



ASSESSMENT OF AUTOMATING TRAILER DOCKING AT DISTRIBUTION CENTRES

Bachelor thesis

ANNEMIEK FLADDERAK
Student Industrial Engineering
and Management
University of Twente

UNIVERSITY
OF TWENTE.

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Author

Annemiek Fladderak

Student Industrial Engineering and Management
Faculty Behavioural, Management and Social Sciences

University of Twente

Drienerlolaan 5
7522 NB, Enschede
The Netherlands

Supervisors University of Twente

P. C. Schuur

B. Gerrits

Department Industrial Engineering and Business Information Systems (IEBIS)

Supervisor INTRALOG

L. R. Buning

PREFACE

This report is the result of my thesis to complete my bachelor Industrial Engineering and Management at the University of Twente. This thesis is conducted in the framework of INTRALOG. During the last months, I learned a lot about automated trailer docking and conducting a research and I am happy that I could contribute to the INTRALOG project.

I could not have made this bachelor thesis without the support of others, so I want to thank some people. First, I would like to thank my supervisors Peter Schuur, Berry Gerrits and Lejo Buning. They provided me with a lot of useful advice and were always willing to help me with my thesis. Also, I would like to thank Terberg Benschop and ROTRA, particularly Pleun Nagtegaal, for showing me around their company and answering all my questions.

Lastly, I would like to thank everyone I did not mention, but who helped me by giving feedback and advice on my report.

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MANAGEMENT SUMMARY

In this thesis we assess the impact of automated versus manual trailer docking on logistic processes at Distribution Centres (DCs). Currently, trailer docking is done manually, but research is done on automating this process. The project Intelligent Truck Applications in Logistics (INTRALOG), in which universities and companies cooperate, is working to make fully automated trailer docking possible. To make the INTRALOG project succeed, it is needed to answer questions about the viability and added value of automated trailer docking. Therefore, the following problem statement is set up:

‘How to assess the impact of automated versus manual trailer docking on the logistic processes in terms of People, Planet, Profit?’

To do this, a Total Cost of Ownership (TCO) calculation tool is developed. This tool gives practitioners insight in the pros and cons of automated trailer docking for their business case. Also, a simpler model, called a quick scan, is developed, for the cases in which a very detailed model is no necessary. Which elements from the TCO calculation tool are necessary for the quick scan, is decided by performing a sensitivity analysis.

The development of the TCO calculation tool and the quick scan are broken down into different steps. First, it is important to understand the process of manual trailer docking. Currently, trailer docking at DCs is done using manual Terminal Tractors (TTs). A picture of a TT is shown at the right. To get to know the process, ROTRA was visited, a logistics service provider with a head office and DC in Doesburg. Then the difference between the current process and the process with automated trailer docking was evaluated. This was done with a literature study and an interview at ROTRA.



The next step was to determine the elements relevant for assessing the impact of automating trailer docking, their relations and their quantifications. During an additional interview with ROTRA, the boundary conditions were discussed and set up. Also, the benefits of automated trailer docking were determined, by doing a literature study and conducting several interviews. Furthermore, the right input characteristics were determined. This was done by conducting interviews with ROTRA, but also with Terberg, a company that produces manual TTs and is developing an automated TT.

After all the elements were known, the TCO calculation tool was developed. After starting with the input characteristics, the different costs for manual and automated trailer docking were implemented in the tool. With the results from the TCO calculation tool, a sensitivity analysis is then done, to find out how much impact each element has on the total costs. Each element is increased and decreased with 10%, and the difference in total costs caused by this increase or decrease is evaluated. Then the elements with the most impact were selected and used to develop the quick scan.

This quick scan uses the same calculations as the ones for the TCO calculation tool. However, in the quick scan a couple of elements can be adjusted, to create different scenarios. With this quick scan, an analysis was done. For this analysis, 3 different scenarios were created: a basic case, a best case and a worst case. These cases are described below. For each scenario will be calculated in which business case automated trailer docking is more beneficial than manual trailer docking.

- Basic case: This case uses the values which were used previously in the research

- Best case: This case uses values that are either increased or decreased with 10%, in such a way that automated trailer docking is more beneficial compared to manual trailer docking than in the basic case.
- Worst case: This case uses values that are either increased or decreased with 10%, in such a way that automated trailer docking is less beneficial compared to manual trailer docking than in the basic case.

Since the research was broken down into multiple steps, there are multiple results as well. First, the process of trailer docking was evaluated. After a truck arrives at the DC with a semi-trailer, a manual TT couples the semi-trailer and moves it to the right dock. There the TT docks the semi-trailer rearwards, decouples and moves to the next job. When the semi-trailer is finished at the dock, the manual TT moves this semi-trailer to another dock, or to the parking place. When automated trailer docking is used instead of manual trailer docking, the process is the same, only the actions are performed by an automated TT instead of a manual TT. However, two difficulties arise. First, the coupling and decoupling of the TT and semi-trailer cannot be automated yet. Second, it is not possible to open the dock doors automatically.

With a clear picture of the process of trailer docking, a start could be made with setting up the boundary conditions for automated trailer docking. The following boundary conditions were found:

- *The area with automated TTs may not be accessible to humans*
To ensure the safety of the humans on the DC and to reduce inefficiency, humans may not enter the area where the TTs move around.
- *Coupling and decoupling must be done automated*
Since humans are not allowed in the area where the automated TTs drive, coupling and decoupling must be done automatically.
- *Dock doors must be opened automatically or from the inside of the dock*
Humans cannot get in the area where the automated TTs move around, so the dock doors must be opened automatically. It could also be possible to buy special dock doors, which can be opened from inside the dock.

Then the costs and benefits were found, based on literature research and interviews. These costs and benefits are listed in the table on the right. Both the benefits and costs mention maintenance. On one hand, automated TTs drive more efficiently, which decreases wear and therefore maintenance. On the other hand, automated TTs have more software and hardware, which may increase maintenance. Therefore, they are mentioned at both the benefits and costs.

Benefits	Costs
No TT drivers necessary	High purchasing costs of the automated TT
Less damage	New coupling system
Always first time right	New infrastructure
No more semi-trailers at the wrong dock	New IT system
More movements per hour	More maintenance
Lower consumption	More ground necessary
Possible subsidy and credit	Training employees
Less maintenance	Less flexibility

The next step of developing the TCO calculation tool, was to determine the input characteristics. The following input characteristics were found: operating times of the DC, number of movements per day, number of weeks per year operating and average time needed to perform one movement. For this research, a *movement* is defined as one time that a semi-trailer is moved by a TT, for example from the parking to a dock or vice versa. The tool is illustrated by a case, loosely based upon the ROTRA

situation. This case is a medium-sized DC, which operates from Monday till Saturday, 16 hours a day and 52 weeks in a year.

Using the input characteristics, the different calculations of the tool can be performed. These calculations are broken down in five steps:

- *Number of TTs to buy*

With the number of movements on one day, the time needed for one movement and the number of hours the DC is operating on a day, it can be calculated how many TTs are needed on each day and should be bought. For automated trailer, an efficiency factor is added. The efficiency factor indicates how much faster an automated TT can dock a semi-trailer, compared to a manual TT.

- *One-time costs*

The one-time costs for manual trailer docking consist of the purchasing costs for the TTs and the charging points. For calculating the one-time costs for automated trailer docking, the costs for the IT system and coupling system are added.

- *Yearly costs*

The yearly costs for manual and automated trailer docking consist of the maintenance costs.

- *Weekly costs*

For manual trailer docking, the weekly costs are the salary for the TT drivers, the energy costs and the costs for damage. The weekly costs for automated trailer docking are only the energy costs.

- *Total costs for 10 years*

To calculate the total costs for the first year, all the costs are added. For the 2nd till 10th year, inflation is also considered, by using a discount factor. Then the costs for all years are added, which gives the total costs.

The results of the calculations are that the total costs for manual and automated trailer docking for 10 years are €874.000 and €453.000, respectively.

Then the sensitivity analysis was done. It appeared that if an element had a big impact on the total costs for manual trailer docking, the same element did not necessarily have a big impact on the total costs for automated trailer docking. This was, for example, the case for the salary. Also, there were 5 elements selected that had the biggest impact on the total costs for automated and manual trailer docking together. These are the salary of the TT drivers, purchase price of the TT, price per kWh, energy consumption and efficiency factor. These 5 elements were selected for the quick scan.

With the quick scan, the 5 selected elements and the different scenarios, an analysis is done. For each scenario is evaluated in which business case automated trailer is more beneficial than manual trailer docking. A threshold is used for this: the total costs for automated trailer docking should be at least 25% lower than the total costs for manual trailer docking. The same example as used for the tool is also used for this analysis. To meet the threshold, the number of movements per day is adjusted. The results of the analysis can be found in the table below.

	Worst case	Basic case	Best case
Minimum number of movements per day for automated trailer docking to be more than 25% less expensive than manual trailer docking	113	85	65

Based on the research, three recommendations are made. These are:

- Perform more research on how much automated trailer docking increases the efficiency. The efficiency is increased because automated TTs always dock first time right and do not drive against something. However, it is not known to which degree the efficiency is increased by this, so the efficiency factor in this research is just an estimation.
- More information needs to be gathered about the exact costs of automated and manual trailer docking. A lot of the costs used in this research is a rough estimation. These estimations could be better if, for example, the prices of the charging points and IT system were known.
- A system for automatic coupling and decoupling should be developed further. There is no sufficient solution yet and it is important that coupling and decoupling is done automatically.

TABLE OF CONTENTS

Preface.....	ii
Management Summary.....	iv
List of abbreviations	ix
List of figures	ix
List of tables	ix
1 Introduction.....	1
1.1 Introduction INTRALOG	1
1.2 Motivation for my research.....	1
1.3 Research goal	2
1.4 Methodology	2
1.5 Research questions.....	3
1.6 Research approach.....	3
1.7 Scope	4
1.8 Deliverables	4
1.9 Report outline.....	4
2 Current situation	5
2.1 Description DCs.....	5
2.2 Description TTs	5
2.3 Current process of trailer docking	5
2.4 Automated process of trailer docking	7
3 Elements considered for automated trailer docking	9
3.1 Boundary conditions.....	9
3.2 Benefits of automated trailer docking when compared to manual trailer docking	10
3.3 Costs	11
3.4 Characteristics of the DC	12
4 TCO analysis and tool	13
4.1 Model of the pros and cons	13
4.2 TCO analysis.....	14
4.3 TCO Calculation tool.....	16
5 Sensitivity analysis and quick scan	21
5.1 Sensitivity analysis.....	21
5.2 Quick scan.....	24
6 Chapter 6 Conclusions and recommendations	27
6.1 Conclusions.....	27
6.2 Recommendations.....	28

References.....	29
Appendices	31
<i>Appendix A: Problem identification</i>	31
<i>Appendix B: Results of the sensitivity analysis</i>	33
<i>Appendix C: Dashboard of the quick scan</i>	44

LIST OF ABBREVIATIONS

- AGV Automated Guided Vehicle
- DC Distribution Centre
- Impact The consequences for People, Planet, Profit
- MPSM Managerial Problem-Solving Methodology
- TCO Total Cost of Ownership
- TT Terminal Tractor

LIST OF FIGURES

Figure 1.1 Partners of the INTRALOG project.....	1
Figure 1.2 A TT with a semi-trailer, retrieved from Gerrits (2016).	2
Figure 2.1 A TT from Terberg.	5
Figure 2.2 An example of the activities of a TT.	6
Figure 4.1 Model of the pros and cons of automated trailer docking.	13
Figure 4.2 Input characteristics of the tool.	16
Figure 4.3 Relative distribution of the costs.....	20
Figure 4.4 Absolute distribution of the costs.	20
Figure 5.1 Absolute results of the sensitivity analysis.....	22
Figure 5.2 Relative results of the sensitivity analysis.	23

LIST OF TABLES

Table 4.1 Results of the tool.....	19
Table 5.1 Sensitivity analysis of the purchase price of a manual TT.	21
Table 5.2 Scenarios for the quick scan analysis.....	24
Table 5.3 Results of the analysis of the quick scan.	25

1 INTRODUCTION

In the framework of completing my bachelor's in Industrial Engineering and Management, I performed research at INTRALOG, into automated trailed docking. This chapter introduces my research. First, section 1.1 introduces INTRALOG and section 1.2 explains the motivation for my research. Then the research goal is described in section 1.3. Section 1.4 discusses the methodology used. Section 1.5 and section 1.6 describe the research questions and research approach, respectively. The scope is set in section 1.7 and section 1.8 presents the deliverables. Finally, section 1.9 explains the outline of this report.

1.1 Introduction INTRALOG

INTRALOG stands for 'Intelligent Truck Applications in Logistics'. It is a project to increase the knowledge on autonomous driving in the transportation sector and to make it available to the sector. The purpose of INTRALOG is to prove and demonstrate that the logistic operations regarding PPP (People, Planet, Profit) is improved when AGTs (Automated Guided Trucks) are used (Tillema, Buning, Gerrits, & Spruijt, 2016). Research is done in multiple disciplines, for example IT, logistics, truck design and business. Partners in the INTRALOG project include for example the University of Twente, HAN, Rotra, Terberg, DAF and Technical University of Eindhoven. Figure 1.1 shows all the partners of INTRALOG.



Figure 1.1 Partners of the INTRALOG project.

1.2 Motivation for my research

A part of the INTRALOG project involves the development of an automated terminal tractor (TT). A TT is used on distribution centres (DCs) to move around semi-trailers. After the semi-trailer arrives at the DC, it is picked up by a TT. The TT then moves it to the right dock and rearward docks it. More about this process can be found in section 2.3.

Up until now, these TTs are operated manually. As said before, INTRALOG is developing fully automated TTs. For the industry to adopt this, it should be clear what the added value of automated trailer docking is, compared to manual trailer docking. Therefore, a study is needed on the pros and cons of automated trailer docking. Also, a model is needed to assess for which business case automated trailer docking is preferred over manual trailer docking. This should result in a tool, which can be used by practitioners to assess whether automated TTs should be implemented for their business case.



Figure 1.2 A TT with a semi-trailer, retrieved from Gerrits (2016).

1.3 Research goal

The goal of my research is to give insights in the impact of automating trailer docking and provide a tool to give advice whether to implement automated trailer docking or not. Not all data may be available, but my research will indicate which aspects need to be researched further to get the full picture.

1.4 Methodology

For my bachelor thesis, the Managerial Problem-Solving Methodology (MPSM) is used. The University of Twente supports to work with this method and I worked with it during the first two years of my study. However, there is one difficulty with this method: it is written with the goal to solve a problem within a certain company, whereas my assignment has the goal to see for which business cases a certain solution works. I still think that it is useful to follow the steps of the MPSM, but some steps must be interpreted in another way. The steps from the MPSM that are followed, are described in this chapter.

1.5 Research questions

The problem statement for my bachelor thesis is:

'How to assess the impact of automated versus manual trailer docking on the logistic processes in terms of People, Planet, Profit?'

To support the problem statement, six research questions are answered. A description on these research questions, can be found listed below.

1. *How is trailer docking performed currently?*
Before the impact of automating trailer docking can be assessed, the current manual process of trailer docking must be known.
2. *Which elements are relevant to assess the impact of automating trailer docking?*
There are multiple elements that determine the impact of automating trailer docking. These can be for instance the amount of docks at a DC or the number of trucks arriving on a DC per day. Before the impact of these elements can be determined, it is important to know which elements have an impact and should be considered.
3. *What are the relations between these elements?*
Once the elements are known, the relations between these elements should be examined. This way, a model can be made for assessing the impact of automating trailer docking.
4. *How can the relations between these elements be quantified?*
To develop a tool from these elements, quantitative values have to be assigned to the elements. These quantitative values are also be used for a TCO framework.
5. *How can this be implemented in a tool to assess the impact of automating trailer docking at DCs?*
All elements should be implemented in a tool, which can be used to assess the impact of automating trailer docking on a business case. This tool should be easy to use and applicable for multiple business cases. An example would be Excel, because most people are familiar with it and have access to it.
6. *How can a quick scan be developed as introduction to the tool?*
Having a tool to assess the impact of automating trailer docking is useful, but in some cases a simplified model is sufficient. Therefore, a simplified model is developed, to indicate whether a practitioner should further investigate the option for automating trailer docking. This is done by means of a sensitivity analysis.

1.6 Research approach

The research questions above are partially answered by literature research. This literature research is mostly used to get an idea about the possible pros and cons of automated trailer docking when compared to manual trailer docking. Since there is very limited information on automated trailer docking, interviews are another important source of information.

First, Rotra is visited. Rotra is a logistic service provider, with a head office and a DC in Doesburg. They are a partner of INTRALOG and are interested in building a new DC, which uses automated trailer docking. The aim of the visit is to find out how the process of trailer docking works, and of which steps this process consists. At another visit, a brainstorm is done to point out possible pros and cons of automated trailer docking, when compared to manual trailer docking.

Next, an interview with Lejo Buning is held. Lejo Buning works at the HAN and is the initiator of the INTRALOG project. The possible pros and cons which are found before are discussed, to obtain more information.

