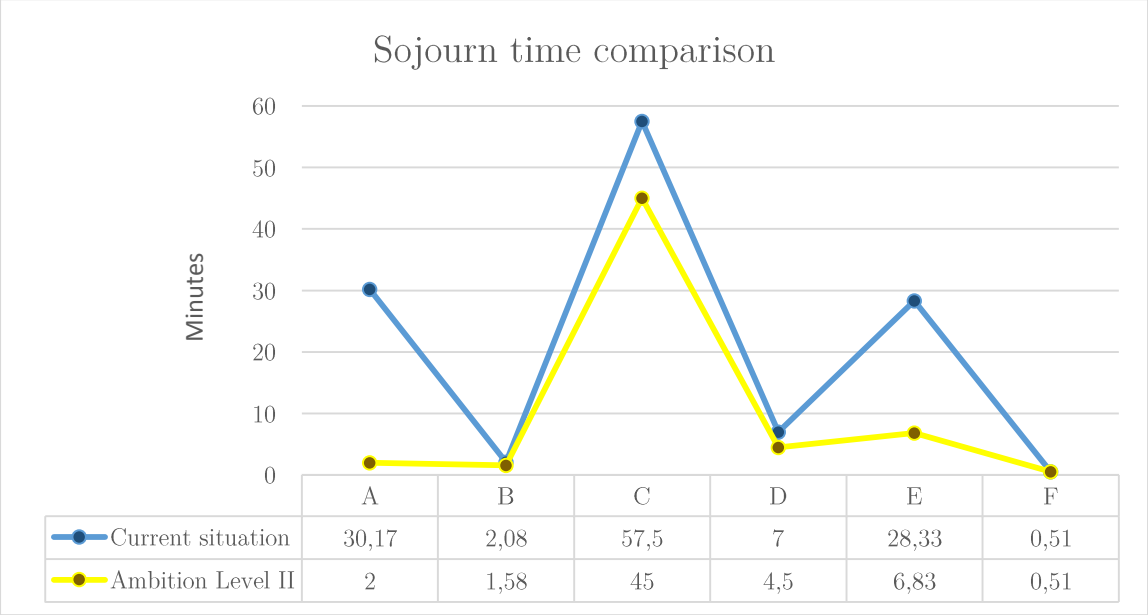
KPI	Input	Calculation	Result
Sojourn time	See Table 18	See Table 18	60.42 minutes
L_q^A	$\lambda = 165/8 = 20.63$ $\mu = 60/1.58 = 37.97$	$\frac{0.536^2}{1 - 0.536}$	0.619 horse trucks
W_q^A	$L_q^A = 0.619$	$\frac{0.619}{20.36} * 60\ minutes$	1.824 minutes
L_q^{HI}	$\lambda = 549/5 = 109.8$ $\mu = 60/0.51 = 117.65$	$\frac{0.933^2}{1 - 0.933}$	12.992 horses
W_q^{HI}	$L_q^{HI} = 12.992$	$\frac{12.992}{109.8} * 60\ minutes$	7.099 minutes

Table 19 - Results of the KPIs for the option with ambition level II

Table 19 shows that the queue at arrival is been reduced to 0.619 horse trucks. The corresponding waiting time is 1.824 minutes. The queue at the horse inspection and the corresponding waiting time is the same as for the option with ambition level I. This can be explained by the fact that the number of horses, the available time, and the duration of the horse inspection do not change in this study. Again, the waiting times in Tables 18 and 19 can be compared. Waiting at arrival at the event contains 1.82 minutes according to Table 19 and 1.58 minutes according to Table 18. For the waiting time at the horse inspection this remains 7.10 minutes in Table 19. In Table 19 the waiting time is 6.83 minutes. Therefore, it can be concluded that the waiting times correspond, with a small deviation by the estimate. In the next section the KPIs are compared to the current situation.

5.4.3 Comparative analysis

As stated before, for the comparative analysis, the results of the KPIs of the option are compared to the current situation. Again, the sojourn time is the only KPI compared with the current situation. For the other KPIs it can be concluded that these have been improved compared with the current situation, as $\lambda < \mu$. Figure 23 shows the activity times comparison, where the times of each activity in the current situation and in the new situation are pointed out, taking into account that there exist probabilities that the sojourn time will be exceeded (see Table 9 and Figure 20).



	A	B	C	D	E	F
Current situation	30,17	2,08	57,5	7	28,33	0,51
Ambition Level II	2	1,58	45	4,5	6,83	0,51

Figure 23 - Activity times comparison for the option with ambition level II

As can be seen in the figure, the activity time of A has again the biggest improvement. Activities B till E are also improved in means of duration. The sojourn time of the current situation, calculated in Section 5.2, is 125.59 minutes. This means that the KPI is 65.17 minutes less than in the current situation, which results in an improvement of 51.89% compared to the current situation.

5.5 Improvement option with ambition level III

This Section describes the option with ambition level III. This option has level III, because the complexity level of implementation is high and the techniques used are complicated. In Section 5.5.1, the option is introduced. Section 5.5.2 calculates the KPIs. These KPIs are compared with the current situation in Section 5.5.2.

5.5.1 Introduction

The complexity level of the improvements for this option is high, and therefore called 'level III'. The technique used for this option is an application (app) for mobile devices. Through this page all Dutch

riders register for international competitions in the current situation. Table 20 shows the approaches for this option to improve the bottlenecks.

