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Analysis of the OCR System Application in Intermodal Terminals. Malmö Intermodal Terminal (Sweden)

Presentado por

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Abstract

This thesis aims to show the advantages that an Intelligent Video Gate, which uses an OCR system, can provide to intermodal terminals where transhipment among trucks and trains is carried out throughout some processes automation that can improve the efficiency of this kind of terminals.

The analysis carried out in this thesis is made from two different points of view, the qualitative and the quantitative, by using the case study of Malmö intermodal terminal. The first analysis is focused on how the intermodal terminals works and which elements of it interact and how, in order to achieve the purpose of the terminal, and how the Intelligent Video Gate is able to affect in any way to this functioning, mainly in a positive way that allows the better functioning of the terminal.

From the quantitative point of view what is carried out is a timing and economic analysis of the Malmö Intermodal Terminal, which is based on the information obtained from the qualitative analysis and from the data provided by the terminal operators that allow to make different simulations to compare the effect of the Intelligent Video Gate implementation in this specific terminal, and that could be extended to similar intermodal terminals located in regions with similar labour conditions and that as the European Union have a huge standardized freight system.

Finally, what is stated with the provided data, despite not allowing to make the most complex and representative simulation, is that the aim of the Intelligent Video Gate is reached successfully with a great improvement of the efficiency what allows to ensure with quite certainty that the system implementation is recommended in this kind of terminals.

Key words: Intermodal Terminal; Intermodal Loading Unit; Intelligent Video Gate; Optical Character Recognition System; Freight transhipment; automation.

Sammanfattning

Denna avhandling syftar till att visa fördelarna som en Intelligent Video Gate (IVG), baserat på ett OCR-system, kan ge intermodala terminaler där omlastning mellan lastbilar och tåg utförs. Detta genom att vissa processer digitaliseras och automatiseras som kan förbättra effektiviteten för denna typ av terminaler.

Analysen som har gjorts i denna avhandling har utförts ur två olika synvinklar, kvalitativ och kvantitativ, och med hjälp av en fallstudie kring Malmö kombiterminal. Den första analysen är inriktad på hur intermodala terminalerna fungerar och vilka delar av som interagerar och hur, för att uppnå syftet med terminalen, och hur en Intelligent Video Gate kan påverka processerna där, främst i ett positivt sätt som möjliggör en bättre funktion av terminalen.

Kvantitativ utförs tid- och ekonomisk analys av Malmö kombiterminal, som bygger på vidare på informationen som erhållits från den kvalitativa analysen och från de uppgifter som tillhandahålls av terminaloperatören. Detta möjliggöra olika simuleringar för att jämföra effekten av den IVG i denna specifika terminal, och som skulle kunna utvidgas till liknande intermodala terminaler belägna i regioner med liknande arbetsförhållanden, där det inom råder ett standardiserat godstransportsystem.

Slutligen, vad som anges med de tillhandahållna uppgifterna, trots att de inte tillåter att göra den mest komplexa och representativa simuleringen, uppnås målen för en IVG framgångsrikt med en stor förbättring av effektiviteten, vilket möjliggör att implementering rekommenderas i denna typ av terminal.

Nyckelord: Intermodal terminal; Intermodala lastbärare; Intelligent Video Gate; Optisk kod; Godsomlastning; automatisering.

Table of Contents

List of Figures

List of Table

Abbreviations (Glossary)

BIC	Bureau of International Containers
EU	European Union
FEU	Forty feet-equivalent unit
FIFO	First in- First out
OCR	Optical Character Recognition
ILU	Intermodal loading unit
ISO	International Organization for Standardization
IVG	Intelligent Video Gate
LU	Loading Unit
RID	Regulations concerning the International Carriage of Dangerous Goods by Rail
RFID	Radio Frequency Identification
TEU	Twenty feet-equivalent unit
UIRR	International Union of Combined road-rail transport companies

1. Introduction

1.1. Background

The increasing demand of transportation all around the world has generated the need of improving the efficiency of supply chain processes as this requires reduction in costs, times and greenhouse gas emission. This is not only a demand from the users who want a best transportation services, but from the government institutions as well, as these improvements are needed to achieve sustainable development objectives that are imposed by international agreements.

Regarding objectives directly related to transportation, the European Union (EU) has published the "*WHITE PAPER. Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system* (*2011)"*, where among other objectives, the reduction of the 60% of the greenhouse gas emissions is established, which requires, as it is stated in the white book, the intermodal transport improvement where the railway transportation has an important role, as it is the least polluting mean of transport. So, improving its efficiency is crucial in achieving a better intermodal transportation, concerning intermodal terminals as this part of the intermodal network is important and necessary to focus on.

Furthermore, at present, some new technologies are being developed or are already developed that can be applied to the transportation infrastructures in order to optimize the processes carried out in freight transportation, as could be the artificial intelligence that Indra is working on and that is the company, which is studying the implementation of an Intelligent Video Gate in Malmö.

One example of these new technologies is the Optical Character Recognition system, the OCR system, with the objective of improving the containers' movements and inspections in yards and intermodal terminals.

Within the framework of H2020 Shift2Rail Programme IP 5 and the research project FR8RAIL III WP3 Intelligent Video Gate, a demonstration gate is currently being installed, planned to be finalized in Spring 2021. The implementation is planned in

Malmö intermodal rail-road terminal, which is a gateway terminal between Sweden and Europe by train, in the vicinity of the Öresund bridge, which connects Sweden and Denmark by rail and, also in connection to some rail-ferry corridors linking Sweden with Poland and Germany.

This system aims at identifying every Loading unit (LU) that goes in and out from the terminal by reading the LU ID. Currently, they are mainly applied in port terminal where the containers are usually more standardized (than other LU types), which makes them easier to identify and reduces errors that are made when the containers' characteristics are more heterogeneous.

1.2. Objectives

This project has as the main objective to show the benefits of installing the OCR system in intermodal terminals in terms of efficiency, what can be expressed in an economic way, in terms of cost savings, and in operational way what means time savings and better planning and organization of the freight movements, and finally results in terms of competence increase.

With the purpose to achieve this objective, secondary goals must be presented. First, it is necessary to describe how an intermodal terminal works, knowing and describing all the activities carried out to achieve the intermodal objectives and to describe the facilities and equipment that are used.

Furthermore, an analysis of the OCR system will be made to get know how it works and how it is implemented in intermodals terminals to obtain a clear image of the advantages this system can provide to these facilities and how it can improve the intermodal terminal automation, a current goal established by some logistic companies.

Finally, after having obtained the knowledge about intermodal terminals and the OCR system, the intermodal terminal efficiency would be assessed by studying a specific case, the intermodal terminal of Malmö, which is the main goal of this project, knowing how the OCR system implementation affects the efficiency in an intermodal terminal, what are the specific restrictions of each particular case, and what could be extrapolated to all the similar intermodal terminals, specifically those located in similar countries with similar procedures and working environment.

1.2.1. Research questions

According to the information stated above, some question can be asked in relation to the intermodal terminals and its efficiency, which must be answered with the objective of improving this kind of terminals and the general functioning of the transport network.

> RQ1. Does the OCR system achieve a real improvement in intermodal processes' efficiency, reducing movement times and energy and employee costs?
>
> RQ2. Does the OCR system help in the objective of achieving a higher level of automation in the processes carried out at intermodal terminals?
>
> RQ3. How is it possible to reduce the actual error that an OCR system has, in order to achieve better accuracy?

1.3. Scope and limitations

The aim of this project is to show how the OCR system can improve the efficiency of the intermodal terminal when it is applied to train gates in this kind of terminals, mainly in economic and time saving terms.

According to the obtained data, an approximation it is going to me made of the handled freight volume, which is needed for the OCR system gate to be a worthy investment taking into account that there is a lack of given data by the companies, as it is not very common they share all the information that would be needed to obtain an accurate approximation of the economic simulation.

The project has some limitations as it is an academic work and there is a lack of resources to obtain more elaborate and greater results. First, as it has been said, private companies do not share easily most of their data, especially, when it is concerning economic data.

Also, as it is a project, which leads to a final thesis the time that can be applied to do it is also quite limited as it is linked to the final thesis credits.

Moreover, concerning the lack of time, it would be necessary to simulate more than one terminal to obtain a result that could be applied generally to more terminals, as it is not enough to simulate one terminal and to extend the result to other terminals, however it can help to know approximately if the system is worth implementing in terminals with similar characteristics.

1.4. Literature review

In order to know more about the topic that is discussed in this thesis and to improve the knowledge about intermodal transportation a literature review has been carried out.

Diego Cantelar Jimënez in his thesis, is focused in the terminal simulation to improve the terminal's efficiency. First, it is seen that the simulation of these terminals is a field where institutions are working on to improve intermodal transportation, especially in Europe, as they have become necessary to achieve the established objectives. Although these results showed some improvements in the efficiency with some adjustments, this thesis doesn't take into account OCR system implementation, however in order to apply some of the measures to achieve some of the improvements, the OCR system implementation could be very useful. (Diego Cantelar, 2015).

In Barcelona port, according to Cadena de Suministros webpage, Intelligent Video gates with OCR in the truck entry were installed, and consequently, nowadays the entry operations are carried out normally and the productivity and the effectiveness have increase in considerable ratios.

Marta Coma, in her document, states that automation systems implementation in freight terminals is related to some factors, as economy of scale, which in ports is not a problem as handled freight volumes are usually enough to establish automatic systems or processes, where it could be a problem in intermodal terminals. Alternatively freight node that have processes that follow patterns that are worthy in terms of time and economic benefits or the need of real time information, which is nowadays very demanded. Also, it is said some other advantages that could have the automation in freight terminals that are not directly related to the efficacy as sustainability or workers' safety. (Marta Coma, 2015).

In the document "*Future of Intermodal terminals"* it is stated that is needed to improve this kind of facilities to reach a higher throughput of the railway network and make the rail transportation more competitive. Among different solutions, it is proposed the automation of the terminals, being as example the Patrick's Sydney Automated Terminal at Port Botany, where some different measures of automation have been applied in order to achieve to double the capacity. In this case, it is a port terminal, so the freight volume is practically granted and the investment return is easily to ensure and maybe in intermodal terminals is not that easily to ensure, however it shows that the automation is already being applied. (PWC/Ranbury, 2017).

In the document, "Estudio de automatización de la terminal portuaria de intersagunto, puerto de Sagunto", is stated that importance of automation to reduce costs in port terminal, as in Spain approximately 60% of the operational costs come from workers' salaries, is crucial, and to get this, in the Sagunto Port, it is already applied the OCR system in truck gates, which is considered essential to reach the higher level of automation that is aimed in this case. (Borja Ferrer Sánchez, 2018).

In document, *D4.1 Description of functional and technical requirements and selection of components* from the project FR8RAIL III WP3, Real-time information applications and energy efficient solutions for rail freight, it is showed that the project aims to reach a reduction of 75% of damages claims, to reduce the processing time per train to 15 mins and to increase 15% the terminal capacity, in terminals with similar features to a one which handles 740 meters trains, by using Intelligent video gates. In the document, it is shown some examples as the Eskilstuna intermodal terminal, where it is applied this gate to identify trucks, which has what could be an inconvenient as it only allows identifying pre-announced trucks however it makes easier the data system introduction and truck identification.

According to Valencia port authority and what is it stated in different articles published in its webpage, and which has already installed gates with OCR system for truck gates, video gates which include an OCR system are going to be installed to help with freight border controls in train entries to improve the opening hours.

2. Methodology

To write this thesis, a methodology has been established in order to reach the objectives previously mentioned that could be divided in two different types, the qualitative and the quantitative analysis. First, it has been made a research on literature review, websites and academic resources to obtain the needed information to know how intermodal terminals work and specifically the Malmö intermodal terminal. With this goal in mind, information about the activities carried out in these kind of facilities, which kind of equipment is used and the actors who operate within in them have been sought.

Once this information has been found, the needed knowledge to make the model on the software Planimate was acquired as after this research it was possible to describe in an accurate way how intermodal terminals work and how the different components of it interact with each other to achieve its main goal, the freight transhipment between trucks and trains.

Continuing with the research, the information has been acquired about how the different freight units are identified. To obtain this information, the legislation and normative about road and rail freight transportation in EU has been consulted, as nowadays it is quite regulated how the freight units have to be identify as well as the dangerous goods, whose signs identification can help to identify the freight units and also is regulated and standardized not only in Europe, but also in most other countries.

After that, the information about how the OCR system works and which are its components has been sought and with it the research has been finished with all the needed information to start the simulation. With this last step, the qualitative part of the thesis has been made and completed.

Once the qualitative aspects of the thesis have been discussed, it has started the quantitative parts of the thesis. First, to make the model, the information obtained before about intermodal terminals has been used as well as the information obtained about the Malmö intermodal terminal, which was needed to know how many objects are in the terminal and how they interact with each other.

