WP4: Intelligent Video Gate

D4.1 Description of functional and technical requirements and selection of components
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Project Coordinator: Trafikverket
Röda Vägen 1
SE - 781 89 Borlänge

Leader of this Deliverable: DUSS mbH
Am Kümmerling 24-26
DE – 55294 Bodenheim

Project Website: http://projects.shift2rail.org/s2r_ip5_n.aspx?p=FR8HUB

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Report Contributors

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<thead>
<tr>
<th>Name</th>
<th>Company</th>
<th>Details of Contribution</th>
</tr>
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<tbody>
<tr>
<td>Roald Lengu</td>
<td>Ansaldo</td>
<td>Task leader</td>
</tr>
<tr>
<td>Giuseppe Gotelli</td>
<td>Ansaldo</td>
<td></td>
</tr>
<tr>
<td>Jürgen Karl</td>
<td>DUSS</td>
<td>WP leader, task leader</td>
</tr>
<tr>
<td>Carlo E. Barbi</td>
<td>DUSS</td>
<td></td>
</tr>
<tr>
<td>Claudio Diotallevi</td>
<td>Ericsson</td>
<td></td>
</tr>
<tr>
<td>Leyre Merle Carrera</td>
<td>Indra</td>
<td></td>
</tr>
<tr>
<td>Héctor Garcés Mencía</td>
<td>Indra</td>
<td></td>
</tr>
<tr>
<td>Adrián Irala Briones</td>
<td>Indra</td>
<td></td>
</tr>
<tr>
<td>Behzad Kordnejad</td>
<td>KTH Royal Institute of Technology</td>
<td>Main editor</td>
</tr>
<tr>
<td>Gunnar Ivansson</td>
<td>LearningWell</td>
<td></td>
</tr>
<tr>
<td>Erich Posseger</td>
<td>ÖBB Infra / EUROC</td>
<td></td>
</tr>
<tr>
<td>Martin Aronsson</td>
<td>RISE</td>
<td></td>
</tr>
<tr>
<td>Martin Kjellin</td>
<td>RISE</td>
<td></td>
</tr>
<tr>
<td>Angelika Treiber</td>
<td>TFK – Transport Research Institute</td>
<td></td>
</tr>
<tr>
<td>Mats Åkerfeldt</td>
<td>Trafikverket</td>
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Executive summary

Intermodal terminals enable the efficient (cost-effective, fast, predictable) transfer of cargo load units (containers, swap bodies, semitrailers) and its suitable rail wagons between different modes of transport. Transhipment of the load units is mostly carried out between the modes of road, rail and water. Intermodal transport by railroad has taken big steps towards playing an important role in international freight transportation. In particular for terminals, efficiency improvements are to be achieved by the use of smart technologies in terminals. The achieved integration will optimize existing business processes, relieve them of manual activities and also enable sustainable new business activities.

A work step at intermodal railway terminals, which is still strongly characterized by a lot of manual activities at the moment, is the recording of the real-time data of the incoming trains with associated wagons and load units and the comparison of those with the pre-advised data of the railway undertakings or intermodal train operators. A physical check of outgoing trains before the departure is carried out purely manually. According to Shift2Rail evaluations, the manual check and documentation handling of a 740 m long freight train can take around 45 min to complete.

This project aims to initiate the next logical step to a higher automation of terminals and to reduce the lead time needed for the identification/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 complains 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 that is produced by/issued to other participants of freight transport.

The projects are divided into two parts where this is the first deliverable report. This report summarizes the situation today, description of functional and technical requirements for the IVG and a presentation of components for the IVG together with their selection process.

Today’s intermodal terminals in Europe consist of a number of crane modules. A crane module for intermodal terminals usually has four tracks of more or less 700 m length, a driving and loading lane and a number of storage lanes as well as up to 3 cranes on the runway. The rail tracks for transhipment can be designed with access at only one side or with a connection on both sides. The IVG-system described in this document is installed on the entrance/exit tracks of the terminal. Ideally, all rail movements in the terminal run over exactly one track. This can however not be achieved in all terminals (for example terminals with several routes into the terminal) and several IVG-systems could be needed.

As a technical system, the IVG consists of structural components (gate components for keeping / housing devices, electrical supply, etc.), technical components (image recording, illumination, RFID-reader, user interfaces) as well as logical components (image processing, RFID-processing, memory, visual data evaluation, etc.).

The main technical components composing the Intelligent Video Gate are:

- Cameras
- Illuminators
- RFID antennas and tags
- Scanners
- Wheel sensors
The idea behind the selection process is to provide a formal methodology for selecting a component. The selection of components is depending on the real terminal characteristics, such as number of tracks, installation position, environmental conditions etc. Further work is however needed to better test the components in laboratory and in relevant environment and to highlight unexpected positive or negative characteristics.
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# Abbreviations

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<tr>
<td>ACEP</td>
<td>Approved Continuous Examination Program</td>
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<tr>
<td>ADR</td>
<td>European Agreement Concerning the International Carriage of Dangerous Goods by Road</td>
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<td>BIC</td>
<td>Bureau International des Containers et du Transport Intermodal</td>
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<td>BLU</td>
<td>Betriebsleitsystem für Umschlagbahnhöfe</td>
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<td>CBTC</td>
<td>Communications-based train control</td>
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<tr>
<td>CCD</td>
<td>Charge-coupled device</td>
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<td>CLC</td>
<td>Connected Logistics Chains</td>
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<td>CMOS</td>
<td>Complementary Metal Oxide Semiconductor</td>
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<tr>
<td>COTS</td>
<td>Commercial off-the-shelf</td>
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<td>CSC</td>
<td>Convention for Safe Containers</td>
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<td>DIS</td>
<td>Detecting and Imaging Subsystem</td>
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<td>DMZ</td>
<td>DeMilitarized Zone</td>
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<td>DB</td>
<td>Deutsche Bahn</td>
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<td>DUSS</td>
<td>Deutsche Umschlaggesellschaft Schienen-strasse</td>
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<td>EBA</td>
<td>Eisenbahnbundesamt</td>
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<td>ERTMS</td>
<td>European Rail Traffic Management System</td>
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<td>EN</td>
<td>European Norm</td>
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<td>ERP</td>
<td>Enterprise Resource Planning</td>
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<td>ETCS</td>
<td>European Train Control System</td>
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<td>FIM</td>
<td>Field Information Matching</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
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<tr>
<td>HF</td>
<td>High Frequency</td>
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<tr>
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<td>Human Machine Interface</td>
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<td>IC</td>
<td>Integrated Circuit</td>
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<td>Identification of Intermodal Loading Units</td>
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<td>IMDG</td>
<td>International Maritime Goods</td>
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<td>IoT</td>
<td>Internet of Things</td>
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<td>Innovation Programme</td>
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<td>Intelligent Video Gate</td>
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<td>ISO</td>
<td>International Standard Organisation</td>
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<td>Light Emitting Diode</td>
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<td>LU</td>
<td>Load Unit</td>
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<td>MTF</td>
<td>Modulation Transfer Function</td>
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<td>mm</td>
<td>millimetre</td>
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<tr>
<td>OCR</td>
<td>Optical Character Recognition</td>
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<td>OCC</td>
<td>Operation Control Centre</td>
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<td>QE</td>
<td>Quantum Efficiency</td>
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<td>Quality of Service</td>
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<td>RDF</td>
<td>Resource Description Framework</td>
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<td>RID</td>
<td>Règlement concernant le transport international ferroviaire de marchandises Dangereuses</td>
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RFID  Radio-frequency Identification
RMG  Rail Mounted Gantry crane
RORO  RORO is short for “roll on, roll off”. And refers to vehicles and machinery that are loaded onto large ocean shipping vessels for transport overseas
RTG  Rubber Tyred Gantry crane
RTLS  Real-time Locations System
RU  Railway Undertakings
SCM  Supply Chain Management
SNR  Signal-to-noise ratio
STS  Ship to Shore
TCCS  Train Conformity Check System
TEU  Twenty foot equivalent unit
TIC  Train Identification and Classification
TMT  Technical Management Team
TOS  Terminal operating system
TSI  Technical Specifications for Interoperability issued by the “European Union Agency for Railways”
UHF  Ultra-High Frequency
UIC  Union Internationale des Chemins de fer (International Union of Railways)
UWB  Ultra-wideband
WTMS  Wayside Train Monitoring System
WP  Work Package
1 Introduction

Intermodal transport by railroad has taken big steps towards playing an important role in international freight transportation.

In particular for terminals, efficiency improvements are to be achieved by the use of smart technologies in terminals. The achieved integration will optimize existing business processes, relieve them of manual activities and also enable sustainable new business activities.

For this purpose, this document presents the ingredients to implement intelligent video gates in intermodal rail freight traffic (hereinafter referred to as "IVG") in terminals.

The project is carried out by representatives from the following organizations/companies:

**Deutsche Umschlaggesellschaft Schiene - Straße (DUSS) mbH**, Germany, operates 22 transhipment stations (intermodal terminals) in Germany on behalf of the infrastructure owner DB Netz AG. A total transhipment volume of approximately 2.2 million load units (ISO containers, truck swap bodies and semi-trailers) per year and thereof 8,000 load units per day are handled in these terminals. Between 900 to 1,400 load units per day are handled in larger terminals such as Duisburg-Ruhrort Hafen, Leipzig, Hamburg-Billwerder, Munich-Riem and Cologne Eifeltor. Thus, e.g. the terminals Cologne-Eifeltor and Munich-Riem are the largest terminals operated by DUSS.

**Trafikverket (Swedish Transport Administration)**

Sweden is a long-term planning authority of traffic systems for road and rail transportation, shipping and aviation as well as construction, operation and maintenance of state roads and railways. In the railway sector Trafikverket manages main haul lines and state owned sidings such as marshalling yards and train formation facilities, shunting facilities, freight terminals and storage sidings. The freight terminals, owned by Trafikverket above mentioned, are simple facilities for use of mainly single wagon operation.

Since the deregulation of the past decades, the Swedish market is highly diversified and the former incumbent operator, SJ, was split in a range of state owned companies. The train operation and business was organized in Green Cargo for freight traffic and SJAB for passenger traffic, the maintenance of vehicles was organized in by Euromaint and the terminals and depots went to the real estate company Jernhusen AB. During the following years of the ongoing deregulation some private companies have emerged in the sector.

Today, the main terminal owner in Sweden is constituted by Jernhusen AB and a range of private and municipal owned terminals. Jernhusen owns nine intermodal freight terminals in Sweden. All main operations at their intermodal terminals such as transhipment, shunting and storage are conducted by a range of tendered operators.

Trafikverket's role is to offer connectivity to the state railway system and to judge whether the traffic situation allows more traffic with or without investments on the main line. Another equally important role is to encourage a socioeconomic and environmentally friendly transport system.
Ansaldo STS (Signalling Transportation Solutions)
Ansaldo STS is a leading company operating in the sector of high technology for railway and urban transport. The Company operates in the design, implementation and management of systems and services for signalling and supervision of railway and urban traffic, as well as lead contractor. Ansaldo STS is headquartered in Genoa, Italy and has over 3,951 employees in 28 different countries. The Fifty-one percent of the share capital is held by shareholder Hitachi Rail Italy Investments. Some of the main implemented advanced technologies on major projects are:

- ERTMS/ETCS solutions combined with High Speed Rail, Conventional lines or Heavy Haul technologies for safer and interoperable networks;
- Satellite positioning technology for safer and more accurate rail traffic management;
- Driverless solutions to improve operational efficiency and flexibility and reduce operation and maintenance costs
- CBTC signalling technology to increase performances and reduce headway through a real moving block
- Broad Components portfolio, covering all aspects of signalling and systems solutions (such as Switch Machines, Signals, Level Crossings, Relays, etc.);
- Train Conformity Check System (TCCS) for predictive maintenance and for safety by automatic stopping of defective/dangerous trains.

Within the scope of FR8HUB – Intelligent Video Gate, the Ansaldo STS’s TCCS (Train Conformity Check System) already applied technologies in many railway contexts, are a useful starting point. The same technologies for images acquisition and information digitalization are immediately applicable as first step in the process of managing incoming and outgoing trains from terminals.

INDRA
Indra has a wide experience in offering technological solutions in transportation networks and infrastructure, for both infrastructure managers and transportation operators. Indra offers solutions for the complete management of land and railway transportation, including real-time control systems, management, control and exploitation systems for railways, subways, trams, buses or fleet operators, as well as communications network implementation for transportation infrastructures.

Apart from the expertise in traffic management and railway operation systems, Indra also brings to the project its know-how in the road domain, in particular in the free-flow solutions. Indra has developed an advanced sensor-based system, which is integrated into a gantry and is able to detect, identify and classify vehicles circulating at high speed in the roads. Indra´s solution has been tested and deployed world-wide and it counts with significant references in Europe, America and Asia. The technologies and equipment used for the detection (cameras, laser, Optical Character recognition, RFID antennas) are also applicable to the video gate proposed in this project, as well as the needed intelligence to process and correlate all the information collected for each of the transit detected (which in this case would be each container and wagon, instead of each car).

EUROC
The railway undertakings SBB and ÖBB are part of the consortium EUROC which is member of the Shift2Rail Joint Undertaking and has a minor advising contribution in IP5. ÖBB and SBB are both in the role of being full suppliers of railway and terminal infrastructure as well as rail freight transportation.
ERICSSON

Ericsson is one of the leading providers of Information and Communication Technology (ICT) to service providers, with about 40% of the world’s mobile traffic carried through our networks across ca. 180 countries worldwide.

Ericsson contribution to IVG aims to identify, describe and evaluate software technologies and network systems that support the key performance indicators of the FR8HUB – IVG initiative.
2 Starting point, joint vision and objectives of the project

2.1 Starting point

Intermodal terminals enable the efficient (cost-effective, fast, predictable) transfer of cargo load units (containers, swap bodies, semitrailers) and its suitable rail wagons between different modes of transport. Transhipment of the load units is mostly carried out between the modes of road, rail and water. However, rail-rail transhipments are particularly important for existing and future terminals with growing turntable functions.

A work step, which is still strongly characterized by a lot of manual activities at the moment, is the recording of the real-time data of the incoming trains with associated wagons and load units and the comparison of those with the pre-advised data of the railway undertakings (RU) or intermodal train operators. A physical check of outgoing trains before the departure is carried out purely manually.

The project is based on the actual fact that since years wagons as well as the load units (as a shell to protect the goods inside) neither have become intelligent nor have been fitted with smart communicative on-board systems that help for the identification in a terminal. More than estimated 200,000 wagons and more than estimated 10 million intermodal load units all over Europe would need to be fitted out with additional technologies on board which is not realistic under current market conditions in a short time. However, there are sustainable minimum standards within Europe to identify UIC-registered wagons and load units by digits and characters written on. The latest change in identification rules for intermodal load units were implemented with the European standard EN 13044 in July 2014, which ensures that the growing number of swap bodies and semitrailers have identification numbers and characters similar to the containers identification codes. It took more than three years to get market players and fleet holders ready to change to the new identification standard, and even today still not all fleets have been changed completely. However, the market especially freight forwarders and fleet owners have taken good move to realize their responsibility to enhance harmonization of standards and common optimization to improve competitiveness in the rail freight sector, but it could be done more.