Bottleneck	Approach
The unknown arrival times of the horse trucks	Let the competitors choose timeslots provided by the app
Search for name and stables at check-in	The app provides a list of the time slot allocation
Going to the show office and fill in paperwork	Let the competitors fill in the paperwork digital by using the app
The unknown arrival times at the horse inspection	Let the competitors choose timeslots provided by the app
Absence of an allocation at the parking lot	Let the competitors indicate the mode of transport and the app will provide an allocation of the parking lot

Table 20 - Approaches for the option with ambition level III to improve the bottlenecks

This app has the same functionalities as the implementation at the KNHS page. However, the range with this app is larger because foreign riders can also use the app. There is a chance of no response, but in this study it is assumed that everybody uses the option. In contrast with the KNHS page, the app can implement more possible functionalities, but this is out of the scope of this study. Through this app all riders can choose the timeslots, fill in the paperwork, and indicate the mode of transport. The app can provide a list with the sequence of names that arrive at each timeslot and an allocation of the parking lot. With this allocation, the OC knows how many electricity poles are needed and which trucks need to park where. However, designing and developing an app cost money. Appendix VIII shows an example of a design for such an app. The option with ambition level III has the following pros and cons:

Pros

- Lists are automatically generated
- Automatic limit on timeslots and manipulation possible
- Modes of transport and amounts known
- Reaching all competitors

Cons

- High complexity
- Additional costs
- Possibility of no response

5.5.2 KPI calculation

In this section the five KPIs, determined in Section 5.2, are calculated. To calculate the sojourn time, we first need to estimate the new activity times. As in Section 4.2, this is done using the Three Times Estimates in PERT. Table 21 shows the expected times and variances for the option with ambition level III. All values in the table are in minutes.

Activity i	Optimistic a	Most likely m	Pessimistic b	Expected time $t_{exp}^{i} = (a + 4m + b)/6$	Variance $\sigma_i^2 = [(b\text{-}a)/6]\hat{}2$
A	0	1	2	1	2.25
B	0.5	1	3	1.25	0.56
C	20	35	60	36.67	44.44
D	1	3	5	3	0.44
E	1	4	15	5.33	5.44
F	0.25	0.45	1	0.51	0.02
Total	22.75	44.45	86	47.76	53.15

Table 21 - The expected times and variances for the option with ambition level III

As can be seen in Table 21, the sojourn time is 47.76 minutes. It is striking that the variance for activity C is large compared to the others. This is because the duration of this process is very different for each truck. It mainly depends on the productivity of the groom works and the number of horses taken. This is also a factor that cannot be influenced. The sojourn time is included in Table 22, which shows the results of the KPIs.

KPI	Input	Calculation	Result
Sojourn time	See Table 21	See Table 21	47.76 minutes
L_q^A	$\lambda = 165/8 = 20.63$	$\frac{0.430^2}{1 - 0.430}$	0.324 horse trucks
	$\mu = 60/1.25 = 48$		
W_q^A	$L_q^A = 0.324$	$\frac{0.324}{20.36} * 60\ minutes$	0.955 minutes
L_q^{HI}	$\lambda = 549/5 = 109.8$	$\frac{0.933^2}{1 - 0.933}$	12.992 horses
	$\mu = 60/0.51 = 117.65$		
W_q^{HI}	$L_q^{HI} = 12.992$	$\frac{12.992}{109.8} * 60\ minutes$	7.099 minutes

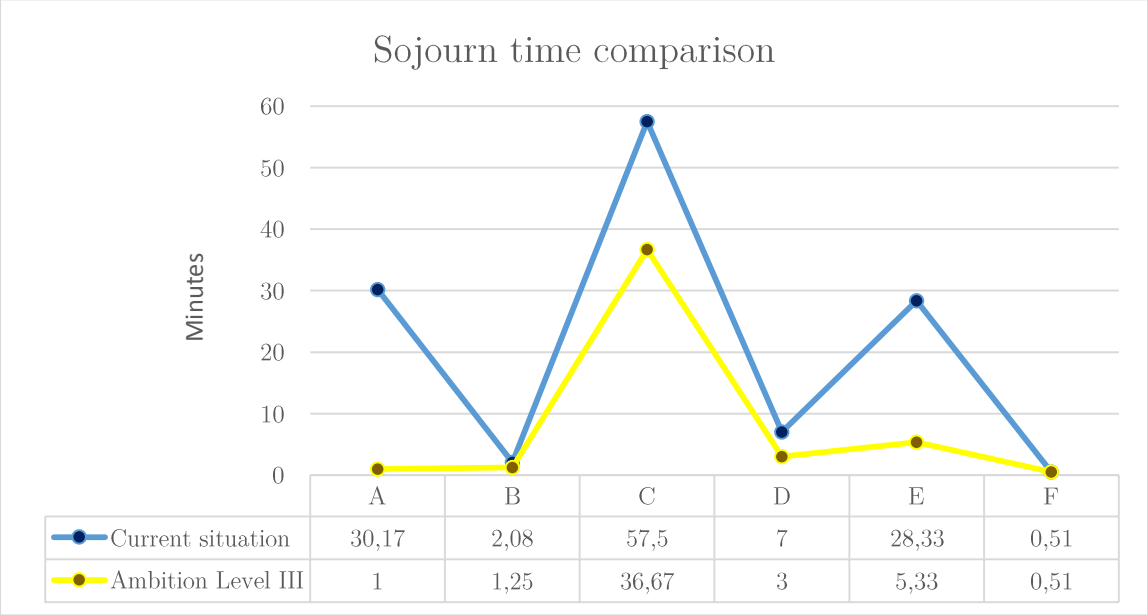
Table 22 - Results of the KPIs for the option with ambition level III

Table 22 shows that the queue at arrival is been reduced to 0.324 horse trucks. The corresponding waiting time is 0.955 minutes, which is less than one minute. The queue at the horse inspection and the corresponding waiting time remains the same as for the options with ambition levels I and II.

