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Intelligent Video Gate – A Conceptual Application of Emerging Technologies in Rail Freight Transports

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Abstract

The emergence of new technologies and their corresponding applications within intermodal and rail freight terminals enable improvements in efficiency in existing business processes, relieving them of manual activities and enabling higher degree of automation and digitalization. To initiate the next logical step to a higher level of automation in terminals and to reduce the lead-time needed for the identification and verification processes of freight trains, the concept “Intelligent Video Gates” (IVG) is introduced within the framework of the H2020 Shift2Rail initiative and FR8HUB project. The project has been bi-sectional, first describing functional and technical requirements and the selection of components and secondly carrying out a technical proof of concept (PoC) and introducing a roll-out and implementation plan (RIP) within a Swedish and German context. This paper presents the main findings from the project, literature review, survey of similar studies and a case study simulating the expected effects of the concept.

Keywords: Intermodal Transports; Rail Freight; Emerging Technologies; Automation; Digitalisation; Shift2Rail

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1. Introduction

Intermodal terminals enable the efficient (cost-effective, fast, predictable) transfer of load units (LU) i.e. containers, swap bodies and semitrailers between different modes of transport. Transshipment of the LUs are carried out between the modes of road, rail and sea. Intermodal transport by rail has taken big steps towards playing an important role in international freight transportation. Moreover, the emergence of new technologies and the corresponding applications within intermodal terminals enable efficiency improvements and optimisation of existing business processes, relieving them of manual activities and enabling higher degree of automation and digitalization. To initiate the next logical step to a higher level of automation in terminals and primarily to reduce the lead-time needed for the identification/verification process of train-sets, a concept named Intelligent Video Gates (IVG) is introduced within the H2020 - Shift2Rail initiative and the project FR8HUB, where the concept's characteristics, opportunities and restrictions have been evaluated.

An operational process at intermodal railway terminals, which is currently still strongly characterized by a high degree of manual work, is the recording of the real-time data of the incoming trains with associated wagons and LUs. This data is compared with the pre-notified data of the railway undertakings (RU) or intermodal train operators. A physical check of outgoing trains before the departure is carried out almost purely manually. According to Shift2Rail evaluations, the manual check and documentation handling of a 740 m long freight train can take around 45 minutes to complete. The aim is to achieve higher automation in terminals and to reduce the lead-time needed for the identification and verification process of train-sets by implementation of Intelligent Video Gates (IVG). The target is to reduce the processing time down to 15 min per train, to increase the terminal capacity/throughput by 15% and to achieve a 75% reduction of complaints and disputes for damages/losses with customers. Both performance indicators depend upon supply chain visibility, based on secure and interoperable exchange of digital information that is generated by IVG scanning or produced by and issued to other stakeholders in the supply chain. (FR8HUB, 2018)

The project has been bi-sectional, the first part describing functional and technical requirements for the IVG as well as the presentation of components and the associated selection process. The second part of the project consists of the technical proof of concept as well an implementation and roll out plan within a Swedish and German context. This paper presents the main findings from the two separate parts of the project as well as a survey of the literature regarding similar conceptual studies.

2. Methodology

The description of functional and technical requirements for the IVG is categorized as structural, logical and technical components. As a technical system, the IVG consists of structural components (gate components/ housing devices, electrical supply, etc.), technical components (image recording, illumination, RFID-reader, sensors, user interfaces) as well as logical components (image processing such as OCR/text recognition, RFID-processing, memory, visualization and analytics, etc.). The main technical components composing the Intelligent Video Gate are:

- Cameras and image processing
- RFID readers and tags
- Illuminators
- Sensors

The selection of components is depending on the real terminal characteristics, such as number of tracks, installation position, environmental conditions, train speed etc. Hence, albeit a technical proof of concept based on a model train has been carried, further work is needed to better test the components in relevant field environment and to highlight unexpected impacts. Thus, the next logical step in the project is a demonstration gate planned in Malmö intermodal terminal.