In addition to that, a visit at Terberg is made. Terberg is a company in Benschop, which is specialized in manufacturing TTs. They are a partner of INTRALOG and are developing automated TTs. The aim of the visit is to get more information on the automated TT that is developed, for example about maintenance and costs. Furthermore, a test site for an automated TT is visited at Terberg. Due to circumstances, there is no demo of this automated TT, but there was the possibility to ask questions about the specifications of the automated TT.

1.7 Scope

The time available for my bachelor thesis is limited, so I need to set a scope for my research. I will research the pros and cons of automated electric TTs at newly built DCs. This means that I do not investigate other kinds of AGVs at DCs or TTs that run on diesel, gas, etc. Also, I do not investigate the case for which automated TTs are used in existing DCs. The reason for this is that converting an existing manual DC into a DC that uses automated TTs costs a lot of money, due to the boundary conditions in section 3.1. Thus, it is not likely that this will be done. Lastly, my research is limited to semi-trailers that are loaded and unloaded at the back, since only a small percentage of the semi-trailers is loaded and unloaded at the side.

1.8 Deliverables

The deliverables are twofold:

- A simple model, which can be used as a 'quick scan': in just a couple of minutes, it should give a rough estimation whether automated trailer docking can be considered or not, based on only the most important elements.
- A tool, which can be used to give insight in the added value of automated trailer docking in a certain business case. It takes all relevant elements into account, instead of only the most important ones, like the simple model. Therefore, it gives a more accurate result than the simple model.

1.9 Report outline

In Chapter 2, the current situation is described. All relevant elements are discussed in Chapter 3. Chapter 4 shows a TCO analysis based on these elements and the tool that is made. In Chapter 5 a sensitivity analysis is done, and a quick scan is made. The conclusions and recommendations are presented in Chapter 6.

2 CURRENT SITUATION

This chapter answers the first research question: *'How is trailer docking performed currently?'*. Section 2.1 describes what a DC is. Section 2.2 elaborates on a description of TTs. How trailer docking is performed currently, is described in section 2.3. Section 2.4 discusses autonomous trailer docking, together with two issues that need to be addressed before autonomous trailer docking can be implemented.

2.1 Description DCs

A DC is a place where products are received from and send to wholesalers, retailers, consumers, etc. It is a key element for processing and moving products in the supply chain. DCs mostly store products prior to their sending, but the emphasis is on the distribution of these products. A special type of DC is a cross-dock. After products are unloaded from the inbound trucks, they are sorted, dispatched and loaded again straight away. They products generally spend less than 24 hours at a cross-dock, which makes that the inventory at a cross-dock is minimal (Ladier, 2015).

2.2 Description TTs

The semi-trailers on a DC are generally moved around by Terminal Tractors (TTs). Figure 1.2 shows a TT. These specific TTs are produced by Terberg, which is one of the partners of INTRALOG. Up until now, TTs are driven by employees of the DC. The INTRALOG project however is working on automated TTs. These automated TTs will be based on the current TTs made by Terberg (Gerrits, 2016). It is very likely that these automated TTs will be electric.



Figure 2.1 A TT from Terberg.

2.3 Current process of trailer docking

In the current process of trailer docking, a person is required to complete each step: for example, driving the TT or coupling the semi-trailer to the TT. An example of how this process is performed currently, is shown in Figure 2.2. When a truck with semi-trailer arrives at the DC, it parks the semi-trailer on a parking spot and decouples the semi-trailer. Then a TT couples to the semi-trailer and drives it to the right dock. The semi-trailer is docked rearwards, the TT decouples, and the semi-trailer can be unloaded. A TT then couples to the semi-trailer again and parks it on a parking spot. When everything is ready (the right dock is free, and the cargo is available at this dock), a TT couples to the semi-trailer and drives it to the dock. The TT docks up the semi-trailer rearward and decouples. The semi-trailer is

loaded and then a TT is coupled again. The TT drives the semi-trailer to a parking spot, parks it and decouples. When a truck is ready, it couples the semi-trailer and leaves the DC.

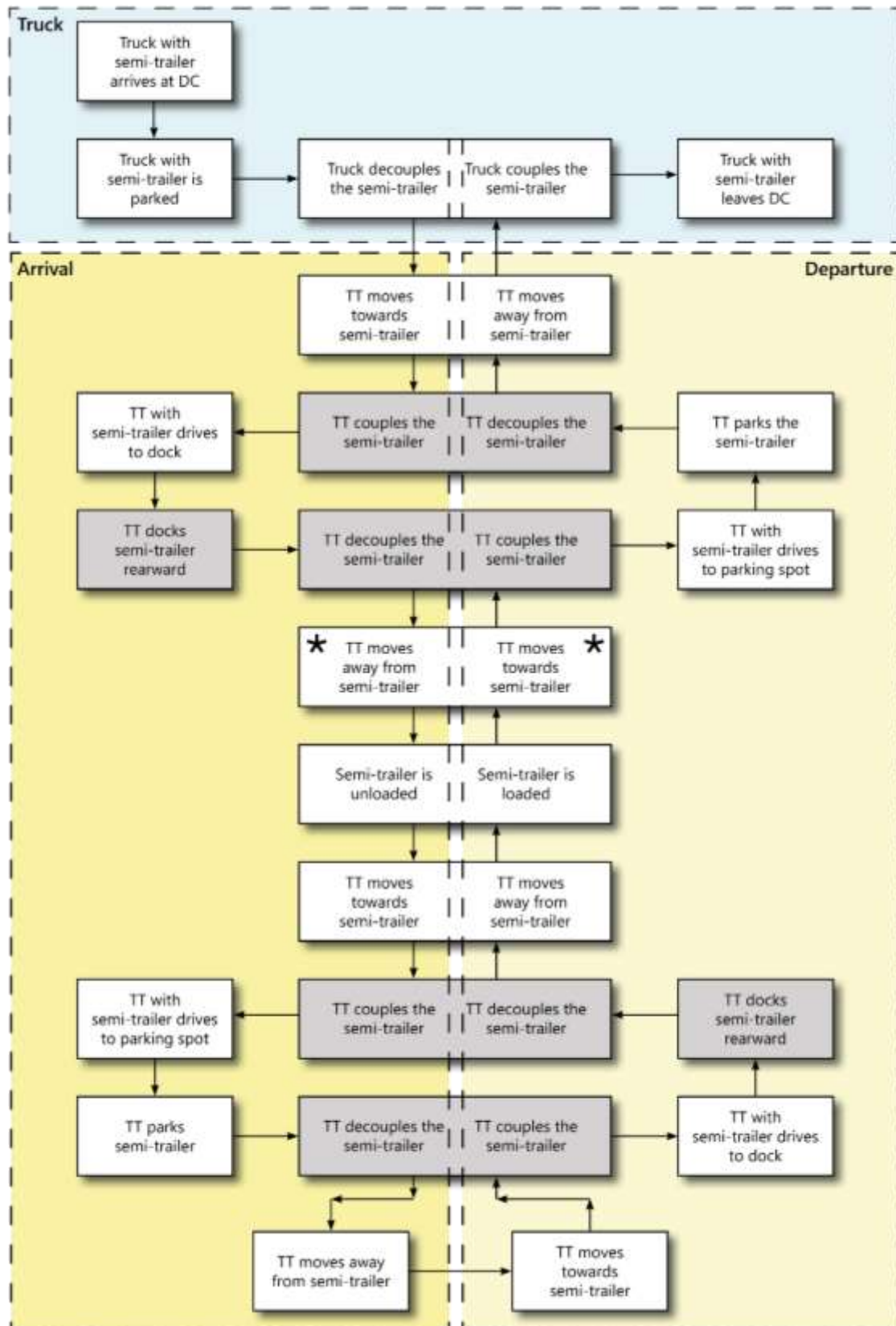


Figure 2.2 An example of the activities of a TT.

* For simplicity, in this scheme, the TT is waiting for the semi-trailer to be loaded. Of course, in practice, the TT may proceed differently (e.g. to go to another semi-trailer to move it).

2.4 Automated process of trailer docking

The INTRALOG project is working on the automation of the process described above. The steps in the current process remain the same when automating the process. However, the TT with driver is replaced by an automated TT with electronics, sensors, etc. The actions regarding the truck stay the same, since automation of these steps lies beyond the focus of this bachelor thesis.

In Figure 2.2, some blocks have a *light grey* colour. These are steps that cannot be completely automated yet and need more research. Two types of steps can be distinguished:

- Most of these steps regard the coupling and decoupling of the TT and the semi-trailer: personnel are still needed for the coupling and decoupling. There are some possible solutions to this issue, but these still need to be tested and developed further (Hülshof, 2016).
- The other steps consider the docking of the semi-trailer by a TT. The issue with these steps is that the doors of the semi-trailer cannot be opened automatically (Gerrits, 2016). Since the use of personnel is not desirable in the automated process, a solution still must be found for this issue as well.

3 ELEMENTS CONSIDERED FOR AUTOMATED TRAILER DOCKING

This chapter answers the research question *'Which elements are relevant to assess the impact of automating trailer docking?'* First, section 3.1 shows and explains the boundary conditions for implementing automated trailer docking. Then section 3.2 describes the benefits of automated trailer docking when compared to manual trailer docking. The costs of automated trailer docking are discussed in section 3.3. Section 3.4 describes which characteristics of a DC must be analysed to assess the impact of automated trailer compared to manual trailer docking

3.1 Boundary conditions

For a DC to implement automated trailer docking, some boundary conditions must be met. These boundary conditions are discussed below.

3.1.1 Area with automated TTs not accessible to humans

It is important that people do not get in the way of the automated TTs. First, the automated TTs would have to drive around them, which decreases the efficiency. Second, it is not 100% sure yet that the technology is capable of always detecting objects and driving around them. This threatens the safety of people on the terrain. Therefore, the area with automated TTs cannot be accessible to humans. Consequences for this are for example that this area should be secluded from the public road and that the areas for automatic and manual trailer docking must be secluded.

3.1.2 Coupling and decoupling must be done automated

Currently, the coupling of the TT with the semi-trailer is done manually. For automated trailer docking, it is necessary that the coupling is done autonomously. The reason for this, is that the goal is to automate the complete process of trailer docking. Also, it is not preferable that employees walk in the area where the automated TTs are moving around. Hülshof (2016) describes four possible solutions for autonomous coupling. However, none of these solutions is perfect and they still need a lot of improvement. Therefore, it is necessary to keep working on a solution for the automatic coupling of TT and semi-trailer.

3.1.3 Dock door

Currently, the doors of the semi-trailer are opened by the TT driver before the semi-trailer is docked. Since no employees are allowed in the area where automated trailer docking is performed, the doors of the semi-trailer must be opened in another way.

A solution for this can be found in the transportation of frozen products. With a special dock door, the doors of the semi-trailer can be opened from inside the dock. This way, the doors of the semi-trailer can be opened without employees that need to walk between the automated TTs.

3.2 Benefits of automated trailer docking when compared to manual trailer docking

Automated trailer docking has multiple benefits when compared to manual trailer docking. In this section, these benefits are discussed.

3.2.1 No TT drivers necessary

When automated trailer docking is implemented, there are no drivers needed for the TTs. Drivers need to receive salary every month, which is a great amount of money. Also, during non-attendance, for example due to sickness, loss of a family member or vacation, TT drivers need to be paid. Using automated TTs therefore saves money that otherwise would have been used to pay the TT drivers.

3.2.2 Less damage

An automated TT is expected not to drive against obstacles like a pole, in contrast to an employee in a manual TT. This makes that an automated TT has damage less frequently, which saves costs. How often a driver with a manual TT drives against objects, is unknown. Thus, the amount of money that is saved with automated TTs not driving against objects should be estimated.

3.2.3 Always first time right

When a TT driver docks a semi-trailer, he does not always dock it the first time right. Sometimes, he makes a mistake and must try again. An automated TT docks a semi-trailer always the first time right, which makes the process more efficient and save money. The amount of times a driver does not dock the semi-trailer first time right is not known yet, so it is not clear how much an automated TT improves this.

3.2.4 No more semi-trailers at the wrong dock

A TT driver sometimes docks a semi-trailer at a dock but enters the wrong location for the semi-trailer in the IT system. It may also be possible that the IT system indicates that a semi-trailer must be docked at one dock, but the driver docks it at another dock. This makes that the semi-trailer cannot be found in the IT system, so the employees need to look for it, which takes time. It is not known how much time this takes and how often this happens. An automated TT will not dock the semi-trailer at the wrong dock, so this saves time, making an automated TT more efficient than a manual one.

3.2.5 More movements per hour

Since an automated TT has a higher ratio of first time right than a manual TT, does not dock semi-trailers at the wrong dock and has routes that can be planned more efficiently, an automated TT is expected to drive more efficiently than a manual TT. Therefore, they can make more movements in an hour.

3.2.6 Lower consumption

As explained in Section 3.2.5, an automated TT is expected to drive more efficiently a manual TT. For this reason, their consumption is lower.

3.2.7 Subsidy and credit

Automatic trailer docking is an innovative concept in logistics, so it may be possible that a subsidy or credit can be requested. However, it is complicated to determine if a subsidy or credit is applicable and each business case is different. Therefore, subsidies and credit are disregarded for now.

3.2.8 Less maintenance

It may be possible that automated TTs need less maintenance, because they drive more efficiently. This decreases wear and therefore also decreases maintenance. On the other side, it may be possible that more maintenance is needed. This is discussed in section 3.3.5.

3.3 Costs

Both automated and manual trailer docking involve multiple kinds of costs. These different costs are described in this section.

3.3.1 Purchasing costs of the automated TT

For the implementation of automated trailer docking, new TTs are necessary. For this thesis, only the case is considered in which new TTs are purchased. Converting the manual TTs into automated TTs is possible, but it would cost a lot of money. Especially since the current TTs drive on diesel and the automated TTs will be electric. The purchasing price is not known yet, because the automated TT is not fully developed yet.

3.3.2 New coupling system

As described in section 3.1.2, the coupling of the TT and the semi-trailer must be automatic for automated trailer docking. The costs for the automatic coupling differ per potential solution and none of the potential solutions investigated by Hülshof (2016) can be implemented currently. Therefore, it is hard to indicate the costs that are involved with automatic coupling.

3.3.3 New infrastructure

To navigate at the DC, automated TTs need a certain infrastructure. This could be for example sensors in the ground or guided tape. These justifications cost money. Also charging stations are needed for the automated TTs to charge.

3.3.4 New IT system

For the automated TTs to drive a certain route, an IT system is necessary. This IT system receives the requests for moving a semi-trailer and assigns it to an automated TT. Then the route of the TTs can be determined. The purchase and implementation of this IT system involves costs.

3.3.5 More maintenance

It could be that automated TTs need more maintenance than manual TTs. Automated TTs have, for example, hardware and software to determine the current location and the path of these TTs, in contrary to manual TTs. These hardware and software also need maintenance. On the side, it may also be possible that automated TTs need less maintenance, as issued in section 3.2.2.

3.3.6 More ground necessary

When automated trailer docking is implemented, a greater area is necessary than the case in which trailer docking is performed manually. The reason for this, is that the area for automated trailer docking must be secluded from the other areas in the DC. On the other side, the path of the TTs should be considered. It is unknown if automated TT's have a more flexible path or not.

3.3.7 Training employees

When implementing automated TTs, it is important that employees know how to work with them. Since the concept of automated trailer docking is new, the current employees are not familiar with it.

This can be solved by training the employees. However, it is not known yet how much training is necessary. Therefore, the training of employees is left outside for now.

3.3.8 Less flexibility

For automated trailer docking, the flexibility is lower than for manual trailer docking. The reason for this is that if there is a small change in the planning, a driver in a manual TT can just do something in between. For an automated TT this is a lot harder, since something in the system must be adjusted.

3.4 Characteristics of the DC

To make an indication whether automated trailer docking is preferred above manual trailer docking for a business case, some characteristics of the business case must be known. These characteristics are discussed in this section.

3.4.1 Operating times of the DC

The days on which a DC operates, has a big influence on the earnings of the DC. It is more expensive to let employees work in on a Saturday and even more expensive to let them work on a Sunday. During the night, employees must get paid more as well. On the other side, this may be the moments at which customers need the service of the DC most. If a DC operates a lot at these moments, it would therefore probably be more beneficial to use automated TTs.

3.4.2 Number of movements per day

The number of movements per day indicates how many employees are necessary at the time in case of manual trailer docking and how many automated TTs are necessary in case of automated trailer docking. It is relevant because automated trailer docking has higher initial costs than manual trailer, but the yearly costs are lower. So, if the number of movements per day increases and thus the number of TTs needed increases, it gets more profitable to use automated trailer docking instead of manual trailer docking.

3.4.3 Number of weeks per year operating

The number of weeks per year that a DC is operating, is important since the initial costs for automated trailer docking are higher than for manual trailer docking, but the yearly costs are lower. When the number of weeks per year that a DC is operating is high, it is therefore more beneficial to use automated trailer docking than for the case that the number of weeks per year that a DC is operating is low.