Once all the objects and interactions have been defined, the properties of every object have been applied to every object after consulting the information that was given to write the thesis "*The effects of emerging technologies in rail yards and intermodal terminals*" (Branko Mitrovic, 2019), a thesis this thesis is a continuation of and from where it has been obtained the data about operations time, as the time needed to handle the freight or the time needed to inspection a train, and then the model can be completed.

With the model finished, it has been possible to run the model and to obtain the data to make comparisons among different scenarios as follow-up to with the main objective of this thesis. These scenarios have been four, the actual one with any modification which has been compare with a scenario with the actual demand but using an Intelligent Video Gate, and two more scenarios using the terminal full capacity, one using the Intelligent Video Gate and the other without using it.

Finally, the comparison among different scenarios explained above, has been made and the conclusions of the thesis and the final objective has been reached.

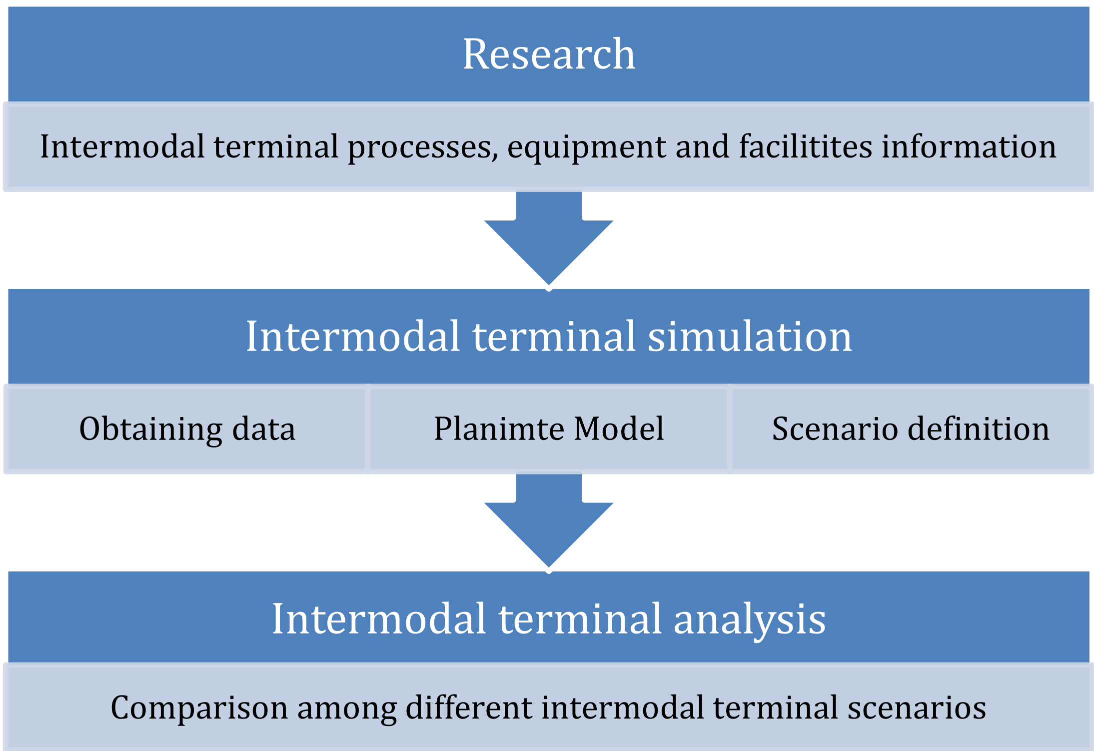


Figure 1. Project steps scheme

3. Intermodal terminals

With the knowledge acquired throughout in different courses it can be said that the terms intermodal transport and intermodal terminals are related to freight transportation chain using two or more than two means of transport while a freight unit remains unmanipulated. Intermodal terminals are considered nodes of the transport network whose function is to transfer freight from one mean of transport to another, specifically from rail to road or from road to train, making them an essential part of the supply chain. They are usually located next to the main rail lines making them more accessible and more efficient as the transported freight flows would pass close to the facilities and small deviation would be necessary.

In these kinds of terminals some different types of loading units (LU) are handled which makes more complicated all the processes that are carried out in these infrastructures unlike what happens in containers' ports terminals where the freight is usually more standardized as usually ISO standardized 20 or 40 feet containers are handled. The term TEU refers to, Twenty Feet-equivalent unit.

3.1. Intermodal terminals zoning

Intermodal terminals can be generally divided in some zones according to the activities that are carried out there. Although the processes are carried out in different places of the terminal, all of them are related, which means that the improvements in one of the zones could improve the operations in the others.

First, the most important area would be the transhipment area as it is the essence of the terminal. In this area, the unloading and loading operations are carried out, which means that freight is transferred from trucks to trains (or vice versa). This area, according to some intermodal terminals studied and stated in "*Intermodal freight terminals challenges and good practices"* (World Road Association, 2013), usually comprises some facilities that are common in most of the actual intermodal terminals rail-road that are located in Europe and have similar distributions although, depending on the needs the number or the distribution of them can vary from one to another.

This area would be formed, as it has been said previously according to what is stated in *"Intermodal freight terminals challenges and good practices"* (World Road Association, 2013 p.62), and some real examples as the Madrid Abronigal Terminal or Årsta Intermodal Terminal, by four or more railway tracks where the wagons would remain while the unloading/loading process last. Next to them two driving lanes are located, one used to unload/load the trucks and the other one used for truck circulation. Also, some lanes for temporary storage are located next to the driving lanes as some freight are not directly transferred from trucks to trains or from trains to trucks. To complete the facilities in the zone, two rail-mounted (sometime rubber tired) gantry cranes are located to cover the surface occupied by the tracks and lanes described above. It is important to highlight, that this area is not electrified as the lifting operations could not be done with the cables, and thus a no electrified locomotive can move the wagons in this area, the train is commonly split up in parts and shunted in and out from the terminal.

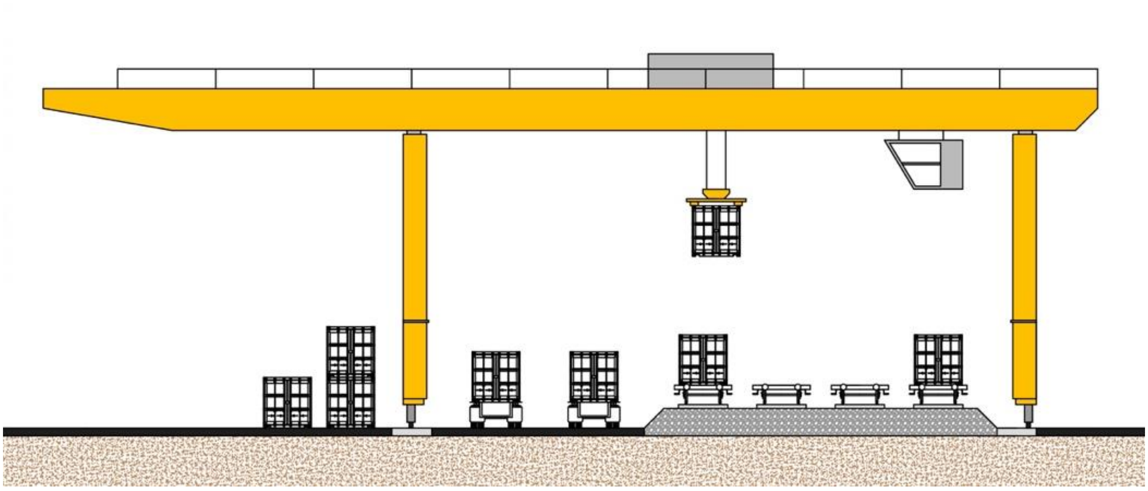


Figure 2. Transhipment area cross section

Another area, the arrival and departure area, would be the one located next to the transhipment area, where trains can remain waiting until the freight is handled or they are ready to leave the terminal, and it would be formed by more than two tracks. Also, in this area the wagon classification and the wagon assembly/disassembly are carried out in order to prepare them to be loaded and unloaded.

Moreover, there is the gate area, which is split between it can be distinguished between the gates for trucks and the gates for trains. In these two areas, the freight identification and the truck identification would be carried out, manually or automatically, depending on the installed systems in the facilities.

Additionally, storage areas, can be found according to the terminal needs as it is not usual to have huge storages areas as the main function of these facilities is to transfer the freight from one mean of transport to another, but some storage space could be necessary and even needing special equipment such as electrical equipment to plug refrigerated freight units and straddle carrier for stacking containers. Furthermore, some container maintenance activities are carried out in this area as some of the containers can get damaged in loading/unloading operations.

Finally, the service area where some offices are located, manages administrative, technical or control activities to operate the terminal in a proper way to achieve the established objectives.

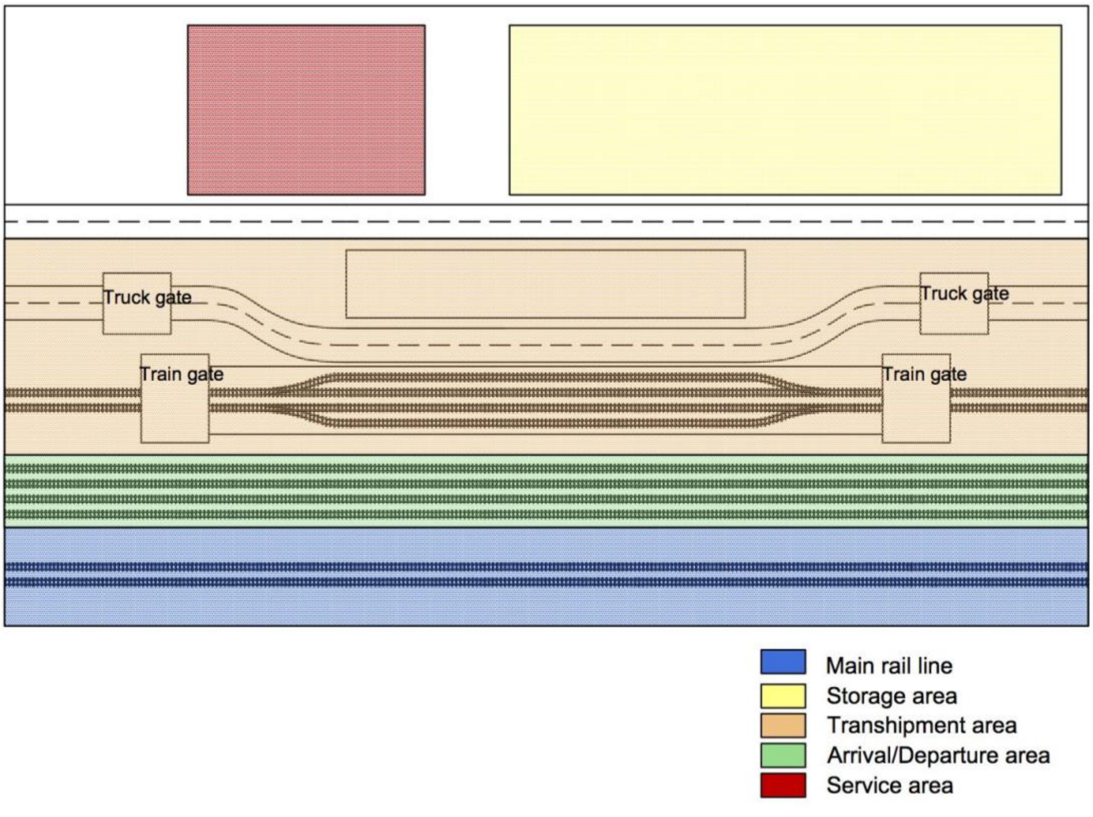


Figure 3. Intermodal terminal scheme

3.2. Freight unit types

Nowadays, there are some kinds of freight units according to the freight needs as depending on the freight kind, volume, size or shape it is needed to choose one or another unit, however, the actual trend is to standardize as much as possible, as it allows more efficient freight transportation, but there is not a unique freight unit.

To refer to those freight units that can be used in intermodal transport, the term Intermodal Loading Unit (ILU) is used, which includes containers, swap body or semitrailers that can be transfer to one mode to another.

It is with the differences between units where some difficulties are found, as handling, identification or transportation cannot be standardized, which makes intermodal transportation more difficult. While maritime transportation practically only utilizes containers, truck transportation uses swap bodies or semitrailers as they have greater freight capacity although also containers are transported by truck but mainly because the freight is not only transported by this mode of transport. However, with railway transportation, swap bodies, semi-trailers and containers are used.