The analysis of the concept is carried out as a feasibility study based on expected benefits and changes in costs. Conclusions are drawn, where the synthesis is based on the feasibility study and the literature review highlighting the state-of-the-art regarding emerging technologies enabling automation and digitalization in intermodal and rail transport chain, a survey of similar conceptual studies as well as a case study simulating the expected effects of the concept on Malmö intermodal terminal.

3. Literature review

3.1. Emerging Technologies

The growth of automatic identification technologies in recent years has contributed to the implementation of tracking systems in different industrial areas, including transportation industry. In the context of intermodal and rail freight transports, emerging technologies enabling automation and digitalization comprise of technologies such as optical code recognition, RFID and sensors. These emerging technologies have been identified as key enablers for automation and digitalization in intermodal and rail transport chains, creating a basis for secure and efficient information exchange within the entire supply chain.

Cameras and image processing

One of the IVG primary goals is to collect high definition images of wagons and LUs. The purpose of having high definition images is to allow automatic code recognition. The main idea is that the camera should make a picture of each wagon (whether loaded or not), where all technical specifications that are written on wagons and LUs, primarily considering wagon unique number, LU unique number, type of wagons and LUs and dangerous goods placards. When visible, all these can be transformed in digital form where the transformation from image to digital form is performed with Optical Code Recognition (OCR). Another purpose of these cameras is to help the staff in identifying damaged wagons and LUs. Knowing the type of wagon and LU digitally enables automation and digitization opportunities for other processes at rail freight nodes primarily for incoming trains providing updated wagon and LU sequences and regarding processes for cleaning and maintenance services. OCR for wagons and LUs can also be useful for outgoing trains, e.g. when performing the braking test or verify that all parts of the train are connected properly, i.e. out-of-gauge control.
There are two different kinds of cameras that could suit the purpose of the IVG, linear scan and matrix cameras. Linear scan cameras can scan moving objects with a high frequency, while capturing many “slices” of an image. This allows taking picture of each wagon and LU at very high definition. The main problem that occurs with this camera is that they work best when the object is moving and when the speed is known. (Mitrovic, 2019). This situation suits the IVG concept, as for example train is moving when entering the intermodal terminal at constant speed. However, if the train stops at the gate, this could result in bad image processing. Matrix cameras, commonly used in video surveillance could be used in IVG as well. They can record a video and give a panoramic view of the train but could be used for damages detection as well. These kinds of cameras could be used for road gates, i.e. gates at the terminal where trucks pass when entering and exiting the terminal area.

RFID readers and tags

RFID technology can identify vehicles at the Swedish Transport Administration's detector stations and sites as well as at some operators’ and shippers’ own facilities. Installations of RFID readers along the rail network in Europe are increasing; enabling opportunities when wagons are equipped with RFID tags. RFID adds increased reliability to the IVG concept as the technology provides a reliable complement to the camera, which does not achieve the same level of reading capability, especially in unfavourable operational situations such as dirty devices and in difficult winter conditions. The RFID technology is based on the use of radio waves that read and record information stored on transponders. Transponders are called tags. Hence, there are two main components in RFID, the tag and the reader. RFID readers interact with the tags with wireless radio waves, but also communicate with "back-end servers" via the Internet or Bluetooth. RFID readers can be active, passive and battery-supported passives (Meyer-Larsen et al., 2012), (Meyer-Larsen et al., 2015).

Illuminators

The IVG operation should be guaranteed during terminal operating hours, meaning day and night, independently from sunlight presence. This is not a problem for RFID antenna functionality, but becomes prohibitive for camera acquisition, which during night requires artificial illumination with determinate characteristics. Illumination is also an issue in particularly cloudy days and helps improves image quality during various weather conditions, such as heavy rain, fog and snow. An important characteristics of an illuminator is the emission spectrum, which defines the interval of wavelength in which the illuminator emits and the emitted intensity for every wavelength. This allows the best integration among a chosen illuminator and camera, in order to efficiently exploit camera sensitivity range and peaks. Today most of the illumination is provided by Light Emitting Diode (LED) types, which have many advantages over incandescent light sources, including lower energy consumption, longer lifetime, improved physical robustness, smaller size, and faster switching. (FR8HUB, 2018)