Again, the waiting times in Tables 21 and 22 correspond, with a small deviation by the estimate. In the next section the KPIs are compared to the current situation.

5.5.3 Comparative analysis

Compared to the expected times in the current situation, this option has a big improvement. As stated before, because the sojourn time is the only KPI calculated for the current situation, only this KPI can be compared quantitatively. The other KPIs also have been improved compared with the current situation, as $\lambda < \mu$. Figure 24 shows the activity times comparison, where the times of each activity in the current situation and in the new situation are pointed out, taking into account that there exist probabilities that the sojourn time will be exceeded (see Table 9 and Figure 20).



	A	B	C	D	E	F
Current situation	30,17	2,08	57,5	7	28,33	0,51
Ambition Level III	1	1,25	36,67	3	5,33	0,51

Figure 24 - Activity times comparison for the option with ambition level III

As can be seen in Figure 24, the activity time of A is almost reduced to nihil. Activities B till E are also improved in means of duration. As stated before, activity F does not change compared to the current situation, because the procedure of the horse inspection remains the same. According to the figure, the total expected time of the arrival process is more than one hour less than in the current situation (a difference of 77.83 minutes), which is a big improvement of the arrival process. This results in an improvement of 61.97% compared to the current situation.

5.6 Other options

In this study, there are several options considered to improve the arrival process. One of these options was to divide the queue into two queues. Two rows of trucks will arrive at the competition, what will speed up the process. However, at several locations the possibilities for this were examined, and it appeared that there is often not enough space to realize this. For example, the Betonweg at CSI Twente is too narrow to allow two trucks to arrive next to each other (See Figure 4). This is also the case with CSI2* Wierden, CSI3* Tubbergen, and CSI4* Ommen.

Another alternative, obtained by analyzing other international horse shows, which could be a solution to the queue is the use of quads with trailers. These kind of flat cars can help unload by getting things from the horse trucks to the stables complex faster. The horse trucks could drive directly to the allocated parking place and unload from there, so they would take a shorter route and thus save time. However, this is not a feasible alternative for CSI Twente, because they have a shortage of volunteers and do not want to incur any extra costs. These quads and trailers cost money to rent and will need drivers.

In addition, the option to deploy a helper at the check-in is considered. In this situation, the stable manager does not have to find the horse trucks on the list all by himself. This changes the M/M/1 model to an M/M/2 model, which will speed-up the check-in process step by using two servers. However, this is not feasible in reality, because many changes are made on the spot itself. In addition, there is room for 25 horse trucks to unload. Even if the check-in goes faster, there will still be a queue when more than 25 trucks arrive. They will not be able to be forwarded immediately. The change of the M/M/1 model to an M/M/2 model is also considers for the horse inspection process step. However, an extra VET leads to extra costs, which is not desired by the OC.

Finally, the use of signs indicating the waiting time at the arrival of the event, as used by the external supervisor in one of his own projects, was examined. However, this is not suitable for this study, because the grooms indicated that, regardless of the waiting time stated on the board, they will always connect in the queue. They won't go for a coffee or anything like that, because the horses are still in the horse truck.

5.7 Conclusions

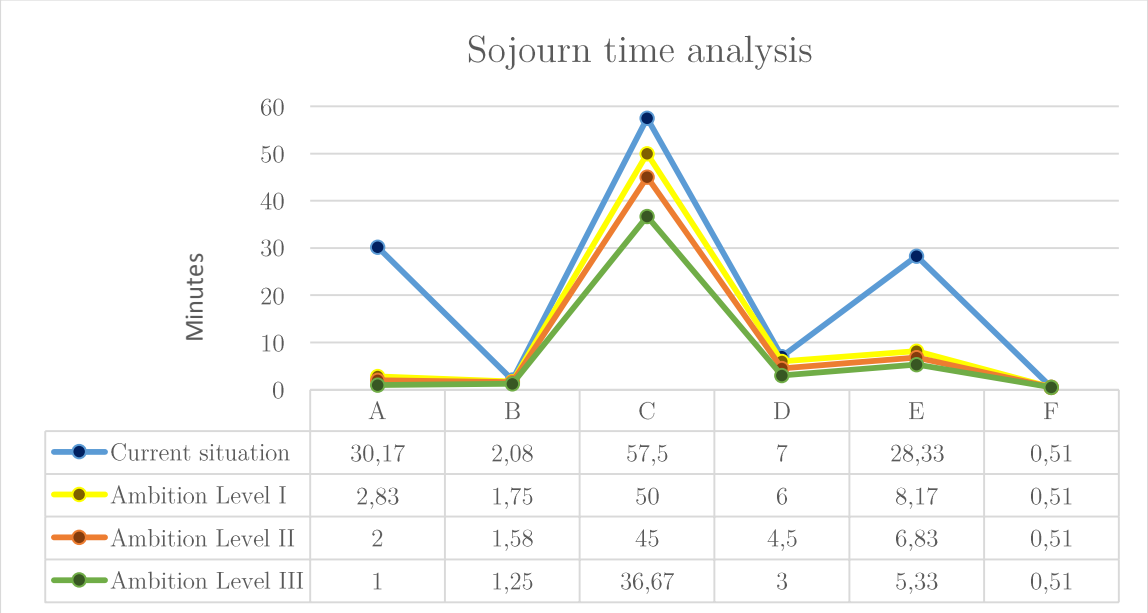
This chapter gives an answer on the research question '*What are improvement options for CSI Twente?*'