To know the features of these loading units, mainly it has been consulted the document "*Análisis, información y divulgación sobre la aportación del transporte por carretera a la intermodalidad. El lenguaje del transporte intermodal. Vocabulario ilustrado" (*Ministerio de transportes, movilidad y agenda urbana (2020), as it is a technical guide published by a Public Administration with competences in the transportation field.

First, the most well-known freight unit is the container (Figure 4), which is a steel box that allows staking in several heights, manipulated from the upper side and used in different means of transport, although it is the freight unit most used in maritime transportation.

Figure 4. Container. (Container Tjänst, 2020)

Though the word container can be used to talk about every steel box used in freight transportation as it is a general term, it is more commonly applied to some containers with some specific measure, 20 and 40 feet long, which are called TEU and FEU, respectively, that are the most used measures worldwide. Within this unit category some other subdivisions exist, as it can be seen in Table 1, according to the transported freight as the container will have some specific features inside the frame that define the standard external dimensions or according to the height that define some specific containers that have their own name, high cube container or super high cube container.

Table 1. Container types and dimensions

<table>
<tr><th>Container type</th><th>Length</th><th>Width</th><th>Height</th></tr>
<tr><td>Dry</td><td rowspan="4">20 or 40 ft
6,1 or 12,19 m</td><td rowspan="4">8 ft
2,44 m</td><td rowspan="4">8,6 ft
2,59 m</td></tr>
<tr><td>Bulk</td></tr>
<tr><td>Reefer</td></tr>
<tr><td>Open top</td></tr>
<tr><td>High cube</td><td>20 or 40 ft
6,1 or 12,19 m</td><td>8 ft
2,44 m</td><td>h>9,6 ft
h>2,9 m</td></tr>
<tr><td>Super high cube</td><td>l> 45 ft
l> 13,71</td><td>8 ft
2,44 m</td><td>h>9,6 ft
h>2,9 m</td></tr>
</table>

Swap bodies (Figure 5) are another type of standardized freight units specifically adapted to the road transportation which are also compatible with rail transportation, so it is a very common freight unit in intermodal terminals. Unlike containers, it is not usually possible to stack them in some heights which means that more surface is needed to store them or to manipulate them, however they have bigger capacity and foldable legs, some reasons why, they are used instead of containers in road transportation.

Figure 5. Swap body. (Alibaba.com, 2020)

Semi-trailers (Figure 6) are another unit used in intermodal terminals to transfer freight between trucks and trains. This unit is a truck semi-trailer that has special support elements in the front and a pneumatic suspension system that allows to place the unit on the wagon platform. Also, it structure allows to be lifted from the ground to the wagon what makes easier the transhipment operations. However not all semi-trailers have attachments required to be carried by rail wagon.

Figure 6. Semi-trailer

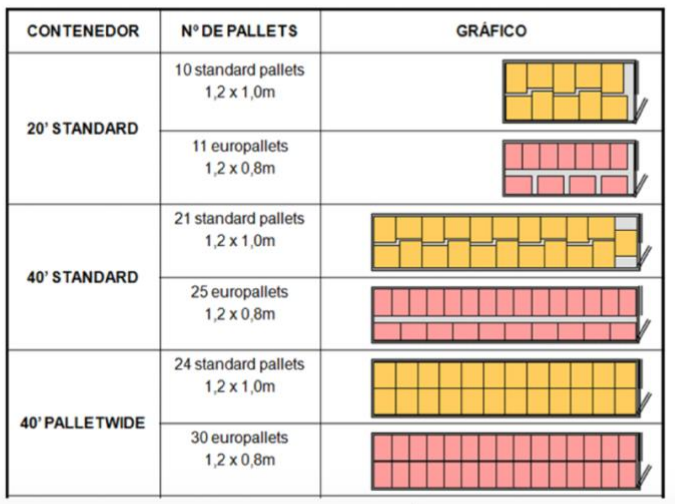
Another standardized unit is the pallet (Figure 7), which is not handled in intermodal terminals where consolidation or deconsolidation of freight does not occur, however it could be possible if the needed machinery is available within the facilities. This freight unit is usually made of wood, usually fits in containers and swap bodies, as the standardized dimensions of them has the dimension for it.

Figure 7. Pallet

Table 2. Pallets types and dimensions

Container type	Length	Width
ISO	1200 mm	1000 mm
CEN	1200 mm	800 mm

According to the specified dimensions in the Table 2 above, there are some common distributions (Figure 8) of this unit within the standardized containers that are usually handled in intermodal terminals as it can be seen in the figure below. Also, it is important to highlight that with the last distribution is also possible to stack two pallets if their height fits within the container.



CONTENEDOR	Nº DE PALLETS	GRÁFICO
20' STANDARD	10 standard pallets 1,2 x 1,0m	
	11 europallets 1,2 x 0,8m	
40' STANDARD	21 standard pallets 1,2 x 1,0m	
	25 europallets 1,2 x 0,8m	
40' PALLETWIDE	24 standard pallets 1,2 x 1,0m	
	30 europallets 1,2 x 0,8m	

Figure 8. Pallets distribution within containers. (2020, Iplacex, tecnológico nacional)

3.3. Equipment

There are some machines that are used in intermodal terminals with the purpose of handling and transferring the freight from one mean of transport to another being some of them common in most of the terminals and platforms where the ILUs named below are handled, though some of them are only used in those where freight transported by train is handled.

One of these machines would be the reach stacker (Figure 9), which is used to move, stack and lift containers when some storage activities are carried out however it can be used to load and unload trains and trucks too, although is not the main activity what it is used for in big terminals.

Figure 9. Reach stacker

When an intermodal terminal handles big volumes of freight then reach stackers would not be efficient enough to handle the total freight and consequently, bigger machines are needed. When this happens gantry cranes, as the one in Figure 10 and mentioned before, are used to load and unload trucks and wagons. These kinds of cranes that are also usually used in containers terminal ports, are formed by two legs where the beam rest on and that are wheeled, most of the times on rails. On this beam, the control cabin is usually located from where the freight elevator is managed, that is also on the beam and has the capability to handle swap bodies and containers as it has the suitable anchors for both ILUs. Furthermore, as it has been said before, these cranes are able to cover the occupied surface by the trucks lines and the railway tracks used to unload and load the freight.

Figure 10. Gantry crane (AICRANE, 2020)

Another machine, the fork lift truck (Figure 11), that is needed in the terminals is used in case some consolidation or deconsolidation operations are carried out to handle pallets so it is not essential in every intermodal machine.

Figure 11. Fork Lift truck. (WRMH, 2020)

With a similar purpose as the reach stacker, there are the straddle carriers (Figure 12), which allow workers to stack such units as the containers, which can be stacked in several heights, as their structures are made with this objective which does not happen with semitrailers, that can only be positioned on the floor. It is important to highlight that these machines have a particularity, as the container position on the floor must allow the straddle carrier transit as a corridor is necessary between containers that are positioned next to each other.

Figure 12. Straddle carrier. (CM Container management, 2020)

The last machine normally used in intermodal terminals is the shunting locomotive (Figure 13). There are two reasons why it is used, the first one is that trains are usually longer than loading/unloading tracks so it is necessary to divide them into smaller wagon groups so that they fit. The second one is that the locomotives, which are used to transport the freight, are usually moved by electric engines and due to operational requirements, cranes and reach stackers need that the pace over tracks is free of cables and obstacles, locomotives powered by combustion engines are needed instead.

Figure 13. Shunting locomotive. (Bemo Rail, 2020)

3.4. Operations

Within the terminal some operations are carried out to get freight arrivals to its destination without any damage and in the shortest time, without any delay, as this is what costumers require from a good service.

3.4.1. Freight inspection

Once wagons are at the transhipment railway tracks, the freight and the waggons are inspected to know the freight state and if it has suffered any damage while it was being transported. This activity is carried out at the same time as the freight identification as it is carried out manually by the terminal employees and takes approximately 50 minutes per train.

3.4.2. Freight identification

When freight arrives by train, wagons are positioned on arrival/departure area or if the loading/unloading area is free, directly on it. Then terminal operators manually identify the ILUs and the wagons to know the information about each ILU and railcar, to know where and when the ILUs must be unloaded. Once all the information is acquired the unloading process can start which would be the next operation.

If the terminal, freight arrives by truck, then the trucks have to be identified manually by the terminals operators at the truck gates where also, the administrative procedures are perfomred and the instructions are given to transfer the freight that must be followed by the drivers as indicated.

3.4.3. Loading and unloading train

Once the wagons arrive to the terminal, usually carried by an electrical locomotive, the wagons are positioned on the loading/unloading tracks by the shunting locomotive, to start the freight transfer between wagons and trucks, for which it is necessary to release the container anchors.

Once the wagons are positioned and the containers anchors are released, by using gantry cranes or reach stackers, the freight is transferred from the train to the trucks directly, if they are already positioned on the trucks lanes, or it is stored in the storage area if trucks are not already in the terminal.

To load a train, the process is quite similar, the ILUs are transferred from trucks directly or from the storage area, but first it is necessary to prepare each railcar platform to the ILU dimensions and type that is going to be loaded. Once the freight is located on the platform, it is fixed with the anchors and the railcar is ready to leave the terminal.

It is important to highlight that both processes can start at a fixed time according to a schedule, which allows planning all the arrivals and departures in advance but if there is any unexpected event could be delays that would affect the entire supply chain, or they can start as soon as tracks are free and then more resources could be used as more ILU movements would be necessary.

3.4.4. Freight storage

When the freight is not directly transferred from trucks to trains or vice versa, the ILUs are stored in the areas enabled for this purpose. In this area, the freight is placed in the most efficient way, so first is placed in one level and then when the entire surface, and then when the surface is totally occupied, those ILUs that can be stacked on the next level.

3.5. Intermodal transport actors

In intermodal transport field, there are some actors involved, from the public authorities that stablished the policies that rule this economic sector to the mail carrier who delivers the post in every house.

Even though all the actors involved in the supply chain may affect in its outcome, this project is focused in those that have a greater incidence in intermodal terminal functioning.

Among all the involved actors, the most related to this project would be the terminal operator as it is the one that manages the operations carried out in intermodal terminals, and the one that must organize the actors that converge in this point of the supply chain, being necessary to coordinate the other actors acquiring all the possible information from them. Generally, this actor is a private company, which receives an administrative concession from the terminal owner, in Europe usually a public authority, which owns the land and part or the entire facilities where the terminal is located. A similar situation happens with railway networks that are owned and managed by public administrations, the railway infrastructure managers, although the transport services are offered by other private or public companies. These last companies, would be the wagon owners, that own the trains and transport the freight throughout the rail network but, with taking into account the limitations that are stablished by the railway infrastructure manager, which has to control the traffic within the network. Finally, there are two main actors, cargo owners, and the truck owners. Following it is attached an scheme to sum up all the actors involved in Figure 14. Intermodal actors scheme

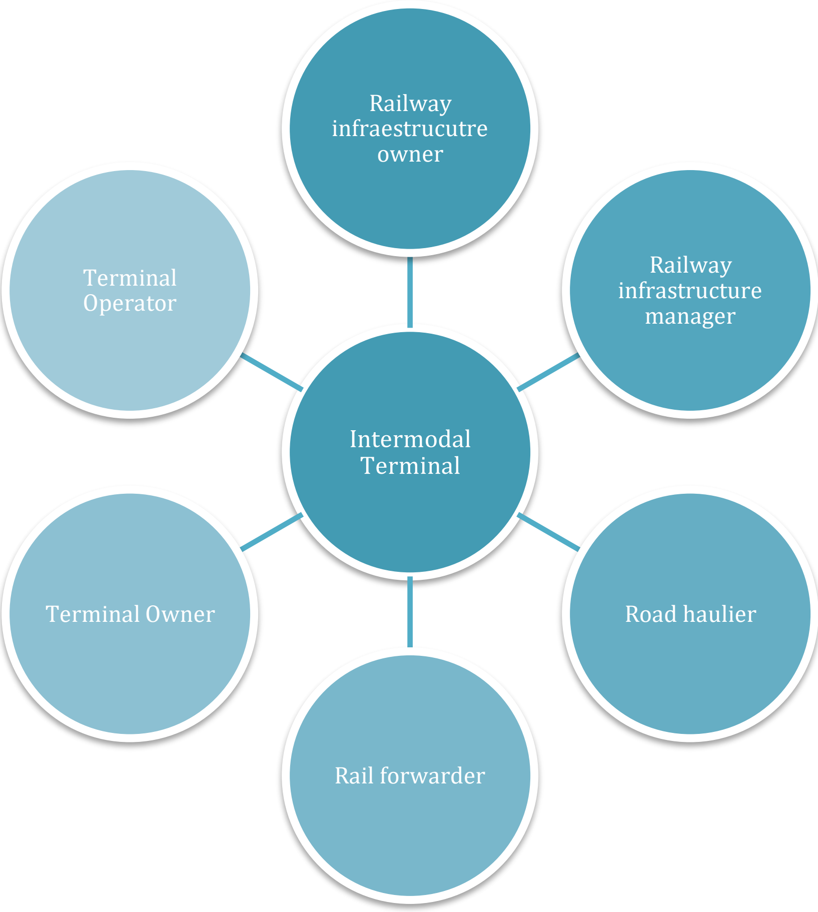


Figure 14. Intermodal actors scheme

4. Intermodal transport units and wagon identification

The OCR system whose function is to identify the freight that comes into the terminal, needs some patterns to achieve its aim, as in the current situation it is not able, without applying any other methods, to identify codes or signs that are not standardized.