Sensors

Sensors as an emerging technology could have several purposes in the IVG concept. For the train detection and consistency, sensors should be positioned before the IVG. Train detection sensors are important in order to send the information to the video gate that train is approaching. These sensors could be used for train speed detection as well. Train consistency sensors are important as they give the information that the train is complete and that there are no wagons missing (accidently decoupled during the trip or similar). Axle counters are usually used for train detection and consistency. Other type of the sensors that could be used as a part of IVG is the sensors that could detect heat, vibrations and lateral forces in bogies. These sensors already exist on the railway and are usually part of so-called *wayside monitoring* (or inspection) equipment. Their main task is not to detect just heat and vibrations, as they can detect many other issues such as angle of bogie attack, tracking position, inter-axle misalignment, tracking error, bogie rotation, lateral shift and instability, etc. Detecting this at the gates could give the information to the terminal staff that there is a problem with the wagon, so that they can react adequately and on time, thus preventing major accidents and damages. There are many different solutions and varieties of purposes for these sensors. Cheap sensor technologies could also be used for better monitoring of movements of wagons and LUs at terminals and yards.

3.2. Survey of similar conceptual studies

There are commercial products similar to the ideas of the IVG on the market, i.e. gates for rail and road intended for automatic detection and verification purposes e.g. [1], [2] and [3]. However, the information around these products are commonly very scarce in particular regarding potential costs and limitations, e.g. component limitations and IT integration issues. Most are also installed at port and maritime terminals where standardized sea containers are handled, as opposed to the variety of LUs handled at an intermodal terminal.

In recent years, development of OCR (optical code recognition) and image processing technologies have enabled development of high-quality images, which can be translated in digital form. This technology could be used in the IVG concept, as it can contribute to collecting data from trucks, rail cars and containers. In 2013, CAMCO Technology presented different technologies for terminal and gate process automation. OCR and image processing technology can read license plates, container ID, ISO code, trailer ID, rail car ID, etc. Furthermore, high quality images could be used for condition check of wagons and trucks as well as recognition of dangerous goods. Advantages of the proposed image processing technology is presented as functional in dynamic environment (drive through), have no speed limitations and fast processing time. [2]

In N. Meyer-Larsen et al. (2015), four different drivers are identified for implementation of RFID technology, such as lower congestion at truck gates, exceedingly time-consuming inspection procedures, unsatisfactory terminal productivity, coordination and information sharing problems. The oceanic container transport industry was first to use RFID technology, where the emphasis was put on improving security and sealing of containers. Beside security advantages, RFID technology could contribute to the IVG concept, by collecting the information from wagons and LUs at their arrival to the intermodal terminal. Moreover, the study of Dotoli et al. (2010) states that the integration of information and communication technologies into the intermodal transport system leads to a more efficient management, in terms of system resources utilization and overall cost index. In addition, the outputs obtained from key performance indicators demonstrate that innovations are able to increase the overall performances of a terminal, enabling an increase in flows as well as a reduction of the duration of various operational phases (Ricci et al., 2016). The study of Zajac et al. (2014) states that “using sophisticated technology, such as full automation of the process can substantially reduce the time of cargo handling, eliminate errors, and increase the level of safety and reliability”.

There are other technologies other than RFID that could contribute to the development of the IVG concept. The study of Schlake et al. (2010) based on lean manufacturing principles, have shown that automated condition monitoring technologies could have an impact on intermodal terminal performance and increase in productivity. Indeed, research have shown that development of wayside condition monitoring technologies corresponds to “eliminating waste” in lean manufacturing principles, which allows automated technology to reduce manual inspections, resulting in more efficient and reliable system.