3.4.4 Average time needed to perform one movement

The average time that is needed to perform one movement, influences the impact of automated trailer docking. One movement is defined, for this research, as one time that a semi-trailer is moved by a TT, for example from the parking a dock or vice versa. This also includes the time that is needed for a TT to drive towards the semi-trailer and couple it.

The reason that this data is important, is that an automated TT can dock a semi-trailer more efficient than a manual TT. Therefore, the time needed to perform one movement is reduced with a certain factor. If the average time needed for one movement is high, the profit of using automated TTs is higher than when the average time needed for one movement is low.

4 TCO ANALYSIS AND TOOL

This chapter answers the research questions ‘What are the relations between these elements?’, ‘How can the relations between these elements be quantified?’ and ‘How can this be implemented in a tool to assess the impact of automating trailer docking at DCs?’. Section 4.1 shows the effects of the pros and cons from section 0 and section 3.3 in a model. Section 4.2 quantifies these pros and cons shows in how the costs of automated and manual trailer docking can be calculated, using a TCO analysis. Then section 4.3 explains the tool that is made based on this TCO analysis and gives an example.

4.1 Model of the pros and cons

For the TCO analysis, it is important to know how the pros and cons relate to each other. This is shown in Figure 4.1.

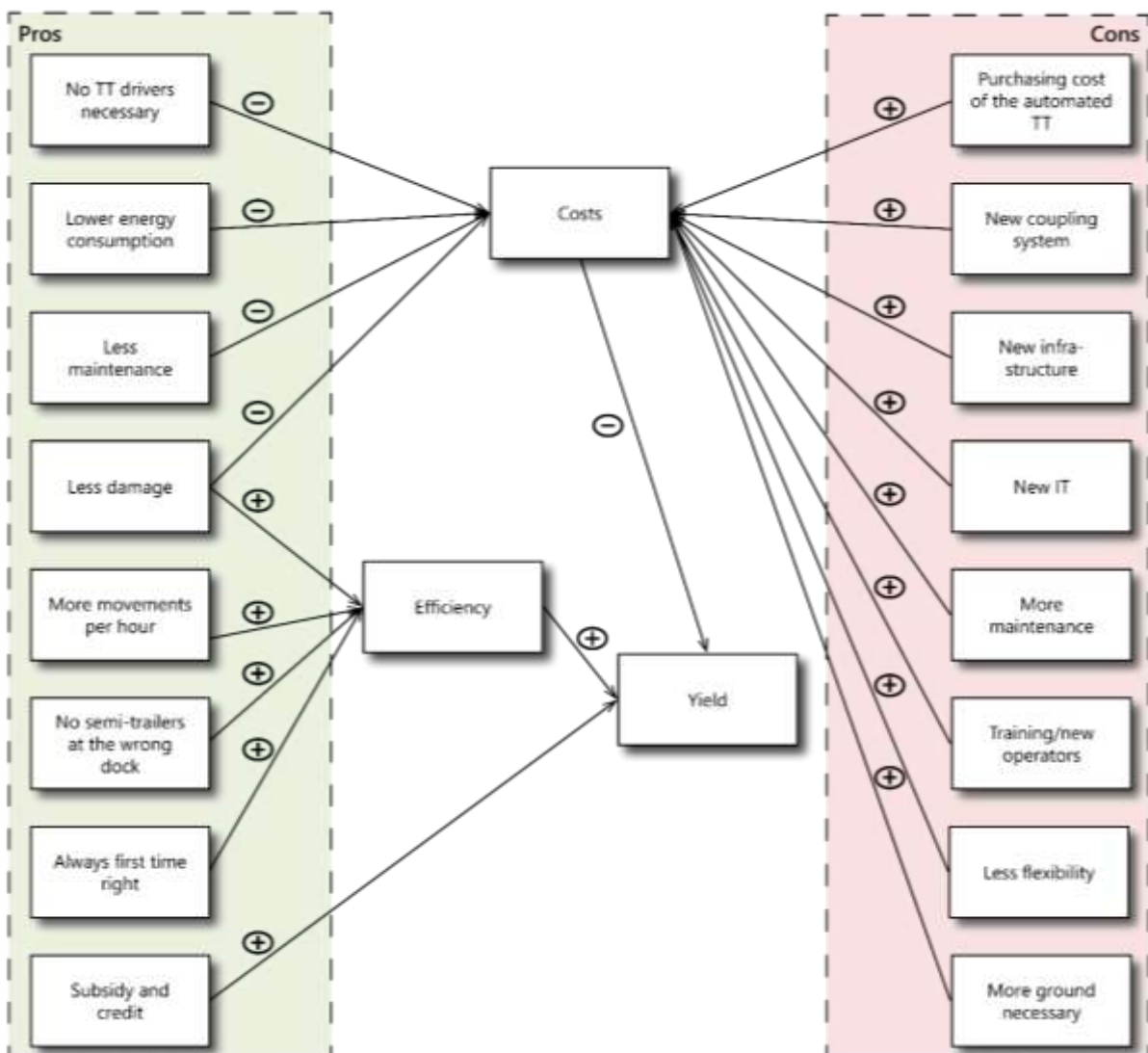


Figure 4.1 Model of the pros and cons of automated trailer docking.

4.2 TCO analysis

The TCO analysis will analyse the costs of automated and manual trailer docking for the coming 10 years. A timespan of 10 years is chosen, because it is realistic that a TT can be used for 10 year.

4.2.1 One-time costs

For both manual and automated trailer docking, initial costs are needed. These include the purchasing costs and costs for the charging points, IT system and coupling system. These costs are discussed in this section.

4.2.1.1 *Purchasing costs of the TTs*

The purchasing costs of the TTs are estimated on €75.000 for a manual TT and €300.000 for an automated TT, based on a meeting with Terberg. However, this price is highly dependent on the number of extras that are needed. For example, a business can choose different materials for the mudguards, extra lights, a better battery, a different colour and so on. All these extras increase the price. For this case, the price without all these extras is used.

4.2.1.2 *Charging points*

There are different ways of charging that can be used, for example charging with wires or wireless. The costs for the charging points are highly dependent on this. At least €10.000 is needed for charging points, but these costs will increase if a better charging method is used. For now, an amount of €10.000 is used.

4.2.1.3 *IT system*

The costs for the IT system are not known yet, because it is not developed completely. For now, the costs are estimated on €10.000.

4.2.1.4 *Coupling system*

As mentioned in section 3.3.2, there is no appropriate automatic coupling system available yet. The estimated prices for the potential solutions range from €1000 per TT and €75 per trailer to €50.000 per TT for the solution from the HAN and the robot arm, respectively. Therefore, the price used can only be a rough estimation. For now, a price of €2000 per TT is used.

4.2.2 Yearly costs

There are also costs that are made on an annual basis. These costs are maintenance costs.

4.2.2.1 *Maintenance costs*

As discussed in sections 3.2.2 and 3.3.5, it is not known yet whether the maintenance costs for automated TTs are higher or lower than for manual TTs, both could be possible. Therefore, the same maintenance costs are used for both automated and manual TTs.

The maintenance costs are estimated on €2.000 per year per TT.

4.2.3 Weekly costs

A couple of costs can be calculated per week. These include the salary of the TT drivers, the energy costs and the damage costs.

4.2.3.1 *Salary TT drivers*

The salary of TT drivers is captured in the CAO (collective agreement on the terms of employment) of transport and logistics. TT drivers are in function class B (Fuwa, n.d.). The CAO gives that the average

salary in this function class is €12,32. Added the holiday allowance, makes an amount of €13,31. The rounded number €13,50 will be used as the salary of a TT driver on a workday. On Saturday and Sunday, a TT driver earns 150% and 200% of the salary, respectively. Therefore, his salary on a Saturday is €20,25 and on a Sunday €27,00. By multiplying these amounts with the number of hours the DC is operating and the number of TTs used on the respective day, gives the salary of the TT drivers.

4.2.3.2 Energy costs

To calculate the energy costs of a TT, the price per kWh in the Netherlands is needed and the energy consumption. The average price per kWh in the Netherlands is €0,20 (Milieu Centraal, n.d.). The average energy consumption is 15 kWh (Gerrits, 2016). Then the energy costs can be calculated by multiplying the price per kWh and the energy consumption with the number of hours the DC is operating and the number of TTs used on the respective day.

4.2.3.3 Damage costs

The amount of damage that is caused by a TT driver on a DC is hard to estimate. It depends on the skills of the TT driver, but also on the DC itself and on luck. For now, it is assumed that for every 1000 movements, an average damage is made of €100.

4.2.4 Formula for the total costs

All the costs that are determined can together be used to calculate the total costs for automated and manual trailer docking for the coming 10 years. This section first discusses the discount rate and then the formula to calculate the total costs for 10 years.

4.2.4.1 Discount rate

Every year, the prices in the Netherlands rise with a certain percentage, due to inflation. To take this into account, a discount rate is used. A discount rate of 1% is used.

4.2.4.2 Structure of the formula

For calculating the total costs, first the weekly costs are multiplied with the number of weeks per year the DC is operating. Then the yearly costs are added. This gives the costs for the first year. For next year, the calculation is the same, but the costs are increased for with the discount rate. For the years after that, the costs are increased with the discount rate to the power of the number of that year. Then the costs for all the years are added up. Last, the initial costs are added, which gives the formula below to calculate the total costs for 10 years.

$$Costs = \sum_{n=0}^9 (C_{Yearly} + Number\ of\ weeks\ operating * C_{Weekly}) * (1 + r)^n + C_{Initial}$$

4.3 TCO Calculation tool

In this section, the TCO calculation tool is discussed. The tool uses three different steps: determining the input characteristics, making calculations and showing the results. The steps are illustrated with an example. The example used is a medium-sized DC, at which it takes 5 minutes to perform one movement. It operates from Monday till Saturday, every week of the year. First, the input characteristics of this example are discussed. Then, the calculations for the example are shown. Lastly, the results of the example are discussed.

4.3.1 Input characteristics

Figure 1.1 shows the input characteristics for the example. The input characteristics must be filled in for an average week at the DC. The motive for choosing a week instead of a month or a year, is that every week has the same number of days and it is not too time-consuming to fill it in for a week.

In the example, the DC is operating 16 hours per day on Monday till Saturday and it is closed on Sunday. It operates every week of the year and 5 minutes are needed for a TT driver to perform one movement.

Monday	
Number of hours operating	16
Number of movements *	150
Tuesday	
Number of hours operating	16
Number of movements *	150
Wednesday	
Number of hours operating	16
Number of movements *	150
Thursday	
Number of hours operating	16
Number of movements *	150
Friday	
Number of hours operating	16
Number of movements *	150
Saturday	
Number of hours operating	16
Number of movements *	150
Sunday	
Number of hours operating	0
Number of movements *	0
Number of weeks per year operating	52
Average time it takes for a TT driver to perform one movement (minutes)	5

* One movement is one time a semi-trailer is moved by a TT, for example from the parking to a dock or vice versa

Figure 4.2 Input characteristics of the tool.

4.3.2 Calculations of the tool

To calculate the total costs for ten years for manual and automated trailer docking, the tool uses several calculations. There are a few differences between manual and automated trailer docking within the calculations, but the same steps are taken. First, the number of TTs that needs to be bought is determined. Next, the initial costs, yearly costs and weekly costs are calculated. At the end, the costs for each year are calculated and these costs are added up to give the total costs for 10 years. The following two sections show these calculations for manual and automates trailer docking

4.3.2.1 Calculations manual trailer docking

This section describes how the total costs for manual trailer docking are calculated.

Number of TTs to buy

The first step of the calculations for the manual TTs is to calculate how many TTs are needed. This is done by multiplying the number of movements at one day with the time needed for one movement and dividing this by the number of minutes the DC is operating that day. This is done for every day that the DC is operating. After that, the number of TTs needed is rounded up, since some calculations need an integer. In the example, the results are that 1 TT is necessary on Monday till Saturday and no TTs are necessary on Sunday. Therefore, 1 TT needs to be bought.

One-time costs

Next, the one-time costs are calculated. As discussed in section 4.2.1, these consist of purchasing costs for the TTs and costs for the IT system, charging points and coupling system. Since an IT system and a coupling system are not necessary for manual trailer docking, these costs are not considered. This leaves the purchasing costs for the TTs and the costs for the charging points. The purchasing costs for the TTs are simply calculated by multiplying the purchasing cost for one TT with the maximum rounded number of TTs that is necessary. The costs for the charging points are fixed costs, so these are €10.000. Adding up the purchasing costs for the TTs and the costs for charging points gives the one-time costs. The price for purchasing the TTs and charging point in the example are €75.000 and €10.000, respectively. Therefore, the one-time costs are €85.000.

Yearly costs

Then the yearly costs are determined. These costs consist of the maintenance costs only. These costs are calculated by multiplying the maintenance costs per year with the number of TTs that is necessary. Since maintenance costs are €2.000 for the example, the yearly costs in this case are €2.000.

Weekly costs

After that, the weekly costs are calculated, based on the salary for the TT drivers, the energy costs and the costs for damage. The salary for the drivers of the TTs on a certain day is calculated by multiplying the salary for one hour with the not rounded number of TTs necessary and the hours that the DC is operating that day. By multiplying the hours that the DC is operating on a certain day with the not rounded number of TTs necessary that day, the energy consumption and the price of a kWh, the energy costs for that day are determined. The damage for a week is calculated by adding up all the movements that the DC is performing in a week, dividing this by 1000 and multiplying this number with the average damage per 1000 movements. At the end, the salary and energy costs for all days in the week are added up to the damage costs, which gives the weekly costs. For the example, the salary for Monday till Sunday is €1096,88, the energy costs are €225 and the damage is €90. Adding this up gives that the weekly costs are €1411,88.

Total costs for 10 years

Lastly, the costs for all 10 years are calculated. For the first year, the weekly costs are multiplied with the number of weeks that a DC is operating. The costs for the second year are the same as the costs for the first year, but they are increased with the discount factor. In the same way, the costs for the third year are like the costs the second year, but increased with the discount factor, etc. At the end, the initial costs and the costs for all the years are added up, which gives the costs for manual trailer docking for 10 years. This results in total costs of €874.000 for manual trailer docking in the example.

4.3.2.2 Calculations automated trailer docking

The calculations for the costs of automated trailer docking are partly done the same way as for manual trailer docking.

Number of TTs to buy

First, the number of TTs needed is determined. This is done the same way as for manual trailer docking, but an efficiency factor is added. An automated TT needs less time for one movement than a manual TT and this is reflected by the efficiency factor. Now the number of TTs needed is calculated by multiplying the number of movements at one day with the efficiency factor and the time needed for one movement and dividing this by the number of minutes the DC is operating that day. This is done for every day of the week. Then the results are rounded up, since part of the calculations need an integer for the number of TTs needed. This results in 1 TT that is necessary on Monday till Saturday and no TT that is necessary on Sunday in the example. Therefore, 1 TT needs to be purchased.

Initial costs

The next step is to calculate the initial costs, based on the purchasing costs of the TTs and the costs for the IT system, charging points and coupling system. The purchasing costs of the TTs are determined by multiplying the purchasing costs for one automated TT with the maximum rounded number of TTs to be bought. The costs for the IT system and the charging points are a fixed number. The costs for the coupling system are determined by multiplying the maximum rounded number of TTs with the price of a coupling system for one TT. Then the purchasing costs of the TTs and the costs for the IT system, charging points and coupling are added up, which gives the initial costs. For the example, 1 TT is bought, so the purchasing costs of the TT and the coupling system are €300.000 and €10.000, respectively. The costs for the IT system and charging points are both €10.000. Adding up these costs gives one-time costs of €322.000.

Yearly costs

After that, the yearly costs are determined, which consist of the maintenance costs. These are determined the same way as for manual trailer docking: by multiplying the maintenance costs per year with the number of TTs that is necessary. The maintenance costs are €2.000 for the example, so the yearly costs in this case are €2.000.

Weekly costs

For automated trailer docking, the weekly costs consist only of the energy costs. It is calculated in the same way as for manual trailer docking. The not rounded number of TTs necessary is multiplied with the number of hours that the DC is operating that day and with the energy consumption and the price of one kWh. Then the energy costs of every day are added up, giving the weekly costs for automated trailer docking. The energy costs are €202,50 per week in the example.

Total costs for 10 years

At the end, the costs for all 10 years are calculated in the same way as for manual trailer docking. First, the yearly costs are added up to the weekly costs, multiplied with the number of weeks per year that the DC is operating. For the second year, the costs of the first year are increased with the discount factor. In the same way, the costs for the second year are increased with the discount factor to calculate the costs for the third year, and so on. Lastly, the costs for all 10 years and the initial costs are added up, which gives the costs for automated trailer docking for 10 years. For the example, this results in total costs of €453.000 for automated trailer docking.

4.3.3 Results of the tool

Given the input characteristics and calculations before, the tool gives the results as shown in Table 4.1. The costs for manual trailer docking for 10 years are €874.000 and the costs for automated trailer docking for 10 years are €453.000. This means that manual trailer docking is almost twice as expensive as automated trailer docking, for this example. However, the costs for other cases can differ a lot from this case, obviously.