The improvement options for CSI Twente to improve the logistics of the arrival process all contain a timeslot allocation system. With this system, riders and/or grooms are able to choose two timeslots. These time slots are for both the arrival at the event and the horse inspection. This chapter provides three improvement options, using this timeslot allocation system, with different levels of ambition. Each improvement option puts five information points forward from 'during the event' to 'before the event' as shown in Figure 21, to tackle the five bottlenecks. By using the timeslot allocation system implemented in the options, the stable manager knows which trucks he can expect at what time. This enables him to find out in advance which stables belong to the arriving trucks and send them in one line to the right stables. This optimizes the inefficient process step of the check-in procedure (see Figure 6). Also the unloading process is improved. At each option, the grooms no longer need to fill in the papers at the show office and indicate whether they need electricity and if they are in possession of health papers, as this information is all obtained before the start of the event. This results in a removal of the detour that is shown in Figure 7. This process step will also be faster because the stable manager has insight in the arrival times and therefore can estimate better where to put each truck. This will, in many cases, reduce the distance that the grooms have to walk from truck to their stables. For the activity 'parking the horse truck' there is a more organized parking lot. In the current situation, grooms were forced to choose a parking space themselves, often in disagreement over the electricity poles. These were frequently all occupied, or inaccessible due to chaotic parking. In the new situation, the OC can obtain how many trucks need electricity and therefore the amount of electricity poles needed. For the more complex options (with ambition level II and III), they even knows what modes of transport will be used and the corresponding quantities. This makes it possible to allocate the parking lot in advance of the event and to ensure that there are enough electricity poles available. Thereby, it is assumed that the OC arrange supervision at the parking lot. The arrival at the horse inspection also improved considerably with the use of the timeslot allocation system. The VET knows which horses he can expect at what time. Like the queue of horse trucks, this queue has been reduced. In order to quantify these improvements of the options compared to the current situation, five KPIs have been drawn up. These KPIs are calculated for each option. For the current situation it was only possible to quantify the KPI 'Sojourn time', because for the other KPIs the model used stated that the queues will explode. Therefore it can be concluded that the options improve these KPIs, as they do not contain exploding queues. Table 23 summarizes the results of the sojourn time improvement. In this table each option is compared to the current situation.

Option	Sojourn time	Improvement (compared to current situation)
Ambition Level I	69.26 minutes	44.85%
Ambition Level II	60.42 minutes	51.89%
Ambition Level III	47.76 minutes	61.97%

Table 23 - Summary of the sojourn time improvements compared to the current situation

Depending on the ambition level of the OC, the improvement percentages in the table can be expected. The option with ambition level I has an improvement of 44.85%, the option with ambition level II an improvement of 51.89%, and the option with ambition level II has the highest improvement of 61.97% compared to the current situation. Figure 25 shows a graphical representation of the sojourn times divided in the activity times of each activity of the arrival process.



	A	B	C	D	E	F
Current situation	30,17	2,08	57,5	7	28,33	0,51
Ambition Level I	2,83	1,75	50	6	8,17	0,51
Ambition Level II	2	1,58	45	4,5	6,83	0,51
Ambition Level III	1	1,25	36,67	3	5,33	0,51

Figure 25 - Graphical representation of the sojourn time analysis

As can be seen in the figure, the queues and corresponding waiting times (activity A and E) have the highest improvements. The waiting time at arrival is even reduced till almost nihil. To conclude that the options with the different ambition levels improve the arrival process compared to the current situation, Table 24 is inserted. This table includes the number of horse trucks waiting in the queue at arrival (L_q^A) and horses at the horse inspection (L_q^{HI}), as well as the waiting time at arrival (W_q^A) and at the horse inspection (W_q^A) for every situation.

KPI	Current situation	Ambition level I	Ambition level II	Ambition level III
L_q^A	Exploding queue	0.911 horse trucks	0.619 horse trucks	0.324 horse trucks
W_q^A	Exploding queue	2.655 minutes	1.824 minutes	0.955 minutes
L_q^{HI}	Exploding queue	12.992 horses	12.992 horses	12.992 horses
W_q^{HI}	Exploding queue	7.099 minutes	7.099 minutes	7.099 minutes

Table 24 - Summary of KPI 2 till 5

As can be seen in Table 24, the exploding queue in the current situation is improved by using one of the options. The greatest improvement is obtained by using the option with ambition level III, where the average number of horse trucks is 0.324 with a corresponding average waiting time of 0.955 minutes by arrival and the average amount of horses of 12.922 and a corresponding waiting time of 7.099 minutes at the horse inspection. The average amount of horses and the average waiting time at the horse inspection are the same for each option. This is because the number of horses, the available time, and the duration of the horse inspection do not change in this study. However, the higher the ambition level, the lower the average number of trucks in the queue at arrival and the lower the corresponding waiting time. In this chapter, it can be concluded that the three options with different ambition levels are improvements compared to the current situation.

6. Conclusions and recommendations

In this final chapter we conclude this study. Section 6.1 provides the final conclusions of this study based on the results found in Chapter 5, followed by the recommendation to the OC of CSI Twente in Section 6.2. In Section 6.3 we provide recommendations for other international horse shows. Section 6.4 desribes the limitations, after which Section 6.5 ideas provide for future research. Finally, Section 6.6 reflects on the process as a student.

6.1 Conclusions

The aim of this section is to answer the research question of this study:

How can we improve the logistics of the arriving horse trucks at the show, in order to reduce waiting times and increase safety and satisfaction?