Wayside condition monitoring technologies that can be incorporated in the IVG concept is based on sensor technology. There are various usages of sensors as described above, including sensors train detection, heat, vibration, lateral forces etc. One interesting application of heat sensors are employed by Canadian pacific where an automated train air brake effectiveness test is carried out, hence reducing valuable operational time for the time consuming and manual task of performing brake tests. This system is also referred to as Technology-Driven Train Inspection (TDTI) and involves the use of strategically located wayside detectors, Hot Box/Hot wheel detectors (HBD/HWD), in order to evaluate the braking performance of the trains by analysing the reported wheel temperatures. Statistical analysis is then used to detect abnormally hot and cold wheel temperature values. (Jamieson et al., 2012). The HBD could complement the components in "detector points" along the rail network, further described in the following chapter and illustrated in figure 1. An alternative approach for facilitating the brake air test could be achieved through automated recognition of wagons types by OCR and RFID that could help to automate the calculations e.g. correct pipe pressure, adding efficiency and safety to current brake test processes.

4. Analysis

The framework for analysis and description of the intelligent video gate concept consists of a feasibility study based on expected benefits and costs. A short description of the technical proof of concept (POC) that has been carried out is presented as well as a case study simulating the expected effects of the concept on Malmö intermodal terminal.

4.1. Expected Benefits

Establishing IVG in intermodal terminals and freight yards can have several positive effects. From the perspective of Terminal Operators (TO) and Yard Managers (YM), the IVG concept would imply an improvement in operational efficiency, mainly due to:

1. Faster *arrival processes* through deviation management and identification of wagons and loading units with higher degree of automation during arrival processes, which will enable:
    a. automatized check-in and documentation handling
    b. handling of dangerous goods
    c. handling of damage claims
    d. automation of other processes through digitalization e.g.; maintenance and cleaning of rolling stock.
2. More efficient and safer *departure processes* through higher degree of automation at departure regarding e.g.:
    a. departure control and braking test
    b. out of gauge control
    c. monitoring and handling of dangerous goods.
3. Improved *internal operations* and interface towards road haulers will be achieved when the sequence of wagons and loading units (LU) and any deviations from pre-notified sequence are known in advance, which enables:
    a. optimisation of transshipment plans / cranes movements at terminals and shunting at yards.
    b. enhanced possibilities for seamless interface towards road haulers as the TO can inform hauliers with better precision, when and where a loading unit is ready for loading and unloading.

From perspective of the railway and road infrastructure managers (IM), the IVG concept would mean an improvements mainly regarding:

4. An improved interface between freight nodes (terminals and rail yards) and the rest of the railway network. More insight into the nodes' capacity and availability would mean an *improved opportunity for traffic management* and utilization of available capacity on the network.
5. Control and monitoring of *dangerous goods,* today operators report to the Swedish Transport Administration when a LU/wagon is loaded with dangerous goods. This reporting is currently inadequate, which means that there is an improvement potential that IVG could contribute to and the IVGs have the ability to play a key role in monitoring hazardous goods.
6. Control and monitoring of *strategic points* in the railway network, e.g. at tunnels where the knowledge of the location of dangerous goods is very important as well as at border crossings. Regarding the latter, IVGs would provide future opportunities for improved monitoring of safety controls of wagons and LUs, primarily with regards to damages and that LUs are properly attached to the wagons e.g. that the semi-trailer's kingpin is

positioned correctly in the wagon (point 2b above i.e. out of gauge control). The IVG could also facilitate the customs process, in terms of handling documentation and identification as well as opportunities of *sealing* LUs.