Results	
Costs for manual trailer docking for 10 years	Costs for automated trailer docking for 10 years
€ 874.000	€ 453.000

Table 4.1 Results of the tool.

4.3.4 Distribution of the costs

Given the results of the tool, each kind of costs had a different contribution to the total costs. The contribution of each cost for the total costs for 10 years is given in Figure 4.3. With these numbers, the share of each costs in the total costs can be evaluated, which is shown in Figure 4.4.

What is remarkable, is the purchase price for the TT is more than 60% of the total costs for automated trailer docking, while it is less than 10% of the total costs for manual trailer docking. The cause of this is that an automated TT is 4 times as expensive as a manual TT, but the total costs for automated trailer docking is twice as inexpensive as manual trailer docking.

Also, the salary contributes to almost 70% of the total costs for manual trailer docking, but automated trailer docking does not even have salary costs. Hiring employees is very expensive and they are necessary for every movement if trailer docking is performed manually.



Figure 4.3 Absolute distribution of the costs.

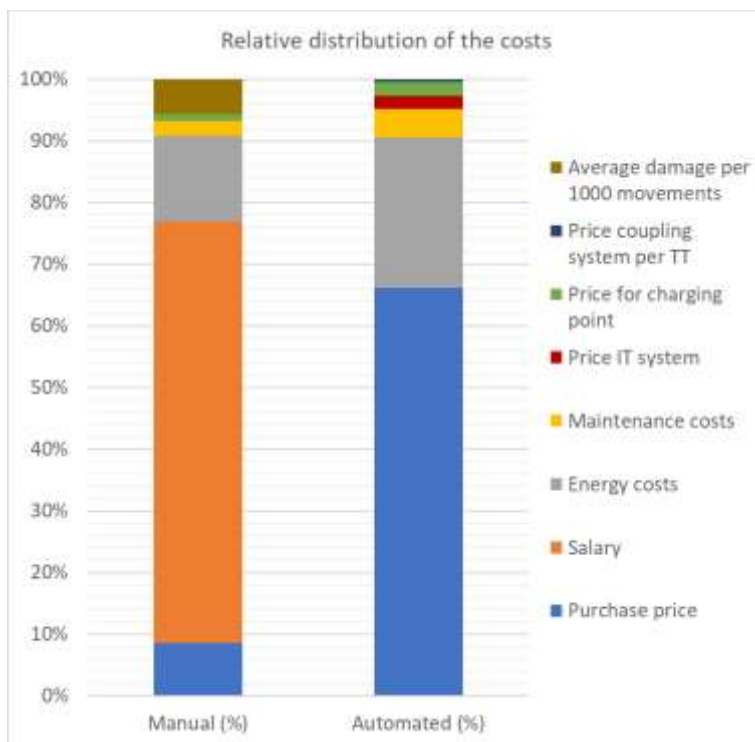


Figure 4.4 Relative distribution of the costs.

The energy costs do not differ a lot, but the share of energy costs for manual trailer docking is almost 15%, while it is almost 25% for automated trailer docking. Also, for the maintenance costs and the costs for the charging points the share for automated trailer docking is higher than for manual trailer docking, while the absolute costs are the same. This is caused by the fact that the total costs of automated trailer docking are lower than those of manual trailer docking.

Last, there are 3 costs that are only relevant for either automated trailer docking or manual trailer docking. These are costs for the IT system, the coupling system and damage. However, these costs only contribute for a small percentage.

5 SENSITIVITY ANALYSIS AND QUICK SCAN

In this chapter, the research question ‘How can a quick scan be developed as introduction to the tool?’. Section 5.1 discusses the sensitivity analysis and section 5.2 describes the quick scan.

5.1 Sensitivity analysis

This section explains the method of the sensitivity analysis and shows the results of the sensitivity analysis.

5.1.1 Method sensitivity analysis

To indicate which elements have the biggest impact on the total costs for both manual and automated trailer docking, a sensitivity analysis is done. For this analysis, the difference in the total costs is calculated if an element increases or decreases with 10 percent. This is done for each element and for both manual and automated trailer docking.

Table 5.1 Sensitivity analysis of the purchase price of a manual TT. Table 5.1 shows how the sensitivity analysis is done for the purchasing price with manual trailer docking. For each change in the purchase price, the weekly, yearly and initial costs are calculated. Based on these numbers, the costs for each year are determined, in the same way as explained in Section 4.2. The columns that are affected by the change in the purchase price, are coloured. Then the difference of the total costs is calculated in the case for which the purchase price is not increased or decreased. At the end, the difference is calculated in percentages. For automated trailer docking and all other elements, this is done in the

		Manual								
		Purchase price	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs (€)	Difference total costs (%)
Change of the purchase price	-10%	€ 67.500	€ 1.412	€ 2.000	€ 77.500	€ 75.000	€ 76.000	€ 865.000	-€ 7.000	-0,80%
	-9%	€ 68.250	€ 1.412	€ 2.000	€ 78.250	€ 75.000	€ 76.000	€ 865.000	-€ 7.000	-0,80%
	-8%	€ 69.000	€ 1.412	€ 2.000	€ 79.000	€ 75.000	€ 76.000	€ 866.000	-€ 6.000	-0,69%
	-7%	€ 69.750	€ 1.412	€ 2.000	€ 79.750	€ 75.000	€ 76.000	€ 867.000	-€ 5.000	-0,57%
	-6%	€ 70.500	€ 1.412	€ 2.000	€ 80.500	€ 75.000	€ 76.000	€ 868.000	-€ 4.000	-0,46%
	-5%	€ 71.250	€ 1.412	€ 2.000	€ 81.250	€ 75.000	€ 76.000	€ 868.000	-€ 4.000	-0,46%
	-4%	€ 72.000	€ 1.412	€ 2.000	€ 82.000	€ 75.000	€ 76.000	€ 869.000	-€ 3.000	-0,34%
	-3%	€ 72.750	€ 1.412	€ 2.000	€ 82.750	€ 75.000	€ 76.000	€ 870.000	-€ 2.000	-0,23%
	-2%	€ 73.500	€ 1.412	€ 2.000	€ 83.500	€ 75.000	€ 76.000	€ 871.000	-€ 1.000	-0,11%
	-1%	€ 74.250	€ 1.412	€ 2.000	€ 84.250	€ 75.000	€ 76.000	€ 871.000	-€ 1.000	-0,11%
	0%	€ 75.000	€ 1.412	€ 2.000	€ 85.000	€ 75.000	€ 76.000	€ 872.000	€ 0	0,00%
	1%	€ 75.750	€ 1.412	€ 2.000	€ 85.750	€ 75.000	€ 76.000	€ 873.000	€ 1.000	0,11%
	2%	€ 76.500	€ 1.412	€ 2.000	€ 86.500	€ 75.000	€ 76.000	€ 874.000	€ 2.000	0,23%
	3%	€ 77.250	€ 1.412	€ 2.000	€ 87.250	€ 75.000	€ 76.000	€ 874.000	€ 2.000	0,23%
	4%	€ 78.000	€ 1.412	€ 2.000	€ 88.000	€ 75.000	€ 76.000	€ 875.000	€ 3.000	0,34%
	5%	€ 78.750	€ 1.412	€ 2.000	€ 88.750	€ 75.000	€ 76.000	€ 876.000	€ 4.000	0,46%
	6%	€ 79.500	€ 1.412	€ 2.000	€ 89.500	€ 75.000	€ 76.000	€ 877.000	€ 5.000	0,57%
	7%	€ 80.250	€ 1.412	€ 2.000	€ 90.250	€ 75.000	€ 76.000	€ 877.000	€ 5.000	0,57%
	8%	€ 81.000	€ 1.412	€ 2.000	€ 91.000	€ 75.000	€ 76.000	€ 878.000	€ 6.000	0,69%
9%	€ 81.750	€ 1.412	€ 2.000	€ 91.750	€ 75.000	€ 76.000	€ 879.000	€ 7.000	0,80%	
10%	€ 82.500	€ 1.412	€ 2.000	€ 92.500	€ 75.000	€ 76.000	€ 880.000	€ 8.000	0,92%	

Table 5.1 Sensitivity analysis of the purchase price of a manual TT.

same way.

5.1.2 Results sensitivity analysis

The results of the sensitivity analysis are shown in Figure 5.1. This figure shows only the increase of the values. Since the graph is symmetrical, it would look the same as for the decrease, but mirrored. Figure 5.2 shows the relative results of the sensitivity analysis instead of the absolute results.

From Figure 5.2 can be concluded that the salary of the TT drivers has the biggest impact on the costs for manual trailer docking. However, it has no impact on the costs for automated trailer docking, since no TT drivers are necessary for automated trailer docking. Elements that do have a considerable impact on the total costs of both manual and automated trailer docking, are the purchase price, price per kWh, energy consumption and efficiency factor. There are also some elements that have little or no impact on manual and automated trailer docking, namely the average damage per 1000 movements, the discount rate, the maintenance per year and the prices for charging points, the IT system and the coupling system.

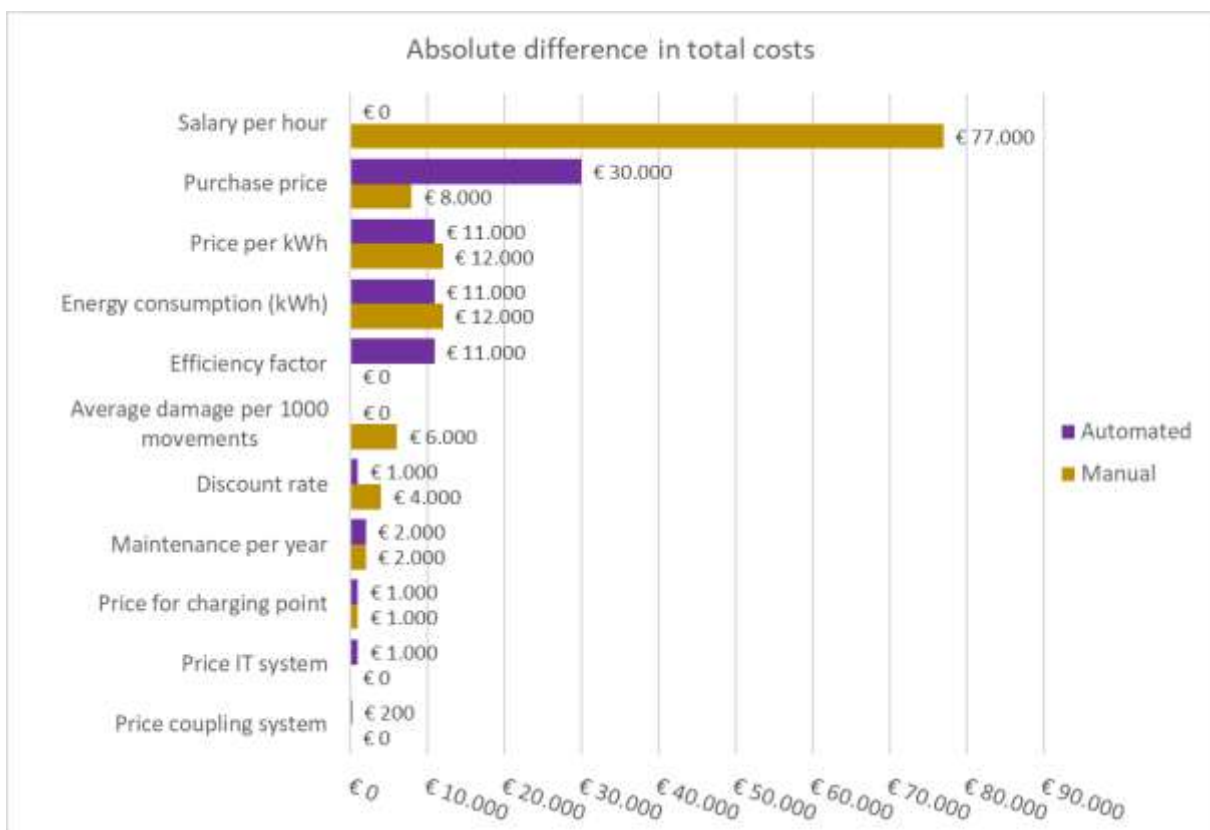


Figure 5.1 Absolute results of the sensitivity analysis.

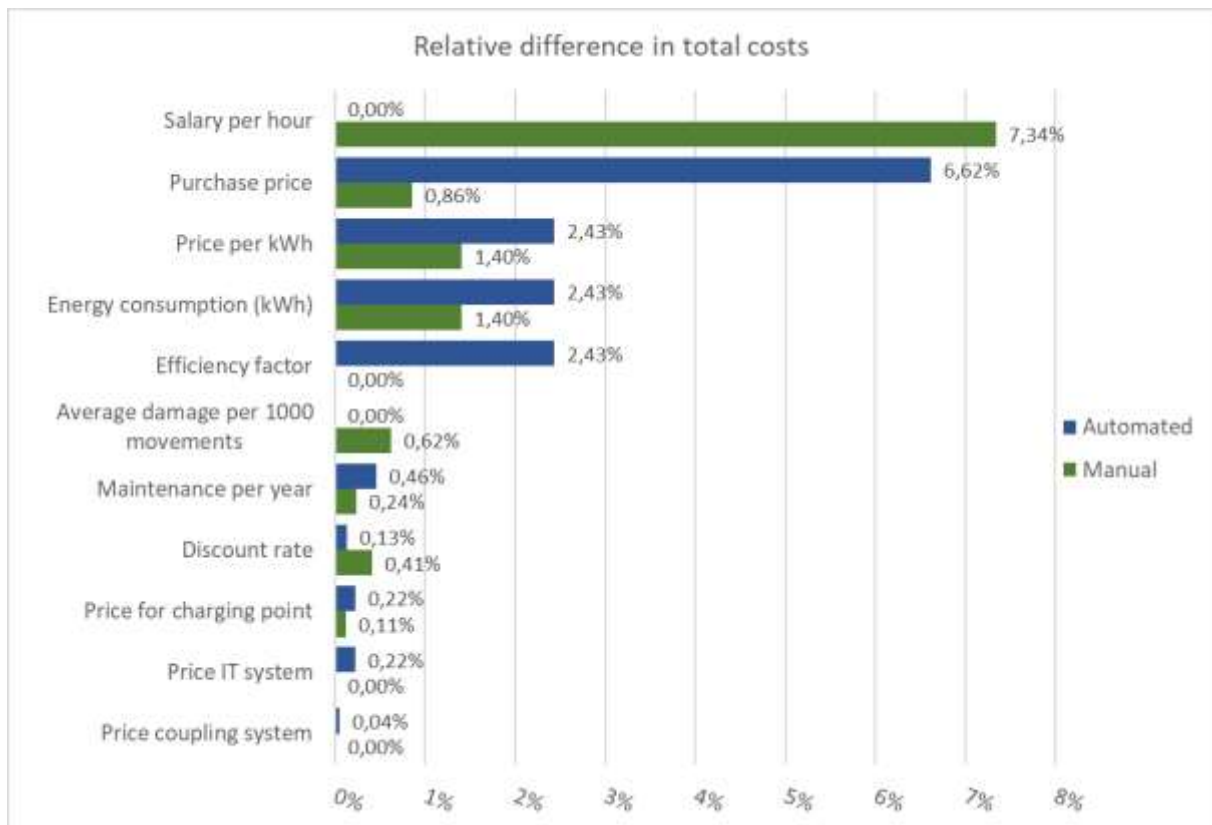


Figure 5.2 Relative results of the sensitivity analysis.

5.2 Quick scan

This section discusses the development of the quick scan, the analysis that is done with it and the results of this analysis.

5.2.1 Development quick scan

For the quick scan, the most relevant elements are evaluated. As described in Section 5.1.2, the salary of the TT drivers has a very big impact on the total costs of manual trailer docking. Therefore, this is the first element to be considered. The purchase price, price per kWh, energy consumption and efficiency factor also have a considerable impact on the total costs, so these are used as well.

The elements mentioned above are now implemented in the tool. This is done in such a way, that they can be adjusted, to see what happens with the total costs of both manual and automated trailer docking. For example, if the salary increases, manual trailer docking gets a lot more expensive, while the costs of automated trailer docking stay the same. The calculations as explained in Section 4.3.2 stay the same. A screenshot of the dashboard of the quick scan can be found in Appendix C: Dashboard of the quick scan.

5.2.2 Scenarios quick scan

By adjusting the elements selected in Section 5.2.2, different scenarios can be created. These scenarios included a basic case, worst case and best case scenario, which are shown in Table 5.2. The costs that they are expected currently and that are implemented in the tool, are used in the basic case. The worst case reflects the scenario for which automated trailer docking compared to manual trailer is less beneficial than in the basic case. This is reflected with an increase or decrease of the selected elements, based on their impact on the total costs of manual and automated trailer docking. For example, the purchase price for a manual TT decreases, while the purchase price for an automated TT increases. The best case is comparable to the worst case, only the best case reflects the scenario for which automated trailer docking compared to manual trailer is more beneficial than in the basic case. All the costs in the best and worst case either increase with 10% or decrease with 10%, because these costs are already calculated in the sensitivity analysis.