Some of the biggest wagon providers in Europe have also taken steps to bring more flexibility in wagon utilization and transport monitoring by using smart technologies. Therefore they have started to fit wagons with RFID or GPS tags to be able to track and trace movements everywhere. Examples exist in Sweden, where Trafikverket is implementing those systems, 340 RFID points are installed so far. Deutsche Bahn has just decided to join the RFID technology. The RFID approach for a terminal application will be also taken into account in this IVG project.

The intelligent video gate described in this project is intended to be a composed subsystem in technical cooperation with the operating control system of a terminal and will take into account optical recognition as well as RFID recognition where suitable.

In the sense of this report document, the project shall lead to the detailed specification of a video gate and the definition of necessary equipment in order to meet the required technical requirements for the use of the IVG.

2.2 Joint vision

The future perspective of freight transport and terminal operations is very tightly connected with the effective use of relevant data. The structure of data and its flow is very dependent on the use cases. To fulfil a transport by train on the railway network a certain amount and structure of data is needed,
as well as the maintenance of rolling stocks in a specialized facility and the operation of an intermodal terminal.

Most common characteristic of all fields of transport is the knowledge of what is currently taking place at a defined site or in the transport chain. Intermodal terminals – mostly operated as separated business entities with defined functions and responsibilities - work with a lot of information on wagons and load units, marshalling yards especially with wagons and its conditions, rail network operators with management information about trains. RUs and intermodal train operators have similar or additional requirements to data and the constant flow of information.

The joint vision of all the involved partners in this project is to have a general possibility and technological support

- to identify, to track and to trace incoming and outgoing real-time information on wagons and load units for a defined site / area of responsibility and
- to ensure safety, security and quality for the special purpose and to keep best service of operation.

This knowledge needs at least the identification of rolling stock and/or freight load, which runs in and out the area.

The IVG can contribute to real-time operation in existing as well as new constructed terminals because it can make the operations visible. The IVG delivers the relevant recognized data to enable better performance of service, improves documentation, handling and reduces manual work. The IVG can lead to a higher degree of automation in a terminal.

![Figure 2-1. Intelligent video gate – contribution to IP5 vision](image)
The IVG project goal is to increase the level of automation of rail logistics terminals, and to reduce
the lead time needed for the identification/verification process of train-sets, that is now carried out
at terminal gates, and that is mainly based on paper documents and manual operations. According to
Shift2Rail evaluations, the manual check and documentation handling of a 740 m long freight train
that corresponds to the new standard length of freight train-sets in Europe, can take around 45 mins
to complete. IVG target is to reduce processing time down to 15 min per train so to make Intermodal
Logistic Units (ILU see picture below) quickly available to already waiting trucks for loading and to
increase speed of container handling and terminal throughput. Overall the target is to increase 1)
terminal capacity/throughput by 15% and 2) 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 that is produced by/issued to other participants of freight transport. Participants to
information-Exchange include origin/destination rail terminals, port sea terminals that manage Ro-Ro
(short for Roll-on Roll-off in Cargo Shipping) or Container Shipping, rail transport operators, rail
infrastructure operators, trucking companies that serve the terminal for last-mile delivery, freight
forwarders and their end-customer, who are keen to achieve visibility and that need proper access to
dispute information.

Machine vision-based applications, which will be implemented by IVG, are able to capture container
codes (e.g. ISO 6346), UIC wagon numbers or goods classification codes, and automatically detect
damages or integrity issues. Therefore, video analytics will produce a considerable amount of digital
information and make it available to administration procedures and container handling operations at
the terminal. To fully leverage this rich amount of digital data, a common information-exchange
platform, or backbone, is needed. This infrastructure enables acquisition and matching of logistic
data that is associated to the train and intermodal containers, and that is produced by Freight
Forwarders, Train Operators or other Rail terminals.
The combination of on-site data capture, performed by IVG, in association with a Logistic Data Interchange backbone, has the potential to:

- Improve efficiency of terminal operations, by reducing the need for paper handling, fax or email messaging. Information should not need to be re-entered into computer systems and built-in logic checks should support getting input right the first time. Transport players could introduce their information only once, and the data could then be made automatically available to all stakeholders that they choose as business partners;
- Reduce 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.
- Allow the optimized scheduling of inbound Trucks, as well as the delivery and pick-up of intermodal containers, thanks to increased visibility of container/train information to third parties.

### 2.2.1.1 Situation of today and long-term vision in Sweden

The 10 largest intermodal terminals in Sweden 2013, as well as the number of handled TEUs at the terminals are shown in the table below.

<table>
<thead>
<tr>
<th>Terminal</th>
<th>TEU (2017)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nässjö intermodal terminal</td>
<td>90 000</td>
</tr>
<tr>
<td>Port of Gävle - Granudden</td>
<td>80 000</td>
</tr>
<tr>
<td>Gothenburg intermodal terminal</td>
<td>80 000*</td>
</tr>
<tr>
<td>Eskilstuna intermodal terminal</td>
<td>75 000</td>
</tr>
<tr>
<td>Port of Helsingborg</td>
<td>54 000</td>
</tr>
<tr>
<td>Årsta intermodal terminal</td>
<td>48 000**</td>
</tr>
<tr>
<td>Vaggeryd intermodal terminal</td>
<td>44 000</td>
</tr>
<tr>
<td>Logent Hallsberg intermodal terminal</td>
<td>40 000</td>
</tr>
<tr>
<td>Sundsvalls intermodal terminal</td>
<td>30 500</td>
</tr>
<tr>
<td>Pampus containerterminal</td>
<td>20 000**</td>
</tr>
</tbody>
</table>

* Opened in December 2017, forecast for 2018
** Data from 2013

Telephone interviews with some of the operators of these terminals have been conducted to map the situation of today at Swedish intermodal terminals and their long-term vision.

Regarding the video gates - in Sweden, most terminals need to have two video gates for arriving and departing trains, but for some terminals, they only need one video gate since arriving and departing trains can pass through the same gate. Some examples over terminal design are shown in Figure 2-3 – Figure 2-4.
Deliverable 4.1

Eskilstuna intermodal terminal
Claes Sörman, technical manager, Eskilstuna combi terminal, interview January 10th 2018

Eskilstuna intermodal terminal has four full-length tracks (750 m) for transhipment. The terminal is operated by Eskilstuna Logistik & Etablering AB, which is a municipal-owned company. The terminal has a capacity of 300,000 TEU/year and has a terminal area of 83,000 square meters. The terminal is completely electrified.

Each week, a total of 10 trains arrive to Eskilstuna intermodal terminal. In total, the terminal handles 75,000 TEU per year. The terminal handles both trailers and containers. Two reach stackers are used for handling the load units. The terminal is open Monday to Friday 05.30 - 21.00 and is open on weekends if required (if a train arrives).

Today the terminal has an automated gate for entry and exit by road. The gate photographs and records the entry and exit of each truck and container/trailer. For load units arriving or leaving the terminal on train only an ocular inspection is made. The automated gate reads the vehicle registration plate. Only pre-announced vehicles may enter the terminal. The terminal operator sees currently no need for an automated gate for incoming and departing trains.
Gothenburg port intermodal terminal

Patrik Theander, site manager Gothenburg port intermodal terminal, interview January 15th 2018

“Real Rail Sweden AB” is operating the new intermodal terminal in Gothenburg port that was opened in December 2017. Real Rail Sweden AB is a freight rail operator that is part of the Sandahl Group. Every week, 6.5 trains arrive to Gothenburg port terminal. The forecast for 2018 is that the terminal will handle 80,000 TEU. The terminal receives all types of intermodal load units. The load units are handled with reach stacker. The terminal has 7 tracks to handle the trains. The opening hours are 06-20 Monday to Friday. Today, the carriers are not photographed or filmed, but the terminal operator can see benefits with this in the future.

Vaggeryd's intermodal terminal

Henning Berggren, salesman PGF Vaggeryd, interview January 9th 2018

Vaggeryd's intermodal terminal is owned by Vaggeryds municipality and is operated by PGF Terminal AB. PGF Rail operates a port shuttle between Gothenburg port and Vaggeryd with a capacity of up to 88 TEU per train. The train arrives five days a week and the terminal only handles maritime containers.

Today the terminal handles 40,000 TEU per year. About 95 % of load units are 45 ft containers. The load units are handled with reach stackers. The terminal currently uses one track for transhipment, but they have 2 tracks of 700 m and a 650 m track that can be used for transhipment. They also have two tracks of 1,000 m.

The terminal is open 05 - 17 Monday to Friday. The terminal operator has been planning to install automated gates for several years, but has not yet done so. Today no documentation or photographing of load units is made when they enter or leave the terminal. One reason is that the terminal operator doesn’t have any problems with complaints about damage to the containers.

Today, RFID chips are not used on the wagons, but the terminal operator is interested in this, mainly to get to know the wagon sequence when the train enters the terminal. The terminal operator is on the other hand about to implement GPS positioning system inside the terminal area by all containers getting a GPS position when the reach stacker puts the load unit down. When the reach stacker puts down a load unit, the reach stacker automatically register the GPS position of where the load unit is.
By this system, no load unit can be placed in the wrong place or be lost. The GPS positioning system was launched in the beginning of 2018.

Today the train is loaded with 88 TEU (both loaded and empty containers) at the terminal in Gothenburg port. Information about containers with cargo are added to the terminal system, whereas the information about empty containers is obtained during the night and have to be added to the system by the terminal workers at Vaggeryd terminal in the morning. The train departs from Gothenburg harbour at 21 and arrives at Vaggeryd approx. 05.30.

**Årsta Intermodal Terminal**

As Stockholm Årsta Intermodal Terminal is located only six kilometres south of Stockholm city centre, it can be regarded as a gate terminal into the city for northbound trains and for city distribution in Stockholm. The owner of the intermodal terminal is Jernhusen - a Swedish state-owned company that owns, develops and manages properties and terminals along the Swedish railway system. As of January 1st, 2017, Väte Trafik is the main terminal operator; previously they have only been providing shunting services for the terminal. As the company still provides the shunting services for the terminal, they ought to have a more advantageous business model as a terminal operator than their predecessors. The main rail operator that currently uses the terminal is Green Cargo.

On weekdays, about three to four trains arrive daily. One train arrives during the night at 01:30, and is then reloaded rather quickly and departures again at 04:00 a.m. i.e. prior to the opening of the other activities at the terminal at 05:00 a.m. During this time, certain functions of the terminal i.e. gate entrance, transhipment and shunting in, are opened only for handling that specific train. Later in the morning another two trains arrive which are handled at the terminal throughout the day. Since it is very costly to operate the terminal on weekends due to the high costs of labour, the terminal is not open during weekends.

In 2014 the terminal was modernized as Jernhusen invested in two cross-dock buildings and two rail mounted gantry cranes, accompanied with a small yard for storage of load units and parking of trucks. There are around 100 parking lots for semi-trailers along the tracks. The main reason for the renovation was to make the terminal more modern and efficient so that more goods could be handled in shorter amount of time (Jernhusen, 2015).

The intermodal terminal mostly handles semi-trailers, about 80% of all incoming units, and only a small number of containers and tanks, about 20% of all incoming units. The terminal is relatively small compared to other terminals that mainly handle containerised freight. Due to this fact and the fact that there is no stacking equipment available such as straddle carriers for stacking multiple containers on top of each other, the terminal cannot handle any large amounts of freight that has to be stored in the terminal area for a longer period of time. The containers can be stacked on one level i.e. two units vertically.

The facility consists of four tracks that are 520-540 meters long. Hence a Swedish full length intermodal train of approximately 630 meters cannot be handled on one track but has to be to split up into approximately 13 and 5 twin wagons on two tracks. Furthermore, as European cross-border trains often exceed 700 meters, the terminal cannot handle them easily hence imports are impeded. The main reason behind the short track lengths is that the IM Trafikverket could not make more land available in the surroundings of the terminal area when Jernhusen modernized the terminal area in 2014.

Hence today there is an overcapacity regarding the number of arriving trains that the terminals serve on a daily basis with respect to the available transhipment and labour capabilities, implying that the
operational procedures in the terminal are stable and function well however with a low resource utilization. According to the terminal operator, more than 90% of the delayed trains out from the terminal are caused by the rail operator; either due to missing engine driver or due to missing train assignment.

Today the terminal operator uses the IT-system Hogia Terminal Operating System (TOS) that is implemented at all of Jernhusen’s intermodal terminals. The system has integrated several previous systems, thereby intending to create an IT standard for Swedish intermodal traffic. The main functions of the TOS are the following:

- Planning and allocating
- Gate solutions
- Booking/Services
- Loading/Unloading
- Web applications
- Invoicing
- Inspection/damage handling

The system is used also in order to gather information about the shippers, load units and cargo characteristics etc.

Figure 2-5. Screen shot from Jernhusen’s terminal operating system - Hogia Terminal Operating System.

The intermodal terminal in Årsta has gates with cameras installed that take pictures of the load units as they arrive or leave the terminal, both by train and by truck. The pictures and videos are mainly used for damage claim situations and the information from them is retrieved manually.
Figure 2-6. Video gates for trains at Årsta intermodal terminal

Figure 2-7. Video gates for trucks at Årsta intermodal terminal

Figure 2-8. Layout of Årsta intermodal terminal and the positioning of the video gates.
The Swedish Transport Administration has also installed RFID readers at the points where the cameras are installed. This in order to get automatic vehicle identification of traffic in and out of the terminal based on the RFID readings.

The video gates are currently not connected to the terminal operating system (Hogia TOS) but to the software Visy as illustrated by Figure 2-9.

Figure 2-9. User frontend to show image results from the Visy-Gate
Summary – situation today and long-term vision in Sweden

The terminals in Sweden are usually only open Monday – Friday during the day.

Video gates for truck access exist in some terminals in Sweden. These gates photograph and record the entry and exit of each truck and load unit. The gates also read the vehicle registration plate. Some terminals do also have video gates for arriving and departing trains. The pictures are mainly used for damage claims and the information from the gates has to be collected manually.

Some terminal operators are interested in automated gates, mainly to handle damage claims, for both arriving and departing trucks and trains.

2.2.1.2 Situation of today and long-term vision in Germany

The 10 largest intermodal DB-terminals in Germany 2017 operated by DUSS, as well as the number of handled load units at the terminals are shown in the table below.

<table>
<thead>
<tr>
<th>Terminal</th>
<th>Load units (2017)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Munich-Riem</td>
<td>315 000</td>
</tr>
<tr>
<td>Cologne Eifeltor</td>
<td>305 000</td>
</tr>
<tr>
<td>Hamburg Billwerder</td>
<td>265 000</td>
</tr>
<tr>
<td>Duisburg Ruhort Hafen</td>
<td>200 000</td>
</tr>
<tr>
<td>Regensburg</td>
<td>170 000</td>
</tr>
<tr>
<td>Kornwestheim</td>
<td>135 000</td>
</tr>
<tr>
<td>Basel / Weil am Rhein</td>
<td>100 000</td>
</tr>
<tr>
<td>Ulm</td>
<td>100 000</td>
</tr>
<tr>
<td>Leipzig</td>
<td>95 000</td>
</tr>
<tr>
<td>Frankfurt</td>
<td>65 000</td>
</tr>
</tbody>
</table>

Video gates for truck access exist in Munich, Hamburg, Cologne and Duisburg mainly just to take images of passing vehicles. The images can be used at a rather low level to document incoming trucks and their load units. They are all stand-alone solutions to serve the basic local needs of the terminals. With a sequence of more than 500 trucks per day especially the large terminals need to invest in more sophisticated technology to connect real data with orders to the terminal operating system (in Germany for DUSS-Terminals it is BLU).