The answer on this question is to implement one of the three improvement options with different ambition levels using a timeslot allocation system. From the literature it became clear that making the service and arrival rates more constant will result in a reduction of queues and a better overall perception of the event. According to this and to the analysis of the current situation, the three option with different ambition levels using a timeslot allocation system are developed. These options are chosen, because each option tackles the five bottlenecks identified in Chapter 4 by combining the problem cluster, the stakeholders' view, the current situation analysis, and the activity times. With the use of one of these improvement options, riders/grooms can choose a timeslot they prefer to or expect to arrive for both the arrival at the event and the horse inspection. By using this timeslot allocation system implemented in the options, the stable manager knows which trucks he can expect at what time. This enables him to find out in advance which stables belong to the arriving trucks and send them in one line to the right stables. In addition, the stable manager can estimate better where to put each truck, which reduces the distance that the grooms have to walk from truck to their stables. The grooms no longer need to fill in the papers at the show office to indicate whether they need electricity and if they are in possession of health papers, as this information is all obtained through using an option. In addition, there will be a more organized parking lot. In the current situation, grooms were forced to choose a parking space themselves, often in disagreement over the electricity poles. These were frequently all occupied, or inaccessible due to chaotic parking. In the new situation, the OC can obtain how many trucks need electricity and therefore the amount of electricity poles needed. For the more complex options (with ambition level II and III), they even knows what modes of transport will be used and the corresponding quantities. This makes it possible to allocate the parking lot in advance of the event and to ensure that there are enough electricity poles available. This will also result in safer positioning of the horse trucks at the parking lot. Thereby, it is assumed that the OC arrange supervision at the parking lot. The queue at the horse inspection is also improved considerably with the use of the timeslot allocation system. The VET

knows which horses he can expect at what time. Like the queue of horse trucks, this queue has been reduced. The improvement options allow the entire process, from arrival at the event to the inspection of the horses, to run without many interruptions.

Option	Sojourn time	Improvement (compared to current situation)
Ambition Level I	69.26 minutes	44.85%
Ambition Level II	60.42 minutes	51.89%
Ambition Level III	47.76 minutes	61.97%

Taken into account, the duration of the whole arrival process, using the option with ambition level I will improve the current situation with 44.85% and using the option with ambition level II with 51.89%. The greatest improvement is gained by using the option with ambition level III. This option has an improvement of 61.97% on to the current situation.

KPI	Current situation	Ambition level I	Ambition level II	Ambition level III
L_q^A	Exploding queue	0.911 horse trucks	0.619 horse trucks	0.324 horse trucks
W_q^A	Exploding queue	2.655 minutes	1.824 minutes	0.955 minutes
L_q^{HI}	Exploding queue	12.992 horses	12.992 horses	12.992 horses
W_q^{HI}	Exploding queue	7.099 minutes	7.099 minutes	7.099 minutes

In addition, the option with ambition level III will reduce the queue at arrival (L_q^A) to an average of 0.324 horse trucks and an average waiting time (W_q^A) of 0.955 minutes. For the queue at the horse inspection, it reduces the average waiting time (W_q^{HI}) to 7.099 minutes with an average of 12.992 horses in the queue (L_q^{HI}). The average number of horses in the queue at the horse inspection and the corresponding average waiting time are the same for the options with ambition level I and II. However, the average number of horse trucks in the queue at arrival and the corresponding average waiting times in this queue are higher, where the ambition levels are lower. Nevertheless, the use of each option will result in an improvement of the current situation, which experience exploding queues and a high sojourn time of the entire arrival process. The improvement options ultimately results in more satisfied fire brigade and police after the inspection, and more satisfied riders, grooms, and horses as the logistics of the entire arrival process are improved.

6.2 Recommendations for the OC

Besides the introduction of this new system, some recommendations are made to the OC for an optimal functioning of the improvement options. The following is recommended to the OC of CSI Twente:

- Change the time for the opening of the stables. In the current situation the stables open at 1:00 pm. It is recommended to change this in 9:00 am. This gives more possible timeslots to the system and will result in an improved distribution of participants' arrival schedules.
- Use timeslots of 1 hour for arrival. A spread of 1 hour gives enough optional time slots (8) in one day and a small chance that the participants will all arrive at the same time within one time slot.
- Use timeslots of 30 minutes for horse inspection. Because the horse inspection takes place over a shorter period of time (5 hours), the time slots are also smaller than the timeslots used for arrival. In addition, it is feasible to let the maximum amount of horses (6) be inspected within one timeslot.
- Use limits of 25 horse trucks for each timeslot for arrival. The limit depends on the number of horse trucks the show can handle to provide service without waiting times. The analysis of the current situation at CSI Twente showed that there is place for 25 horse trucks to unload at the stable complex. All the 165 trucks can be served with this limit, because the maximum is set to 200 horse trucks in 8 hours.
- Use limits of 58 horses for each timeslot for the horse inspection. The limit depends on the number of horses the VET can handle to provide service without waiting times. All the horses can be served with this limit, because the maximum is set to 580 horses in 5 hours.
- Appoint someone to provide guidance at the parking lot. The OC have to place one traffic controller with a map at the parking lot on the day of arrival, who will guide the trucks to their place. This will lead to safer, less chaotic, and more efficient parking.
- Change the day of the horse inspection. In the current situation the horse inspection takes place on Thursday. However, in order to make this process step more compatible and to avoid queues, it is recommended to change this day to Wednesday. In addition, the riders and grooms indicated that they prefer the inspection to be on Wednesday.
- Optional: Change the location of the horse inspection. According to the riders and grooms, the current location is chaotic and confusing.