4.1. Intermodal transport unit identification

As it has been said in previous sections, there are different ILUs, and according to the European rules following the ISO standards, they are identified with different code systems depending on the ILU type.

The containers, the most used ILU in maritime transportation, following European rule ISO 6346:1995, must be identified with a code as the one in Figure 15, and generated by:

- Owner code: three letters
- Product Group code: one letter
- Serial number: six figure
- Check digit: one figure

It is important to highlight owner code is unique and it is mandatory to be registered in the Bureau of International Containers (BIC).

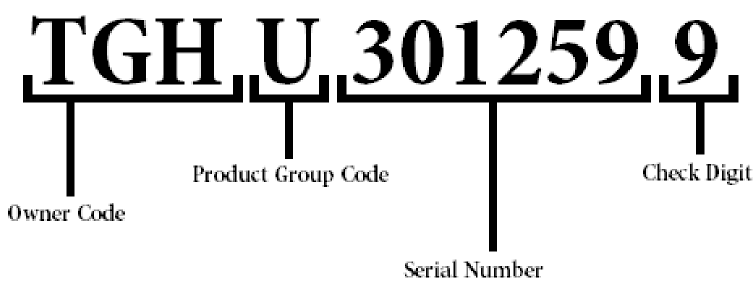


Figure 15. Container identification code example. (Container Technology Inc. 2020)

This identification number must be located on 5 mandatory positions, which are marked in the Figure 16 attached below.

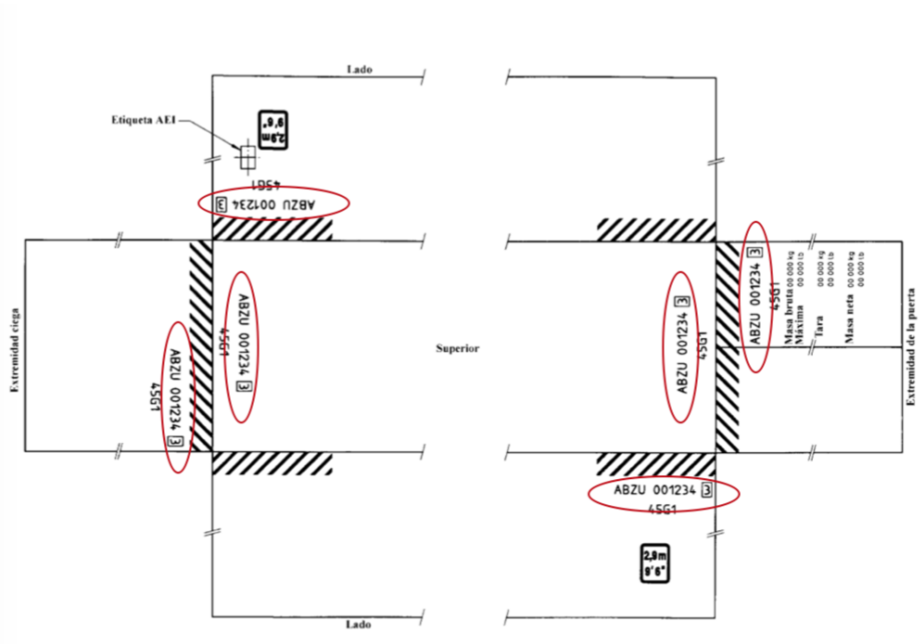


Figure 16. Container code identification position. (UNE-EN ISO 6346, 2020)

In the case of semi-trailer and swap bodies the identification codes follow a similar structure to the container codes as the rule EN 13044-1:2011, which defines the identification code of these ILUs, is based in the ISO 6346:1995 mentioned before being an example of it the one shown in Figure 17.

- Owner code: four letters
- Serial number: six figures
- Check digit number: one figure

While containers where registered in the BIC, swap bodies and semi-trailers are registered in International Union of Combined road-rail transport companies (UIRR)

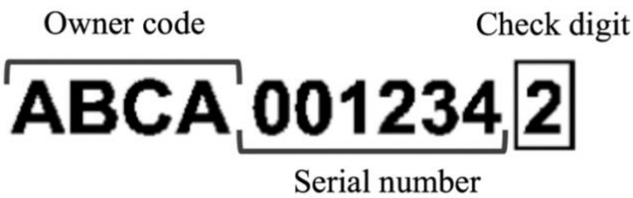
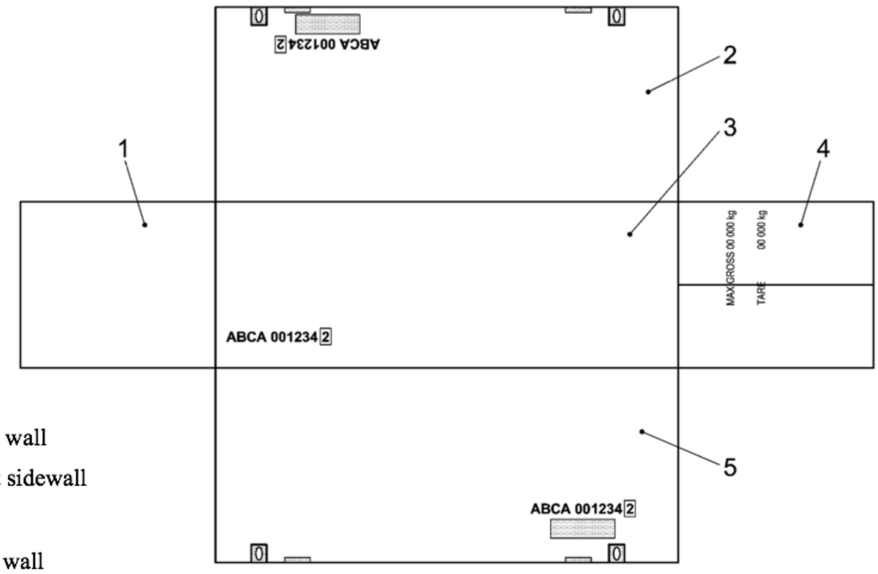


Figure 17. ILU identification code example.

This identification number must be located on three mandatory positions, which corresponds with the ones where the code is written in the Figure 18 and optionally, it can be located on other two positions, on the front and back of the ILU.



1. Front wall
2. Right sidewall
3. Roof
4. Back wall
5. Left sidewall

Figure 18. ILU identification code positions. (UNE-EN 13044, 2020)

4.2. Wagons identification

ILUs and wagons need to have an identification code, which in the EU is ruled by the European Railway Agency, which is the one in charge to write the Recommendation on the specification for the European Vehicle Register, where it is established how this identification code is written and which information it has to contain. It is done according to the instructions established in *"Commission Implementing Decision (EU) 2018/1614 of 25 October 2018 laying down specifications for the vehicle registers referred to in Article 47 of Directive (EU) 2016/797 of the European Parliament and if the Council and amending and repealing Commission Decision 2007/756/EC.*

The wagons codes are formed by the character sets explained below:

- Vehicle Keeper marking: Three letters
- Interoperability capability and vehicle type number: 2 figures
- Country in which the vehicle is registered number: 2 figures
- Technical characteristics number: 4 figures
- Serial number: 3 figures
- Check digit: 1 figure

4.3. Dangerous goods

While identifying wagons and ILUs would be enough to transfer the freight correctly between means of transport, sometimes could be necessary to know more information to handle it or in case the first identification was wrong, as the system applied could have some error percentage, additional verification could help to reduce this error.

According to *"The Commission Directive (UE) 2018/1846 has modified the Commission Directive 2008/68/CE"* dangerous goods identification in rail transportation is ruled. It is in these modified sections where Regulations concerning the International Carriage of Dangerous Goods by Rail (RID) are included and as a result these regulations are the ones that are applied in the EU.

In these regulations, the specifications are included that must be followed to identify the dangerous freight that is transported by train among the countries that belong to the EU and within these countries. This means that placards and signs are quite standardized so it would help to identify the freight by some automated systems.

According to these regulations, the placards minimum dimensions and their shape (Figure 19) are stablished and regulated as well as some identification numbers that allows to identify the kind of dangerous freight that is being transported and to know the level of risk that supposed this freight. This establishes a standardized frame that could allow the process of automated identification of the freight and would reduce the percentage error. However, it is not specified where the placards must be allocated, only it is said that it is mandatory to stick them in each container side which makes more difficult to identify them as they are not always in the same position.

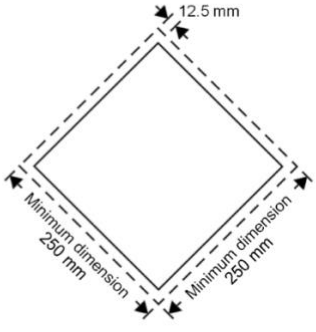


Figure 19. Dangerous freight placards dimensions (Expect class 7). (Regulations concerning the International Carriage of Dangerous Goods by Rail (RID, 2020))

Also, orange placards (Figure 20) must be attached to the container which specify the dangerous identification number and the UN number. In this case, there are not minimum dimensions but specific dimensions, the placards must be 30 cm high and 40 cm long and the numbers must be 10 cm high.

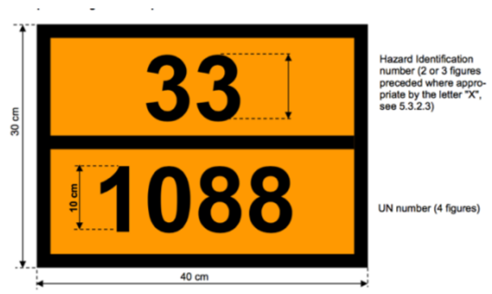


Figure 20. Orange placard example. (Regulations concerning the International Carriage of Dangerous Goods by Rail (RI)D, 2020)

Also, both kind of placards when they are not completely visible must be attached to the wagons what could help in the identification process as it is sure that the dangerous signs are always visible.

5. Optical Character Recognition System

The Optical Character Recognition System, OCR system and its role in intermodal terminal, is the system this paper focuses on and what is going to be written about as it is going to be studied how it could help in intermodal terminals management to obtain an efficiency increase in the supply chain, specifically at the point that concerns intermodal terminals about.

The OCR system is not exclusively used in transportation field, as it is used in more activities that need the character identification. The system function is to obtain from physical characters a digital version of them and then work with the information obtained. This means that the software used allows identification of text written on one paper, on a stone wall or on other kind of surfaces.

To obtain the digital version the software must take pictures of what is going to be digitalized, then it is able to separate the picture information to obtain the characters that are in the picture and that are sought.

The whole process which is carried out by the Intelligent Video Gate,and which includes the OCR system, in order to get the characters' information can be defined in the following ten steps that are explained below, which have been obtained from *Los diez elementos de un sistema OCR (Optical Character Recognition)* (Ignacio G.R. Gavilán, 2019) although older softwares could be less complex and avoid some of the steps.

1. **Character input.** The object where the text, which is going to be analysed, arrives to the point where the scan is located, which in the specific case of an intermodal terminal would be the IVG.

2. **Optical scanner**. The image of the characters that is going to be processed is taken by the cameras located in the IVG to obtain the digital version of the text, which is the first information the software is going to work with.

3. **Location segmentation.** It uses algorithms, to separate the picture elements that are characters from the rest of objects that are not profitable to the system aim, which means locating the character's position in the whole picture.

4. **Pre-processing.** The images are manipulated to reduce picture noise and picture defects by using some algorithms and then obtaining a better image quality to work with.

5. **Segmentation.** After obtaining a good quality image, the characters are separated from the image by recognizing character shapes or some characteristics that allow the identification of those parts of the image that are text from those that are not text.

6. **Representation.** The information that is going to be used in the recognition process is generated.

7. **Characteristics extraction.** With the information generated in the last step symbols' main characteristics are obtained and then, they are classified.

8. **Training and recognition.** Once the main characteristics have been obtained they are compared with patterns from data bases where the character's characteristics are located. After this comparison is made, if the characteristics obtained match in a certain percentage with the data base characteristics, a character will be associated with the character image.