The video gate in Hamburg-Billwerder is combined with a local driver’s card that allows access to the terminal with an order-related dedicated truck number plate. Biometric scan function (hand scan) was prepared to allow security tests for registered drivers. But this function is not used because of significant driver fluctuation, technical aspects and high administrative requirements for personal data protection. After the manual check-in-procedure the truck driver receives the driver’s card with its order code, has to put the card on a reader to pass through the video gate. In order with the history of the terminal operation system the time stamp of the video image can be searched and found in the image archive. There is no other data connection of captured load units to the terminal operation system yet. The system is used only for damage research and documentation of placard conditions for dangerous cargo on trucks.
The **video system in Munich** monitors incoming and outgoing trucks as a recording surveillance camera. It is mainly used to support operations at the public road entrance of the terminal and for documentation. Search functions are reduced to replay and save images according to investigated time stamps of the order history from the terminal operation system.

The **video gate in Duisburg** is located at the runway entrance to document incoming trucks and their load units. Due to a lot of damage claims in the past it supports the manual check-in procedure in a long-term archive comparable to the solution in Hamburg. The check-in-procedure for load units is still carried out manually.

The **terminal Cologne** has been fitted with a more developed truck video gate in 2016/2017. It was inaugurated after longer repair, test and calibration phase in May 2018. It is located at the entrance of road to the terminal check-in area. Meanwhile the gate delivers vertically stitched images, number plates of the trucks and chassis/trailers by OCR-recognition as well as load unit numbers (BIC-Code/ILU-Code) and dangerous cargo information for supporting the check-in process. On May 2018, after an initial learning phase, the accuracy of the OCR-recognition is about 96 % of all cases. It allows all modes of operation day and night. The speed of the passing truck is limited to 20 km/h, but it can also vary down to 0 km/h due to traffic jam at the entrance area. Due to a truck accident with the video gate in the past a complete re-implementation was necessary and reflects that video gates also need functional collision protectors.

![Figure 2-10. Road gate Cologne Eifeltor and result of high resolution image](image-url)
The trains that arrive in the DUSS-terminals are getting checked manually and mainly with printed lists from the terminal order management system BLU. Additional data and conditions of load units that have not been transmitted via electronic data interface, need to be collected and recorded also by paper.

Damages and other quality claims as well as recorded incidents can vary from year to year due to different operational effects on highly frequented lines. On average about 12% of the total transhipment volume leads to the documentation of irregularities of load units, most of them on demand of the truck drivers when they take over the load unit and want to leave the terminal. From DUSS experience the customers/carriers of maritime containers show a higher level of acceptance for small damages and bumps than for continental freight units (such as intermodal trailers, swap bodies and tanks).

The cost of compensation very much depend on the ability of DUSS (but also other terminal operators in general) to reduce handling mistakes, but also immediately proof, report and confirm already existing damages or poor load unit conditions at their own interest and upon customer request. In Cologne Eifeltor alone - with a high frequency of south and south eastern Europe traffic - more than 1500 – 1800 records of irregularities and damages per year (up to 10 per day) are documented manually when truck drivers collect load units from the terminal. Not counted is the number of repeating old damages that show up and are investigated from time to time. Not all of the damage request, but an increasing number in the past, resulted in serious or attempted compensation requests. However this absolute figure shows the potential amount of documentation, investigation and the need to take measures against potentially attempted claims with the real inbound documentation when the train arrived. Since the road gate has started to work, the number of damage requests and claim attempts has decreased in Cologne significantly. If the process of inbound check is carried out without optimal technical view on the objects the cost of compensation could increase significantly again. To solve this problem video gates on the railway entrance are highly appreciated.
In the long-term vision of DUSS all these inbound and outbound documentations are no longer carried out manually. They are carried out with a sustainable higher level of automation. The IVG will support sufficient search and archive functions to reduce inefficient work for local staff. Wagons and load units can be identified automatically and processed. DUSS wants to provide excellent proof of “quality as it is” at the point of access and exit to the terminal. Disputes with customers and supervisor authorities on terminal processes will become more transparent and objective.

All check-procedures concentrate on a lot of detailed questions that are related mainly to the following use cases:

1. identification of the objects (Which load unit on which vehicle enters or leaves the area?)
2. relevant quality and legal aspects (Does the object has the appropriate permission, numbers, signs, plates etc. for allowed transhipment?)
3. images as far as possible (What is the visual status of the object?)
4. automatic data procedure (How can relevant data be digitalized, easily handled and processed?)
5. automatic data archive. (Where and how can relevant object processes be archived?)

Intermediate steps towards smarter processes and automation

In order to reduce paper registration of incoming load units and trucks DUSS has started in September 2017 the development of a tablet based application (DUSS-check-in-app) with a development partner. The app supports the formal check-in procedure for incoming trucks and collects repeating fix data and variable data of load units in digital format and report. Fix or at least long-lasting data, such as ILU-/BIC-Code, size type code, length, height and profile information on codification signs, CSC-safety plates, etc. which need to be proofed in context with legal reasons and liability before transhipment and transport on rail are stored in a central load unit database of the company, as there is no other public register available for technical data of load units.

It is also possible to integrate damage pictures by using the app-triggered photo function of the tablet. Fix and variable data are still necessary to check to fulfil the numerous legal requirements and duties especially for the transhipment of dangerous cargo according to RID/ADR. The load unit database delivers now already known data on loads unit to reduce repeating manual work. The structure of the central database allows all connected DUSS-Terminals to feed captured data and to autofill necessary data on request of the load unit identifier (ILU-/BIC-code).

Between September 2017 and May 2018 more than 23’500 individual load units of different types (trailers, containers, tanks, swap bodies) have been saved in the database which daily grows, improves and speeds up check-in procedures in 11 small and medium-sized DUSS-Terminals. The quality of all check-in protocols on the road side has improved since the introduction of the check-in-app, especially for dangerous cargo and errors in data processing have been reduced to almost zero. It is planned to integrate the load unit database also into the larger DUSS-Terminals and to connect road and rail video gates with the database to reduce complexity of requirements for IVGs at DUSS terminals and IVG costs. It is expected to have up to 800’000 known load units in the DUSS-database within the next 3 years. The check-in-app would be also very useful in terminals without video gate systems, lower level of utilization and suboptimal cost-benefit-ratio for advanced technology investments.
Application areas

Figure 2-12– DUSS-Check-in-App for paper reduction in check-in processes with user web front end and better dangerous cargo documentation

Situation and vision of ÖBB

The IVG project has been on ÖBB’s priority agenda for several reasons, not at least because ÖBB Infra opened a new intermodal terminal in Vienna South in 2017 (capacity 200,000 load units) and will put the conversion in Wolfurt / Vorarlberg (190,000 load units) into operation again in October 2018. At both locations, the installation of a video gate is already planned both on the road and on the rail side, both structurally and in terms of process flow. Also ÖBB’s third large location in Wels (capacity 235,000 load units) should be equipped accordingly.
From ÖBB’s perspective the IVG has to interact with the local terminal management system (KLV 2000) as well, so accompanying process analysis is needed to create a roadmap for the further development of the system which, among many other requirements, also includes these two sides (road / rail) of the terminal.

2.2.2 Areas of applications and target groups

The IVG needs to be used by experienced personnel in terminals. Depending on the business model and data protection requirements decisions should be made, who would invest into the IVG.

Roles in the sense of use-case modelling can be:

- “Terminal Dispatcher”
- “Load Unit Checker”
- “Wagon Dispatcher”

The IVG needs to be built and connected by experienced service providers in terminals.

Roles in the sense of obvious parties involved:

- “telecommunications companies” (infrastructure) and telecommunications provider
- “electricity provider”

The connection possibilities for any kind of IVG-hard-/software must be completed before the electrical inauguration of the IVG and steady power supply for operation needs to be guaranteed.
Failure of power supply could result in delayed performance of the terminal, return to complete manual check procedures and claims caused by insufficient performance

- "Service provider for terminal management system” for providing software interface from and to the IVG

The terminal management system should be prepared for the communication with an IVG. Due to the fact, that various terminal management systems are available in the market, secured interfaces need to be taken into account. Especially when handling dangerous cargo those information about the hazard need to be protected against “data sniffers”.

- “Terminal Operator” for organizational preparation of use

The operator of the terminal has to determine appropriate staff for the operation of the user specific control components of the IVG. Any changes in process sequences by integration of the IVG and its data results in the terminal management system and in the physical operation must be prepared.
3 Business framework

The top-down developed process framework creates a process view on the individual performance in the field of terminals. The use of the IVG is integrated into these processes.

3.1 Processes at the terminals today

The main business processes of the terminals are presented as processes. The IVG-system supports these general processes at several points. From the user experiences of different terminal operators seen in chapter 2 the general business processes will be summarized and treated partly in more depth now.

3.1.1 Process for incoming trains today (example DUSS-Terminals)

Figure 3-1 illustrates the main activities conducted in an intermodal transport chain and the corresponding main responsible stakeholders. The IVG design has to take into consideration the potential impact on automation and digitalization that IVG could imply - both for the entire chain as well as for the individual stakeholders.

The chain starts at shippers sending one or several loading units through road hauliers for pre-haulage to the intermodal terminal where the LU’s are transhipped on to an intermodal train. The outbound intermodal train can also be loaded with LU’s carried by other incoming trains. Commonly the next step before liability is shifted on to the rail undertaking and where the interaction with the network infrastructure manager is initiated i.e. during the line haul on the main rail network – a local rail operator also known as shunting operator or near field operator is responsible for any re-configuration of the train before entering the main rail network.

The corresponding procedure takes place when exiting the main rail network and before incoming trains enter the arrival intermodal terminal. The transport chain with the intermodal LUs is then concluded after the post-haulage to the consignee where the LUs are unloaded.

Figure 3-1. Typical configuration of actor profiles and activities in rail based intermodal transport chains
After the train arrival in an arrival track outside the transhipment area the train will be pulled or pushed into the terminal transhipment zone. Depending on the type of terminal and business model of the terminal operator the near field operation could be either subject to specialized shunting partners (railway undertaking) or to the terminal operator itself. In case of DUSS-Terminals in Germany terminal operation starts when the train composition arrives in the transhipment track, DUSS is not responsible for shunting and near field operations.

Inbound inspection of load units on wagons is an important step in the process of transferring liability for the freight units from the train operator to the terminal operator. The terminal operator therefore identifies and checks the objects “on wagon before transhipment” with the check staff and crane drivers all incoming load units and wagons visually and compares them with announced data first. The announced data today are printed mainly on lists based on provided data of the train operator that show:

- The train number and responsible train operator
- the expected arrival train composition, UIC-wagon numbers, wagon serialization, position of dangerous cargo in the train
- load units on the wagons (ILU-Code/BIC-Code, type of unit, unit length)
- etc.

These lists will be checked and validated by the terminal operator staff and forwarded with the identified real information to the local agent office of the train operator who checks the validated real data with the freight papers that accompany the train.

The terminal operator that takes over the load units in his responsibility needs to contradict or complain about differences and damages “before starting transhipment”, otherwise his own responsibility and liability will be claimed as result of improper terminal handling and he has to prove that later problems with the load did not happen for his responsibility. In case of serious differences.
(e.g. missing or supernumerary wagons, missing or supernumerary units, other units than expected, damages, dangerous cargo differences or other issues that could affect the permission to tranship and the liability of the terminal) the terminal operator needs to contact the train operator first for common solution. This process requires at least 30 min up to 1 hour, depending on the status of the incoming train, the number of units to be checked and differences found. The quality of announced and real data has improved over the last years since train and terminal operators have established electronic data interface communication.

However, the real validation and damage status of load units and wagons is still subject to critical evaluation before liability changes from the train operator to the terminal operator. DUSS receives misdirected load units on international trains from time to time, mostly as a result of wrong confirmation of crane orders in the terminal that has sent the train or insufficient data accuracy in the transport chain. For this purpose the IVG train gate would be helpful to digitalize the identification and status documentation. After that the transhipment is carried out due to orders from the train operator (e.g. load units from wagon to truck or into storage zone or to another wagon). The carried out transhipment will be confirmed from the terminal operator to the train operator that gave the order to the terminal operator. After the train was unloaded and depending on follow up procedures the empty train is allowed to leave the terminal or is ready for loading outgoing freight.

### 3.2 Processes at railway intermodal terminals with IVG integrated

Figure 3-3 illustrates the intermodal supply chain considered in this study and the positioning of video gates and detection points. The main position considered is marked 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 mainly due to:

1. Faster arrival process (Deviation handling, automated arrival e.g. check/damage claims/handling of dangerous goods)
2. Faster departure process (Automated departure check, improved safety, handling of dangerous goods)
3. Improved and faster operational handling as wagon and ILU sequence (and any deviations) are known in advance, enabling optimized transhipment plans and interface towards road hauliers. The latter in particular when combined with road video gates, marked as “Z” in the figure.

These factors 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.

Detection points—in this context defined as gates with only partial functionality of the intelligent video gates, which can use RFID readers for detection purposes. Cameras and scanners can be excluded from these points if classification or other functionalities are not required. The positioning of the detection points is marked as “O” in Figure 3-3 and is 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 reconfigure of the train along the route is known in advance by the terminal operator who could then re-plan their processes.
Within the Fr8hub project there are eight work packages (WP’s) which are outlined by the Grant Agreement (GA) of the project. The closeness of the relation between the work packages is varying, where an especially close cooperation is outlined for this work package WP4, Intelligent Video gate (IVG) and WP3 Network management. The following objectives of WP3 are related to WP4:

- To follow and monitor the results and performance effects of WP4 Intelligent Video gate on freight traffic.
- In correlation with WP4, establish the format of input data (identities of in- and outbound trains, wagons and LUs) from the Intelligent Video Gate.
- To describe how a multimodal exchange platform could connect and exchange data between the video gate and infrastructure manager, railway undertakings and other stakeholders.

Four project partners are involved in both WP3 and WP4; Trafikverket, DB (DUSS in WP4), Indra and KTH. Other partners in WP3 include DLR and Linköping University. The latter as well as KTH are linked in third-parties from Sweden contracted by Trafikverket.

As stated above one main task of WP3 consists of establishing the format of input data (identities of in- and outbound trains, wagons and LUs) that can be derived from WP4 the Intelligent Video Gate. The main data correlations between the two work-packages have been identified thus far are:

- identities of in- and outbound trains, wagons and LU
- central connection to databases (train data, wagon data, LU data)
- communication of data deviations between pre-notified data and IVG real-time data
• automatic check of incoming wagons and load units are expected to yield time savings, thus reducing the terminal throughput time.

• automatic check and increased safety for outbound trains

• improved operations at nodes is not achieved only through automatic checks and deviation handling, but also through optimizing the transhipment process and the interface towards road transportation as well as other benefits that improved and digitalized information exchange can imply.

• more reliable ETA and ETD of trains and initiation of terminal services in case of deviations.

3.2.1 Ideal processes

Ideal processes within the transport chain make manual work obsolete and fulfil practical requirements to a maximum. The IVG overall process is to support the general functions of the terminal operator to identify, verify and document the main steps within the transport chain due to the upcoming change of responsibility and liability for the freight, such as automatic identification of vehicles and load units as well as image documentation of quality and damages.