6.3 Recommendations for other horse shows

This research is new, innovative, and started from sketch. As mentioned earlier, there is no literature available of on (international) horse shows. In addition, no scientific research has been done before into the logistics of such an event. For the above reasons this research is of both practical as theoretical relevance for other horse shows. This whole research can be seen as an action plan for other horse shows by implementing and using the app. However, there are also some specific recommendations for the logistics of a horse show, whether or not the improvement options are used. These are the following:

- Keep a lot of space for unloading around the stable complex. As mentioned in Chapter 2 by the stable manager, a big advantage of the process by CSI Twente is the space they own for handling the unloading around the stables. The more space there is, the less the waiting time will be.
- First things first. This recommendation find its origin also in Chapter 2. The stable manager from CSI Twente tells the grooms/riders to first unload everything and to park the truck and afterwards to do the paperwork at the show office. This also reduces the waiting time.
- Use a pencil. The last recommendation gained during the interview with the stable manager is that he uses a pencil and a gum by developing the stable plan. This makes it flexible for changes and saves time in the end.
- Volunteers are always a good idea. The help of volunteers during the unloading process can have an advantage. This will speed up the unloading process and reduce the waiting time.
- Keep municipality satisfied. During this study, the municipality was often dissatisfied with the progress of certain matters. They want to have certain information on time, such as drawings and tent books, so that they can complete the permit. For this reason, it is strongly recommended to get in touch with the municipality early and keep them continuously up to date.

Despite these useful tips, it is a goal in the future that one day all shows will use the option with ambition level III and there are hardly any queues in the arrival process.

6.4 Limitations

Although this study shows positive results, it also has some limitations. One of the largest limitations was the lack of available literature. There was - to the best of our knowledge - no literature available about horse shows. We also could not find literature about the logistics of such an event.
Another limitation was the lack of historical data on waiting times. This forced us to estimate the activity (and waiting) times with the help of the Three Times Estimates in PERT and the experiences of the riders and grooms. This makes the results inaccurate and not completely reliable.

In addition, it is assumed that the weather is good. The reason for this assumption is the month in which the event takes place, i.e. June. However, there is a chance that the weather is bad and the unloading cannot take place around the stables, but is moved to the parking lot. For this research this will mean that the times of activity C and D will differ and that the order of the process is different. In this situation, the horse truck is first parked and then unloaded.

Another assumption is that the groom does all the activities in the arrival process. However, at some stables the rider also helps or even does all the work himself. In addition, it is assumed that all competitors use the improvement options provided. In reality it is possible that riders and grooms are not convinced about the advantages of the options and they will not use the improvement options.

In this research, we only interviewed 10 riders and 10 grooms. However, there were 241 riders and therefore around 250 grooms present at the show. As a result, only a limited amount of opinions have been taken into account in the study. However, this was not possible due to time constraints.

6.5 Further research

In this research, the activity times of the process activities are mostly estimated. For further research, this study can be adapted with real-time data. By doing fieldwork and measuring the activity times at CSI Twente the results can differ from the results in this study. This proposal for further research is, based on our opinion, the most recommended, as it can show accurate results of the current situation. Therefore, it can demonstrate that improvements are necessary and that the bottlenecks are correct. However, it is proven in this study that the estimates are reliable.

In addition, this study provides three options using time slots allocation. However, due to time constraints, it was not possible to implement one of the options. For this reason it is advised, for further research, to implement the options and analyze the results in practice. For the options with ambition levels II and III, this can be done with a pilot version for one international show and a group of riders using it. If the results of the pilot are positive, it is advised to use the option for other horse shows that are familiar with the problem of queues in the arrival process. Thereby, the improvement options can also be extended with more functions. An example is to implement the accreditation.

In addition, further research into the logistics of such events is recommended, as this has not been researched before. For example, a study could be carried out into the logistics of the shavings,

which is briefly discussed in section 2.2. There is a storage of shavings in the stable complex, but riders and grooms indicated that they would rather have the bale with shavings already in the stable at arrival, so that they do not have to pick it up themselves. However, the need for this research is not high and therefore it is not highly recommended.

Finally, further research can be done into the stable layout. This could be based on the order of arrival of the trucks. However, the preferences of riders and grooms must be taken into account and the fact that stallions cannot be stabled next to mares. This research can become complex, because you have to deal with continuous changes and unattainable preferences. For these reasons, this study is not very recommended either.

6.6 Personal reflection

A master title is the highest attainable level for a student, which does not make it easy to obtain it. There will be several obstacles in your path, which you have to learn to deal with. You always pass failure on your way to success. For me, the first obstacle was finding a place to graduate. I have been in contact with several companies, but I was told every time that I did not come at the right time for them. This was because I would not start in the most common period. When I told a friend about this, she came up with the proposal to carry out my master thesis at her father's company, called Nijhof-Wassink. Nijhof-Wassink is the transport arm of Nijhof-Wassink Group and is responsible for the transportation of dry and liquid bulk products by road, rail, and water. The company has branches in the Netherlands, Belgium, Germany, Poland, and Hungary. I was very interested and motivated to start at this company and be part of such a big organization. My friend arranged a meeting with the Logistics Manager of the company on September 5th and within one week everything was arranged and I could start my project plan. The objective of the research was to design a plan to get a more optimal transport planning for the division Fuel Distribution. The company wanted to know if it is feasible to transfer the planning in Excel to the planning software ORTEC. For this reason, the main research question was: Is the planning software ORTEC suitable for a more optimal planning of Fuel Distribution than the current situation offers? As ambitious as I was, I wrote the entire plan, including the action plan, in the shortest possible time. Eight weeks after my first meeting at Nijhof-Wassink, I mailed the project plan to my then graduation supervisor Leo van der Wegen and to my supervisor at Nijhof-Wassink, called Martin Pastink. Nevertheless, I did not get such good news back. A representative of ORTEC had visited the company and, in short, largely carried out my assignment. It was a big setback, but okay; that's life. The only thing I could do was put my shoulders under it and look for something new. So, my journey continued..