	Worst case	Basic case	Best case
Purchase price manual TT	€ 67.500,00	€ 75.000,00	€ 82.500,00
Purchase price automated TT	€ 330.000,00	€ 300.000,00	€ 270.000,00
Salary per hour	€ 12,15	€ 13,50	€ 14,85
Average reduction	€ 0,99	90,00%	81,00%
Energy consumption	17 kWh	15 kWh	14 kWh
Price per kWh	€ 0,22	€ 0,20	€ 0,18

Table 5.2 Scenarios for the quick scan analysis.

5.2.3 Analysis quick scan

The scenarios described in Section 5.2.2 can be used to analyse in which cases automated trailer docking is more beneficial than manual trailer docking. To do this, a certain threshold is necessary. This means that if automated trailer docking is just a little more beneficial than manual trailer docking, for example €20,00, it might not be worth the effort for a business to implement automated trailer docking. Therefore, a threshold is used that automated trailer docking is implemented if it has at least 25% lower costs than manual trailer docking.

	Worst case	Basic case	Best case
Minimum number of movements per day for automated trailer docking to be more than 25% less expensive than manual trailer docking	113	85	65

Table 5.3 Results of the analysis of the quick scan.

In a certain scenario, the input characteristics can be varied to reach the threshold. Different input characteristics can be varied, but for this case, the number of movements is varied. With help of the solver in Excel, the specific number of movements is determined, for which the threshold is exactly 25%, while the other input characteristics remain the same as in the example in Section 4.3.1. This is done for each scenario that is described in Section 5.2.2. The results are shown Table 5.3. For the worst case, at least 113 movements per day are necessary. For the basic case and the best case, this is 85 and 65 movements per day, respectively.

6 CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

This chapter examines the results from my bachelor thesis. First, the conclusions will be drawn in section 6.1. Then section 6.2 lists the recommendations.

6.1 Conclusions

During this research, we investigated the impact of automated versus manual trailer docking on the logistic processes in terms of People, Planet, Profit. In this section, the conclusions are discussed based on the research questions of Section 1.5.

How is trailer docking performed currently?

First, the current process of trailer docking was investigated. This was done by conducting a literature review and interviewing people related to INTRALOG and/or ROTRA. It became clear that the steps in the process would not change if the process would be automated instead of manual. Only the TT with driver is replaced by an automated TT. There are only two difficulties. First, the coupling and decoupling of the TT with the semi-trailer cannot be done automatically yet. Second, the dock doors cannot be opened automatically as well.

Which elements are relevant to assess the impact of automating trailer docking?

Then interviews were held to find the elements that are relevant for assessing the impact of automated trailer docking. Also, information from the literature was found. These include the boundary conditions, benefits, costs and characteristics of the DC. The boundary conditions are that the area with automated TTs cannot be accessible to humans and solutions must be found to automatically couple and decouple the TT and semi-trailer and to automatically open the dock doors. The benefits of automated trailer docking are that there are no drivers necessary, less damage, semi-trailers are always docked first time right, no more semi-trailers at the wrong dock, more movements per hour, lower consumption, possible subsidy and credit and less maintenance. Then there are costs for purchasing the TT, a new coupling system, new infrastructure, new IT, possibly more maintenance, more ground, training of employees and less flexibility. Last, the relevant characteristics of the DC include the operating times, number of movements per day, number of weeks per year operating and the average time needed for one movement.

What are the relations between these elements and how can these relations be quantified?

The relations between the relevant elements were found and they were quantified. This was also done by conducting interviews. A formula to calculate the total costs for 10 years of automated and manual trailer docking was made.

How can this be implemented in a tool to assess the impact of automating trailer docking at DCs?

With the information gathered, a tool was developed. The input of this tool are the characteristics of the DC that were found. Then the total costs were calculated with the relations and quantifications of the relevant elements that were found. For the example that was set up, the costs for manual trailer docking for 10 years are €874.000 and the costs for automated trailer docking are €453.000.

In the last chapter, a sensitivity analysis was done, and a quick scan was made. The sensitivity analysis evaluated which element had the biggest impact on the total costs. Every element was increased and decreased with 10% alternately and the difference in the total costs were calculated. It became clear that the salary per hour, the purchase price, price per kWh, energy consumption and efficiency were the elements that had the biggest impact on the total costs. These elements were used in the quick scan in a way that they could be modified easily, to create different scenarios. Next, 3 different scenarios were analysed: a basic case, worst case and best case. This analysis was done with a threshold that the costs for automated trailer docking had to be at least 25% lower than for manual

trailer docking. With this threshold, 113 movements per day must be performed for the worst case, 85 movements for the basic case and 63 movements for the best case.

6.2 Recommendations

Based on the research conducted, a couple of recommendations are provided.

First, more research should be done into the efficiency factor of automated trailer docking. The efficiency factor is one of the five elements that has the biggest impact on the total costs of automated trailer docking. Also, more efficient trailer docking is a big advantage of automated trailer docking, compared to manual trailer docking. However, there is no data about how often a semi-trailer is docked first time right and how often not. Also, it is unknown how long it takes to try to dock a semi-trailer again, if it was not docked the first time right. It is unknown how often a TT driver drives against something as well. Since the time for this research was limited, it was not possible to do not an extensive research on these data. Therefore, the number used in the research is just an estimation. To get a more accurate result, more research into the increased efficiency of automated trailer docking is necessary.

Next, more information needs to be gathered about the precise costs of manual and automated trailer docking. Multiple costs were not clear (yet), for example the costs for charging points, the IT system and the amount of training necessary for employees. Other costs strongly differ per case, like the extra ground needed and the possible damage when a TT driver drives into an obstacle. Especially the first category of costs needs to be researched further.

The last recommendation is to further develop a solution for automatic coupling and decoupling. It is essential that coupling and decoupling is automatic, since no humans are allowed at the area with automated TTs and since it takes away the advantage that humans are not necessary. Currently, there some possible solutions with potential, but these still need to be developed further.

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APPENDICES

Appendix A: Problem identification

Problem context

One of the first steps of the MPSM is to make a problem cluster. This is an overview of the problems and their coherence. The problem cluster is shown in Figure A.1. A short explanation of each problem is now given:

1. Drivers of the TTs are inaccurate: Drivers are only human and can make mistakes therefore. There are two kind of mistakes they can make. Firstly, rearward docking up a semi-trailer is hard, especially if the driver does not have a lot of experience. Sometimes the driver has to try two or more times, before the semi-trailer is docked up. Second, the location of a semi-trailer in the system does not always match its actual location. The IT system tells the drivers where to dock up the semi-trailer. Sometimes the driver makes a mistake and docks up the semi-trailer at the wrong dock. This makes it hard to find the semi-trailer and/or gives problems if a second semi-trailer has to be docked up at that dock.
2. Drivers of the TTs do not work efficient: Because of the mistakes of the drivers, their efficiency decreases.
3. Delay occurs: Since the efficiency of the drivers of the TTs is low, it takes more time to dock up a semi-trailer. This causes delay for that semi-trailer, but also for other semi-trailers, since they may have to wait. This is especially the case when it is busy at the DC.
4. The arrival times of trucks are uncertain: The traffic is not 100% predictable, due to traffic jam. Therefore, it is uncertain at which time a truck exactly arrives.
5. More fuel and energy are used than needed: due to the inefficiency of the process, trucks and TTs (with semi-trailers) have to drive more than needed. This makes that the amount of fuel and energy used is higher than necessary.
6. The efficiency of the process is low: Because of the delay and the uncertain arrival times, certain actions take longer and waiting times increase. This makes that the efficiency of the process is low.
7. The costs for the drivers of TTs are high: Drivers have to get salary, which makes that the drivers are expensive.
8. High costs: Problem 4, 5 and 6 together increase the total costs for the distribution centre.

Core problem

The core problem is indicated in the problem cluster with a colored block, which is that the drivers make mistakes. I chose this problem, since it is a problem that can be solved (the uncertain arrival times of the trucks cannot be solved for example) and because it is as far back in the chain of problems as possible. A norm and reality for this core problem can be expressed in the average number of mistakes made by drivers of a TT on one day. At this moment, I don't have exact values for the norm and the reality.

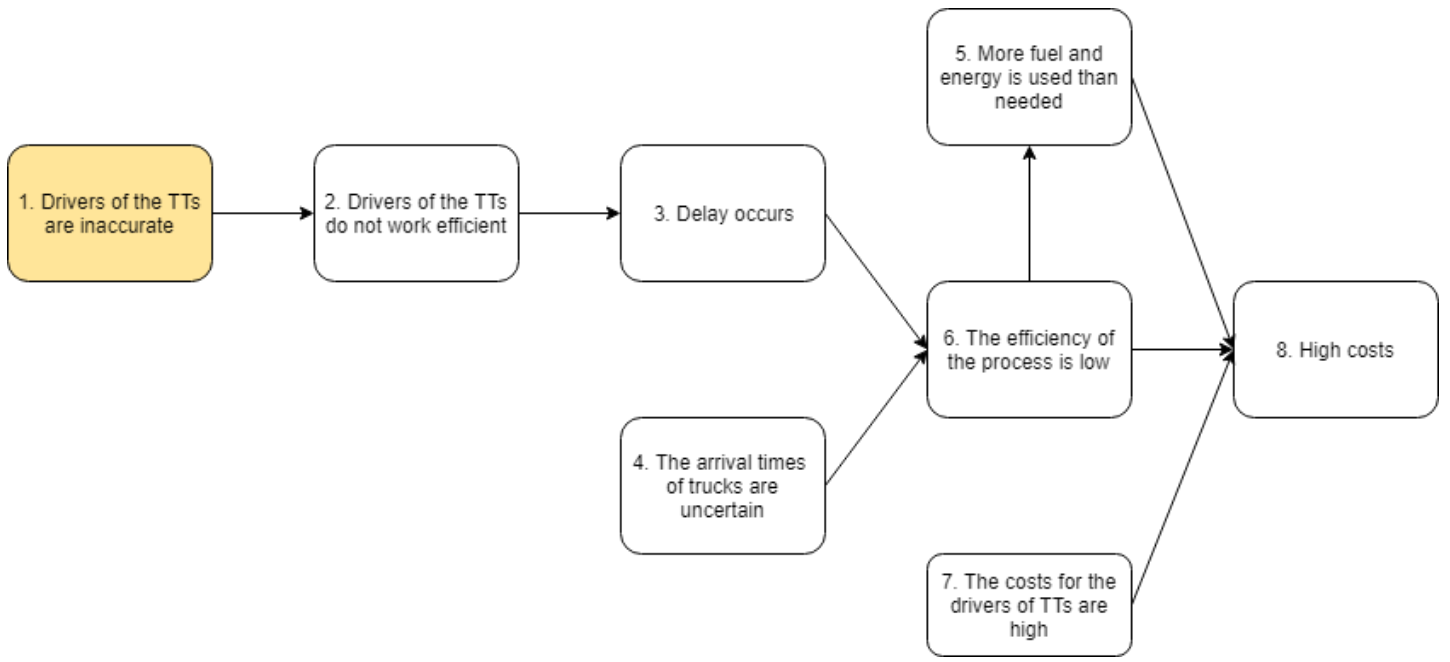


Figure A.1 Problem cluster.

Appendix B: Results of the sensitivity analysis

Purchase price

		Manual								
		Purchase price	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs (€)	Difference total costs (%)
Change of the purchase price	-10%	€ 67.500	€ 1.412	€ 2.000	€ 77.500	€ 75.000	€ 76.000	€ 865.000	-€ 7.000	-0,80%
	-9%	€ 68.250	€ 1.412	€ 2.000	€ 78.250	€ 75.000	€ 76.000	€ 865.000	-€ 7.000	-0,80%
	-8%	€ 69.000	€ 1.412	€ 2.000	€ 79.000	€ 75.000	€ 76.000	€ 866.000	-€ 6.000	-0,69%
	-7%	€ 69.750	€ 1.412	€ 2.000	€ 79.750	€ 75.000	€ 76.000	€ 867.000	-€ 5.000	-0,57%
	-6%	€ 70.500	€ 1.412	€ 2.000	€ 80.500	€ 75.000	€ 76.000	€ 868.000	-€ 4.000	-0,46%
	-5%	€ 71.250	€ 1.412	€ 2.000	€ 81.250	€ 75.000	€ 76.000	€ 868.000	-€ 4.000	-0,46%
	-4%	€ 72.000	€ 1.412	€ 2.000	€ 82.000	€ 75.000	€ 76.000	€ 869.000	-€ 3.000	-0,34%
	-3%	€ 72.750	€ 1.412	€ 2.000	€ 82.750	€ 75.000	€ 76.000	€ 870.000	-€ 2.000	-0,23%
	-2%	€ 73.500	€ 1.412	€ 2.000	€ 83.500	€ 75.000	€ 76.000	€ 871.000	-€ 1.000	-0,11%
	-1%	€ 74.250	€ 1.412	€ 2.000	€ 84.250	€ 75.000	€ 76.000	€ 871.000	-€ 1.000	-0,11%
	0%	€ 75.000	€ 1.412	€ 2.000	€ 85.000	€ 75.000	€ 76.000	€ 872.000	€ 0	0,00%
	1%	€ 75.750	€ 1.412	€ 2.000	€ 85.750	€ 75.000	€ 76.000	€ 873.000	€ 1.000	0,11%
	2%	€ 76.500	€ 1.412	€ 2.000	€ 86.500	€ 75.000	€ 76.000	€ 874.000	€ 2.000	0,23%
	3%	€ 77.250	€ 1.412	€ 2.000	€ 87.250	€ 75.000	€ 76.000	€ 874.000	€ 2.000	0,23%
	4%	€ 78.000	€ 1.412	€ 2.000	€ 88.000	€ 75.000	€ 76.000	€ 875.000	€ 3.000	0,34%
	5%	€ 78.750	€ 1.412	€ 2.000	€ 88.750	€ 75.000	€ 76.000	€ 876.000	€ 4.000	0,46%
	6%	€ 79.500	€ 1.412	€ 2.000	€ 89.500	€ 75.000	€ 76.000	€ 877.000	€ 5.000	0,57%
7%	€ 80.250	€ 1.412	€ 2.000	€ 90.250	€ 75.000	€ 76.000	€ 877.000	€ 5.000	0,57%	
8%	€ 81.000	€ 1.412	€ 2.000	€ 91.000	€ 75.000	€ 76.000	€ 878.000	€ 6.000	0,69%	
9%	€ 81.750	€ 1.412	€ 2.000	€ 91.750	€ 75.000	€ 76.000	€ 879.000	€ 7.000	0,80%	
10%	€ 82.500	€ 1.412	€ 2.000	€ 92.500	€ 75.000	€ 76.000	€ 880.000	€ 8.000	0,92%	
		Automated								
		Purchase price	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs (€)	Difference total costs (%)
Change of the purchase price	-10%	€ 270.000	€ 203	€ 2.000	€ 292.000	€ 12.530	€ 12.655	€ 423.000	-€ 30.000	-6,62%
	-9%	€ 273.000	€ 203	€ 2.000	€ 295.000	€ 12.530	€ 12.655	€ 426.000	-€ 27.000	-5,96%
	-8%	€ 276.000	€ 203	€ 2.000	€ 298.000	€ 12.530	€ 12.655	€ 429.000	-€ 24.000	-5,30%
	-7%	€ 279.000	€ 203	€ 2.000	€ 301.000	€ 12.530	€ 12.655	€ 432.000	-€ 21.000	-4,64%
	-6%	€ 282.000	€ 203	€ 2.000	€ 304.000	€ 12.530	€ 12.655	€ 435.000	-€ 18.000	-3,97%
	-5%	€ 285.000	€ 203	€ 2.000	€ 307.000	€ 12.530	€ 12.655	€ 438.000	-€ 15.000	-3,31%
	-4%	€ 288.000	€ 203	€ 2.000	€ 310.000	€ 12.530	€ 12.655	€ 441.000	-€ 12.000	-2,65%
	-3%	€ 291.000	€ 203	€ 2.000	€ 313.000	€ 12.530	€ 12.655	€ 444.000	-€ 9.000	-1,99%
	-2%	€ 294.000	€ 203	€ 2.000	€ 316.000	€ 12.530	€ 12.655	€ 447.000	-€ 6.000	-1,32%
	-1%	€ 297.000	€ 203	€ 2.000	€ 319.000	€ 12.530	€ 12.655	€ 450.000	-€ 3.000	-0,66%
	0%	€ 300.000	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	1%	€ 303.000	€ 203	€ 2.000	€ 325.000	€ 12.530	€ 12.655	€ 456.000	€ 3.000	0,66%
	2%	€ 306.000	€ 203	€ 2.000	€ 328.000	€ 12.530	€ 12.655	€ 459.000	€ 6.000	1,32%
	3%	€ 309.000	€ 203	€ 2.000	€ 331.000	€ 12.530	€ 12.655	€ 462.000	€ 9.000	1,99%
	4%	€ 312.000	€ 203	€ 2.000	€ 334.000	€ 12.530	€ 12.655	€ 465.000	€ 12.000	2,65%
	5%	€ 315.000	€ 203	€ 2.000	€ 337.000	€ 12.530	€ 12.655	€ 468.000	€ 15.000	3,31%
	6%	€ 318.000	€ 203	€ 2.000	€ 340.000	€ 12.530	€ 12.655	€ 471.000	€ 18.000	3,97%
7%	€ 321.000	€ 203	€ 2.000	€ 343.000	€ 12.530	€ 12.655	€ 474.000	€ 21.000	4,64%	
8%	€ 324.000	€ 203	€ 2.000	€ 346.000	€ 12.530	€ 12.655	€ 477.000	€ 24.000	5,30%	
9%	€ 327.000	€ 203	€ 2.000	€ 349.000	€ 12.530	€ 12.655	€ 480.000	€ 27.000	5,96%	
10%	€ 330.000	€ 203	€ 2.000	€ 352.000	€ 12.530	€ 12.655	€ 483.000	€ 30.000	6,62%	