In the ideal scenario of intermodal transport the announced wagon (UIC-wagon number and wagon serialization) and freight data (load unit number, correct size, correct hazardous cargo signs) as well as the conditions during the transport are reliable to a maximum and neither have become critically to identify nor have led to stop of operation elsewhere. Otherwise the process is not ideal anymore and requires human action for intervention.

The following aspects show the general view on the terminal processes.

3.2.2 Simplified ideal IVG-process: Train to Terminal/storage/truck

1. Train operator sends information (announcement) to the terminal operator (train number, UIC-wagon numbers + load unit numbers to terminal operating system), ideally the load units already fulfil all admission requirements for transhipment as they have been proofed, accepted and trusted from the roadside of the other terminal

2. IVG-train gate recognition of real data from train in the train gate (UIC-wagon number + load unit numbers) and images of the objects

3. IVG-video gate sends recognized data to the terminal operating system

4. terminal operating system validates announced data details with real IVG-train gate data, status report OK

5. Terminal operator sends feedback to train operator (status report)

6. Terminal operator processes verified data for transhipment in his terminal operating system

7. Terminal operator processes transhipment (load unit from wagon to storage or truck) and sends confirmation to train operator
8. Terminal operating system sends information about truck composition to IVG-road gate (outbound)

9. IVG-road gate recognition of real data from truck in the gate (truck number plate, load unit number on the truck)

10. IVG road gate sends recognized data and images to the terminal operator

11. terminal operating system validates announced data details with real IVG-road gate data, status report OK

12. Terminal operator sends feedback to train operator (status report)

Images and recognized data need to be saved on the IVG-management platform for maximum 13 month due to legal evidence requirements.

The result would be as well a 1:1-okay-status. The former manual work of the load unit checker is obsolete and will be replaced by complete automatic check within the IVGs.

If the terminal or yard from which a train departs is equipped with an IVG, information about the train and its composition can directly (and possibly automatically) be made available to the rail infrastructure operator on one hand and the receiving terminal on the other hand via a Connected Logistics Chains system (see section 6.2.6) long before the train arrives. This makes it possible to save time by starting transhipment planning in advance (see 3.2.6.).

Step No.7 requires a confirmation for the realized transhipment down from the wagon. Depending on the contractual situation the collecting truck is loaded but has not departed yet and maybe waits another day for a delivery schedule inside the terminal area. The understanding of steps No. 8 to 12 would be rather a double verification. If the terminal operator really had done a mistake, later on the IVG-road gate would deliver the result of wrong allocation, when the truck departs from the terminal with the wrong load unit. Stop information for the truck could be at least processed immediately.

Imagination about additional IVG-functions and use cases in ideal surroundings is not limited.

3.2.3 Simplified ideal IVG-process: Truck to Train

1. Train operator sends information (announcement) to the terminal operator (truck number plate + load unit number) to his terminal operating system, ideally the load units fulfil all admission requirements for transhipment, is accepted and is already technically proofed by a trusted carrier in advance

2. IVG-road gate recognition of real data from truck in the road gate (real number plate truck + load unit number) and images of the objects

3. IVG-road gate sends recognized data to the terminal operator

4. terminal operating system validates announced data details with real IVG-road gate data, status report OK
5. Terminal operator sends feedback to train operator (status report)

6. Terminal operator processes verified data for transhipment in his terminal operating system

7. Terminal operator tranships and sends confirmation to the train operator

8. Terminal operator sends information about completed train composition to IVG-train gate (outbound), after that train departure

9. IVG-train gate recognition of real data from train in the gate (UIC-wagon number, load unit number on the wagon)

10. IVG train gate sends recognized data and images to the terminal operator

11. Terminal operating system validates announced data details with real IVG-train gate data, status report OK

12. Terminal operator sends feedback to train operator (status report)

Images and recognized data need to be saved on the IVG-management platform for maximum 13 month due to legal evidence requirements.

The result would be a 1:1-okay-status. The former manual work of the load unit checker is obsolete and will be replaced by complete automatic check within the IVGs.

Step No.7 requires a confirmation for the realized transhipment while the train is still standing still in the transhipment track and has not departed yet. The understanding of steps No. 8 to 12 would be rather a double verification on someone else’s interest. According to transport law and from the legal point view the train operator – as he takes over the responsibility - would have to check before departure, if the train composition is okay or not. But in most cases it is also possible to close contracts between terminal operator and train operator, that the terminal operator does the double check. If the terminal operator really had done a mistake, later on the IVG-train gate would deliver the data result of wrong allocation, when the train departs from the terminal. So at least stop information for the train could be processed immediately. This way of dealing with the problem of fault freight could be better than waiting for the train to arrive at a terminal 1’000 km far away and then send the wrong wagon or load unit back to origin.

### 3.2.4 Practical problems and complexity in real life

In practice, however, the most common problems and cost drivers in the transport chain likely occur by different understanding of the different frameworks of the transport market:

- different or complicated (national and international) rules of transportation and admission requirements for load units that demand more than just checking the existence and correctness of an ILU- or BIC-Code (a revision of regulations on international level is highly recommended)
- poor optical condition of numbers on wagons and load units for OCR-identification (for wagons the RFID-approach should bring more quality and reliability to the data, for the load units RFID identification could be a future option)
• different transport and customer policies of train operators, e.g. acceptance of extra-size units that need special admission and special gauge codification in addition to regular numbering
• acceptance of non-standardized load units (such as asymmetric load units, load units with incorrect ILU-codes or numbers, individual sizes, etc.) on behalf of customers
• different load unit types and standards (that make OCR-recognition at different positions much more difficult)
• inappropriate positions of signs, markings, CSC-approval plates, stamp location for last inspection dates
• existence of transport/transhipment critical damages, losses, open doors or manhole covers on load units (customers liability vs. transport/transhipment liability)
• incorrect hazardous cargo status of placards (e.g. scratched off, blown or ripped away during transport due to insufficient quality of placards)
• breach of (customs) seals due to (attempted) theft, insufficient material quality or attachment by the customer
• expired CSC-safety approval plates or load unit revision dates (due to insufficient maintenance attention of load unit owners)
• handling or shunting mistakes (e.g. wrong load unit on the wagon, wrong wagon in the train composition).

All these factors do not allow smooth and efficient terminal or transport operations without stress at the moment. Moreover, they partly require highly qualified human intervention in a time, where human resources are limited to the market and qualification as well as experience in intermodal operations developing towards more automatization. It needs a similar understanding of quality in the transport chain of all involved parties and also the support of transport authorities to rethink the amount of rules, check requirements, etc. before, during and after intermodal transports by rail as well as a harmonization of standards to have fewer barriers for automatization.

In particular IVG-technology especially in train gates will solve some of above addressed issues by better performance via optical character and number as well as RFID-recognition. But in addition to all other aspects that cannot physically be recognized by IVG on a vehicle terminal operators and responsible partners in the transport chain should work together to reduce “workarounds” and enable collaboration, e.g. load unit and wagon databases as well as input devices to enhance paperless and environmental friendly data processing.

3.2.5 Big variety of intermodal load units and wagons

The IVG and its capabilities need to cover a big variety of load units. Different from the sea port experience with a “mono-culture” of highly standardized load unit types (i.e. box containers) and wagons intermodal terminals in the hinterland have to deal with a growing number of different load unit types, wagon types and also partly exotic forms and sizes. The following abstract illustrates a summary of possible constellations in hinterland terminals which is the challenge for all operations.
If digitalization and automation in intermodal transport and transhipment should be successful, identification standards and load unit development as well as lifetime maintenance need to be taken into account by all market players.
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<th>22 - 45 foot</th>
<th>13,60 m – 14 m</th>
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<td>Swap body</td>
<td>Semi-trailer</td>
</tr>
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<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open Top</td>
<td>x</td>
<td>x</td>
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<tr>
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<td>x</td>
<td></td>
</tr>
<tr>
<td>Hard body</td>
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</tr>
<tr>
<td>Curtainsider</td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3-5. Simplified overview of different load unit types (DUSS, Müller/Karl, 2015) and examples (Source: DUSS/Barbi/Check-in-app)

Figure 3-6. 20-foot box container

Figure 3-7. 20-foot silo container
Figure 3-8. Semi-trailer.

Figure 3-9. Swap body with hard body.
3.2.6 Management and Planning of Transhipments

A transhipment plan for an intermodal terminal prescribes when and where each loading unit should be moved, as well as where trains and trucks should be placed and moved. The use of an efficient transhipment plan decreases the time and cost of transhipment and thus makes intermodal transports more attractive. Investigating how to create better transhipment plans with the help of data captured by intelligent video gates is therefore an important part of this project. Useful data are, for example, the size, type, destination and location of each loading unit that arrives at the terminal.

Data that are used in transhipment planning at a certain terminal might have been delivered by an intelligent video gate at that terminal. However, if data from a gate at the terminal from which a train departs are made available to the terminal that will receive the train, planning at the latter terminal can start before the train arrives. This means that there will exist a valid plan for (the beginning of) the transhipment process already when the train arrives at the terminal. The role of the intelligent video gate at the receiving terminal would then be to confirm that the data received from the sending terminal are correct. This is one example of several of how data from intelligent video gates can contribute to more efficient planning and execution over the whole intermodal transport chain.

Apart from being efficient, transhipment plans should preferably be flexible and robust. That is, they should be easily adaptable to changing transport needs, and they should be executable (possibly after some smaller changes) even in case of disturbances such as delays of trains and trucks. This means that plans should leave many replanning possibilities open. Since a high theoretical efficiency
(short calculated makespan) doesn’t necessarily mean that many re-planning possibilities are left open, these objectives might have to be combined to form a suitable objective function that indicates the quality of different possible plans.

Flexibility and robustness can also be increased using rolling planning. This planning strategy means that only an initial part of each plan is executed. Since the full plan concerns a longer period, data about the expected future are taken into consideration in the planning process. The following plan will be based on the part of the first plan that is under execution and on other available information (including information that was not known when the first plan was made, such as new bookings, changes in expected arrival times and other deviations). This process can be repeated for as long as desired. See the figure below.

![Figure 3-11. An example of rolling planning showing six plans.](image-url)
4 IVG-design for railway intermodal terminals

Terminals are mostly existing sites that have developed in line with the specific demand of operation.

The set of IVG-components and functions must be designed to fit into an overlapping framework of the terminals and railway infrastructure. For this purpose, requirements according to most common (existing) terminal designs are set which all new components must observe to meet most standardized conditions.

General recommendations for implementation also in newly designed sites are given based on several construction plans that have been taken into account within the scope of the IVG.

As a technical system, the IVG consists of

- **structural components** (gate components for keeping / housing devices, electrical supply, etc.)
- **technical components** (image recording, illumination, RFID-reader, user interfaces)
- **logical components** (image processing, RFID-processing, memory, visual data evaluation, etc.)

More precise specifications for development plans are made in the following sections for the structural components and for the logical components. There are no specifications for the technical components in the sense of a development plan; however, the conditions are set for the technical components within the necessary functional requirements. It is part of the project to choose suitable technical components.

4.1 Structural components

Intermodal terminals are mostly built in modular construction.

Today’s intermodal terminals in Europe consist of a number of crane modules e.g. Munich-Riem consists of 3 crane modules and a shunting yard “Y” as illustrated by Figure 4-1. A crane module for intermodal terminals usually has four tracks of more or less 700 m length, a driving and loading lane and a number of storage lanes as well as up to 3 cranes on the runway. The rail tracks for transhipment can be designed with access at only one side or with a connection on both sides.
Since there are currently no standardized “one size fits all” video gates for terminals operations yet, it should be considered that a different number and designs of IVGs could be necessary to be defined depending on the existing track situation and planned access situation of the terminal, such as:

- Single rail gates for inbound / outbound train operations one track
- Double rail gates for parallel train operations through a gate bridge spanning 2 or more tracks.

All railway systems in terminals correspond to national railway engineering guidelines. In particular, the gauge area, which is to be kept clear, is of relevance for the construction of the IVG. The applicable guidelines should be verified due to the local conditions; in particular the maximum permitted speed of trains, the existence of electrified rail tracks, the height of electric wires, etc.

The IVG-system described in this document is installed on the entrance / exit tracks of the terminal. The results of the movements of the trains and wagon groups need to be documented in line with the movement in and out. In case rail movements in the terminal run over exactly one track (see...
Figure 4-2) only one IVG would be necessary. Since this access option cannot be achieved in all terminals (for example, two-way connection, several routes into and out of the terminal), several IVG-systems could be needed, installed and orchestrated (see Figure 4-2).

Due to practical reasons, rail gates over electrified tracks – consisting of at least two columns with only left/right scan – could be more practicable than a bridge construction.

![Image](image.png)

**Figure 4-2 Track situation in a terminal access area and possible positions of IVG-installations**

In principle, the IVG-system in the "desired" location should be placed as close as possible to the transhipment tracks or at least very near to the operational area that is directly influenced by or under responsibility of the terminal operator. Regulations for how close to the tracks the installation can be made have to be taken into account. In close proximity to the installation site, an outdoor control cabinet needs to be provided, which enables connections for power supply and network (Ethernet, WLAN and need to meet the local regulation and standards to avoid electromagnetic interference, etc.) for the IVG-components.

Depending on the place of construction and amount of engineering, permissions from the Federal Railway Authority (e.g. EBA in Germany) should be obtained.

### 4.2 Logical components

The core application of the most common terminal operating systems (TOS) is order management and the tracking of the movements and transhipments within the terminal.

The IVG will support order and the liability management by means of identification, picture documents of incoming and outgoing load units and wagons as well as data collection from the passing objects.
Data allocation concerning the state of wagons and load units currently takes place purely manually on form sheets with paper archive. The IVG will support the data collection concerning the identification of the wagons and load units by means of image documents.

The data collection begins in the Detecting and Imaging Subsystem (DIS) and RFID Identification module (RI), see Figure 4-3:

- **Detecting and Imaging Subsystem (DIS):** This subsystem includes the sensors and other technical components installed sideways or overhead of the rails on the Intelligent Video Gate: wheel sensors, linear cameras and laser scanners. The train is first detected by the first wheel sensors installed several meters before the measurement zone, where DIS components are installed. The correct distance where to install these “wakeup” sensors is defined by the train maximum speed, providing sufficient time for the DIS components to perform necessary activation and calibration, before the train reaches the measurement zone. When the train passes through the measurement zone, the system captures greyscale/coloured images of all the wagons and units (and identifies them with timestamps and other internal classifiers). These images contain raw information of codes, numbers and different signs (such as dangerous cargo), as well as the current physical state and possible damages of the wagon and units that will be processed later on by other logical components. A set of wheel sensors on the measurement zone acquires the correct time of passage of each wheel, providing information such as axle distance, train accurate speed at every instant and train composition in terms of rolling stocks number and models. Moreover, this module generates a 3D point cloud recreation for each wagon and cargo unit, providing out of gauge and out of conformity alarms. This system should be able to work at all light conditions, meaning day and night. Finally, the images captured, point clouds and train composition are sent to the FIM subsystem through a dedicated interface.

- **RFID Identification (RI):** This subsystem uses the RFID readers installed on the IVG as input devices. These devices read the RFID tags of each one of the wagons and freight units and identify them with an associated timestamp. The information of the RFID tags includes the company code, side indicators and UIC-wagon numbers. This subsystem sends the information read to the FIM module through a dedicated interface.