9. **Post-processing.** Once all the characters are obtained, they undergo a process, which using data bases, is able to make some corrections. These processes could be for example, using syntactic laws in case of texts, to change some characters that would not be correct according to these laws or in number recognition, knowing that one number is impossible to appear for another that would be more likely to be the correct one.

10. **Character output.** Finally, the characters are shown digitally and the sought information is obtained and it is ready for use.

6. Intelligent video gate

Once it has been explained what the OCR system consists of, being a system that can be applied in many fields, this section is going to be focused on its application in the intermodal terminals, specifically in train gates.

In the previous section, it has been explained how the OCR software works, which is the core of the system, and which steps are followed to obtain the information demanded by the user. However, the two first steps that have been mentioned in the previous section are related to the acquisition of images from the technical components of the IVG, the ones where the intelligent video gate is going to work as is this facility the one that is going to obtain the pictures the system is going to work with.

6.1. Gate components

The gate, according to the CAMCO and CERTUS, is composed of different equipment according to its functions, as there are systems that have could offer less capacities according to the intermodal terminal manager needs or the investment that is wanted to be made. However, a common gate would be composed of cameras, illuminators, RFID antennas and tags, scanners and wheel sensors.

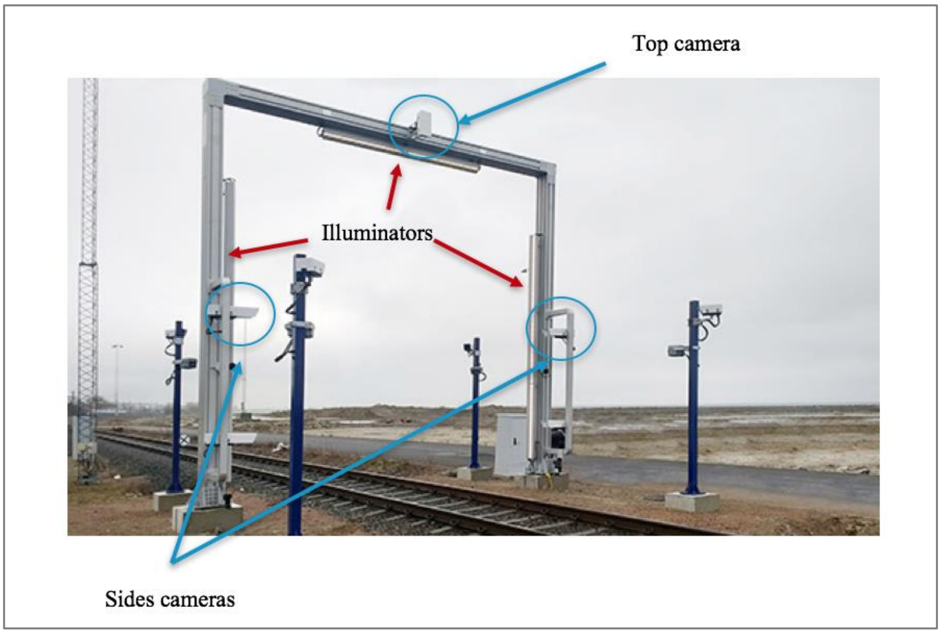


Figure 21. Intelligent video gate components. (CAMCO, 2020)

- **Cameras.** They are the main equipment located in the gate, as they provide the information the system is going to work with. They must provide enough quality container and wagon pictures to be able to identify them, which means that the cameras must be able to take pictures where the identification codes and sings can be read from a picture that had been taken while wagons and containers were in motion. Usually some cameras are installed in the gates which allow taking picture from the top and the sides, being the cameras used, linear cameras which, according to STEMMER Imaging web page, are used to take pictures of motion objects as they can generate a fixed picture of long objects, as a container, that keeps in motion.

- **Illuminators.** To obtain good quality pictures, a good illumination is needed as the natural light is constantly changing as the weather conditions are not always the same and the terminal operations are carried at night as well. For these reasons, artificial illumination is needed to obtain good pictures and that is why the illuminators are installed in rail gates.

- **RFID antennas and tags.** Radio Frequency Identification (RFID) antennas and tags may be used to identify containers and wagons. This component works when a tag is attached to the wagons or the container and then, when they pass by the reader, this one is able to send the information which corresponds to the tag to the system to operate with it. It only can be used if the wagons or freight units have a tag to identify them which is not very common especially in freight units what it is practically non-existent.

- **Laser scanners.** They are used to obtain information about train acceleration, train speed and some features in advance that help the camera software adapt its sensors to the conditions which the pictures are going to be taken in, and as a result, the camera will be enable to take correct pictures of the train.

- **Wheel detector.** This component allows detecting when a train is approaching the gate to turn on the other components so what it is not located at the same place as other components. At the same time, it could provide more information about the train features such as the distance between axels, the train speed or how many wagons are composing the train. Also, if fibre optics wheel detectors are used, the wagon and freight can be weighted.

6.2. Information obtained

From the different gate components, some data is obtained according to the information provided by some companies as CAMCO, HUPAC, CERTUS or DIS Middle. This information, is related to the train features and its freight that can help with the following operations carried out in the freight terminal (Table 3).

According to the systems offered by some manufacture companies, the collected data about the train and its freight when the system is used are the ones shown in the Table 3 attached below. Furthermore, if a fibre optic wheel detector is used, wagons can be weighted acquiring additional information about the train and its freight that can be useful to handle the freight, specially to distribute the containers that are going to be storage in an efficient way. Other data collected are the pictures of the wagons and the freight units that are used to obtain some of the data exposed on the table below but also, they can be used to analyse the unit and the wagons state if one of both suffers any kind of damage and it is necessary to know when this damage was done and to know who is the responsible of it.

Table 3. Intelligent video gate obtained data

Collected Data	
Train information	Railcar number
	Wagon number
ILU information	Container number
	ISO code
	Non-ISO container number
	Container size
	Container type
	Container position
	Seal presence

6.3. System improvements

Nowadays, these systems can be improved in different ways, first, from the point of view of their accuracy. Although their actual accuracy is around the 90-95% depending on the kind of obtained data, it is not the most desirable accuracy as it means that employees must check manually for mistakes, wrong or missed data.

Also, in relation to the damages suffered by the freight and the wagons, the system can be improved to, automatically, obtain information about which unit and wagons has suffered the damage without needing any visual inspection carried out by the terminal workers. This could be achieved by using artificial intelligence as it is a project the European Union with some private companies and public agencies is working on.

In both improvements explained, the efficiency in the terminal would increase as the processes would reach a greater level of automation and at the same time, the number of needed workers would be reduced as well as the operational costs.

7. Study case Malmö intermodal terminal

The study case of this project is the intermodal terminal located in the city of Malmö, in the west coast of Sweden and in the south of the country. It is an intermodal terminal, which allows transhipments between trucks and trains, the kind of terminals, which has been written about in this document. It is the largest in terms of freight volume as it handles 120.000.000 kilograms of goods per year, and after the renovation carried out in 2018, which transformed the terminal into a crane-terminal, it is also the most modern intermodal terminal in the country. As it has been said previously in the section about the actors involved in the processes carried out in the intermodal terminals, the terminal is managed by a private company, and in this particular case it is Mertz Transport AB.

Figure 22. Malmö intermodal terminal location. (Google earth, 2020)

As it has been said, the terminal is located on a strategic point as it allows the freight connection between Europe and Sweden by road and by train, as the Öresund Bridge connects Sweden with Denmark and therefore with the other countries of Europe. Also, this location allows the connection with other countries by boat, as next to the terminal is located the Copenhagen Malmö Port. Moreover, next to the terminal a marshalling yard is located and can help with the train operations needed in the terminal. All these features, make the city of Malmo and specially the area where the terminal is located, a great node of freight transportation in Sweden, and, also in the Scandinavian region.

7.1. Facilities

The Malmö intermodal terminal (Figure 23) is composed of some facilities that allows the infrastructure to achieve the freight transhipment between trains and trucks. Some of these facilities can be identified in the aerial picture attached below. This information has been obtained from Mertz Transport AB website and from "*The effects of emerging technologies in rail yards and intermodal terminals"* (Branko Mitrovic, 2019).

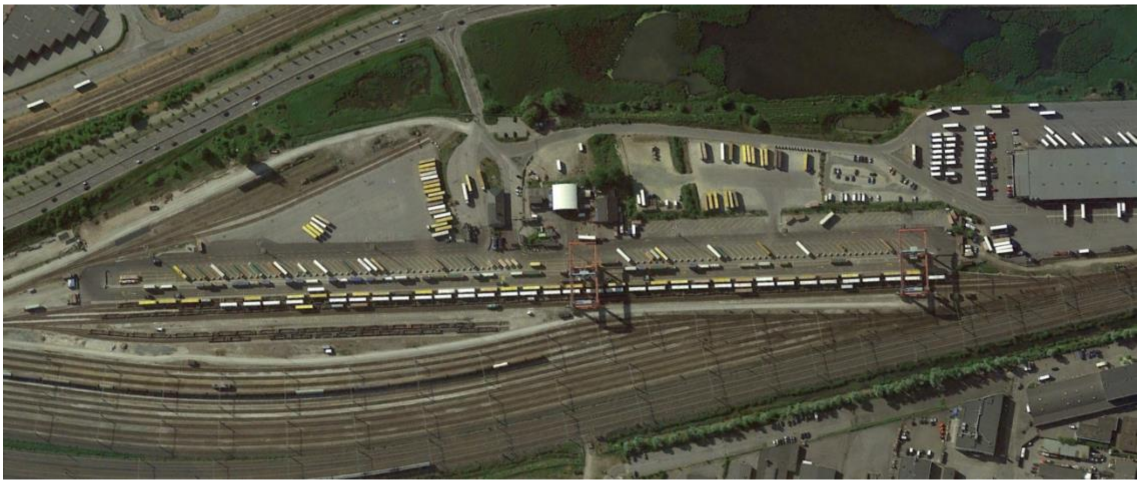


Figure 23. Aerial photo from Malmö intermodal terminal. (Google Earth, 2020)

The most important area, as it is where the essential activity is carried out, is the transhipment area and it can be divided in some parts. First, there can be found four railway tracks, where the split trains remain to be loaded and unloaded. The length of these tracks is 800 metres however the operational length is 660 meters which means that the split trains have to be shorter.

Next to the railway tracks two truck lines are located, where one of these lines is used to park the trucks while they are waiting to pick up or to drop off the freight, and the other one is used for the trucks transit without interfering with the transhipment activities.

Finally, just next to the trucks lines there is a zone where some ILUs can be stored directly from the train without needing any other movement. This zone can be divided in two different areas according to the kind of ILUs that are stored in it. One area that is located as if it was another line truck, is used for storing containers in parallel. The other one is for semi-trailer storage and it is separated from the trucks lines by one of the cranes railways.

Figure 24. Årsta terminal distribution. (Transport nytt., 2020)

To carry out the transhipment activities, at the transhipment area two gantry cranes have been installed. They cover the 660 metres railway tracks length and the cross distance occupied by the railway trucks, trucks lines and the storage area located next to them.

Next to the transhipment area, an empty area is located, which is used to store freight and where trucks can park and remain while the transhipment area is full or while they are waiting to the train arrival.

Also, into the terminal facilities one building is included, which allows the freight collection, consolidation and loading on trucks. It has 46 docks, which allows it to receive different types of trucks and 6000 m_2 of surface where the freight is handled.

All the terminal facilities are summed up in Table 4 as well as the equipment used within it, which is attached below.

Table 4. Malmö intermodal terminal facilities and equipment

Malmö intermodal terminal facilities and equipment
4 transhipment railway tracks
2 transhipment line trucks
1 container storage line
1 semi-trailer storage line
2 gantry cranes
3 reach stackers
Services building
46 docks building for consolidation, collection and loading freight
Parking area
Storage area

7.2. Intermodal terminal freight data

From the intermodal terminal, some data has been collected to know how the work is developed there, and to have the information that is needed to simulate the different scenarios that are going to be modelled with the software Planimate. To do that, it was planned to visit the Malmö intermodal terminal, to make some questions to the operators, to measure how much time takes to carry out some of the processes and to have information about the handled freight, however due to some inconvenient as the project that was being carried out there to build the IVG has been delayed, and the public health situation, it was impossible to go there and consequently, the necessary data were taken from "*The effects of emerging technologies in rail yards and intermodal terminals*" (Branko Mitrovic, 2019).

Once the information about how intermodal terminals work and what processes are carried out within them has been collected and understood, a list of questions has been made with the objective to know the information that would be needed to simulate in an accurate way the Malmö terminal and to obtain in the next sections the most accurate results that lead to the needed conclusions in order to know, how effective is the implementation of the OCR system in the Malmö Terminal and if it could be useful in similar intermodal terminals.