Salary

		Manual										
		Salary Monday-Friday	Salary Saturday	Salary Sunday	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs
Change of the salary	-10%	€ 12,15	€ 18,23	€ 24,30	€ 1.579	€ 2.000	€ 85.000	€ 84.087	€ 84.928	€ 965.000	-€ 76.000	-7,30%
	-9%	€ 12,29	€ 18,43	€ 24,57	€ 1.593	€ 2.000	€ 85.000	€ 84.817	€ 85.665	€ 972.000	-€ 69.000	-6,63%
	-8%	€ 12,42	€ 18,63	€ 24,84	€ 1.607	€ 2.000	€ 85.000	€ 85.547	€ 86.403	€ 980.000	-€ 61.000	-5,86%
	-7%	€ 12,56	€ 18,83	€ 25,11	€ 1.621	€ 2.000	€ 85.000	€ 86.277	€ 87.140	€ 988.000	-€ 53.000	-5,09%
	-6%	€ 12,69	€ 19,04	€ 25,38	€ 1.635	€ 2.000	€ 85.000	€ 87.008	€ 87.878	€ 995.000	-€ 46.000	-4,42%
	-5%	€ 12,83	€ 19,24	€ 25,65	€ 1.649	€ 2.000	€ 85.000	€ 87.738	€ 88.615	€ 1.003.000	-€ 38.000	-3,65%
	-4%	€ 12,96	€ 19,44	€ 25,92	€ 1.663	€ 2.000	€ 85.000	€ 88.468	€ 89.352	€ 1.011.000	-€ 30.000	-2,88%
	-3%	€ 13,10	€ 19,64	€ 26,19	€ 1.677	€ 2.000	€ 85.000	€ 89.198	€ 90.090	€ 1.018.000	-€ 23.000	-2,21%
	-2%	€ 13,23	€ 19,85	€ 26,46	€ 1.691	€ 2.000	€ 85.000	€ 89.928	€ 90.827	€ 1.026.000	-€ 15.000	-1,44%
	-1%	€ 13,37	€ 20,05	€ 26,73	€ 1.705	€ 2.000	€ 85.000	€ 90.658	€ 91.564	€ 1.033.000	-€ 8.000	-0,77%
	0%	€ 13,50	€ 20,25	€ 27,00	€ 1.719	€ 2.000	€ 85.000	€ 91.388	€ 92.302	€ 1.041.000	€ 0	0,00%
	1%	€ 13,64	€ 20,45	€ 27,27	€ 1.733	€ 2.000	€ 85.000	€ 92.118	€ 93.039	€ 1.049.000	€ 8.000	0,77%
	2%	€ 13,77	€ 20,66	€ 27,54	€ 1.747	€ 2.000	€ 85.000	€ 92.848	€ 93.777	€ 1.056.000	€ 15.000	1,44%
	3%	€ 13,91	€ 20,86	€ 27,81	€ 1.761	€ 2.000	€ 85.000	€ 93.578	€ 94.514	€ 1.064.000	€ 23.000	2,21%
	4%	€ 14,04	€ 21,06	€ 28,08	€ 1.775	€ 2.000	€ 85.000	€ 94.308	€ 95.251	€ 1.072.000	€ 31.000	2,98%
	5%	€ 14,18	€ 21,26	€ 28,35	€ 1.789	€ 2.000	€ 85.000	€ 95.038	€ 95.989	€ 1.079.000	€ 38.000	3,65%
	6%	€ 14,31	€ 21,47	€ 28,62	€ 1.803	€ 2.000	€ 85.000	€ 95.768	€ 96.726	€ 1.087.000	€ 46.000	4,42%
	7%	€ 14,45	€ 21,67	€ 28,89	€ 1.817	€ 2.000	€ 85.000	€ 96.499	€ 97.464	€ 1.095.000	€ 54.000	5,19%
	8%	€ 14,58	€ 21,87	€ 29,16	€ 1.831	€ 2.000	€ 85.000	€ 97.229	€ 98.201	€ 1.102.000	€ 61.000	5,86%
9%	€ 14,72	€ 22,07	€ 29,43	€ 1.845	€ 2.000	€ 85.000	€ 97.959	€ 98.938	€ 1.110.000	€ 69.000	6,63%	
10%	€ 14,85	€ 22,28	€ 29,70	€ 1.859	€ 2.000	€ 85.000	€ 98.689	€ 99.676	€ 1.118.000	€ 77.000	7,40%	
		Automated										
		Salary Monday-Friday	Salary Saturday	Salary Sunday	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs
Change of the salary	-10%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	-9%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	-8%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	-7%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	-6%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	-5%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	-4%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	-3%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	-2%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	-1%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	0%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	1%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	2%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	3%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	4%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	5%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	6%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	7%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
	8%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%
9%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%	
10%	€ 0,00	€ 0,00	€ 0,00	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0,00	0,00%	

Energy consumption

		Manual								
		Energy consumption	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs
Change of the energy consumption	-10%	13,50 kWh	€ 1.389	€ 2.000	€ 85.000	€ 74.248	€ 74.990	€ 862.000	-€ 12.000	-1,37%
	-9%	13,65 kWh	€ 1.392	€ 2.000	€ 85.000	€ 74.365	€ 75.108	€ 863.000	-€ 11.000	-1,26%
	-8%	13,80 kWh	€ 1.394	€ 2.000	€ 85.000	€ 74.482	€ 75.226	€ 864.000	-€ 10.000	-1,14%
	-7%	13,95 kWh	€ 1.396	€ 2.000	€ 85.000	€ 74.599	€ 75.344	€ 865.000	-€ 9.000	-1,03%
	-6%	14,10 kWh	€ 1.398	€ 2.000	€ 85.000	€ 74.716	€ 75.463	€ 867.000	-€ 7.000	-0,80%
	-5%	14,25 kWh	€ 1.401	€ 2.000	€ 85.000	€ 74.833	€ 75.581	€ 868.000	-€ 6.000	-0,69%
	-4%	14,40 kWh	€ 1.403	€ 2.000	€ 85.000	€ 74.950	€ 75.699	€ 869.000	-€ 5.000	-0,57%
	-3%	14,55 kWh	€ 1.405	€ 2.000	€ 85.000	€ 75.067	€ 75.817	€ 870.000	-€ 4.000	-0,46%
	-2%	14,70 kWh	€ 1.407	€ 2.000	€ 85.000	€ 75.184	€ 75.935	€ 872.000	-€ 2.000	-0,23%
	-1%	14,85 kWh	€ 1.410	€ 2.000	€ 85.000	€ 75.301	€ 76.054	€ 873.000	-€ 1.000	-0,11%
	0%	15,00 kWh	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	1%	15,15 kWh	€ 1.414	€ 2.000	€ 85.000	€ 75.535	€ 76.290	€ 875.000	€ 1.000	0,11%
	2%	15,30 kWh	€ 1.416	€ 2.000	€ 85.000	€ 75.652	€ 76.408	€ 876.000	€ 2.000	0,23%
	3%	15,45 kWh	€ 1.419	€ 2.000	€ 85.000	€ 75.769	€ 76.526	€ 878.000	€ 4.000	0,46%
	4%	15,60 kWh	€ 1.421	€ 2.000	€ 85.000	€ 75.886	€ 76.644	€ 879.000	€ 5.000	0,57%
	5%	15,75 kWh	€ 1.423	€ 2.000	€ 85.000	€ 76.003	€ 76.763	€ 880.000	€ 6.000	0,69%
	6%	15,90 kWh	€ 1.425	€ 2.000	€ 85.000	€ 76.120	€ 76.881	€ 881.000	€ 7.000	0,80%
	7%	16,05 kWh	€ 1.428	€ 2.000	€ 85.000	€ 76.237	€ 76.999	€ 883.000	€ 9.000	1,03%
	8%	16,20 kWh	€ 1.430	€ 2.000	€ 85.000	€ 76.354	€ 77.117	€ 884.000	€ 10.000	1,14%
9%	16,35 kWh	€ 1.432	€ 2.000	€ 85.000	€ 76.471	€ 77.235	€ 885.000	€ 11.000	1,26%	
10%	16,50 kWh	€ 1.434	€ 2.000	€ 85.000	€ 76.588	€ 77.353	€ 886.000	€ 12.000	1,37%	
		Automated								
		Energy consumption	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs
Change of the energy consumption	-10%	13,50 kWh	€ 182	€ 2.000	€ 322.000	€ 11.477	€ 11.592	€ 442.000	-€ 11.000	-2,43%
	-9%	13,65 kWh	€ 184	€ 2.000	€ 322.000	€ 11.582	€ 11.698	€ 443.000	-€ 10.000	-2,21%
	-8%	13,80 kWh	€ 186	€ 2.000	€ 322.000	€ 11.688	€ 11.804	€ 444.000	-€ 9.000	-1,99%
	-7%	13,95 kWh	€ 188	€ 2.000	€ 322.000	€ 11.793	€ 11.911	€ 445.000	-€ 8.000	-1,77%
	-6%	14,10 kWh	€ 190	€ 2.000	€ 322.000	€ 11.898	€ 12.017	€ 446.000	-€ 7.000	-1,55%
	-5%	14,25 kWh	€ 192	€ 2.000	€ 322.000	€ 12.004	€ 12.124	€ 448.000	-€ 5.000	-1,10%
	-4%	14,40 kWh	€ 194	€ 2.000	€ 322.000	€ 12.109	€ 12.230	€ 449.000	-€ 4.000	-0,88%
	-3%	14,55 kWh	€ 196	€ 2.000	€ 322.000	€ 12.214	€ 12.336	€ 450.000	-€ 3.000	-0,66%
	-2%	14,70 kWh	€ 198	€ 2.000	€ 322.000	€ 12.319	€ 12.443	€ 451.000	-€ 2.000	-0,44%
	-1%	14,85 kWh	€ 200	€ 2.000	€ 322.000	€ 12.425	€ 12.549	€ 452.000	-€ 1.000	-0,22%
	0%	15,00 kWh	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	1%	15,15 kWh	€ 205	€ 2.000	€ 322.000	€ 12.635	€ 12.762	€ 454.000	€ 1.000	0,22%
	2%	15,30 kWh	€ 207	€ 2.000	€ 322.000	€ 12.741	€ 12.868	€ 455.000	€ 2.000	0,44%
	3%	15,45 kWh	€ 209	€ 2.000	€ 322.000	€ 12.846	€ 12.974	€ 456.000	€ 3.000	0,66%
	4%	15,60 kWh	€ 211	€ 2.000	€ 322.000	€ 12.951	€ 13.081	€ 457.000	€ 4.000	0,88%
	5%	15,75 kWh	€ 213	€ 2.000	€ 322.000	€ 13.057	€ 13.187	€ 459.000	€ 6.000	1,32%
	6%	15,90 kWh	€ 215	€ 2.000	€ 322.000	€ 13.162	€ 13.293	€ 460.000	€ 7.000	1,55%
	7%	16,05 kWh	€ 217	€ 2.000	€ 322.000	€ 13.267	€ 13.400	€ 461.000	€ 8.000	1,77%
	8%	16,20 kWh	€ 219	€ 2.000	€ 322.000	€ 13.372	€ 13.506	€ 462.000	€ 9.000	1,99%
9%	16,35 kWh	€ 221	€ 2.000	€ 322.000	€ 13.478	€ 13.612	€ 463.000	€ 10.000	2,21%	
10%	16,50 kWh	€ 223	€ 2.000	€ 322.000	€ 13.583	€ 13.719	€ 464.000	€ 11.000	2,43%	

Price per kWh

		Manual								
		Price per kWh	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs
Change of the price per kWh	-10%	€ 0,180	€ 1.389	€ 2.000	€ 85.000	€ 74.248	€ 74.990	€ 862.000	-€ 12.000	-1,37%
	-9%	€ 0,182	€ 1.392	€ 2.000	€ 85.000	€ 74.365	€ 75.108	€ 863.000	-€ 11.000	-1,26%
	-8%	€ 0,184	€ 1.394	€ 2.000	€ 85.000	€ 74.482	€ 75.226	€ 864.000	-€ 10.000	-1,14%
	-7%	€ 0,186	€ 1.396	€ 2.000	€ 85.000	€ 74.599	€ 75.344	€ 865.000	-€ 9.000	-1,03%
	-6%	€ 0,188	€ 1.398	€ 2.000	€ 85.000	€ 74.716	€ 75.463	€ 867.000	-€ 7.000	-0,80%
	-5%	€ 0,190	€ 1.401	€ 2.000	€ 85.000	€ 74.833	€ 75.581	€ 868.000	-€ 6.000	-0,69%
	-4%	€ 0,192	€ 1.403	€ 2.000	€ 85.000	€ 74.950	€ 75.699	€ 869.000	-€ 5.000	-0,57%
	-3%	€ 0,194	€ 1.405	€ 2.000	€ 85.000	€ 75.067	€ 75.817	€ 870.000	-€ 4.000	-0,46%
	-2%	€ 0,196	€ 1.407	€ 2.000	€ 85.000	€ 75.184	€ 75.935	€ 872.000	-€ 2.000	-0,23%
	-1%	€ 0,198	€ 1.410	€ 2.000	€ 85.000	€ 75.301	€ 76.054	€ 873.000	-€ 1.000	-0,11%
	0%	€ 0,200	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	1%	€ 0,202	€ 1.414	€ 2.000	€ 85.000	€ 75.535	€ 76.290	€ 875.000	€ 1.000	0,11%
	2%	€ 0,204	€ 1.416	€ 2.000	€ 85.000	€ 75.652	€ 76.408	€ 876.000	€ 2.000	0,23%
	3%	€ 0,206	€ 1.419	€ 2.000	€ 85.000	€ 75.769	€ 76.526	€ 878.000	€ 4.000	0,46%
	4%	€ 0,208	€ 1.421	€ 2.000	€ 85.000	€ 75.886	€ 76.644	€ 879.000	€ 5.000	0,57%
	5%	€ 0,210	€ 1.423	€ 2.000	€ 85.000	€ 76.003	€ 76.763	€ 880.000	€ 6.000	0,69%
	6%	€ 0,212	€ 1.425	€ 2.000	€ 85.000	€ 76.120	€ 76.881	€ 881.000	€ 7.000	0,80%
	7%	€ 0,214	€ 1.428	€ 2.000	€ 85.000	€ 76.237	€ 76.999	€ 883.000	€ 9.000	1,03%
	8%	€ 0,216	€ 1.430	€ 2.000	€ 85.000	€ 76.354	€ 77.117	€ 884.000	€ 10.000	1,14%
	9%	€ 0,218	€ 1.432	€ 2.000	€ 85.000	€ 76.471	€ 77.235	€ 885.000	€ 11.000	1,26%
10%	€ 0,220	€ 1.434	€ 2.000	€ 85.000	€ 76.588	€ 77.353	€ 886.000	€ 12.000	1,37%	
		Automated								
		Price per kWh	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs
Change of the price per kWh	-10%	€ 0,180	€ 182	€ 2.000	€ 322.000	€ 11.477	€ 11.592	€ 442.000	-€ 11.000	-2,43%
	-9%	€ 0,182	€ 184	€ 2.000	€ 322.000	€ 11.582	€ 11.698	€ 443.000	-€ 10.000	-2,21%
	-8%	€ 0,184	€ 186	€ 2.000	€ 322.000	€ 11.688	€ 11.804	€ 444.000	-€ 9.000	-1,99%
	-7%	€ 0,186	€ 188	€ 2.000	€ 322.000	€ 11.793	€ 11.911	€ 445.000	-€ 8.000	-1,77%
	-6%	€ 0,188	€ 190	€ 2.000	€ 322.000	€ 11.898	€ 12.017	€ 446.000	-€ 7.000	-1,55%
	-5%	€ 0,190	€ 192	€ 2.000	€ 322.000	€ 12.004	€ 12.124	€ 448.000	-€ 5.000	-1,10%
	-4%	€ 0,192	€ 194	€ 2.000	€ 322.000	€ 12.109	€ 12.230	€ 449.000	-€ 4.000	-0,88%
	-3%	€ 0,194	€ 196	€ 2.000	€ 322.000	€ 12.214	€ 12.336	€ 450.000	-€ 3.000	-0,66%
	-2%	€ 0,196	€ 198	€ 2.000	€ 322.000	€ 12.319	€ 12.443	€ 451.000	-€ 2.000	-0,44%
	-1%	€ 0,198	€ 200	€ 2.000	€ 322.000	€ 12.425	€ 12.549	€ 452.000	-€ 1.000	-0,22%
	0%	€ 0,200	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	1%	€ 0,202	€ 205	€ 2.000	€ 322.000	€ 12.635	€ 12.762	€ 454.000	€ 1.000	0,22%
	2%	€ 0,204	€ 207	€ 2.000	€ 322.000	€ 12.741	€ 12.868	€ 455.000	€ 2.000	0,44%
	3%	€ 0,206	€ 209	€ 2.000	€ 322.000	€ 12.846	€ 12.974	€ 456.000	€ 3.000	0,66%
	4%	€ 0,208	€ 211	€ 2.000	€ 322.000	€ 12.951	€ 13.081	€ 457.000	€ 4.000	0,88%
	5%	€ 0,210	€ 213	€ 2.000	€ 322.000	€ 13.057	€ 13.187	€ 459.000	€ 6.000	1,32%
	6%	€ 0,212	€ 215	€ 2.000	€ 322.000	€ 13.162	€ 13.293	€ 460.000	€ 7.000	1,55%
	7%	€ 0,214	€ 217	€ 2.000	€ 322.000	€ 13.267	€ 13.400	€ 461.000	€ 8.000	1,77%
	8%	€ 0,216	€ 219	€ 2.000	€ 322.000	€ 13.372	€ 13.506	€ 462.000	€ 9.000	1,99%
	9%	€ 0,218	€ 221	€ 2.000	€ 322.000	€ 13.478	€ 13.612	€ 463.000	€ 10.000	2,21%
10%	€ 0,220	€ 223	€ 2.000	€ 322.000	€ 13.583	€ 13.719	€ 464.000	€ 11.000	2,43%	