- **Field Information Matching (FIM):** This subsystem receives and matches the information produced by the DIS and RI modules, associating each tag with the corresponding wagon and container, offering the aggregated information as an output to the TIC module. This aggregated information is also stored on a database and a file repository.

- **Train Identification and Classification (TIC):** This module uses OCR technology on the images captured by the DIS and aggregated by the FIM to locate and obtain the plate numbers, codes and different written tags on the containers (ILU/BIC code for load unit identification, unit type, unit height and wagon identifier with UIC wagon number). With this information, together with the information provided by the 3D point cloud recreation of each wagon and cargo unit generated by the Detecting and Imaging Subsystem (for double-check purposes), this subsystem also classifies the containers, completing the aggregated information received from the FIM subsystem.

- **Internet of Logistics Data Database:** “Internet of Logistics” refers to the adoption of Semantic Web technology to support secure and automatic data interchange of logistics data among participants of a Supply Chain process in order to increase visibility for better planning and control. In perspective IVG should generate and store transit events and data in a format that
enables automatic processing (e.g. Artificial Intelligence algorithms) that supports access, sharing and searching of data in a controlled and secured way. Based on **Internet of Logistics** technology, IVG can produce information in an open and machine readable format, by using a common “vocabulary” (language, formats, contents) that can be interpreted by software applications and other participants of the supply chain. Such a common language and vocabulary will be based on Semantic Web standards, such as OWL and Resource Description Framework (RDF), in order to model, share and search Rail Freight data that is generated by IVG. RDF is a standard model for data interchange on the Web, defined by RDF 1.1 suite of W3C Recommendations ([https://www.w3.org/standards/techs/rdf#w3c_all](https://www.w3.org/standards/techs/rdf#w3c_all)). The Data Store associated to IVG will be design and developed as an RDF data stores or knowledge graphs that can be queried with standard tools (SPARQL). Existing identification code standards (ILU codes, UIC codes, RFID standards, GS1 EPC/RFID.) will be incorporated into the design. Other industry sectors as Health Care and Finance have already applied semantic web standards and have created common vocabularies that ensure data interchange and collaboration.

Finally, all the information captured, processed, generated and aggregated by this chain of logical components is sent from the TIC module to the Integration Layer and to the GUI for different Web and App purposes.
4.3 Technical components

4.3.1 RFID

RFID stands for Radio Frequency Identification and is based on the use of radio waves to read and capture information stored on a transponder, also known as a tag (sometimes called an “electronic barcode”). The RFID tags are normally attached to an object and can be read from several meters away and do not require a clear line-of-sight to be read. The reading units can either consist of fixed installations or various kind of handheld devices.
How does it work?
A RFID system consists of two major parts: a tag and a reader. RFID tags can have a shape of a label or hard tag. The RFID tag is embedded with a transmitter and a receiver, implying that it can collect data as well as send out data to/from an RFID reader.

The technology is divided in two major areas, named Passive and Active RFID. Active RFID means the tag is powered by a battery and Passive technology has no battery in the tag, it get its energy from the radio signals send out by the RFID reader.

In railway applications, Passive UHF technology is commonly employed which implies that the tag has no battery and will be “powered” by a RFID reader, either through fixed installations or handheld mobile scanners.

![Figure 4-4. Fixed RFID readers along a track in Sweden](image)

The following examples are some of the main requirements on RFID systems used for automated reading of data from a wagon in a train-set and transmission to an IT system:

- **Trackside reader can be positioned at:**
  - entry and exit points of locations where a train formation can be changed (yards and terminals)
  - In and out from station areas
  - combined with other detector installations for ex. hot box, vibrations, sound/noise etc.
  - strategic key points for logistic purpose

- **Typical installation constrains are given in the TSI WAG where the reader position is defined, normally 2.5 to 3 meters from track side.**
- **Tags to be mounted on the vehicle 0.5 to 1.1 meter “above the rail”**.
- **Rugged industrial design, no battery and long-life time makes the tag suited for all uses.**
- **Tags are required to operate at the maximum speed for the wagon as well as the max/low temperature where the wagon will be in operation.**
- **RFID ISO standard 18000-6 will be used means that any standard reader as well RFID tags can be used if they follow the standard.**
- **Very long readout range, <10 meter depending on tag format etc.**
• High speed detection, well over 200 Km/h (which will not be reached in the context of IVG-application in intermodal terminals).

The following examples are some of the main advantages with RFID systems using passive UHF tags:

• Passive tag does not contain any battery and stays for decades.
• Huge variety of suppliers of open standard product in the UHF segment.
• Tag can be mounted easily on any surfaces, including metal, either with industrial adhesive or mechanically.
• Extreme weather conditions resistant (IP 68)
• Read/Write capability
• User memory, 96-512 bit
• Up to 10 meters read range (tag dependent)

Detailed description of these IVG components is reported in section 6.3.4.

Figure 4-5: Area where the RFID tags shall be placed on a railway wagon. IVG-important measure: A1 = 500 mm, A2 = 1.100 mm (source: LearningWell/Deutsche Bahn)
4.3.2 Trains Detecting and Consistency Evaluation sensors

In order to allow IVG sensors to wake-up as a train is going to pass through the gate, it is necessary to adopt some kind of sensors at a reasonable distance away from the gate able to recognize that a train is approaching.

It is also necessary to evaluate with a good accuracy the train speed during its passage along the gate.

One more function to be performed is the detection of train consistency. Train Consistency is very important in IVG high level functions. The classification of each rolling stock helps the localization of texts and information to be digitalized and managed in TIC (ref. 4.1) module.

Typically, to perform these functions track sensors are used which are able to recognize axles passage. Electromagnetic wheel sensors are the most common COTS but also proprietary solutions can be used. In this case sensors based on optic fibre has the interesting property of working without power supply and so being less intrusive and more compliant to electromagnetic emission standard.

Detailed description of these IVG components is reported in section 6.3.1.

4.3.3 Digital Camera

IVG primary mission is to acquire high definition pictures of wagons and carried goods (typically LU) to allow automatic recognition of relative codes performed by Train Identification and Classification (TIC – see section 4.2) processes.

The imaging acquisition technology and process, which is part of “Detecting and Imaging Subsystem”, DIS (see section 4.2), requires high definition cameras able to take pictures of each single and complete wagon along with its load. Pictures acquired must have the sufficient quality to allow OCR functions to recognize and digitalize all standardized information readable within wagon and load.

Another requirement that digital camera have to perform is allow personnel to evaluate damages to the wagons / LUs that may be occurred during operations from the inbound to the outbound of the same object.

Typically the fittest kind of camera performing these requirements is the **linear scan camera**. These types of cameras are able to acquire, with a very high frame rate, a thin slice of the target to be acquired (in this case the train). It is then required a real time post-acquisition process able to recreate the entire picture of the subject. This process leads to take wagon pictures of extraordinary high definition and quality (in terms, e.g. of noise, contrast, etc.).

Of course, this technology requires the target is moving during the acquisition and requires the exact knowing of its speed. Train stops during the pictures acquisition can cause problems and unjustified costs if not explicitly required.

Calibrated camera in IVG context allows performing measurements of length and height of each LU and wagon passing through the gate.

**Matrix cameras** in this environment are typically used for video surveillance but for IVG purposes, they can provide a panoramic but detailed view of the passing train with video clip and still images useful to identify possible damages that occurred during the operations. In fact IVG environment is
typically different from a road gate where pictures for plate recognition are taken from the front side or from the back. In this environment, pictures have to be taken from side of the running train.

Given the low speed of the trains passing through the gate, matrix camera are useful also to perform pictures compliant to the IVG requirements. Even if resolution and quality is lower respect to the linear ones, in as many cases later OCR capabilities works correctly.

So, both kind of camera can be used within an IVG to perform the same requirements with different strengths.

Linear scan cameras are most adequate to perform high resolution pictures for ILU and wagon codes recognition but require a minimal speed of the train and a good knowing of its speed.

Matrix cameras are more adequate for surveillance since they make available video clip and time evolution of the train passing. In this context they could have fewer problems in case of very lower train speed.

Detailed description of these IVG components is reported in section 6.3.2.

### 4.3.4 Illuminator

IVG requires taking high definition picture in order to read automatically information printed along with rolling stocks and loads in different environmental condition: night and day, sunny and cloudy, dry and wet, etc.

Allowing cameras to take pictures in these different environmental conditions requires lighting up the camera field of view in different way during the different conditions.

The most appropriate illuminator for this issue is the led based one. It is easy to adjust light level to the required one and has a very short switch on and switch off time. Furthermore it is possible to select infrared light emission led not visible or quite not visible to human eyes.

Since illuminator has to lighten the camera field of view, linear scan camera requires only a “light blade” able to light up its scanning plane. Matrix cameras require more powerful and great illuminator since its field of view is being widened in the vertical plane but also in the horizontal one.

Detailed description of these IVG components is reported in section 6.3.3.

### 4.3.5 Scanner

Typical scanner sensor is a device able to make distance measurement on its slewing scanning plane and so allows creating 3D images of the trains passing in its field of view.

It is a useful technology as auxiliary components in IVG context in order to detect alarm due to imperfect loaded wagon or in case of defective wagon (out of gauge alarm).

In IVG it is useful as assistance to verify damages in the loads or in rolling stocks or even to detect automatically damages of known LU or rolling stocks.
To properly work, laser scanner requires target being moving in its field of view. To perform the above mentioned functions it is required to know with good accuracy train speed that shouldn’t be less of a predefined value.

Detailed description of these IVG components is reported in section 6.3.5
5 Requirements

5.1 Details of the functional requirements

The functional requirements are described in the following chapters on the core areas. These are the requirements on the structural components, the requirements for the technical components, and the requirement for the logical components.

5.1.1 Functional requirements for structural components

For a full scale solution a video gate for rail should be equipped with systems for

(1) RFID tags scanning
(2) image acquisition and analysis at all three visible sides.

These modules could be and are not limited to:

- RFID reader (left/right)
  - identifies the wagon
  Requirement: to be filled with information regarding RFID-tag (UIC-number, side indicator, etc.)

- OCR recognition (left/right/above)
  - identifies ILU/BIC Code
  - identifies code size (if existent)
    - Delivers unit size/length type (20 foot, 23', 24', 30', 40', 45', different semi-trailers)
    - Delivers unit height (8 foot 6 inches or 9 foot 6 inches)
  Requirement: Database with information regarding different code sizes

- Video camera scanner (left/right/rooftop)
  - Creates a grayscale/coloured image of the wagon and its units
    - Delivers number of load units on wagon in real time performed by OCR
    - Delivers unit size (20 foot, 40 foot)
    - Delivers unit height (8 foot 6 inches or 9 foot 6 inches)
    - Delivers information on dangerous cargo signs
    - Delivers information on existing aggregates on load units (thermal units)
    - Delivers information on damages (via image as such)
    - Human control on number of load units
    - Human control on unit size (20 foot, 40 foot)
    - Human control on unit height (8 foot 6 inches or 9 foot 6 inches)
    - Delivers information on dangerous cargo signs
    - Delivers information on existing aggregates on load units (thermal units)
    - Human control on damages (via image as such).

The cameras and photo modules can be used to either extract information (for example via OCR) or to verify information by a human being in front of a monitor.
5.1.2 Available and necessary data, data quality

Wagon identifier (see Figure 4-3):
Necessary for identification is the unique registered UIC-wagon number\(^1\) according to UIC-standards. The number consists of 12 digits and is printed on the left and right long-side of each wagon. Validation of digits, letter type and letter size are standardized according to leaflet UIC 438-2. The position of the digits can vary in the following horizontal and vertical directions.

Example 1 (horizontal only):

\[
31 \ 80 \ 4556 \ 381 – 0
\]

Example 2 (vertical & horizontal):

\[
31 \\
80 \\
4556 \ 381 – 0
\]

The UIC wagon number is located on every UIC-registered freight wagon and is used for the separation of train composition.

\(^1\) UIC wagon numbers, http://enacademic.com/dic.nsf/enwiki/11556540
Today the data quality of written letters depends on the quality of maintenance of the wagon. It can be scratched or bleached so that contrast problems need to be taken into account for correct identification. To ensure high accuracy the UIC-wagon number needs to be validated automatically by default. The UIC-number sequence is finished by a check digit (one numeral). Optical hyphen character “-” to separate the check digit is not relevant and does not influence the correctness of the digit sequence.

Optical character recognition shall offer opportunity to reconstruct at least one digit that could not be identified. As far as digits could not be identified by OCR-validation the IVG shall mark the corrupted data position and/or insert automatically the missed digit for correction. Automatically inserted digits shall be marked for acceptance.

**Wagon identification with RFID:**
With reference to chapter 4.3.1 wagons can and will be fitted with RFID-tags in the near future. The IVG shall read the saved UID-information on the tag.

The UID contains the main public information:
- company code
- side indicator
- wagon number

Definition of standards developed by the railway industry together with the standardization organization GS1 is to be found at: [www.gs1.org/rail-standards](http://www.gs1.org/rail-standards)

According to use cases and experience in Sweden with Trafikverket wagons can be fitted with 2 RFID-tags, located at both ends of the wagon on the long-side. The RFID tags have the same information stored in the tag except for “side indicator” that differ with side A and side B.

There are several solutions to detect movement and direction of a trainset, Sweden is using wheel sensors in combination with RFID readers. This solution has an advantage as it can detect wagons without RFID tags (wagons not yet tagged or broken tags). Another alternative can be to use other technologies like laser, ultrasonic etc. to detect directions. Dual RFID antennas connected to one reader can also be an alternative to detect movements.

Swedish installations just contain RFID reader installations at one side of the track, dual installations with readers on both sides will of course be possible. This will increase the functionality if a reader is broken or to detect if a RFID tag is “dead” or dropped off on any side of a wagon.
If the IVG detects an RFID-tag with the wagon number optical OCR-recognition of the wagon number can be used for comparison. Based on both information sources (RFID or OCR-identification) the more reliable information shall be used for further data handling. Both results of identification can show differences. In that case further steps have to be addressed to the railway undertaking.

**Unexpected detection:**
In case of unexpected IVG-detection (unidentified rolling stock) without identification results further image capturing is necessary to find out, what passed through the IVG at this moment. This information should be available for security or maintenance alert.

**Load unit identifier:**

Intermodal load units are identified in the following standardized ways:
- identification by unique BIC-Code\(^2\) for registered box containers and tank containers according to ISO 6364
- identification by unique ILU-code\(^3\) for registered intermodal load units (containers, swap bodies, cranable semi-trailers) according to European standard EN 13044-1

The load unit identifier includes the 4-characters prefix (e.g. BIC-code: 3 letters owner code, 1 letter equipment category identifier) and 6-digits serial number finished by the check digit (one numeral). The validation of digits follows the same algorithms for BIC/ILU-codes.

- **Example BIC-code:** TEMU 100701-0 (box container) or ANHU 225023-3 (tank container)
- **Example ILU-code:** SJSB 001327-1 (swap body) or LKWA 007859-0 (semi-trailer)

The load unit number is printed at least on each side of the load unit (left, right, front, rear) either horizontally or vertically.

---

\(^2\) Container Identification, https://www.bic-code.org/identification-number/

\(^3\) ILU-code, https://www.ilu-code.eu/en/about/standardised-owner-codes
Figure 5-4. Intermodal load units – side view.

Figure 5-5. Semi-trailer – side view.