The question list has been attached in Table 5, however as it has been said in the previous section about the scope and limitations of this project, there are some limitations that do not allow to answer all of them or in the desire way as it explain in the answers to the questions made.

Table 5. Questions related to the terminal functioning

QUESTIONS ABOUT THE NEEDED DATA
1- What are the terminal employees' salaries?
2- What is the needed time to identify the containers?
3- What is the needed time to inspect a train?
4- Are ILUs movements reduce with the OCR system?
5- How much is the construction cost of the OCR gate?
6- How much is the maintenance cost of the OCR gate?
7- How much is the operation cost of the OCR gate?
8- How much is the cost of the OCR gate failure?
9- How many employees are needed in the terminal?
10- How many employees are working identifying ILUs?
11- How many ILUs are handled in the terminal?
12- How many ILUs of each kind is handled?
13- What is the OCR system gate accuracy?
14- When is the terminal opened?
15- Is it needed specialized workers?
16- What is the OCR system maintenance need?

Once the questions have been formulated, they have been answered as good as it has been possible with the available information from the different resources what has been consulted.

1- **Employees' salaries.** The salaries that are important in this thesis are the ones that are given to the cranes drivers and to the employees who are handling the freight, as the administrative employees are not going to be directly affected by the video gate implantation, and it can be established as 28.000 euros per year in average.

2- **Inspection and identification time.** As the identification and the inspection are two activities, which are carried out at the same time it is going to be supposed that the average time needed to complete those activities is 50 minutes per train as it is the given information by the terminal operators.

3- **Movements reduction.** There is no certainty about that as usually ILUs are directly transhipped to trucks and if the information about which is the departure order of the ILUs is known without the OCR gate, it would not reduce the ILUs movements.

4- **OCR system costs.** The construction and the software cost is 154.500 euros and its maintenance cost is 8500 per trimester.

5- **OCR system failure cost.** If the system fails it would be necessary to pay employees extra hours however, as it is said in most of the OCR suppliers they have twenty-four hours' assistance services which would mean a quick response in case the system fails. As it is not a system that is exposed to great physical wear, and according to the brands, which supply these systems, a strict maintenance is carried out, the failure possibility could be considered quite small as different supplier companies ensure its reliability, and it is not going to be taken into account in this thesis.

6- **Terminal employees.** In the Malmö terminal 6 employees are carrying out the freight handling and the identification and inspection activities

7- **Handled ILUs.** In the Malmö intermodal terminal 200.000 ILUs per year are handled, 4.000 ILUs in a week on average where can be found semi-trailers, swap bodies and containers. The time needed for each transhipment on average is 3 minutes and there is no difference among the ILUs types. These ILUs are transported by 27 trains per week, which are shown in Table 6, and as a result, the trains carry 150 ILUs on average which is the number of ILUs that is going to be used to simulate the train arrivals in the model.

Table 6. Malmö Intermodal terminal train arrivals

Trains arrivals		
Number	From/to	Company
5	Malmö/Köln Eifeltor	Hupac
5	Malmö/Stockholm Bro	Coop
5	Malmö/Eskilstuna	TX Logistics
6	Malmö/Norway	CargoNet
6	Malmö/Germany	TX Logistics, Kmobi Verkehr, Van Dieren

8- **Operational timetable.** The Malmö intermodal terminal works 7 days a week and the timetable is the one attached below in Table 7.

Table 7. Malmö Intermodal terminal opening hours

Malmo intermodal terminal working hours						
Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
5:30-1:00	5:30-1:00	5:30-1:00	5:30-1:00	5:30-18:00	6:00-15:00	9:00-19:00

9. Malmö intermodal terminal simulation

In this thesis, the case study is the Malmö intermodal terminal, and according to the existing infrastructure, a model with the software Planimate has been made to obtain different possible future scenarios of the terminal functioning to make some analysis about the terminal.

The software Planimate has been chosen because it is a freeware software, which allows to modelling, planning and scheduling systems in an intuitive way. Also, it is possible to observe on the screen how the different objects interact and work while it is working, what makes easier to know if it is working properly according to the model objectives and the expectations.

This software allows, throughout some objects and items with different attributes, to simulate each of the processes that are carried out in the terminal by the different actors and their equipment. The objects are the ones that carried out the process that the items suffer, being the first ones the processes carried out by the equipment, as cranes or terminal employees, and the second ones the ILUs or the vehicles, as trucks or trains.

The model made with the software represents the infrastructure located in Malmö and according to the data obtained from the terminal, these have been introduced to obtain the different scenarios that are going to be studied in this section.

Following that, the different object introduced are explained into the software to represent the terminal and how they work and how they interact in order to obtain a good representation of the terminal functioning. However, as there was a lack of information it two models have been done, one with all the current interactions (Figure 26) and another one simplified (Figure 25) with the available data that allows to make an approximation of the terminal functioning and to evaluate different scenarios.

1- **Train entry**. Throughout this object as it is called in the software, the trains are introduced in the model following the arrival schedule, which is actually represented as single arrivals according to the Malmö schedule arrivals that has been introduced in the previous section.

2- **Inspection point.** To simulate the time that is spent to inspect the train and to position it to know the damages suffered by the freight and to identify every ILU it is used a Multiserver object, which would and object that consumes time, and in this case, a fixed time.

3- **Train split.** As the terminal has two Gantry cranes to serve the train tracks, in the model the trains are split in two. This action simplifies the model and assumes that every crane manages half of the freight volume carried by every train that arrives to the terminal, what is a proper assumption, as the rail tracks served by each one is the same and the kind of ILUs handled too.

4- **Gantry cranes.** They are modelled as splitters combined with Multiservers. The combination of both objects allows splitting every half train into the total number of ILUs carried by every train and assign a transhipment time to every ILU. As some of the ILUs are directly transferred to trucks and others are stored after the ILU handling, there are two different destinations within the model for the ILUs, the trucks and the storage.

5- **Storage.** In the model the ILUs storage is modelled as a queue where the ILUs wait until a truck arrives to the terminal to pick up the stored ILUs after an undefined time.

6- **Transhipment pick up.** The operation of those ILUs that are directly transferred from the cranes to the trucks are defined in the model as pick up objects that allow throughout carrier items pick up simple items.

7- **Storage pick up.** As the stored ILUs are modelled as a queue when trucks arrive to the terminal they pick up the ILUS without waiting as the ILUs are already ready to be picked up.

8- **Truck entries.** To model the truck entry, two different entries have been introduced, one that goes to pick up the storage ILUs and another one that goes to pick up the ILUs directly from the transhipment tracks. On one hand, the first one works without queuing as it is not necessary to wait to pick up the freight. On the other hand, the second entry goes to a queue where the trucks wait until the freight is ready to be picked up. In the simplified model only one is introduced as there is no difference between ILUs.

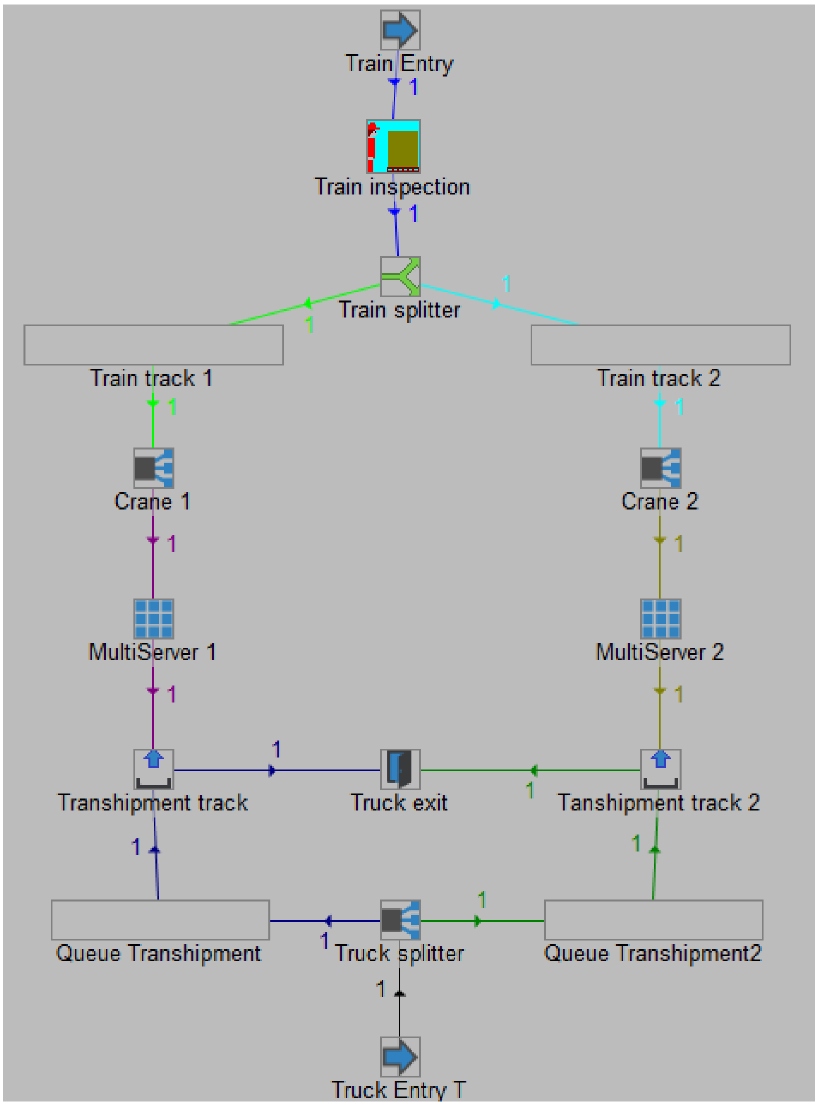


Figure 25. Planimate simplify model.

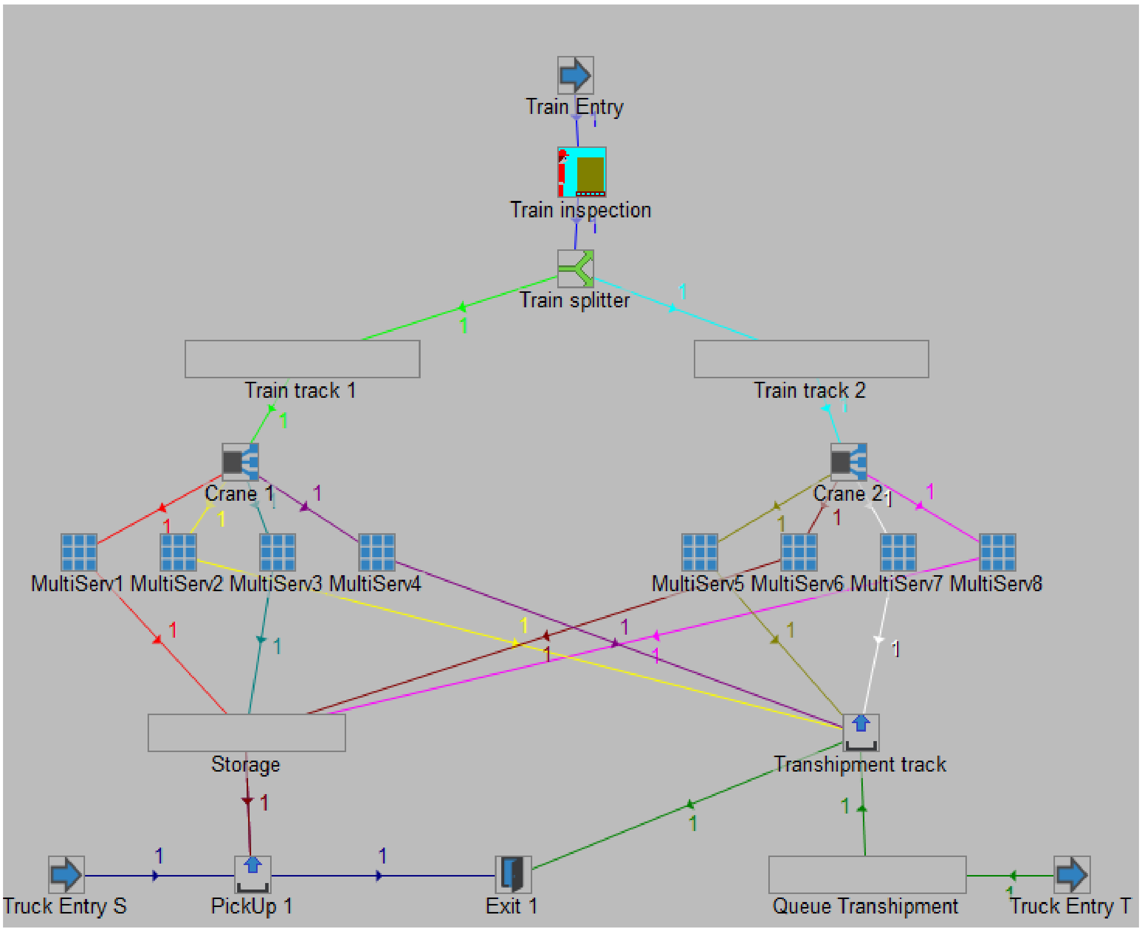


Figure 26. Planimate complex model.