Maintenance costs per year

		Manual									
		Maintenance costs per year	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs	
Change of the maintenance costs	-10%	€ 1.800	€ 1.412	€ 1.800	€ 85.000	€ 75.218	€ 75.970	€ 872.000	-€ 2.000	-0,23%	
	-9%	€ 1.820	€ 1.412	€ 1.820	€ 85.000	€ 75.238	€ 75.990	€ 872.000	-€ 2.000	-0,23%	
	-8%	€ 1.840	€ 1.412	€ 1.840	€ 85.000	€ 75.258	€ 76.010	€ 872.000	-€ 2.000	-0,23%	
	-7%	€ 1.860	€ 1.412	€ 1.860	€ 85.000	€ 75.278	€ 76.030	€ 873.000	-€ 1.000	-0,11%	
	-6%	€ 1.880	€ 1.412	€ 1.880	€ 85.000	€ 75.298	€ 76.050	€ 873.000	-€ 1.000	-0,11%	
	-5%	€ 1.900	€ 1.412	€ 1.900	€ 85.000	€ 75.318	€ 76.071	€ 873.000	-€ 1.000	-0,11%	
	-4%	€ 1.920	€ 1.412	€ 1.920	€ 85.000	€ 75.338	€ 76.091	€ 873.000	-€ 1.000	-0,11%	
	-3%	€ 1.940	€ 1.412	€ 1.940	€ 85.000	€ 75.358	€ 76.111	€ 873.000	-€ 1.000	-0,11%	
	-2%	€ 1.960	€ 1.412	€ 1.960	€ 85.000	€ 75.378	€ 76.131	€ 874.000	€ 0	0,00%	
	-1%	€ 1.980	€ 1.412	€ 1.980	€ 85.000	€ 75.398	€ 76.151	€ 874.000	€ 0	0,00%	
	0%	€ 2.000	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%	
	1%	€ 2.020	€ 1.412	€ 2.020	€ 85.000	€ 75.438	€ 76.192	€ 874.000	€ 0	0,00%	
	2%	€ 2.040	€ 1.412	€ 2.040	€ 85.000	€ 75.458	€ 76.212	€ 874.000	€ 0	0,00%	
	3%	€ 2.060	€ 1.412	€ 2.060	€ 85.000	€ 75.478	€ 76.232	€ 875.000	€ 1.000	0,11%	
	4%	€ 2.080	€ 1.412	€ 2.080	€ 85.000	€ 75.498	€ 76.252	€ 875.000	€ 1.000	0,11%	
	5%	€ 2.100	€ 1.412	€ 2.100	€ 85.000	€ 75.518	€ 76.273	€ 875.000	€ 1.000	0,11%	
	6%	€ 2.120	€ 1.412	€ 2.120	€ 85.000	€ 75.538	€ 76.293	€ 875.000	€ 1.000	0,11%	
7%	€ 2.140	€ 1.412	€ 2.140	€ 85.000	€ 75.558	€ 76.313	€ 875.000	€ 1.000	0,11%		
8%	€ 2.160	€ 1.412	€ 2.160	€ 85.000	€ 75.578	€ 76.333	€ 876.000	€ 2.000	0,23%		
9%	€ 2.180	€ 1.412	€ 2.180	€ 85.000	€ 75.598	€ 76.353	€ 876.000	€ 2.000	0,23%		
10%	€ 2.200	€ 1.412	€ 2.200	€ 85.000	€ 75.618	€ 76.374	€ 876.000	€ 2.000	0,23%		
		Automated									
		Maintenance costs per year	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs	
Change of the maintenance costs	-10%	€ 1.800	€ 203	€ 1.800	€ 322.000	€ 12.330	€ 12.453	€ 451.000	-€ 2.000	-0,44%	
	-9%	€ 1.820	€ 203	€ 1.820	€ 322.000	€ 12.350	€ 12.474	€ 451.000	-€ 2.000	-0,44%	
	-8%	€ 1.840	€ 203	€ 1.840	€ 322.000	€ 12.370	€ 12.494	€ 451.000	-€ 2.000	-0,44%	
	-7%	€ 1.860	€ 203	€ 1.860	€ 322.000	€ 12.390	€ 12.514	€ 452.000	-€ 1.000	-0,22%	
	-6%	€ 1.880	€ 203	€ 1.880	€ 322.000	€ 12.410	€ 12.534	€ 452.000	-€ 1.000	-0,22%	
	-5%	€ 1.900	€ 203	€ 1.900	€ 322.000	€ 12.430	€ 12.554	€ 452.000	-€ 1.000	-0,22%	
	-4%	€ 1.920	€ 203	€ 1.920	€ 322.000	€ 12.450	€ 12.575	€ 452.000	-€ 1.000	-0,22%	
	-3%	€ 1.940	€ 203	€ 1.940	€ 322.000	€ 12.470	€ 12.595	€ 452.000	-€ 1.000	-0,22%	
	-2%	€ 1.960	€ 203	€ 1.960	€ 322.000	€ 12.490	€ 12.615	€ 453.000	€ 0	0,00%	
	-1%	€ 1.980	€ 203	€ 1.980	€ 322.000	€ 12.510	€ 12.635	€ 453.000	€ 0	0,00%	
	0%	€ 2.000	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%	
	1%	€ 2.020	€ 203	€ 2.020	€ 322.000	€ 12.550	€ 12.676	€ 453.000	€ 0	0,00%	
	2%	€ 2.040	€ 203	€ 2.040	€ 322.000	€ 12.570	€ 12.696	€ 454.000	€ 1.000	0,22%	
	3%	€ 2.060	€ 203	€ 2.060	€ 322.000	€ 12.590	€ 12.716	€ 454.000	€ 1.000	0,22%	
	4%	€ 2.080	€ 203	€ 2.080	€ 322.000	€ 12.610	€ 12.736	€ 454.000	€ 1.000	0,22%	
	5%	€ 2.100	€ 203	€ 2.100	€ 322.000	€ 12.630	€ 12.756	€ 454.000	€ 1.000	0,22%	
	6%	€ 2.120	€ 203	€ 2.120	€ 322.000	€ 12.650	€ 12.777	€ 454.000	€ 1.000	0,22%	
7%	€ 2.140	€ 203	€ 2.140	€ 322.000	€ 12.670	€ 12.797	€ 455.000	€ 2.000	0,44%		
8%	€ 2.160	€ 203	€ 2.160	€ 322.000	€ 12.690	€ 12.817	€ 455.000	€ 2.000	0,44%		
9%	€ 2.180	€ 203	€ 2.180	€ 322.000	€ 12.710	€ 12.837	€ 455.000	€ 2.000	0,44%		
10%	€ 2.200	€ 203	€ 2.200	€ 322.000	€ 12.730	€ 12.857	€ 455.000	€ 2.000	0,44%		

Price IT system

		Manual								
		Price IT system	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs
Change of the price for the IT system	-10%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-9%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-8%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-7%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-6%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-5%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-4%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-3%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-2%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-1%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	0%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	1%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	2%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	3%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	4%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	5%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	6%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	7%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	8%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
9%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%	
10%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%	
		Automated								
		Price IT system	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs
Change of the price for the IT system	-10%	€ 9.000	€ 203	€ 2.000	€ 321.000	€ 12.530	€ 12.655	€ 452.000	-€ 1.000	-0,22%
	-9%	€ 9.100	€ 203	€ 2.000	€ 321.100	€ 12.530	€ 12.655	€ 452.000	-€ 1.000	-0,22%
	-8%	€ 9.200	€ 203	€ 2.000	€ 321.200	€ 12.530	€ 12.655	€ 452.000	-€ 1.000	-0,22%
	-7%	€ 9.300	€ 203	€ 2.000	€ 321.300	€ 12.530	€ 12.655	€ 452.000	-€ 1.000	-0,22%
	-6%	€ 9.400	€ 203	€ 2.000	€ 321.400	€ 12.530	€ 12.655	€ 452.000	-€ 1.000	-0,22%
	-5%	€ 9.500	€ 203	€ 2.000	€ 321.500	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	-4%	€ 9.600	€ 203	€ 2.000	€ 321.600	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	-3%	€ 9.700	€ 203	€ 2.000	€ 321.700	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	-2%	€ 9.800	€ 203	€ 2.000	€ 321.800	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	-1%	€ 9.900	€ 203	€ 2.000	€ 321.900	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	0%	€ 10.000	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	1%	€ 10.100	€ 203	€ 2.000	€ 322.100	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	2%	€ 10.200	€ 203	€ 2.000	€ 322.200	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	3%	€ 10.300	€ 203	€ 2.000	€ 322.300	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	4%	€ 10.400	€ 203	€ 2.000	€ 322.400	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	5%	€ 10.500	€ 203	€ 2.000	€ 322.500	€ 12.530	€ 12.655	€ 454.000	€ 1.000	0,22%
	6%	€ 10.600	€ 203	€ 2.000	€ 322.600	€ 12.530	€ 12.655	€ 454.000	€ 1.000	0,22%
	7%	€ 10.700	€ 203	€ 2.000	€ 322.700	€ 12.530	€ 12.655	€ 454.000	€ 1.000	0,22%
	8%	€ 10.800	€ 203	€ 2.000	€ 322.800	€ 12.530	€ 12.655	€ 454.000	€ 1.000	0,22%
9%	€ 10.900	€ 203	€ 2.000	€ 322.900	€ 12.530	€ 12.655	€ 454.000	€ 1.000	0,22%	
10%	€ 11.000	€ 203	€ 2.000	€ 323.000	€ 12.530	€ 12.655	€ 454.000	€ 1.000	0,22%	

Price charging points

		Manual									
	Price charging points	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs		
		Change of the price of the charging points	-10%	€ 9.000	€ 1.412	€ 2.000	€ 84.000	€ 75.418	€ 76.172	€ 873.000	-€ 1.000
-9%	€ 9.100		€ 1.412	€ 2.000	€ 84.100	€ 75.418	€ 76.172	€ 873.000	-€ 1.000	-0,11%	
-8%	€ 9.200		€ 1.412	€ 2.000	€ 84.200	€ 75.418	€ 76.172	€ 873.000	-€ 1.000	-0,11%	
-7%	€ 9.300		€ 1.412	€ 2.000	€ 84.300	€ 75.418	€ 76.172	€ 873.000	-€ 1.000	-0,11%	
-6%	€ 9.400		€ 1.412	€ 2.000	€ 84.400	€ 75.418	€ 76.172	€ 873.000	-€ 1.000	-0,11%	
-5%	€ 9.500		€ 1.412	€ 2.000	€ 84.500	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%	
-4%	€ 9.600		€ 1.412	€ 2.000	€ 84.600	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%	
-3%	€ 9.700		€ 1.412	€ 2.000	€ 84.700	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%	
-2%	€ 9.800		€ 1.412	€ 2.000	€ 84.800	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%	
-1%	€ 9.900		€ 1.412	€ 2.000	€ 84.900	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%	
0%	€ 10.000		€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%	
1%	€ 10.100		€ 1.412	€ 2.000	€ 85.100	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%	
2%	€ 10.200		€ 1.412	€ 2.000	€ 85.200	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%	
3%	€ 10.300		€ 1.412	€ 2.000	€ 85.300	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%	
4%	€ 10.400		€ 1.412	€ 2.000	€ 85.400	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%	
5%	€ 10.500		€ 1.412	€ 2.000	€ 85.500	€ 75.418	€ 76.172	€ 875.000	€ 1.000	0,11%	
6%	€ 10.600		€ 1.412	€ 2.000	€ 85.600	€ 75.418	€ 76.172	€ 875.000	€ 1.000	0,11%	
7%	€ 10.700	€ 1.412	€ 2.000	€ 85.700	€ 75.418	€ 76.172	€ 875.000	€ 1.000	0,11%		
8%	€ 10.800	€ 1.412	€ 2.000	€ 85.800	€ 75.418	€ 76.172	€ 875.000	€ 1.000	0,11%		
9%	€ 10.900	€ 1.412	€ 2.000	€ 85.900	€ 75.418	€ 76.172	€ 875.000	€ 1.000	0,11%		
10%	€ 11.000	€ 1.412	€ 2.000	€ 86.000	€ 75.418	€ 76.172	€ 875.000	€ 1.000	0,11%		
		Automated									
	Price charging points	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs		
		Change of the price of the charging points	-10%	€ 9.000	€ 203	€ 2.000	€ 321.000	€ 12.530	€ 12.655	€ 452.000	-€ 1.000
-9%	€ 9.100		€ 203	€ 2.000	€ 321.100	€ 12.530	€ 12.655	€ 452.000	-€ 1.000	-0,22%	
-8%	€ 9.200		€ 203	€ 2.000	€ 321.200	€ 12.530	€ 12.655	€ 452.000	-€ 1.000	-0,22%	
-7%	€ 9.300		€ 203	€ 2.000	€ 321.300	€ 12.530	€ 12.655	€ 452.000	-€ 1.000	-0,22%	
-6%	€ 9.400		€ 203	€ 2.000	€ 321.400	€ 12.530	€ 12.655	€ 452.000	-€ 1.000	-0,22%	
-5%	€ 9.500		€ 203	€ 2.000	€ 321.500	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%	
-4%	€ 9.600		€ 203	€ 2.000	€ 321.600	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%	
-3%	€ 9.700		€ 203	€ 2.000	€ 321.700	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%	
-2%	€ 9.800		€ 203	€ 2.000	€ 321.800	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%	
-1%	€ 9.900		€ 203	€ 2.000	€ 321.900	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%	
0%	€ 10.000		€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%	
1%	€ 10.100		€ 203	€ 2.000	€ 322.100	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%	
2%	€ 10.200		€ 203	€ 2.000	€ 322.200	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%	
3%	€ 10.300		€ 203	€ 2.000	€ 322.300	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%	
4%	€ 10.400		€ 203	€ 2.000	€ 322.400	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%	
5%	€ 10.500		€ 203	€ 2.000	€ 322.500	€ 12.530	€ 12.655	€ 454.000	€ 1.000	0,22%	
6%	€ 10.600		€ 203	€ 2.000	€ 322.600	€ 12.530	€ 12.655	€ 454.000	€ 1.000	0,22%	
7%	€ 10.700	€ 203	€ 2.000	€ 322.700	€ 12.530	€ 12.655	€ 454.000	€ 1.000	0,22%		
8%	€ 10.800	€ 203	€ 2.000	€ 322.800	€ 12.530	€ 12.655	€ 454.000	€ 1.000	0,22%		
9%	€ 10.900	€ 203	€ 2.000	€ 322.900	€ 12.530	€ 12.655	€ 454.000	€ 1.000	0,22%		
10%	€ 11.000	€ 203	€ 2.000	€ 323.000	€ 12.530	€ 12.655	€ 454.000	€ 1.000	0,22%		