Figure 5-5 “LKWA 007859-0” shows a modern semi-trailer. Beyond the ILU-code further profile information are given by yellow codification signs according to EN 13044-standard. Also optional attached is “HRO-A7859” representing the vehicle number plate for public road transportation as not all involved parties in the transport chain work with the ILU-code (such as police, customs authorities, etc.).

The load unit number could also be found on the roof as far as applicable (see also example semi-trailer ARCE 0030067-8). Necessary for the railway oriented IVG-identification is at least the left and right side of the load unit due to the fact that load units could stand very close door to door on a wagon and rooftop information could be covered with water/snow/ice or dirt.
The data quality of printed characters depends on the quality of maintenance of the load unit. It can be scratched or bleached so that contrast problems need to be taken into account for correct identification. To ensure high accuracy the load unit number needs to be validated automatically by default. Acquisition of different sides and top could also reduce detection problems due to poor data quality only on one side. The prefix and number sequence is finished by a check digit. Optical hyphen character “-“ or frames are not relevant and do not influence the correctness of the digit sequence.

Optical character recognition by the IVG shall offer opportunity to reconstruct for sure at least one digit that could not be identified. As far as digits could not be identified by OCR-validation the IVG shall mark the corrupted data position and/or insert automatically the missed digit for correction. Automatically inserted digits shall be marked for manual acceptance.

**Container size and type code:**
The measures (length and height) of the intermodal load unit **according to ISO-standard** are represented by a 4-characters size and type code. The code is written at least on the left and right side of the container (see Figure 5-1). The size of ISO-standardized load unit is important for further terminal handling activities such as suitable spreader position of the crane and dispatching of storage area. The first two digits of the size and type code are most relevant to encode length and height. The 3\(^{rd}\) and 4\(^{th}\) position encodes additional container characteristics.

**Example code for size and type:**
22G1 means
- 22 = length of 20’ and height 8’6 ft. (8 foot, 6 inches)
- G1 = General purpose container without ventilation: Passive vents at upper part of cargo space (not relevant for core identification within IVG)

---

The container size and type code is written at least on each long side of the load unit (left, right) either horizontally or vertically and needs to be identified. The position of the code is located closely to the load unit number. Optional decoding of real measures should be subject to additional features and code tables (from year 1995).

**Exemptions:**
It is possible that ISO-size and type codes can be interfered by other codes on the load unit. This can occur in connection with RID/ADR-tank containers. The list of exemptions (black list) consists at the moment of the following codes: L4BN, L4BH and L4DH. These codes are not ISO-size and type codes and should be blocked or filtered for recognition.

![Figure 5-7. Formats of signs on intermodal load units](image)

As far as digits could not be identified by OCR-validation the IVG shall mark the corrupted data position for correction. Corrections shall be marked for acceptance.

**Dangerous cargo information:**

Dangerous cargo information is explained by signs according to the description of the international dangerous goods conventions\(^6\) RID, ADR and IMDG on each side of the load unit. As far as more than one load unit enter the terminal on one wagon in most cases only the left and the right side of the load unit or wagon can be identified with high accuracy.

Important dangerous cargo signs are:

- placards showing the different classes (class 1 – 9 including their sub classes)

\(^6\) Regulations concerning the International Carriage of Dangerous Goods on Rail, Road and Sea
- sign for dangerous cargo in “limited quantities”
- sign for maritime pollutant / environmental hazard (same format as placards)
- sign for orange coloured plates including imprints (see Figure 5-8).

<table>
<thead>
<tr>
<th>Dangerous goods signs/marks</th>
<th>Specification</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placards, class 1-9 incl. sub classes (RID)</td>
<td>Chapter 5.3.1.7 RID</td>
<td></td>
</tr>
<tr>
<td>Sign “Limited Quantity”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sign “Maritime pollutant”/environment hazard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orange-coloured plate with imprints, up to 4 characters or digits in line 1, 4 digits in line 2 (RID)</td>
<td>Chapter 5.3.2.2 RID</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 400 x 300 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- dimension of the sign</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 100 mm height of the digits</td>
<td></td>
</tr>
<tr>
<td>Orange-coloured half plate with imprints, 4 digits in line (IMDG-code)</td>
<td>Chapter 5.3.2.1 IMDG-Code</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- min. 300 x 120 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- dimensions of the sign</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- 65 mm height of digits</td>
<td></td>
</tr>
<tr>
<td>Sign “elevated temperature”</td>
<td>Chapter 5.3.3 RID</td>
<td></td>
</tr>
</tbody>
</table>

![Figure 5-8. Formats of dangerous cargo signs on intermodal load units](image)
Figure 5-9. Position of dangerous cargo signs on intermodal load units

Figure 5-10. Evaluation of general dangerous cargo constellations in DUSS-Terminals
The IVG shall identify, if and what kind of dangerous cargo sign is attached at the load unit. The measures for the identifying of signs follow the description in the RID document chapter 5.3.1.7 and 5.3.2.2.

5.1.3 Requirements for the IT-system architecture and interface content

The IT-system has to comply with some requirements related to networking, systems software and data information storage:

**Networking:**

The networking solution is based on the following features, which are designed to minimize or eliminate downtime.

- Reliability based on redundant equipment avoiding single points of failure.
- High-speed Gigabit communications to transmit images and data
- Routing IP policies applied to enable traffic filtering procedures, providing a high level of versatility when defining access policies
- Rapid spanning tree and EtherChannels to provide link redundancies
- Quality of Service (QoS) functions implemented in order to measure and control the quality of the communications being provided while detecting and reporting incidents in real time
- Secure architecture including a DMZ network and firewalls to protect the installation from any type of external attack.

**System Software:**

- The operative system of all IVG computers has to be multi-user, multi-tasking and 64 bits platform.
- The operating system must support the proposed communications architecture, redundant configuration, database software, and IVG application software.
- The proposed operating system should have a future upgrade path and must be supported for up to five (5) years.
- In case of needing it all the IVG application software must be properly licensed.
- All licenses must be provided by the Consortium for all off-the-shelf operating system software.

**Information Storage:**

- The IVG system requires a high level of reliability and security from the database used for the storage of transaction data and a file repository for other data such images or information files.
- The database software must be compatible with the operating system and application software and must support the redundant architecture.
- Appropriate licenses must be provided by the Consortium for all off-the-shelf database software.
- The chosen database should have an upgrade path and should support upgrades to components including but not limited to the operating system, application, memory, and processors.
- The database software must be supported for up to five (5) years from the date of System Acceptance.
- The file repository will have a sufficient capacity to store the information generated by the IVG in three months.
5.1.4 Local requirements for the pilot site(s)

At this point of the requirements of a local terminal should be focussed. Additional requirements in general and in specific should be taken into account, such as:

- track number
- train speed (up to 100 km/h) and behaviour during IVG-passage (start/stop, speed increase/decrease, etc.)
- train maximum length and expected number of wagons
- track requirements (curve, joints, etc.)
- lateral space requirement (for equipment installation, helpful existing installations)
- power and data communication requirements,
- elaboration cabinet/shelter requirements, etc.
- Typical installation of RFID readers are to be positioned normally 2.5 to 3 meters from track side.

5.1.5 Requirements for transhipment plans

In order to create efficient, flexible and robust transhipment plans, the following data (captured by an intelligent video gate) are needed:

- size and type of each arriving loading unit
- size, type and position of each wagon in the arriving trains
- location on the train and on the wagon for each loading unit arriving by train
- arrival and departure of each loading unit, train and truck
6 Components

This chapter focuses on the definition and detailed description of the Intelligent Video Gate main technical components, such as cameras, RFID antennas, etc., together with the definition and exemplification of a components selection process. A state of the art analysis is performed in 6.1, showing the current video and RFID gate technologies available mainly for the road market, but also with a few examples of railway ones, being this a relatively new market. Then section 6.2 goes in detail in partners’ best practices, already developed and commissioned systems that provide the necessary technical know-how for building a railway terminal intelligent video gate. Section 6.3 defines the main technical components of the intelligent video gate together with their major characteristics, providing the bases for a better evaluation during the components selection process described in 6.4 and performed in 6.5. Section 6.6 finally provides chapter conclusions, including the components selection ones.

6.1 State of art & process beyond the state of art

All the information regarding components and named suppliers in this section are just examples and should not influence the process of selection and possible acquisition of components.

To identify suitable ingredients of hardware components and software/algorithms that could be sufficient for further IVG solutions composition, a market state of the art study has been done. There are a lot of road gates examples and most of the systems are designed to read codes on containers only and not on trailers or swap bodies. Video gates and OCR (Optical Character Recognition) systems for rail applications are, however, rarer. Numbers of OCR systems installed in the world in 2011 are shown in Table 6-1 bellow. The OCR systems installed on cranes can be at intermodal terminals. This shows that only approximately 1.5 % - 19 % of the installed OCR systems are for rail or intermodal applications. (Thomas et al., 2012)

<table>
<thead>
<tr>
<th>System type</th>
<th>No of systems reported (2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate OCR</td>
<td>577</td>
</tr>
<tr>
<td>Truck license plate recognition</td>
<td>447</td>
</tr>
<tr>
<td>Rail/intermodal</td>
<td>20</td>
</tr>
<tr>
<td>RMG/RTG yard crane</td>
<td>60</td>
</tr>
<tr>
<td>STS quay crane</td>
<td>159</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1263</strong></td>
</tr>
</tbody>
</table>

6.1.1 Code recognition

Automatic container code recognition systems with recognition from a single view can achieve an accuracy of approximately 70 %. With multiple views, the accuracy can be 96 % (Yoon et al., 2016). The two most common solutions for automatic container code recognition systems are radio frequency identification (RFID) and OCR. RFID-systems have nearly perfect accuracy but require that the containers are equipped with RFID-tags. Existing OCR-systems have accuracies of approximately 92 %. The relatively low accuracy is because the codes can be damaged or contaminated and therefore hard to recognize correctly. (Yoon et al., 2016)
Some examples of commercial products for code recognition are listed below.

- **Intelligent security systems (ISS)**
  Container recognition solution recognizes characters from containers, both above, below and from the side. The solution has an automated ISO code recognition system. The solution can by integrated with the cargo management process. The solution provides verification against cargo manifests. The information is collected in a database. (ISS, 2018)

- **ARH**
  The company ARH has systems for recognitions of container codes, railway codes, dangerous goods and license plates. System for recognition of wagon numbers can recognize UIC codes from an image or a video signal. The system uses an optical character recognition (OCR) technology. Similar systems can recognize ADR Hazard Identification Numbers (HIN), container codes and license plates. (ARH, 2018)

- **Gatekeeper Intelligent Security**
  Gatekeeper Intelligent Shipping Container Detection (ISCD) can recognize container codes and turn the image to an alpha-numeric data file. The system can also recognize license plates. (Gatekeeper, 2018)

### 6.1.2 Damage detection

There are also solutions to detect damages on containers.

- **LaseCDI-Container Damage Inspection**
  One example of systems that can detect damages on containers is the damage detection system *LaseCDI-Container Damage Inspection*. The system is a solution for gates or crane operations and detects structural damages (dents, deformities, scratches, holes, etc.), as well as dangerous goods labels, seal presence and door orientation of containers (Visy, 2018a). The system uses laser technology combined with OCR and visual imaging application. The laser scanner together with application software produces a profile image of the container. The damage recognition is achieved by comparing the container to an ideal container. (CM, 2018)

- **TREX-container**
  *TREX-container* is a system for code recognitions and damage inspection. All the collected data is stored and available in a database via a web service but can also be transmitted to any other system (Nestor technologies, 2018).

### 6.1.3 Rail gates

Some companies also have solutions for rail gates and not only road gates, see examples below.

- **Camco**
  Camco’s Rail OCR Portal identifies containers and railcars. The portal takes images of each container’s left, right and top side. From the images, container numbers, ISO codes, non-ISO container numbers, wagon and chassis numbers, IMDG and seal presence and door direction are provided. The system also provides the exact position of every container on an identified wagon. The data from the gate is sent to a Train Gate Operator application where the OCR-processed data are validated from an operator (locally or remotely). (Camco technologies, 2018)

- **Visy**
  Visy Train Gate uses OCR, RFID and other technologies to identify container number, dangerous goods and ISO codes and railcar/wagon number. The system has also solutions for damage inspections (Visy, 2018b). A snapshot of the software is illustrated by Figure 2-9.
6.2 Best practice

Starting from the state of the art on technologies and solutions existing on the market, some best practices already belonging or being used by project’s partners are presented in this section. The best practices are to be considered as the starting point over which the final IVG will be defined and developed, providing the necessary know how on its overall functionality, integration in the Terminal operation and more in general in the logistics world, technical components and algorithms.

6.2.1 Roadside Videogate at DUSS-terminal Cologne Eifeltor (ASE)

A new video gate for the road entry was set up at the DUSS-terminal Cologne Eifeltor in 2018. The gate provided by developer ASE can recognize ILU-/BIC-codes and truck license plates at a recognition rate of 96 %. The system can separate load units on double loaded trucks and has a visual recognition of dangerous cargo and/or waste signs. An automatic recognition of the dangerous cargo signs will be introduced later. Since June the recognition of the official waste sign "A" (German: Abfall) on the truck (rear/front) is possible and reliable. At the moment the system recognizes orange-coloured UN-number plates on the load unit. There is a search function in the system which makes it possible to search for events, LU-number, truck number plate, time stamps, etc.

The system at Cologne Eifeltor does not at the moment recognize ISO-size type codes on the load unit, tank codes on the load unit, yellow codification signs (for intermodal swap bodies, semi-trailers or load units with special sizes), CSC-/ACEP-plates for proofed container safety and latest stamps of technical inspection. Dangerous cargo placards as well as more than 40 different options of signs are under review (Karl, 2018).

6.2.2 Train Conformity check system (Ansaldo)

The TCCS ™ (Train Conformity Check System) is a system that aims to automatically detect "anomalous situations" of rolling stock in transit. The System analyses the data acquired by its subsystems to detect any faults and risk conditions, such as the following:

- out of shape conditions;
- rolling stock components overheating;
- on board fire detection;
- faults verification by means of high resolution images (the system selects and highlights certain risk areas).

The TCCS ™ performs verification functions on the trains passing through the "Measurement Zone", where the acquisition and control devices are present, for both the tracks and in both directions. It is however possible to configure the TCCS ™ to operate only partially (mono-directional / bidirectional). The TCCS ™ signals any anomalous conditions to the Operators present at the "Control Centre" so that they can take the necessary actions. The system is also set up to send alarms to signalling in order to automatically stop the train.

TCCS is a modular Wayside Train Monitoring System (WTMS) able to detect diverse hazards and rolling stock defects; it is primarily intended to reduce risks and rail traffic downtime by recognizing rail vehicles with a hazardous defect, allowing immediate arrest of trains at the next station or side track without disturbing or blocking normal train circulation.
TCCS™ is also capable of identifying lower severity defects and checking certain rolling stock conditions in order to optimize maintenance and reduce track wear, all this resulting in lower maintenance costs for both the infrastructure network manager and rolling stock operators. A TCCS™ installation is particularly useful for preventing accidents at critical locations (e.g. in long tunnels and bridges). Other strategic installation sites are at borders between countries or railways networks and at junctions of inter-modal terminals and loading yards.