9.1. Data and hypothesis related with each scenario.

Once the model has been made different scenarios have been simulated, the current one and the one with the video gate where some different hypothesis has been made in order to obtain a wider approximation of the future which will allow to make a better analysis of the gate implantation.

In both scenarios, there are common hypothesis and the main variations are made in relation with the ILUs identification and the ILUs handling, although with a deeper information about the percentage of the different ILUs types and the number of movements needed, the simulation would be more accurate. However, it is going to be assumed that all the ILUs handled are of the same type and the time needed to handle them is the same.

9.1.1. Actual scenario

To simulate the actual scenario the hypothesis (Table 8) and the data used in each object and item of the model are the following.

Table 8. Hypothesis actual scenario

Actual scenario	
Train entry	Single arrivals following the schedule in Table 7.
Inspection point	Fixed time for each train has been stablished to 50 minutes.
Train split	Half of the freight is handled by each gantry crane.
Gantry cranes	Fixed time for each ILU has been stablished to 3 minutes, there is no differentiation among ILUs' types.
Storage	Some of the units are storage no more than 24 hours (information not available).
Pick up	Trucks wait until there's one ILU ready to be picked up.
Truck entries	Single arrivals in each virtual entrance equal to the number of ILUs every minute since the train arrival.

In this scenario, it is important to highlight that, the ILUs are following the rule FIFO (first in-first out) and that ILUs are the items, which lead the activity, as trucks must queue until one ILU is ready to be picked up.

Also, it is assumed that three employees per crane are working in the handling activities which is important in order to carry out the economic analysis in the next section.

Moreover, in order to obtain comparison data, a simulation will be done where the opening hours are increased but keeping the current operational features of the terminal.

9.1.2. Futures scenarios

To simulate future scenarios some hypothesis (Table 9) has been made to reduce the uncertainty that is caused by the lack of knowledge in some variables and the uncertainty that is usually attached to any future prediction.

Table 9. Hypothesis future scenario

Future scenario	
Train entry	Single arrivals following the schedule in Table 7.
Inspection point	Fixed time for each train has been stablished to 15 minutes.
Train split	Half of the freight is handled by each gantry crane.
Gantry cranes	Fixed time for each ILU has been stablished to 2,5 minutes, there is no differentiation among ILUs' types.
Storage	Some of the units are storage no more than 24 hours, (information not available).
Pick up	Trucks wait until there is one ILU ready to be picked up.
Truck entries	Single arrivals in each virtual entrance equal to the number of ILUs every minute since the train arrival.

In the future scenarios, it is important to highlight that the time used to handle the freight is reduce to 2 minutes and 30 seconds as the crane driver reduce the time checking the identification of each ILU as the information is directly sent to the cabin from the gate. Also, as the inspection is made automatically the time is 15 minutes, however, in the model extra time will be included that represents 5% more, as it would represent the error that the system has on average and it would be necessary to spend time to identify manually those ILUs that are not correctly identified by the video gate.

As it happens in the actual scenario, FIFO system is applied the to pick the ILUs and ILUs are the items that lead the process as trucks must wait until they are ready to be picked up.

The two scenarios that are going to be simulated in the future include the video gate implementation, however one is going to take into account the actual demand of trains, with the actual schedule without considering any future demand increasing, and the other one considering that the opening hours increase and more freight is handled due to the time needed to handle each train being reduced and as a consequence the terminal capacity is increased.

10. Time and economic analysis

Once the terminal has been modelled on Planimate some results can be obtained from it and some analysis can be made with them and with the answers to the formulated questions in the section about the freight data.

10.1. Time analysis

To elaborate the time analysis, some scenarios have been modelled in Planimate with some different hypothesis to know how much would be the difference between the actual situation and future situations.

The first scenario, which has been simulated is the actual scenario, taking into account the hypothesis stated in the previous section. As a result, it has been obtained that the time needed to handle every train that arrives to the terminal, from when it arrives until every ILU is dropped off in one truck is 4 hours and 50 minutes including, train position, ILUs inspection, identification, and handling, and train leaving, which represents approximately, taking into account the number of trains handle per week, the total opening hours that are specified in the schedule attached in one of the previous sections.

Second, a future scenario has been simulated where the video gate is working and helping to handle the freight, and as a result the needed time to handle the freight of one train is 3 hours and 40 minutes.

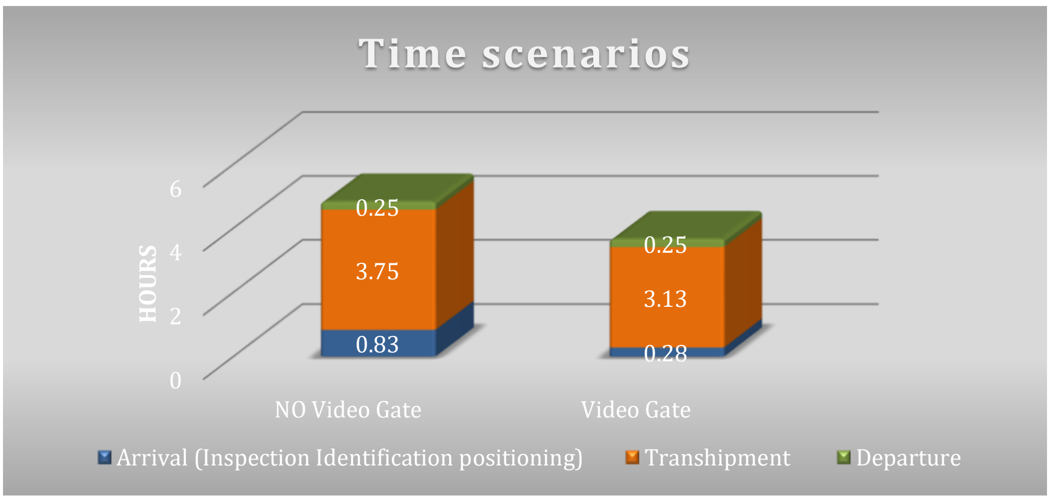


Figure 27. Malmö terminal time scenarios

This means that the difference between using the IVG and not using it is 1 hour and 10 minutes per train, which represents an efficiency increase of 24 % per handled train in the intermodal terminal. Also, that means that the terminal capacity would be increase as more ILUs could be handled.

10.2. Economic analysis

To make the economic analysis it is necessary the previous time analysis stated in the previous section, as it was necessary to know how many work hours were necessary to handle the ILUs that are manged nowadays in the terminal. Moreover, it has been established that six employees are needed to handle the two cranes and to do the related activities, as storage some ILUs, guide trucks or identify unknown ILUs as their work hours are the ones that are going to be directly affected by using IVG in the terminal whereas the administrative work is going to be less or no affected.

Table 10. Data for the Malmö intermodal terminal economic analysis.

Data for economic analysis		
	Without video gate	With video gate
Number of workers	6	6
Hours per train (h)	4.83	3.67
Hours per month (h)	559.29	424.29

To obtain the data presented in Table 10, what it has been made in the case of the hours per train is simulate the time needed to handle each train with Planimate, and to obtain the working hours per month, it has been multiplied this hours by 30 days (one month) and by the number of trains handled per day.

Also, it has been necessary to obtain the main costs of the transhipment, which are basically related, with the employee crane salaries, which has been obtained from Lönestatistik.se, as in the present scenario would be the main cost (Table 11). Moreover, in the future scenarios there is a second cost that must be added, the video gate and its maintenance that would be added to the salaries, which has been obtained from the project FR8RAIL III WP3 Intelligent Video Gate supplier, Hitachi.

Table 11. Main cost of the transhipment operations

Main costs	
Crane driver salary	28.000 €/year
Video gate construction	154.500 €
Video gate maintenance	2.833,33 €/month

In the economic analysis, what is seen is if the video gate investment is worthy in less than two years after its implantation, taking into account how many less hours are needed to handle the freight, which means less salary costs. This result is expressed in Figure 28 attached below where the aggregated monthly cost is represented in both scenarios, with video gate and without it.

In the case with the video gate implantation, the first month has a great cost as it is included the video gate construction, however from this month on, the monthly cost are reduced and consequently in the month twenty the total cost related to the ILUs transhipment is lower in the video gate case than without it.

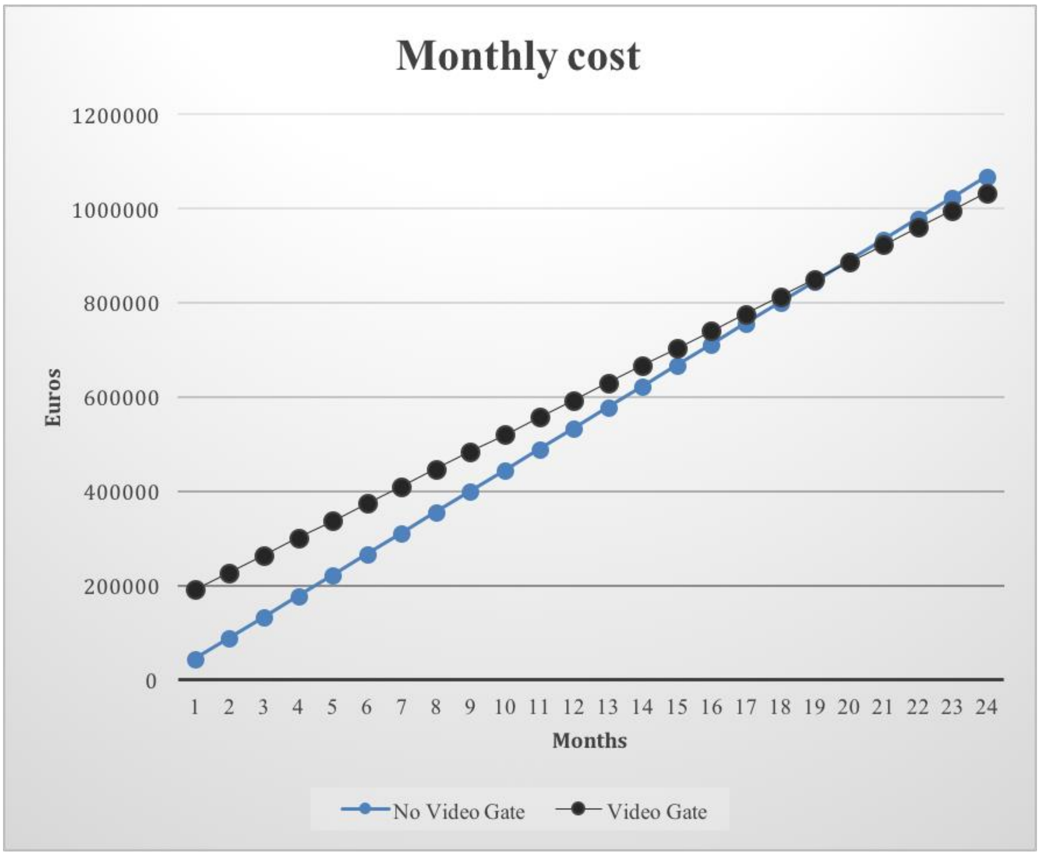


Figure 28. Aggregated monthly cost

With the video gate implementation also, it is possible to handle more trains per day which would mean more profits, as working twenty-four hours per day it would be possible to handle six trains per day whereas without the video gate it would be possible to handle five trains per day. To know how many trains per day would be handle if the full capacity of the terminal is used, it has been assumed that the terminal is working twenty-four hours per day and according to the time needed to handle a train, with and without video gate, it is concluded that the investment, taking into account only the costs reduction and not the benefits increase that would exist due to the handled freight increase, would be worthy before the first year after the video gate implementation (Figure 29).