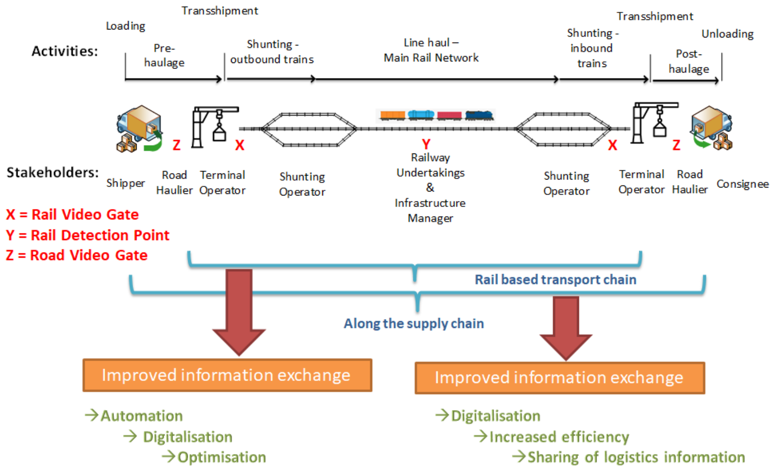

Fig. 1. Potential benefits for intermodal supply chains integrated with IVG and the positioning of gates and detection points.

Figure 1 illustrates the intermodal supply chain considered in this study and the positioning of video gates and detection points. The main position considered is labelled as "X" in the figure and positioned in-between the rail entrance/exit of the intermodal terminal and the shunting operator. These gates would imply enabling improvement of information exchange between terminal-to-terminal/rail undertakings and network managers. For the terminal operator the gates would imply improvement in operational efficiency, which can lead to significant reduction of service times at terminals thus reducing the disturbance sensitivity of the entire transport chain as probability of the terminal constituting a capacity bottleneck is reduced. Moreover, as stated in point 3b above, the interface towards road hauliers will become more seamless, in particular if combined with road video gates, marked as "Z" in figure 1. "Detection points" are in this context defined as installations with only partial functionality of the intelligent video gates, using primarily RFID readers and sensors for detection purposes. OCR can be excluded from these points if classification or other functionalities are not required. The positioning of the detection points is labelled as "Y" in figure 1, located between the shunting operator and the main rail network. The points can also be added to any other yard managers' facilities along the train's route thus contributing to traceability and higher efficiency, as any reconfiguration of the train along the route is known in advance by the terminal operator who could then re-plan their processes.

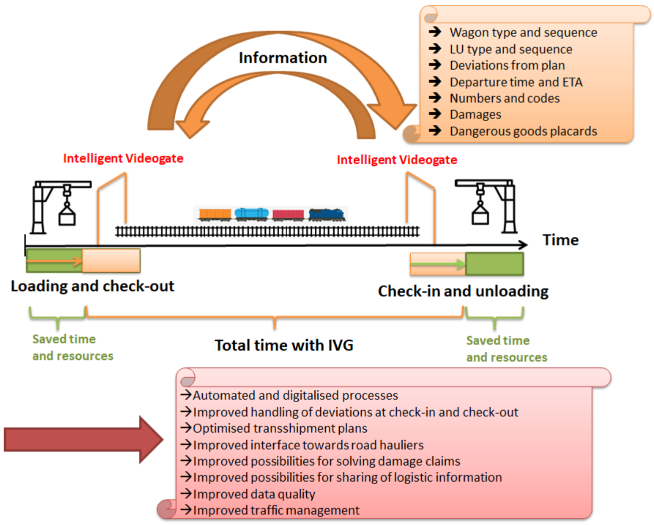

Fig. 2. The main identified benefits of the IVG concept. Data (orange box) that can be identified and benefits (pink box) that it can lead to.

Figure 2 illustrates the main data that can be automatically and digitally retrieved from the IVG and the main operational benefits that this could lead to. It is then essential that the retrieved data is distributed smoothly and safely along the supply chain. An approach that has been studied in the project is defined as “Internet of Logistics” (IoL), which aims at creating a common, distributed and interoperable data exchange infrastructure that overcomes the limitations of traditional supply chain communication systems based on one2one messages (e.g. EDI), and the complexity associated to ad-hoc IT system implementations. Something that current camera gates at freight nodes experience, connecting the gate software’s to terminal operating system (TOS). Current systems also require human interaction, e.g. for damage identification, something that could be potentially be carried out AI and machine leaning could help in improving OCR capabilities.