TCCS™ proprietary core includes:

- a “tracking subsystem”,
- full 3D profile scan of rolling stock surface,
- full thermographic scan,
- high-resolution imaging,
- Human Machine Interface -HMI- to remotely manage in the OCC the alarms, train data and diagnostics information.

In particular, The TCCS™ detects high-resolution images with high-definition linear black and white cameras. The image acquisition and processing process is composed of the following steps:

- Acquisition of vertical linear frames of the transiting train at a constant acquisition rate;
- Use position and displacement information from the appropriate functions for the correct creation of 2D images. Vertical frames are put together side by side and the image is correctly re-proportioned to compensate for over-sampling and possible variations in speed.
- Use the information related to the train decomposition in individual rolling stock to isolate the part of the image corresponding to each individual rolling stock.
- Use the information related to the type of each single rolling stock to select the reference map defining the areas of interest for each type of rolling stock.

The system operates both day and night, using a solid-state NIR (quasi-infrared) illumination, which avoids any disturbance to drivers, being almost invisible to the human eye.

The high-resolution images (Figure 6-1) are used by remote Operators to check the generated alarms, without the need to stop the trains for further verification. Images are stored for online and off-line use.

The visible system can be configured and can automatically select the most important components of the vehicle on the basis of specific customer requirements, for example:

- brake shoes;
- couplers;
- suspension springs;
- decoupling levers;
- anti-friction wedges and ends of bolster areas;
- steps of the thresholds;
- bearing end caps;
- side frames;
- brake hoses.

The high-resolution image production subsystem generates a very high resolution image of approximately 70 MB for each wagon. Automatic image processing, aiming at recognizing and measuring configured parts is performed on these original images. Lower quality images are produced for the user interface, still being of very good quality for the human eye, to allow fast visualization.
To ensure correct functionality and measurement each camera produces a set of diagnostic data. These data are monitored by the TCCS™ in order to generate self-diagnostics and to ensure the correct functioning.

Figure 6-1. High resolution image obtained by the TCCS system (grey scale)

6.2.3 Automation Gate for harbour inbound/outbound (Aitek)

Aitek Sesamo-Gate is a complete solution for managing all people, vehicle and container control procedures for any pedestrian, roadway or train entry gate. Sesamo-Gate is a solution for the remote, automated control of gates and it is already employed by important operators in Italy’s larger ports and freight terminals. It does not require the presence of personnel at the gate, therefore greatly improving safety and the accuracy of acquired data and considerably reducing the time required for vehicle inspection and transit procedures.

The features of the system are:

- Manages sensors, actuators and interfaces for automated lane control procedures
- Functionalities: vehicle plate acquisition (tractor units and trailers), reading of container, swap body and semi-trailer codes (ISO6346, ILU), reading of railway wagon numbers (UIC), reading of ADR codes, volumetric measurement of vehicles
- Acquisition and recording of HD footage per single transit
- The system can be completely integrated with third-party supervisory systems and TOS (Terminal Operating System) systems and provides the acquired data and images in real time
- Remote/unmanned control of transit procedures
- Simplification of control procedures, tracking/tracing and customs management
- The software modules can be completely integrated for the development of applications which meet specific terminal operator requirements
Installation is possible even in scenarios with critical infrastructure constraints, in terms of both geometry and available space.

High performance standards (measurement reliability > 95%) are achieved with minimal operating requirements.

The technological infrastructure is composed of sensors, actuators and interfaces allowing the automation of the control processes performed in the gate lanes. All technological components of the railway gate are installed on a single gate. In railway scenarios the infrastructure constraints depend on the availability of an appropriate site for the installation on a railway stretch where trains travel at low speed.

The user interface is the frontend application allowing the complete control of the Sesamo-Gate system. Access to the application is given by using an Internet browser and allows viewing the stored transits. For each transit the following information is available:

- Date / time of the transit
- Lane
- Codes and plates recognized by the OCR subsystem
- Reliability percentage of the OCR detection
- HD recordings of the transit

The system main strengths are:

- Full automation of transit control procedures at access gates
- Highly modular platform tailored to specific operational needs
- Manages sensors, actuators and interfaces for automated lane control procedures
- Acquisition and recording of HD footage per single transit
- Full integration with TOS (Terminal Operating System)
- Remote/unmanned control of transit procedures
- Minimum operational requirements with high performance standards (>95% accuracy)

### 6.2.4 Automatic Highway toll system

Toll free-flow solutions are based on the use of gantries (or “gates”) with adequate equipment (cameras, Laser, RFID antennas) that allows the electronic collection of tolls in multi-lane environments, without affecting traffic flow. The technological approach of the video gate proposed for this project is very similar, and therefore it is worth presenting this solution as best practice to have as reference in the project.

Indra has its proprietary solution of free-flow gate, an electronic toll system that eliminates any barrier or toll lane, permitting the free flow of vehicles and avoiding congestion caused by traditional toll collection processes. The term Free-Flow implies that traffic does not stop or decelerate because the vehicle is detected, classified and identified automatically in real time, allowing for free driving, without the need for reducing speed or changing lanes.

The collection point is comprised of a metallic or gate structure that covers various lanes and is fitted with sensors that comprise the solution’s different modules, Figure 6-2.
The main modules of the gantry are the following:

- Module responsible for automatically detecting and classifying vehicles: uses laser sensors that detect the vehicle, calculate its speed and dimensions and extract a 3D profile. All of that information is processed by algorithms based on neural networks that make it possible to classify vehicles into predetermined categories. Optionally, this module makes it possible to integrate other types of sensors such as smart loops and piezoelectric sensors placed in the asphalt.

- The electronic toll collection module: makes it possible to automatically identify the vehicle through communication based on a microwave link (RFID) that is created between an antenna placed on the gate and the device on-board the vehicle (TAG). Upon passing under the gate a transaction is generated that is subsequently used at a back office level for the toll collection process.

- Violator enforcement system module: makes it possible to identify users who cross the collection point without a valid payment method. To do so, the system captures a front and rear image of the vehicle making it possible to automatically read the license plate using OCR technology.

- Multi-lane controller: processes all this information in real time, correlating it, generating a transaction and sending it to a higher level. The system offers: high availability through a redundant setup that avoids a single point of failure, high accuracy in generating the transaction, high malfunction tolerance, operation in degraded mode and integration with the central monitoring system.
Additionally, its modular and flexible design makes it highly adaptable to project requirements and allows it to implement other applications, such as detecting oversized vehicles, detecting vehicles carrying hazardous goods, performing traffic audits for the authorities or for third parties, obtaining traffic statistics (IMD, number of occupants, speed, etc.), and detecting restricted vehicles, among others.

In FR8HUB, the partners will also use as reference this technology and use the knowledge brought from the road domain in order to assess a non-intrusive technical solution to inspect the train features. Not only the technologies are similar (cameras, laser, RFID antennas, OCR), but also the way of correlating the acquired information. For example in roads the plates should be correlated with RFID Tags, while in rail the container ID can be correlated with their corresponding RFID tags, or with the size detected by the sensors.

### 6.2.5 RFID in Railway Systems

In railway applications, Passive UHF technology is commonly employed which implies that the tag has no battery and will be powered by a RFID reader, either through fixed installations or handheld mobile devices.

The RFID technology follow the open UHF standards, also called ISO18000-6C or better, meaning that different types of readers and tags from different vendors can be used and mixed. It’s also called “open air protocol” and used by most of the RFID vendors/suppliers around the world.

The air protocol handles only the communication between an RFID reader and a tag and will not consider the content stored in the tag. A major player who structures and standardizes the information in a tag is the Global standardization organization GS1, widely used in this kind of applications. GS1 also provides the standard of how to share information in a structured way called EPCIS that has become de facto standard within the railway industry in Europe.

The concept with EPCIS is a structured way to share information amongst different parties in Europe with information containing: What, Where, When and Why, as illustrated by Figure 6-3.

![Air protokoll: ISO18000-6 type C UHF Gen2 Class1](image)

EPC = Electronic Product Code
EPCIS = Electronic Product Code Information Sharing

*Figure 6-3. Standardization of information structure as well as communication between a reader and a tag.*
The concept has been widely adopted and implemented in several countries around Europe to track and trace railway vehicles along the tracks. The same concept is intended to be used for trucks/lorries as well.

According to the directive TSI WAG (861/2006/EC):

- Two passive tags shall be fitted, one on each side or the wagon, such that the unique identification number of the wagon can be read by a reader
- The Identification of a tag shall follow the given GS1 standard, EPC
- The EPC code will contain Wagon owner/operator + side indicator + EVN number
- Possibility to read the tag with the wagon speed well over 200 km/h

According to the GS1-Standard described the Swedish Rail has already fitted their wagons with RFID-tags in the last years with success. In October 2017 Deutsche Bahn AG also decided to follow the GS1-standard and to fit all wagons with suitable RFID-tags (Karl/Balters, 2018).

### 6.2.6 Internet of Logistics (IoL)

Internet of Logistics (IoL) system provides the secure, flexible, interoperable exchange of container and wagon information and digitized documents across participants of a multimodal transport. As such IoL overcomes the limitations of traditional supply chain communication system (e.g. EDI), that require the establishment of individual connections for each pair of supply chain partners or that demand the development software interfaces with legacy systems.

**The Intelligent Video Gateway (IVG): a powerful source of Digital Data**

The Intelligent Video Gateway (IVG) that is the central piece of our Shift2Rail project is a combination of cameras, 3D laser scanners and RFID readers that register a detailed “snapshot” of the characteristics of train, on the fly, while the train passes by the check-point.

As such, the IVG is a powerful and reliable tool that detects important facts (departure, transit, arrival etc.), that tracks cargo units (identity codes, location, load unit type, category of content), and checks asset conditions (damages), in real time, directly from the field. Therefore, the IVG produces a data set that includes the sequence and type of wagons that compose the train, the identity and type of each individual load unit carried by each wagon, special content information and constrains (e.g. dangerous goods signs) and related multimedia documents, such as images and 3D laser scans. Therefore, the IVG produces a “Train Data Set” that consists of a digital and faithful representation of the Train that is generated automatically at the departure Rail Terminal.

During the Train travel, the “Train Data Set” that was produced at the departure IVG could be cross-checked automatically at any IVG check-point along the route and, finally, it could be automatically validated at the Arrival Terminal. At arrival the IVG could eventually confirm the information that has been announced by other IVGs. In fact this Train Data Set is a digital representation, a sort of “Digital Twin” of the Train, that provides valuable input for receiving Interchange Terminals and Road Companies that are waiting for the cargo. Receiving Terminals and Road Companies, that cover the last mile of shipping, can use this data to take informed decisions, schedule operators, drivers,
vehicles, shunting personnel, cranes, warehouses and terminal space .... well in advance of Train arrival.

Smart applications can be developed using IVG data sent: for example a destination Terminal could determine the parking positions of trucks along the loading lane, that match the sequence of wagons and associated containers, so to minimize the movements of the crane, that operates above the tracks and that performs the train-to-truck and the truck-to-train loading activities (see Figure 6-4)

![Figure 6-4. Crane at DUSS Hamburg Billwerder.](image)

Even personnel and shunting agents at Rail Terminal, could take advantage of digital data, by using Mobile Devices, to identify or search wagons and load units and retrieve related information. The access to digital data can also enable operators to execute new inquiries across the entire network of IVGs, as for example they would be able to search by container type, identity, origin/destination, shipping company or even image searches, against the multimedia database produced by IVG.

Overall Freight-rail operators can use big data to improve their operations and overall business performance. Big data—massive data sets generated by vehicles, cameras, detectors and other unstructured data sources such as reports on production flows—can be applied to process-optimization and decision support. Big data technologies provide transparency into operations and can help Railways focus on inefficiencies.

The introduction of automated tools and digital technology has the potential to increase the utilization and capacity of each terminal, when all IVG checkpoints and databases work as a single common network, that we call Internet of Logistics.

**How to make IVG Data available and useful to Rail Industry Players**

To increase the level of automation (i.e. adoption of software algorithms), it’s necessary to produce and distribute the “Train-Data-Set” in a machine-readable format, that must be easily accessible by Terminal Operators and Transport Companies. On the other end, technical complexities and market conditions discourage from the adoption of a traditional IT implementation that would be needed to consolidate and distribute the IVG data sets from a central system.
The Freight Rail Market has become increasingly diverse, and it includes many different actors such as rail network managers, train operating companies, corridor specialists, service providers (e.g. locomotive/wagon rental companies), freight forwarders, terminal operators etc. Various businesses and operators share the rail infrastructure and the physical resources on the same network, but they rarely exchange digital information. Therefore, any initiative, aimed at establishing a common software data base or traditional IT central system to centralize the IVG data, would be extremely complex to coordinate and deliver, when confronted with the multinational and diverse nature of the rail freight sector.

Moreover, additional complexity is brought by the ever-increasing number of controls, visual signs, placards, identification codes, load units types that the rail industry needs to maintain, in order to accommodate the needs of multiple industries i.e. Petro-Chemicals, Automotive and Manufacturing, Waste Management, Food, Construction etc..

Therefore, in order to exchange useful IVG data, we must avoid “big bang” software integration projects, that bring together Rail Terminals and Operators from multiple countries, to define and implement a monolithic system that could cope with all possible containers codes and transport conditions. The European Freight Rail industry needs a different strategy and the World Wide Web, with its universally accepted standards, represents the best model of cooperation and data sharing infrastructure, that is not centralized but it’s based on a completely distributed approach, where a distributed network of web pages can refer to one another with global links called Uniform Resource Locators (URLs).

The World Wide Web is now so universally adopted, that its concepts and standards are familiar to anyone, and virtually everyone can use a standard tool, like a web browser, to make free text searches and to navigate across an extensive web of relationships that connect disparate subjects. A simple search about a historical figure or artist for example, can rapidly retrieve all facts, career, locations, works, friends that are associated to her /his identity.

Among major search engines, Google developed the so-called “Knowledge Graph” that is a knowledge base used to enhance search results, with information gathered from a variety of sources, where information is presented to users in an infobox next to the search results, almost in real-time when users type their queries (see Figure 6-5 below).

Figure 6-5. Knowledge Graph data about Thomas Jefferson (rightmost box) displayed on Google Search (Source Wikipedia)
The fundamental concept is to store information available on the web, as a Graph of Data items, such that people, events, documents, pictures and multimedia files etc. are connected by properties that relate such disparate items. This Graph Database is the most flexible data model, as new data can be added without the need to apply a predetermined rigid schema (as for example with tabular databases with fixed rows and columns) and user inquiries are performed by navigating through a vast web of concepts.

Besides, large social networks such as Facebook and LinkedIn, have been using these Graph Databases to model relationships between people, friends and colleagues, into so-called Social Graphs (Figure 6-6).

![Figure 6-6. Social Graph (Source Quora - https://www.quora.com/What-are-social-graphs - posted by V. Shetty – 2013)](image)

Similarly, DBpedia\(^7\) organizes the massive amount of information contained in the Wikipedia knowledge base, and Google develops its search and recommendation engine on the DBpedia knowledge base and the CIA World Factbook\(^8\), that includes 600Mil terms/topics and 20Bil related facts and events.