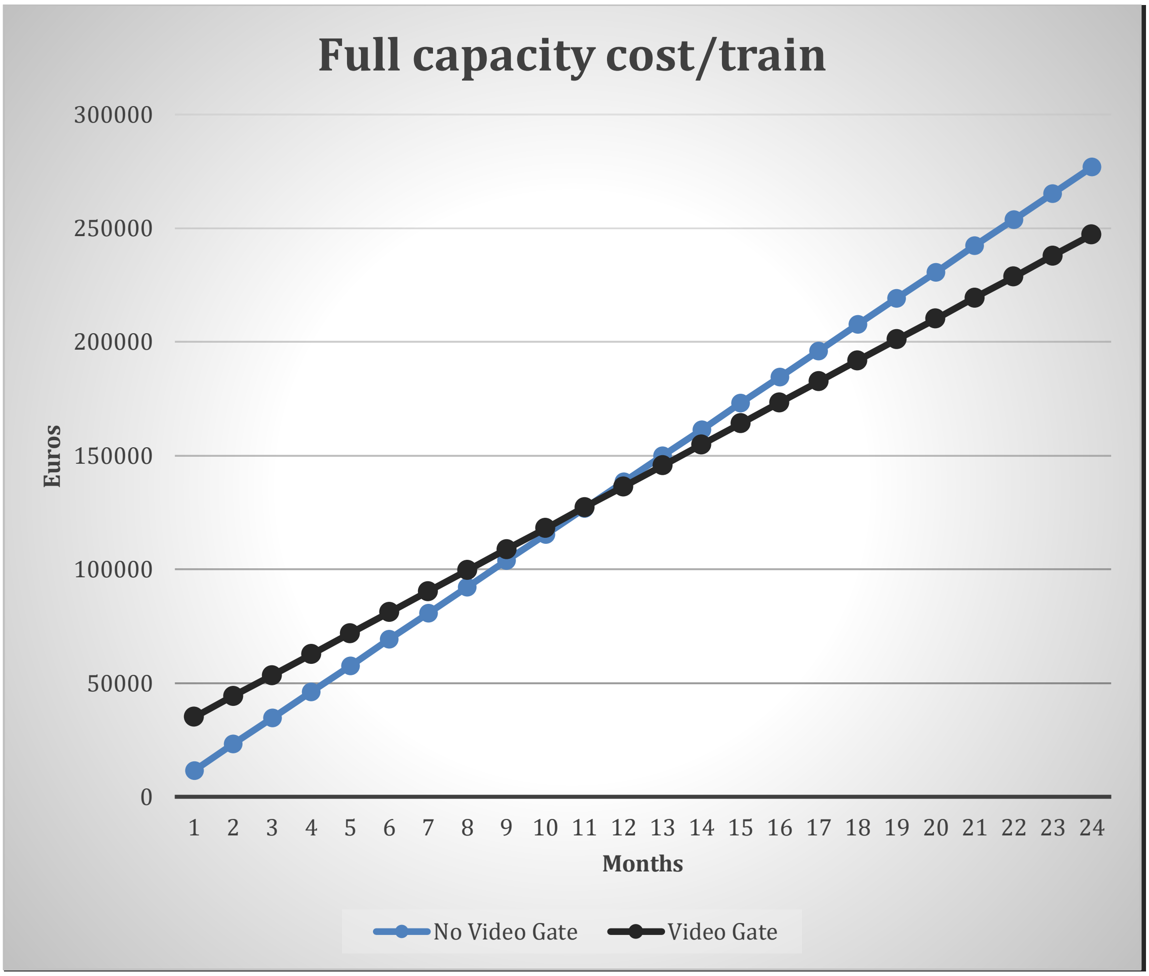


Figure 29. Aggregate monthly cost terminal full capacity

To sum up, as it has been seen in this economic analysis, the video gate investment in term of cost would be worthy in a period of time quite sort in both studied scenarios.

However, it would have to be done more accurate with, the real employee salaries in the Malmö Intermodal Terminal and taking into account the benefits increase in those scenarios where the demand increases.

10.3. Further economic benefits

Added to the cost reductions are other benefits that are related with the IVG installation, that are not as important as the ones mentioned before but that must be taken into account in order to have a better knowledge of its implantation.

First, one of the primary benefits, would be the ones related to the ILUs damages, as it would be a reduction in claims as the IVG would take pictures of every ILU and it would be easier to identify when the damage has happened. That would mean, less payments due to damages responsibility, less administrative work, and less insurance costs as insurance prices are based in events risk probability and uncertainty, and with the IVG the uncertainty is reduced as it is easier to know who is guilty for the ILU damage.

Moreover, as the transhipment time is reduced as the ILU identification from the crane cabin is quicker, the energy cost is lower as the time operating is shorter.

Finally, the administrative cost also would be reduced as the information about every ILU would be easier to obtain, as well as the information related to the damages, and the organization of the pick-up would be faster and easier as the information about all the processes is easier to get access to.

11. Gothenburg Port Terminals

Throughout the last sections, it has been stated how IVG can help reducing costs in an intermodal terminal when the IVG is installed within it, however the IVG can be installed in different points of the railway network as could happen in the Gothenburg port terminal.

In this case, the terminals located in this port allow the transhipment from vessels to truck or trains and vice versa and within the port, there are located between eight and ten facilities owned by different companies. This would mean that the IVG location outside the terminals would serve more than one terminal and consequently the investment to build the gate would be share among the companies which would lead to a lower investment.

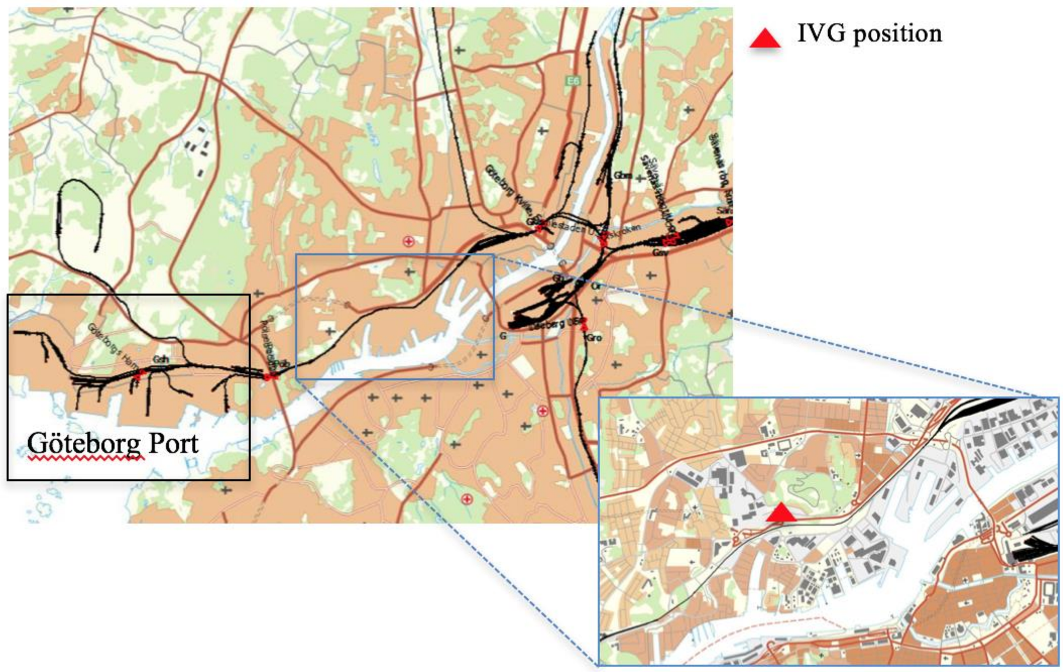


Figure 30. IVG location for the Gothenburg Port Terminal (Anex from Genomförbarhetsstudie om "Videogates med RFID" vid Trafikverkets spår och anläggningar – fallstudie av Göteborgs hamn)

The greater benefit obtained from the IVG in this case would be the same as in the Malmö terminal, the time reduction in the inspection and identification chores, however it would be another important improvement, the freight organization in advance as in this kind of terminals it is more important, as the ILUs placement within the vessels must be made carefully as the freight has to be placed taking into account the fright weight. However, as the IVG is located far away from the terminals, the ILUs damage control is not possible as some damages can be generated in the distance between the IVG and the terminal.

As it is seen in the Figure 30 attached above, in the Gothenburg case the IVG would be located before the terminal entrance which, according to the estimations, would provide information 30 minutes in advance to know which ILUs are going to be handled and their position in the train which would allow to organize the ILUs movements more accurately. Also, the IVG would work with the trains leaving the terminal and the information of its position an identification could be send in advanced to the destination terminals where the ILUs are going to be picked up what would help in these terminals in a similar way as in the port terminals.

In summary, what can be stated from this case, in comparison with the Malmö terminal, is that some of the benefits are shared, mainly, the ones in relation with time savings, although the damage control would be necessary to be carried it out in the terminal and the activities related to it. Furthermore, another advantage in this specific case would be the investment sharing which would reduce individual investment costs even more worthy than in the Malmö case.

12. Comparison with previous studies

This thesis has been an extension of a previous thesis, "*The effects of emerging technologies in rail yards and intermodal terminals"* (Branko Mitrovic, 2019), which made an analysis of the same terminal and that was not focused on the OCR system implementation but also in other technologies that can be applied to improve the terminals automation.

As it has been said previously, some of the data used in to model the terminal were obtained from this thesis, however, different results have been obtained. These differences came from the different hypothesis taken into account. First, there's a difference between the transhipment time as in this thesis it is considered the system reliability which is 95% and consequently 5% of the containers should be identified manually what would consume time. Moreover, in this thesis it has been considered the departure time which is needed to remove the wagons from the terminal and that would be time the cranes are not operating, or the arrival time that would be the same, as this time needed to place the train doesn't vary with an IVG.

Moreover, in the previous thesis it wasn't made an economic analysis, what is useful in order to obtain the system benefits as if the time savings are not translated to economic benefits it is not worthy in the private companies' field as what they mainly demand are improving their benefits and some other advantages are only a plus in performing their activities.

As a result, what can be said is that the previous results in relation with time efficiency where more optimistic as some of the savings were overestimated, however in both studies what is stated is that the IVG would provide an efficiency increase to this terminal. Moreover, although the previous thesis did not extend the study to the economic field, in this thesis what can be seen is that the time efficiency improvement is linked with an economic improvement what at the end is what is looked for by the companies who run these terminals.

Furthermore, what has been seen in this thesis, throughout the Gothenburg Port Terminal study case, is that an IVG alternative location is possible, and from a qualitative perspective, it has been analysed its benefits and differences between both locations, something that wasn’t analysed in the other thesis and it could have been useful to study different project alternatives.

13. Conclusions

Throughout this thesis it has been tried to answer the research questions what meant knowing how the OCR systems are applied to Intelligent Video Gates, if they can provide advantages to intermodal terminal functioning, an important element of the supply chain, which is becoming more important in the current situation, a situation where the reduction of truck transportation is essential in order to reduce greenhouse gases emissions and where the use of these intermodal terminals can have a significant role.

These terminals, as it is known, are becoming essential in order to reduce the freight distance travelled by truck, as the current objectives by some organizations are focused on mainly using trucks in the first and the last kilometres of the freight travel, and as a result improve the processes efficiency carried out within them has become an important task in order to improve the rail transportation and make it more competitive in comparison with truck transportation.

In order to improve this efficiency, it has been shown that the OCR system applied to IVG can help to reduce cost and time in the terminal operations, especially in the transhipment process where this thesis has been focused on. Specifically, what has been stated throughout the Malmö terminal example is that, the implementation of IVG would reduce considerably the time needed in the train inspection and ILUs identification as the actual error of this system makes almost inexistent the manual work that is carried out nowadays in this kind of terminals which means that time used in this process is practically reduced to zero.

In relation with this efficiency improvement, it can be said that in intermodal terminals as the Malmö terminal, this system would produce an improvement in the train transportation competitiveness as it would reduce the time per ILU around thirty-five minutes which added to some other variables of the train transportation, as it is not mandatory to stop at particular intervals and that it can work more hours in a row, which would mean that freight travel times are closer to the freight travel times by truck.

Also, in relation with the time reduction which has been stated is that the terminal capacity increases when the IVG is installed as the trains are handled in shorter periods of time and then, it could be possible to handle more trains per day. This increase of the capacity would mean also greater revenues if this increase of capacity is linked to a demand increase and as a consequence the period of investment amortization would be reduced.

Nevertheless, in intermodal terminals where less trains are handled, what would mean less hours of work and less workers, the time needed to the investment be worthy, would be longer and then it would be necessary a more accurate analysis and it could be possible that the IVG wasn’t worthy.

Furthermore, as it has been stated, there are some other indirect benefits that must be taken into account as the ones obtained relating to the ILUs damages as the insurance payments or the claims procurements, or the ones related to the easier organization.

Finally, in relation with the third research question, what has been stated is that there are current improvements that can be applied in order to increase even more, the efficiency in this kind of terminals, and that it would be important to focus on this, as it would allow to make even more attractive the investment in these systems and would make the investments in terminals, which handle less ILUs, worthy as the cost reduction would be greater.

On the whole, what can be said is that this kind of new technologies, specifically the OCR system, that has been already applied in other fields and that are still suffering some improvements, are going to increase its presence in the intermodal transportation in the future as it has been demonstrate that they increase the efficiency, what is already needed and it is going to be even more needed in a world where the transportation demand is constantly growing.

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