When studying the benefits and added value that the two technologies, image processing and RFID will imply, they are considered as good complement to each other. The image processing can read codes and placards of dangerous goods without extra equipment on the wagon or LU, unlike other technologies, where RFID requires that the units are pre-installed with tags. The camera can also be used for other purposes than purely detecting and identifying devices, such as damage inspection and departure control. Other operational functions at terminals and yards could also be improved through automatic identification of wagons and LUs. Improved services at terminals would imply an improved and more attractive range of services, which in the long perspective should lead to a higher degree of customer satisfaction.

4.2. Expected Changes in Costs

The costs for the constituent components are in many cases very difficult to pinpoint and monetize, depending on local cost structures and the design of the concept regarding e.g. single or double track construction and the number of cameras. However, the cost components of the system have been identified and their expected changes regarding installation and variable costs are estimated in this section and presented in table 1.

Costs related to the implementation of an IVG are mainly focused to the initial costs for the gate’s physical construction and the IT-system needed. The terminal management system should be prepared for the communication with an IVG including updates in hardware (e.g. exchange server) and software (e.g. data exchange converter) as well as training for staff, software licenses, support costs and potential fees for using a common information-exchange platform. Expected reduction in costs are initially related to less time spent on manual inspections along trains during arrivals, within the terminal/yard and during departure, offering new opportunities for businesses and planning due to increased level of automation and possibilities for optimisation as described in the previous chapter. The business costs for an intermodal rail terminal can be described as fixed installation or variable costs and a summary of expected changes in costs are shown in table 1. The categorization of fixed and variable costs are based on terminal characteristics presented by Wiegmans and Behdani (2018).

IVG-installation costs are related to the administrative preparation, the equipment, the building of the gate, electric installation and connection to IT systems. Administrative costs are related to planning and potential permissions. Costs for IT-system are related to purchasing of new software and hardware, support during the installation and preparations of the local terminal management systems, in order to be able to communicate with the IVG.
The building and setting up of the IVG include costs for components related to the construction, the electrical installation and the data connection, cameras, RFID, illuminators and sensors and costs for workers. Expected changes in fixed costs are mainly related to the fact that IT systems are expected to increase due to licenses and fees for using a common information-exchange platform, or backbone. Other fixed costs are not expected to change such as the costs for cranes and/or reachstackers, land area, fence, lighting poles, rail track(s), office/buildings, rail connection to the network and realisation costs (total infrastructure and pavement). Variable costs expected to change include costs related to administration, employees, energy, insurances, maintenance, and support for IT-systems and management/manager(s). There are no expected changes in variable costs regarding security, interest rate, network fee for rail access and terminal licenses or other taxes.

Table 1. Expected changes in costs for intermodal rail freight terminal connected to IVG implementation.

Costs	**Expected changes**	**Cost Increase**	**Cost Reduction**
Fixed installation costs			
Administration	1. New costs related to administrative preparation: planning and potential permissions	+	

Building and connection of the IVG	2.	New costs due to structural, technical and logical components related to the construction, electrical installation and data connection	+	
	3.	New costs due to the building and installation	+	
Cameras, RFID, illuminators and sensors	4.	New costs for purchasing and installing cameras, RFID-readers and tags, illuminators and sensors	+	
IT systems	5.	New costs for preparations of local terminal management systems, in order to enable communication via IVG. Due to data protection requirements, there is a need of secured interfaces in terminal management systems, especially when handling dangerous cargo.	+	
	6.	New costs for purchasing new hardware and software	+	
	7.	New costs due to support during installation	+	
	8.	Increased costs for new software (licenses, potential fees for using a common information-exchange platform)	+	
Variable costs				
Administration and organizational costs	9.	Reduced costs associated with documentation handling, fax or email messaging		-
	10.	Reduced administrative cost of compliance and cost of dispute resolution with customers, as stakeholders would be able to handle all administrative tasks online instead of filling in paper documents.		-
	11.	Increased costs due to training/reorganization of staff	+	
Energy (mainly electricity and diesel)	12.	Reduced costs due to decreased amounts of energy needed per ton cargo.		-
Employees	13.	Reduced costs due to increased automation		-
	14.	Increased costs due to training/reorganisation of staff are however expected.	+	
Insurance (staff + cargo)	15.	Reduced costs due to decreased insurances due to safer work environment and more surveillance of incoming cargo		-
Maintenance	16.	Increased support costs related for IT-systems, cameras, RFID-readers, illuminators and sensors	+	
Management/manager(s)	17.	Reduced costs due to increased automation		-
	18.	Initially increased costs related to the determination of appropriate staff for the operation of the IVG.	+	