Price coupling system

		Manual									
	Price coupling system	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Costs year 10	Total costs	Difference total costs	Difference total costs	
	Change of the price of the coupling system	-10%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0
-9%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
-8%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
-7%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
-6%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
-5%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
-4%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
-3%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
-2%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
-1%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
0%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
1%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
2%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
3%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
4%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
5%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
6%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
7%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
8%		€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%
9%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%	
10%	€ 0	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 82.483	€ 874.000	€ 0	0,00%	
		Automated									
	Price coupling system	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Costs year 10	Total costs	Difference total costs	Difference total costs	
	-10%	€ 1.800	€ 203	€ 2.000	€ 321.800	€ 12.530	€ 12.655	€ 13.704	€ 452.900	-€ 200	-0,04%
-9%	€ 1.820	€ 203	€ 2.000	€ 321.820	€ 12.530	€ 12.655	€ 13.704	€ 452.900	-€ 200	-0,04%	
-8%	€ 1.840	€ 203	€ 2.000	€ 321.840	€ 12.530	€ 12.655	€ 13.704	€ 452.900	-€ 200	-0,04%	
-7%	€ 1.860	€ 203	€ 2.000	€ 321.860	€ 12.530	€ 12.655	€ 13.704	€ 453.000	-€ 100	-0,02%	
-6%	€ 1.880	€ 203	€ 2.000	€ 321.880	€ 12.530	€ 12.655	€ 13.704	€ 453.000	-€ 100	-0,02%	
-5%	€ 1.900	€ 203	€ 2.000	€ 321.900	€ 12.530	€ 12.655	€ 13.704	€ 453.000	-€ 100	-0,02%	
-4%	€ 1.920	€ 203	€ 2.000	€ 321.920	€ 12.530	€ 12.655	€ 13.704	€ 453.000	-€ 100	-0,02%	
-3%	€ 1.940	€ 203	€ 2.000	€ 321.940	€ 12.530	€ 12.655	€ 13.704	€ 453.000	-€ 100	-0,02%	
-2%	€ 1.960	€ 203	€ 2.000	€ 321.960	€ 12.530	€ 12.655	€ 13.704	€ 453.100	€ 0	0,00%	
-1%	€ 1.980	€ 203	€ 2.000	€ 321.980	€ 12.530	€ 12.655	€ 13.704	€ 453.100	€ 0	0,00%	
0%	€ 2.000	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 13.704	€ 453.100	€ 0	0,00%	
1%	€ 2.020	€ 203	€ 2.000	€ 322.020	€ 12.530	€ 12.655	€ 13.704	€ 453.100	€ 0	0,00%	
2%	€ 2.040	€ 203	€ 2.000	€ 322.040	€ 12.530	€ 12.655	€ 13.704	€ 453.100	€ 0	0,00%	
3%	€ 2.060	€ 203	€ 2.000	€ 322.060	€ 12.530	€ 12.655	€ 13.704	€ 453.200	€ 100	0,02%	
4%	€ 2.080	€ 203	€ 2.000	€ 322.080	€ 12.530	€ 12.655	€ 13.704	€ 453.200	€ 100	0,02%	
5%	€ 2.100	€ 203	€ 2.000	€ 322.100	€ 12.530	€ 12.655	€ 13.704	€ 453.200	€ 100	0,02%	
6%	€ 2.120	€ 203	€ 2.000	€ 322.120	€ 12.530	€ 12.655	€ 13.704	€ 453.200	€ 100	0,02%	
7%	€ 2.140	€ 203	€ 2.000	€ 322.140	€ 12.530	€ 12.655	€ 13.704	€ 453.200	€ 100	0,02%	
8%	€ 2.160	€ 203	€ 2.000	€ 322.160	€ 12.530	€ 12.655	€ 13.704	€ 453.300	€ 200	0,04%	
9%	€ 2.180	€ 203	€ 2.000	€ 322.180	€ 12.530	€ 12.655	€ 13.704	€ 453.300	€ 200	0,04%	
10%	€ 2.200	€ 203	€ 2.000	€ 322.200	€ 12.530	€ 12.655	€ 13.704	€ 453.300	€ 200	0,04%	

Efficiency factor

		Manual								
		Efficiency factor	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs
Change of the efficiency factor	-10%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-9%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-8%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-7%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-6%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-5%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-4%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-3%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-2%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	-1%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	0%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	1%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	2%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	3%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	4%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	5%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	6%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	7%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	8%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
9%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%	
10%	0,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%	
		Automated								
		Efficiency factor	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs
Change of the efficiency factor	-10%	81,00%	€ 182	€ 2.000	€ 322.000	€ 11.477	€ 11.592	€ 442.000	-€ 11.000	-2,43%
	-9%	81,90%	€ 184	€ 2.000	€ 322.000	€ 11.582	€ 11.698	€ 443.000	-€ 10.000	-2,21%
	-8%	82,80%	€ 186	€ 2.000	€ 322.000	€ 11.688	€ 11.804	€ 444.000	-€ 9.000	-1,99%
	-7%	83,70%	€ 188	€ 2.000	€ 322.000	€ 11.793	€ 11.911	€ 445.000	-€ 8.000	-1,77%
	-6%	84,60%	€ 190	€ 2.000	€ 322.000	€ 11.898	€ 12.017	€ 446.000	-€ 7.000	-1,55%
	-5%	85,50%	€ 192	€ 2.000	€ 322.000	€ 12.004	€ 12.124	€ 448.000	-€ 5.000	-1,10%
	-4%	86,40%	€ 194	€ 2.000	€ 322.000	€ 12.109	€ 12.230	€ 449.000	-€ 4.000	-0,88%
	-3%	87,30%	€ 196	€ 2.000	€ 322.000	€ 12.214	€ 12.336	€ 450.000	-€ 3.000	-0,66%
	-2%	88,20%	€ 198	€ 2.000	€ 322.000	€ 12.319	€ 12.443	€ 451.000	-€ 2.000	-0,44%
	-1%	89,10%	€ 200	€ 2.000	€ 322.000	€ 12.425	€ 12.549	€ 452.000	-€ 1.000	-0,22%
	0%	90,00%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	1%	90,90%	€ 205	€ 2.000	€ 322.000	€ 12.635	€ 12.762	€ 454.000	€ 1.000	0,22%
	2%	91,80%	€ 207	€ 2.000	€ 322.000	€ 12.741	€ 12.868	€ 455.000	€ 2.000	0,44%
	3%	92,70%	€ 209	€ 2.000	€ 322.000	€ 12.846	€ 12.974	€ 456.000	€ 3.000	0,66%
	4%	93,60%	€ 211	€ 2.000	€ 322.000	€ 12.951	€ 13.081	€ 457.000	€ 4.000	0,88%
	5%	94,50%	€ 213	€ 2.000	€ 322.000	€ 13.057	€ 13.187	€ 459.000	€ 6.000	1,32%
	6%	95,40%	€ 215	€ 2.000	€ 322.000	€ 13.162	€ 13.293	€ 460.000	€ 7.000	1,55%
	7%	96,30%	€ 217	€ 2.000	€ 322.000	€ 13.267	€ 13.400	€ 461.000	€ 8.000	1,77%
	8%	97,20%	€ 219	€ 2.000	€ 322.000	€ 13.372	€ 13.506	€ 462.000	€ 9.000	1,99%
9%	98,10%	€ 221	€ 2.000	€ 322.000	€ 13.478	€ 13.612	€ 463.000	€ 10.000	2,21%	
10%	99,00%	€ 223	€ 2.000	€ 322.000	€ 13.583	€ 13.719	€ 464.000	€ 11.000	2,43%	

Discount rate

		Manual								
		Discount rate	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs
Change of the discount rate	-10%	0,90%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.096	€ 870.000	-€ 4.000	-0,46%
	-9%	0,91%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.104	€ 871.000	-€ 3.000	-0,34%
	-8%	0,92%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.111	€ 871.000	-€ 3.000	-0,34%
	-7%	0,93%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.119	€ 872.000	-€ 2.000	-0,23%
	-6%	0,94%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.126	€ 872.000	-€ 2.000	-0,23%
	-5%	0,95%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.134	€ 872.000	-€ 2.000	-0,23%
	-4%	0,96%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.142	€ 873.000	-€ 1.000	-0,11%
	-3%	0,97%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.149	€ 873.000	-€ 1.000	-0,11%
	-2%	0,98%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.157	€ 873.000	-€ 1.000	-0,11%
	-1%	0,99%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.164	€ 874.000	€ 0	0,00%
	0%	1,00%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	€ 0	0,00%
	1%	1,01%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.179	€ 874.000	€ 0	0,00%
	2%	1,02%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.187	€ 875.000	€ 1.000	0,11%
	3%	1,03%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.194	€ 875.000	€ 1.000	0,11%
	4%	1,04%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.202	€ 875.000	€ 1.000	0,11%
	5%	1,05%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.209	€ 876.000	€ 2.000	0,23%
	6%	1,06%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.217	€ 876.000	€ 2.000	0,23%
	7%	1,07%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.224	€ 877.000	€ 3.000	0,34%
	8%	1,08%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.232	€ 877.000	€ 3.000	0,34%
	9%	1,09%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.240	€ 877.000	€ 3.000	0,34%
10%	1,10%	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.247	€ 878.000	€ 4.000	0,46%	
		Automated								
		Discount rate	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs
Change of the discount rate	-10%	0,90%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.643	€ 452.000	-€ 1.000	-0,22%
	-9%	0,91%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.644	€ 453.000	€ 0	0,00%
	-8%	0,92%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.645	€ 453.000	€ 0	0,00%
	-7%	0,93%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.647	€ 453.000	€ 0	0,00%
	-6%	0,94%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.648	€ 453.000	€ 0	0,00%
	-5%	0,95%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.649	€ 453.000	€ 0	0,00%
	-4%	0,96%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.650	€ 453.000	€ 0	0,00%
	-3%	0,97%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.652	€ 453.000	€ 0	0,00%
	-2%	0,98%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.653	€ 453.000	€ 0	0,00%
	-1%	0,99%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.654	€ 453.000	€ 0	0,00%
	0%	1,00%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	1%	1,01%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.657	€ 453.000	€ 0	0,00%
	2%	1,02%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.658	€ 453.000	€ 0	0,00%
	3%	1,03%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.659	€ 453.000	€ 0	0,00%
	4%	1,04%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.660	€ 453.000	€ 0	0,00%
	5%	1,05%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.662	€ 453.000	€ 0	0,00%
	6%	1,06%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.663	€ 453.000	€ 0	0,00%
	7%	1,07%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.664	€ 454.000	€ 1.000	0,22%
	8%	1,08%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.665	€ 454.000	€ 1.000	0,22%
	9%	1,09%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.667	€ 454.000	€ 1.000	0,22%
10%	1,10%	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.668	€ 454.000	€ 1.000	0,22%	

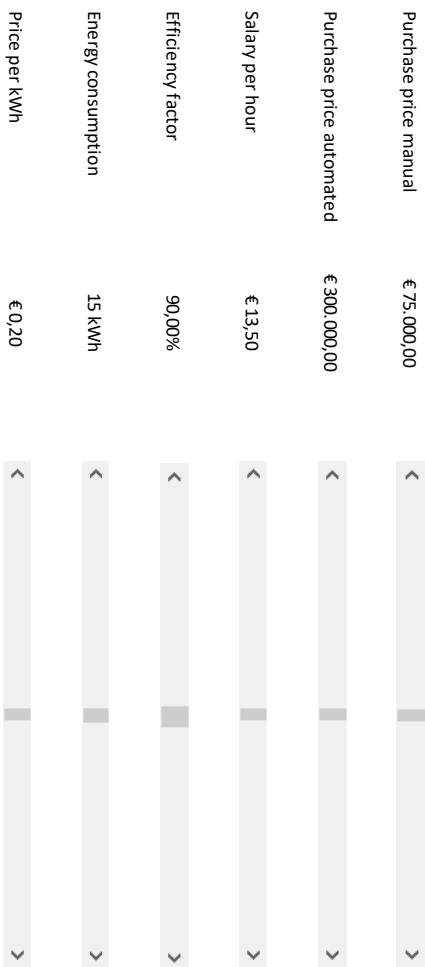
Average damage per 1000 movements

		Manual								
		Average damage per 1000 movements	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs
Change of the average damage per 1000 movements	-10%	€ 90	€ 1.412	€ 2.000	€ 85.000	€ 75.418	€ 76.172	€ 874.000	-€ 5.000	-0,57%
	-9%	€ 91	€ 1.413	€ 2.000	€ 85.000	€ 75.470	€ 76.224	€ 875.000	-€ 4.000	-0,46%
	-8%	€ 92	€ 1.414	€ 2.000	€ 85.000	€ 75.522	€ 76.277	€ 875.000	-€ 4.000	-0,46%
	-7%	€ 93	€ 1.415	€ 2.000	€ 85.000	€ 75.574	€ 76.329	€ 876.000	-€ 3.000	-0,34%
	-6%	€ 94	€ 1.416	€ 2.000	€ 85.000	€ 75.626	€ 76.382	€ 876.000	-€ 3.000	-0,34%
	-5%	€ 95	€ 1.417	€ 2.000	€ 85.000	€ 75.678	€ 76.434	€ 877.000	-€ 2.000	-0,23%
	-4%	€ 96	€ 1.418	€ 2.000	€ 85.000	€ 75.730	€ 76.487	€ 877.000	-€ 2.000	-0,23%
	-3%	€ 97	€ 1.419	€ 2.000	€ 85.000	€ 75.782	€ 76.539	€ 878.000	-€ 1.000	-0,11%
	-2%	€ 98	€ 1.420	€ 2.000	€ 85.000	€ 75.834	€ 76.592	€ 878.000	-€ 1.000	-0,11%
	-1%	€ 99	€ 1.421	€ 2.000	€ 85.000	€ 75.886	€ 76.644	€ 879.000	€ 0	0,00%
	0%	€ 100	€ 1.422	€ 2.000	€ 85.000	€ 75.938	€ 76.697	€ 879.000	€ 0	0,00%
	1%	€ 101	€ 1.423	€ 2.000	€ 85.000	€ 75.990	€ 76.749	€ 880.000	€ 1.000	0,11%
	2%	€ 102	€ 1.424	€ 2.000	€ 85.000	€ 76.042	€ 76.802	€ 881.000	€ 2.000	0,23%
	3%	€ 103	€ 1.425	€ 2.000	€ 85.000	€ 76.094	€ 76.854	€ 881.000	€ 2.000	0,23%
	4%	€ 104	€ 1.426	€ 2.000	€ 85.000	€ 76.146	€ 76.907	€ 882.000	€ 3.000	0,34%
	5%	€ 105	€ 1.427	€ 2.000	€ 85.000	€ 76.198	€ 76.959	€ 882.000	€ 3.000	0,34%
	6%	€ 106	€ 1.428	€ 2.000	€ 85.000	€ 76.250	€ 77.012	€ 883.000	€ 4.000	0,46%
7%	€ 107	€ 1.429	€ 2.000	€ 85.000	€ 76.302	€ 77.065	€ 883.000	€ 4.000	0,46%	
8%	€ 108	€ 1.430	€ 2.000	€ 85.000	€ 76.354	€ 77.117	€ 884.000	€ 5.000	0,57%	
9%	€ 109	€ 1.431	€ 2.000	€ 85.000	€ 76.406	€ 77.170	€ 884.000	€ 5.000	0,57%	
10%	€ 110	€ 1.432	€ 2.000	€ 85.000	€ 76.458	€ 77.222	€ 885.000	€ 6.000	0,68%	
		Automated								
		Average damage per 1000 movements	Weekly costs	Yearly costs	Initial costs	Costs year 1	Costs year 2	Total costs	Difference total costs	Difference total costs
Change of the average damage per 1000 movements	-10%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	-9%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	-8%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	-7%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	-6%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	-5%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	-4%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	-3%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	-2%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	-1%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	0%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	1%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	2%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	3%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	4%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	5%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
	6%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%
7%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%	
8%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%	
9%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%	
10%	€ 0	€ 203	€ 2.000	€ 322.000	€ 12.530	€ 12.655	€ 453.000	€ 0	0,00%	

Appendix C: Dashboard of the quick scan

<i>Monday</i>		
Number of hours operating		16
Number of movements *		85
<i>Tuesday</i>		
Number of hours operating		16
Number of movements *		85
<i>Wednesday</i>		
Number of hours operating		16
Number of movements *		85
<i>Thursday</i>		
Number of hours operating		16
Number of movements *		85
<i>Friday</i>		
Number of hours operating		16
Number of movements *		85
<i>Saturday</i>		
Number of hours operating		16
Number of movements *		85
<i>Sunday</i>		
Number of hours operating		0
Number of movements *		0
Number of weeks per year operating		52
Average time it takes for a TT driver to perform one movement (minutes)		5

* One movement is one time a semi-trailer is moved by a TT, for example from the parking to a dock or vice versa



Results	
Costs for manual trailer docking for 10 years	€ 541.000,00
Costs for automated trailer docking for 10 years	€ 405.000,00

Threshold	25,00%
Difference	25,14%