After the big disappointment and the poor treatment of Nijhof-Wassink I decided to make a total change regarding my research. The more you like something, the more motivated you are. So that's how I decided, as a fanatical horse rider, to approach horse-related organizations. I contacted Equestrian Centre Peelbergen, Sentower Park, Tops International Arena, Hippisch Centrum vliegveld Twente, CSI Eindhoven, and CSI Twente. The latter became the place where I can make my hobby and sports my thesis. Despite the fact that this is extremely interesting and very appropriate for me, it is also extremely new and unknown within the graduation of my studies. And not only for me was this all new, also the organization of CSI Twente had never worked with a scientific student before. That meant I had to start from sketch, which was not easy to do. The first weeks I had multiple conversations with Rob Maathuis and we went together to Gemeente Tubbergen and the company V2-Facility in the Southern of The Netherlands, who takes care of all the logistics of the event. I have filled in the application form for the event, which is sent to the municipality every year. This gave me more insight into all aspects of such an event. After a few weeks of studying all the information, I came to a suitable research question that could be useful for both parties. What I needed now was data and information about last year. However, V2 facility

did not send the information. After asking three times, I tried to get it on a different way, which was successful. This is one out of many examples that I have learned to take the initiative and to stand up for myself by occasionally being a bit cheeky. However, the data was very limited. In addition, there was a lack of literature. Apparently, no scientific research has ever been done on (international) horse shows before. This made it very difficult for me to find suitable literature and to apply it.

In the second week of February I faced another obstacle. My boyfriend broke up our relationship. For me this came as a surprise, which made me feel very bad. The following two weeks I was not focused on my thesis, but only thinking about him and my future. I realized that getting my master degree was one of my future goals and I picked myself up again.

After this period I was fully focused on my thesis and very motivated to finish it. I made plans for my future job, which gave me some extra motivation to first finish my studies. I had multiple conversations with Peter, after which I worked hard on the feedback. The enthusiasm and positivity of Peter is one of the main reasons that I was able to finish my thesis. There were also some conversations with the presence of my external expert Henk Kroon, who was also very enthusiastic about the research as he is a horse lover too. In this period I made great strides forward and fortunately everything went a lot smoother than the difficult beginning. In short, my graduation period was not always easy, but in the end I managed to make the best of it and I can look back on an educational and good time. And thereby, without failure there is no achievement.

I'm very proud to be able to put down this report for you.

Ellemijn Ensink

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I – Region Twente

II - List of winners of the GP

1975	Henk Nooren	Funest
1976	Hartmut Röder	Dukat
1977	Dick Wieken	Sultan
1978	Hugo Simon	Gladstone
1979	Hugo Simon	Gladstone
1980	Gerd Meier	Casimir
1981	Johan Heins	Larramy
1982	Hugo Simon	Gladstone
1983	Hugo Simon	Gladstone
1984	Ralf Runge	Fair Lady
1985	Henk Nooren	Glenn
1986	Gerardo Tazzer	Puntero
1987	Dion van Groesen	Expo Matchline
1988	Jos Lansink	Felix
1989	Thomas Fuchs	Dollar Girl
1990	Peter Eriksson	Moritz
1991	Thomas Fuchs	Dollar Girl
1992	Lesley McNaught-Mändli	Panok Pirol
1993	Jos Lansink	Bollvorm's Libero H
1994	Franke Sloothaak	San Patrignano Joli Coeur
1995	Henri Prudent	Fair Lady IV
1996	Otto Becker	Argelith's Bellenuit
1997	Rodrigo Pessoa	Loro Piana Special Envoy

1998		Hugo Simon	ET FRH
1999		Robert Smith	Senator Tees Hanauer
2000		Thierry Pomel	Thor des Chaines
2001		Markus Beerbaum	Royal Discovery
2002		Emile Hendrix	Audi's Finesse
2003		Gianni Govoni	Loro Piana Havinia
2004		Lars Nieberg	Lucie 55
2005		Jurgen Stenfert	BMC's Octavia
2006		Meredith Michaels-Beerbaum	Shutterfly
2007		Gerco Schröder	Eurocommerce Milano
2008		Patrice Delaveau	Katchina Mail
2009		Eric van der Vleuten	VDL Groep Tomboy
2010		James Paterson-Robinson	Niack L'Abbaye
2011		John Whitaker	Argento
2012		Laura Kraut	Teirra
2013		Dermott Lennon	Loughview Lou Lou
2014		Jur Vrieling	VDL Zirocco Blue
2015		Bertram Allen	Molly Mallone
2016		Philip Rüping	Copperfield
2017		Laura Renwick	Bintang II
2018		Antonio Alfonso	Chic Hin d'Hyrencourt

III - Paperwork at show office

CSI Twente 2018

(LAND)(Ruiter)

ELECTRICITY YES / NO
HEALTH PAPERS YES / NO

Phonenumber: +_____

Accreditation Stables:
Athlete:_____
Partner: _____
Groom: _____
Owner 1: _____
Owner 2: _____

Horses:

(NR) (HORSE)

IV - Respondents

Riders

Event category	Country	Name	Amount of horses
1*		Vasco Campana	2
1* & 4*		Conor Drain	4
1* & 2*		Remy Ellis	2
2*		My Lagerberg	1
4*		Wilton Porter	2
1*		Maud Wiefferink	1
1* & 4*		Willem Greve	4
1* & 2*		Sjaak Sleiderink	3
2*		Peter Olthof	2
4*		Gerco Schröder	-

Grooms

Event category	Country	Name	Amount of horses
1*		Manfredi Campana	2
1* & 4*		Ludivine Etore	3
1* & 2*		Steffi Bong	4
2*		Iaggo Fratti	2
4*		Isabel Ledin	1
1*		Bas Westerhof	1
1* & 4*		Lisa van Schaik	5
1* & 2*		Ben Steggink	4
2*		Rick Plegt	2
4*		Jet Gerridzen	2