4.3. Technical proof of concept (POC) and the Case study of Malmö Intermodal Terminal

The PoC has been vital for the further project work to achieve higher TRLs in the succeeding project. To test the functionalities of the logical modules, software and algorithms, the approach was to use a train model as the physical input to the system in a laboratory environment. The image processing functionalities developed were also tested with real images obtained on-site with two different cameras, which also provided successful results in the detection and identification of LU and UIC codes, as well as different dangerous cargo signs. However, the functionalities of the IVG system developed could only be tested partially in a real scenario, feeding the system with images previously captured. Therefore, only the image processing module could be tested, limiting the system abilities to the identification of the LU, UIC codes and dangerous cargo signs of real images. Further work is needed to integrate and deploy the complete system in a real scenario. Out of the scope of this proof of concept was the recognition of damages on wagons and LUs, a functionality to be of great value to the different stakeholders of the IVG. This functionality needs to be developed and included in future versions of the IVG. (FR8HUB, 2018)

Within the project, a Rollout & Implementation Plan (RIP) was created bearing in mind potential sites in Sweden and Germany. The main aspects considered in the RIP are categorized as administrative preparation, construction requirements, business impact and stakeholders involved. The potential sites considered in Sweden are Malmö intermodal terminal, Port of Gothenburg, Eskilstuna and Katrineholm intermodal terminal. The most likely site for a pilot seems to be Malmö intermodal terminal, where a full-scale demonstration of the IVG is planned.

Simulation was carried out for terminal operations and data concept made for Malmö Intermodal terminal and presented in detail in the study of Mitrovic (2019). The simulation is performed in the software Planimate, developed by InterDynamics. This software was chosen because its features suits the purpose of the case study well. It enables the creation of highly interactive and animated scenarios for a wide range of dynamic systems, including transportation and logistics networks. Planimate allows the simulation of a process as a set of discrete events, in series or in parallel, by means of hierarchical networks (Baldassarra et al., 2010). Moreover, the model permits to quantify the effects of possible implementations of new technologies or operational measures (Ricci et al., 2016). The simulation software is based on graphical programming where different objects e.g. terminal entrance, transshipment tracks, parking area, are connected along the network. Different items are sent from one object to another. These items could be wagons, LUs, trains, trucks etc.. The simulation model is based on intermodal terminal operations and input data is provided for Malmö Intermodal terminal. The following assumptions are made:

1. Operations that are simulated are for a fully loaded train that *arrives* to the intermodal terminal,
2. Check-in procedures including all inspections are set to 50 minutes
3. Transshipment operations are only indirect (from train to parking), as there was no information regarding the share of direct and indirect transshipments. This could be further elaborated by applying statistical distributions or historical date.
4. Transshipment operations are set to 3 minutes per transshipment
5. Truck check-in procedure is set to 10 minutes, with the inter-arrival time between trucks normally distributed,
6. Simulation is performed for track length of 660 meters, as that is maximum crane serving area in Malmö Intermodal terminal. Assumption is that no split-up shunting activities occur in simulation, even if this happens sometimes in the terminal.