V - Key interview questions

- Which day you went to the show (the 2018 edition)?
- How late you arrived at the show?
- Did you experienced a queue on the roads last year?
  - If yes, can you estimate the time you were waiting?
- What is your opinion about changing the opening of the stables from 1:00 pm to 8:00 am?
- What do you think about a reservation system with time slots for the arrival process?
- How much slack would you recommend between the time slots?
- Around which part of the day/time would you prefer to arrive at the race and why?
- Did you experienced a queue at the horse inspection last year?
  - If yes, can you estimate the time you were waiting?
- Do you prefer the horse inspection on Thursday morning, just before the start of the classes, or on Wednesday at the end of the day? Explain this if necessary.
- Do you have any remarks/improvements for the horse inspection?
- How did you experienced the parking of the truck?
  Do you have any comments or remarks about this?
- Do you have any other ideas/alternatives to solve the queues at CSI Twente?
- Do you have any other comments/improvements for the event regarding logistics?

VI - Fieldwork at CSI Tubbergen

Number of trial	Duration
1	00:20:57
2	00:18:92
3	00:43:77
4	00:59:23
5	00:26:19
6	00:28:02
7	00:16:51
8	00:34:89
9	00:40:30
10	00:31:08

VII - Standard normal distribution table

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.50000	.50399	.50798	.51197	.51595	.51994	.52392	.52790	.53188	.53586
0.1	.53983	.54380	.54776	.55172	.55567	.55962	.56356	.56749	.57142	.57535
0.2	.57926	.58317	.58706	.59095	.59483	.59871	.60257	.60642	.61026	.61409
0.3	.61791	.62172	.62552	.62930	.63307	.63683	.64058	.64431	.64803	.65173
0.4	.65542	.65910	.66276	.66640	.67003	.67364	.67724	.68082	.68439	.68793
0.5	.69146	.69497	.69847	.70194	.70540	.70884	.71226	.71566	.71904	.72240
0.6	.72575	.72907	.73237	.73565	.73891	.74215	.74537	.74857	.75175	.75490
0.7	.75804	.76115	.76424	.76730	.77035	.77337	.77637	.77935	.78230	.78524
0.8	.78814	.79103	.79389	.79673	.79955	.80234	.80511	.80785	.81057	.81327
0.9	.81594	.81859	.82121	.82381	.82639	.82894	.83147	.83398	.83646	.83891
1.0	.84134	.84375	.84614	.84849	.85083	.85314	.85543	.85769	.85993	.86214
1.1	.86433	.86650	.86864	.87076	.87286	.87493	.87698	.87900	.88100	.88298
1.2	.88493	.88686	.88877	.89065	.89251	.89435	.89617	.89796	.89973	.90147
1.3	.90320	.90490	.90658	.90824	.90988	.91149	.91309	.91466	.91621	.91774
1.4	.91924	.92073	.92220	.92364	.92507	.92647	.92785	.92922	.93056	.93189
1.5	.93319	.93448	.93574	.93699	.93822	.93943	.94062	.94179	.94295	.94408
1.6	.94520	.94630	.94738	.94845	.94950	.95053	.95154	.95254	.95352	.95449
1.7	.95543	.95637	.95728	.95818	.95907	.95994	.96080	.96164	.96246	.96327
1.8	.96407	.96485	.96562	.96638	.96712	.96784	.96856	.96926	.96995	.97062
1.9	.97128	.97193	.97257	.97320	.97381	.97441	.97500	.97558	.97615	.97670
2.0	.97725	.97778	.97831	.97882	.97932	.97982	.98030	.98077	.98124	.98169
2.1	.98214	.98257	.98300	.98341	.98382	.98422	.98461	.98500	.98537	.98574
2.2	.98610	.98645	.98679	.98713	.98745	.98778	.98809	.98840	.98870	.98899
2.3	.98928	.98956	.98983	.99010	.99036	.99061	.99086	.99111	.99134	.99158
2.4	.99180	.99202	.99224	.99245	.99266	.99286	.99305	.99324	.99343	.99361
2.5	.99379	.99396	.99413	.99430	.99446	.99461	.99477	.99492	.99506	.99520
2.6	.99534	.99547	.99560	.99573	.99585	.99598	.99609	.99621	.99632	.99643
2.7	.99653	.99664	.99674	.99683	.99693	.99702	.99711	.99720	.99728	.99736
2.8	.99744	.99752	.99760	.99767	.99774	.99781	.99788	.99795	.99801	.99807
2.9	.99813	.99819	.99825	.99831	.99836	.99841	.99846	.99851	.99856	.99861
3.0	.99865	.99869	.99874	.99878	.99882	.99886	.99889	.99893	.99896	.99900
3.1	.99903	.99906	.99910	.99913	.99916	.99918	.99921	.99924	.99926	.99929
3.2	.99931	.99934	.99936	.99938	.99940	.99942	.99944	.99946	.99948	.99950
3.3	.99952	.99953	.99955	.99957	.99958	.99960	.99961	.99962	.99964	.99965
3.4	.99966	.99968	.99969	.99970	.99971	.99972	.99973	.99974	.99975	.99976
3.5	.99977	.99978	.99978	.99979	.99980	.99981	.99981	.99982	.99983	.99983
3.6	.99984	.99985	.99985	.99986	.99986	.99987	.99987	.99988	.99988	.99989
3.7	.99989	.99990	.99990	.99990	.99991	.99991	.99992	.99992	.99992	.99992
3.8	.99993	.99993	.99993	.99994	.99994	.99994	.99994	.99995	.99995	.99995
3.9	.99995	.99995	.99996	.99996	.99996	.99996	.99996	.99996	.99997	.99997

VIII - Design of an application for mobile devices