Two scenarios are compared to show how the system changes when certain processes are automated. The first scenario is without IVG considered in terminal operations, while the other scenario is with the IVG included in the terminal operation. Two different times are measured to show how different parts of system react on the IVG implementation. Figure 3a shows the total transit time that LU spend from arriving to the terminal with the train until leaving the terminal with the truck. Results have shown that total transit time with IVG implemented in terminal is shorter than the total transit time without IVG in the system. In fact, results have shown that total transit time with IVG is almost 2 hours shorter than the operation without the IVG. The results could be different if truck arrivals were differently distributed, but in ideal situation this would be the case. It should be noted that the simulation was carried out for a single train arriving at the terminal. Figure 3b shows the results of total transshipment time of LU from train to parking area, where loaded semi-trailers are transhipped from the train to the parking with the cranes. This figure shows also that time savings can be achieved with the IVG implemented. In this case, only the crane operations are considered as an improvement in processes. As crane movement optimisation is not considered here, but rather improvements in regular operations such as inspection and LU validation, time savings are not much higher, but are still considered as valuable.

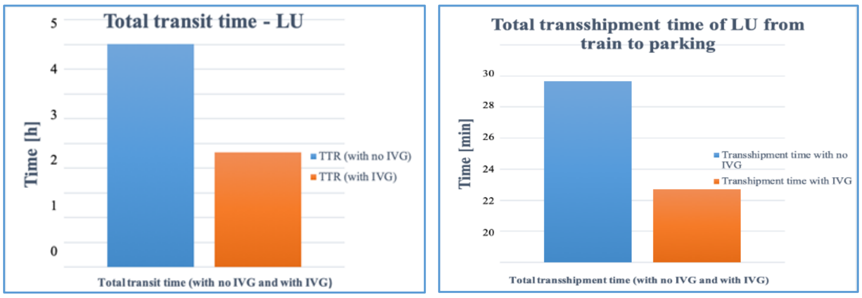

Fig. 3 (a). Total transit time for a LU in the simulation model. (b.) Total transshipment time of LU from train to parking

5. Conslusion

This study has analysed the concept of "Intelligent Video Gate" from a technical and logistical perspective, and it has not been an aim to make any in-depth economic calculations, a part from the generalised changes in costs that have been identified. The concept has been defined and presented as a feasibility study in this paper. As a result of this feasibility study we have found that the two different technologies RFID and OCR image processing from camera pictures complement each other. In principle and for the overseen future all LUs will not have RFID tags while wagons are currently being equipped with RFID tags. Thus, the camera can read codes and placards of dangerous goods without extra equipment on the wagon or LU, unlike other technologies, where RFID requires that the units are pre-installed with tags. An important aspect with image processing is that it can also be used for other purposes than purely detecting and identifying devices, such as damage inspection and departure control. RFID on the other hand is a technology that can identify vehicles at infrastructure managers' detector stations as well as on some operators' and shippers' own facilities. In particular, RFID adds increased reliability to the IVG concept, which does not achieve the same level of reading capability, especially in unfavourable operational situations such as detecting and identifying dirty devices and in difficult winter conditions.

The technical proof of concept (POC) carried out on a model train in the project has proven successful and the results will be transferred to a full-scale demonstration gate is planned in the next coming stages of the project. To test the functionalities of the logical modules, software and algorithms, the approach was to use a train model as the physical input to the system in a laboratory environment. The results of the POC will be transferred to a full-scale demonstration gate that is planned in the next coming stages of the project, most probably in Malmö intermodal terminal. Moreover, the results of the simulation carried out on Malmö intermodal terminal shows that there are considerable time savings to be achieved with the IVG concept implemented. The simulation was based on several assumptions and further studies are required, however the results are good indicators of the potential effects when implementing the IVG concept in the terminal.

To conclude, the IVG enables more efficient and safer arrival and departure processes of trains at intermodal terminals and will help the intermodal operator in time savings, as these procedures are time consuming when done manually. Moreover, having information and documentation in advance will improve and lead to faster operational handling regarding e.g. transshipments, pick-ups and other operational functions. Safety is an essential aspect of the concept, in particular considering information exchange and the handling and monitoring of dangerous goods.

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