**The World Wide Web evolves into the Semantic Web**

The Web, as a global information space, evolves from linking documents (such as web pages), to linking both documents and data\(^9\), so to supports the design of innovative applications and relationships between elements of information. (Curé, 2015) Such an evolution of the World Wide Web is referred to as Semantic Web, and it enables the access and sharing of information, in ways that are much more efficient and more open than traditional database IT solutions. The Semantic Web supports links between distributed data sources, with a structure that is defined and managed

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\(^7\) DBpedia is a project aiming to extract structured content from the information created in the Wikipedia project. This structured information is made available on the World Wide Web (Source Wikipedia)

\(^8\) The CIA World Factbook provides information on the history, people, government, economy, energy, geography, communications, transportation, military, and transnational issues for 267 world entities (CIA, 2018)

\(^9\) From “RDF Database Systems” Olivier Curé and Guillaume Blin – Elsevier Inc. 2015
by open standards and tools. The World-Wide Consortium (W3C\textsuperscript{10}) has provided these tools in the form of standard Semantic Web languages, complete with abstract syntax, model-based semantics, reference implementations, test cases (Hendler, 2011). The standard that the Semantic Web uses to model a distributed web of data, is called the Resource Description Framework (RDF) which precisely structures information as a Graph Database, as specified by W3C (W3C, RDF Current Status, 2018).

Professional Communities (e.g. Scientists, Researchers, Media Publishers) that need to share and reuse complex knowledge, can adopt the Semantic Web standards, to establish a common vocabulary, a common “language” that maps the concepts and properties of their domain of interest\textsuperscript{11}.

Time to make few examples: innovative industries as Health Care and Life Sciences, provide significant examples of Semantic Web applications, where large numbers of professional users, from different organizations, in multiple countries, formalize a common vocabulary, share information and execute projects. This Semantic Web application manages complex knowledge domains such as Biology, Genomics or Drug Development Cycle:

- The Open Biological and Biomedical Ontology (OBO) Foundry (OBO_Technical_WG, 2018), is a collective of ontology developers that work to create and maintain controlled vocabularies for shared use across different biological and medical domains, from Antibiotic resistance genes and mutations to cell types in animals and Potential Drug-drug Interaction.

- Gene Ontology (GO) Consortium (The Gene Ontology Consortium, 2018) is a bioinformatics initiative, to unify the representation of gene and gene product attributes. GO aims to maintain and develop its controlled vocabulary of gene and gene product attributes and provide tools for easy access to all aspects of the data.

- SNOMED Clinical Terms is a systematically organized computer processed collection of medical terms providing codes, terms, synonyms and definitions used in clinical documentation and reporting. The primary purpose of SNOMED CT is to encode the meanings that are used in health information and to support the effective clinical recording of data with the aim of improving patient care. SNOMED CT provides the core general terminology for electronic health records. SNOMED CT comprehensive coverage includes: clinical findings, symptoms, diagnoses, procedures, body structures, organisms and other etiologies, substances, pharmaceuticals, devices and specimens (source Wikipedia).

Such bioinformatics tool and databases, that are shared among large communities of medical scientists and practitioners, can accelerate Drug discovery, with virtual screening and computer simulation, while reducing the need for expensive lab work and clinical trials, for example by producing and screening drug candidates more effectively.

\textsuperscript{10} The World Wide Web Consortium (W3C) is an international community where Member organizations, a full-time staff, and the public work together to develop Web standards. Led by Web inventor and Director Tim Berners-Lee and CEO Jeffrey Jaffe, W3C’s mission is to lead the Web to its full potential. Contact W3C for more information - Copyright © 2018 W3C - \url{https://www.w3.org/Consortium/} (W3C, About W3C, 2018)

\textsuperscript{11} Such common vocabularies and languages are called Semantic Models or “Ontologies”. RDF data sets can be described with expressive schema languages, that can specify concepts and relationships (that is the “Ontology”); examples of standard ontology languages are RDF Schema (RDFS) or Web Ontology Language (OWL).
Internet of Logistics – Application to Freight Rail

FR8HUB WP4 IVG is open to adopt the Semantic Web standards and Resource Description Framework (RDF) to model, share and search Freight Rail Container and Wagon data, and to design and pilot RDF databases that collect and expose IVG information. Access to interested and authorized parties depend on further partner agreements and content definitions.

With this first generally descriptive approach, IVG databases could be stored, managed and published at each Rail Terminal, so that Rail Terminals could establish a web of connected databases. This network of IVG could be linked according to Semantic Web standards. Data items (i.e. load units, vehicles, shipping documents, images and 3D scans, train composition etc.) can point to corresponding items, using global references, similar to web addresses\(^\text{12}\).

As required, such a structure provides a data model, where information is distributed across different IVG databases, but still it can be searched and analysed as a common knowledge base. This approach guarantees the maximum level of flexibility and distribution, but it also allows various stakeholders (Rail Terminals, Trucking Companies, Warehouse Operators, Rail Operators) to build their own IVG and to join the initiative, according to their own tempo and needs. Each IVG owner will keep full control over the data that they publish, while other Terminals will able to search and analyse the Rail data, even though the information is distributed and controlled by more than one organization.

![Figure 6-7. Example of Graph Database for Rail Industry](image)

Particular attention must be paid to access control to data. Developments in social networking have brought concerns about privacy and ownership of data because these powerful web technologies

\(^{12}\) The Web Addresses that are used as identification are called Uniform Resource Identifiers (URIs)
make it possible to discover all sort relationships, between people, their preferences and places, events and lifestyles. Big Internet Companies have made extensive use of web technologies to build their business models and to monetize people profiles and preferences. As a rule, on the World Wide Web the data should be in the hands of the content producer.

EU Shift2Rail organization could be a suitable community forum to establish the rules of data sharing in the Rail sector, and to define the checks that need to be applied when publishing of the Train Data Set, with full compliance to the frameworks of EU rail market regulations and also EU Personal Data Protection Regulation (GDPR). As a basis the fundamental rule is that the Rail Terminal where the Train originates from, and that produces the Train Digital Twin, retains full control of users who are granted access to information and remains the owner of images, documents and data records that are published by its own IVG system.

The new Internet of Logistics could extend and grow as new terminals and rail operators will set up their own IVG and start to generate and read data, a virtuous cycle called network effect. As more Rail Terminals and IVGs would join the initiative, the value of the distributed and linked data would increase exponentially and could provide Rail Stakeholder the opportunity to make new types of queries (image search, partial match, type of goods) and to develop new smart applications.

The adoption of the Internet of Logistics technology is complementary, not mandatory and not overlapping with Ip2 and Ip3 objectives. Requirement would be to define a common structure and semantic for the data that is generated by IVGs. IVG RDF technology could help to facilitate and automate data access and analysis by external stakeholders, so to enable IP2 and IP3 to design optimal data integration solutions across the entire Freight Network.

Internet of Logistics supports a distribute “backbone” that collects and publishes IVG. Internet of Logistics makes IVG data available to entitled and authorized partners on a “need-to-know” basis, without any replication of data records and without the need to establish a centralized database instance of all logistic data.

### 6.3 Components

The main technical components composing the Intelligent Video Gate are:

- Cameras
- Illuminators
- RFID antennas and tags
- Scanners
- Wheel sensors

For each of these components a detailed description is provided, together with its main technical characteristics, necessary for component evaluation during the selection process described in the following sections.

#### 6.3.1 Train Detection and Consistency Evaluation System

This system is already present in the market at a TRL9 level and used in some bigger systems such as Trafikverket RFID recognition system and Ansaldo STS TCCS.

The main objectives of the system are:

- Detection of a new approaching train and its speed
- Detection of the train composition in terms of locomotive and wagon models
• Detection of the speed of the train and its longitudinal displacement function (displacement along the rail)
• Detection of the train end

Figure 6-8 shows an example of a freight train composition, consisting on a 6 wheels locomotive model E632-633-652, followed by 14 freight wagons with different axles number ranging from 4 to 8.

This train detection and consist elaboration system is normally based on same wheel sensors types used for axle counter signalling. See Figure 6-9 for an example of wheel sensor and evaluation board. Each train wheel passing at the proximity of a wheel sensor is acquired and recognized by the evolution board.

The wheel sensors are used both for detecting a new train (wakeup sensor), identifying its composition through algorithms that calculate the precise distance between consecutive axles and for elaborating the longitudinal displacement function of the train.

All the above information is required by other system components (e.g. camera, scanner and RFID antenna) to:
• Start acquiring and elaborating the new train
• Produce single vehicles images correctly proportioned independently from the train speed and acceleration (camera and scanner only)
• Analyse the train vehicles for defects detection and features measurement (camera and scanner only)
• Stop acquiring data from the train when it passes away
Some work is necessary in the selection of components of the system, with a particular attention on the choice of the correct wheel sensor to use, depending on installation site characteristics such as train speed, power supply, track characteristics etc. The main classes of wheel sensor components to be used are:
- Proximity (electromagnetic) sensors
- Fibre optics sensors

Fiber optics sensors provide some very interesting advantages such as full Electromagnetic Compatibility (EMC), no need for power supply on the track and the possibility to be used also for weight, imbalances and wheel defects detection function.

6.3.2 Cameras

One of the most important components of the intelligent video gate is a digital camera, capable of acquiring images of rolling stock sides.

A standard camera is composed of a lens, exposure controls, image capture and storage components as shown in figure. The lens together with the exposure control defines the optical characteristics of the camera such as field of view, focus, depth of view, luminosity, integration time, etc.

The image capture and storage components replace the old fashioned photographic film. The capture part is a matrix or array of single sensible elements called pixels. The storage part is an internal memory or a buffer used to pack and transfer data via a communication channel such as a camera link, usb or ethernet cable.

Below a high level description of a digital camera’s main characteristics is provided.
Digital cameras come in two primary types based on the sensor technology they use and these are CCD’s, and CMOS cameras. There are positive and negative points in both depending on the context bringing to not a clear supremacy of one over the other.

The spectral response of a camera refers to the detected signal response as a function of the wavelength of light. This parameter is often expressed in terms of the Quantum Efficiency (QE), a measure of the detector’s ability to produce an electronic charge as a percentage of the total number of incident photons that are detected.

The sensitivity of a camera is the minimum light signal that can be detected and by convention we equate that to light level falling on the camera that produces a signal just equal to the camera’s noise. Hence the noise of a camera sets an ultimate limit on the camera sensitivity. Digital cameras are therefore often compared using their noise figures and noise derives from a variety of sources principally:

- **Read Noise**: inherent output amplifier noise
- **Dark Noise**: thermally induced noise arising from the camera in the absence of light (can be reduced by lowering the operating temperature)
- **Shot Noise (Light Signal)**: noise arising out of the stochastic nature of the photon flux itself

Dynamic Range is a measure of the maximum and minimum intensities that can be simultaneously detected in the same field of view. It is often calculated as the maximum signal that can be accumulated, divided by the minimum signal which in turn equates to the noise associated with reading the minimum signal. It is commonly expressed either as the number of bits required to digitise the associated signals or on the decibel scale.

A camera’s signal-to-noise ratio (commonly abbreviated S/N or SNR) is the comparison measurement of the incoming light signal versus the various inherent or generated noise levels and is a measure of the variation of a signal that indicates the confidence with which the magnitude of the signal can be estimated.

Digital cameras have finite minimum regions of detection (commonly known as Pixels), that set a limit on the Spatial Resolution of a camera. However the spatial resolution is affected by other factors such as the quality of the lens or imaging system. The limiting spatial resolution is commonly determined from the minimum separation required for discrimination between two high contrast objects, e.g. white points or lines on a black background. Contrast is an important factor in resolution as high contrast objects (e.g. black and white lines) are more readily resolved than low contrast objects (e.g. adjacent grey lines). The contrast and resolution performance of a camera can be incorporated into a single specification called the Modulation Transfer Function (MTF).

The Frame Rate of a digital camera is the fastest rate at which subsequent images can be recorded and saved. Digital cameras can readout sub sections of the image or bin pixels together to achieve
faster readout rates, therefore typically two frame rates are defined, i.e. one is a full frame readout rate and the other is the fastest possible readout rate.

All cameras, to some degree, exhibit blemishes which affect the reproduction of the light signal. This is due to several variables, i.e.:

- Gain variations across the sensor
- Regional differences in noise

### 6.3.3 Illuminators

Intelligent Video Gate 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 some not extreme weather conditions, such as heavy rain, fog and snow.

One of the most important characteristics of an illuminator is illuminance, defined as the total luminous flux incident on a surface, per unit area. This is shown in figure for visible light measured in lumen/m² (cd*sr/ m²), where cd is the candela SI unit and sr the steradian solid angle SI unit. If visible light is not used for illumination, but other types such as UV or NIR the unit used for illuminance is W/ m². Other important derived unit is radiant intensity measured in W/sr.

Another very 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 coupling among a chosen illuminator and camera, in order to efficiently exploit camera sensitivity range and peaks.

![Illuminance E](image)

**Figure 6-11. Illuminator**

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.
6.3.4 RFID antennas and tags

Radio Frequency Identification is a technology that allows almost any object to be wirelessly identified using data transmitted through radio waves. This technology allows you to identify and track individual items, as well as multiple items simultaneously, without a direct line of sight. RFID tag antennas are designed for a unique purpose, and their design can actually reveal some information about the tag itself.

It is generally quite easy to detect the frequency with which the tag operates only by examining the tag. This is because the correlation between the tag’s antenna design and the way the tag talks to the RFID reader / antenna will reveal the frequency. The following are the three main types of frequencies used:

Low Frequency (LF):
- **Frequency**: 125 – 135 kHz – generally, 124 kHz, 125 kHz, or 135 kHz;
- **Read Range**: Touch to 45.7 cm (18 in) under ideal conditions;
- **Coupling Technique**: Inductive coupling – reader’s antenna generates a magnetic field to activate an electric current in the tag’s antenna;
- **Antenna Design**: Typically, circularly coiled tag antenna

High Frequency (HF):
- **Frequency**: 13.553 – 13.567 MHz – generally, 13.56 MHz;
- **Read Range**: Touch to around 1.5 m (5 ft.) under ideal conditions;
- **Coupling Technique**: Inductive coupling – reader’s antenna generates a magnetic field to activate an electric current in the tag’s antenna;
- **Antenna Design**: typically, rectangular or circular-shaped, small tag antenna

Ultra-High Frequency (UHF):
- **Frequency**: 400 – 1000 MHz – generally, 860 – 960 MHz;
- **Read Range**: Up to 35 m (115 ft.) under ideal conditions;
- **Coupling Technique**: Backscatter coupling – reader’s antenna generates RF energy to activate the RFID tag, which modulates the information and reflects the remaining energy back to the reader antenna;
- **Antenna Design**: Typically, dipole-shaped tag antenna;
- **Near-Field Capabilities**: If it has a small loop-shaped antenna in the middle, it usually has near-field capabilities.

Most UHF tag antennas are designed with a dipole-type structure. This means they generally are long and thin visually, and operate similar to a magnet. The similarity is apparent because they have two ‘open’ ends, or poles, for the energy to build up and, consequently, allow a current flow to the Integrated Circuit (IC), or chip.

The most well-known RFID tags on the market that are not structured like a typical dipole antenna are similar to the SMARTARAC Frog and the Alien Spider. The most common RFID tag used for railway vehicles is the Confidex Ironside tag. These tags are square-shaped in order to best display their omni-directional properties and are sometimes called “dual-dipole” tags.

Tag antennas are made from a metal wire or metallic sheet in order to provide an adequate conductor for the RF energy. Then, depending on the type of tag, other types of materials like PET, plastic, paper, and polyester are used to provide the base around the tag antenna.
6.3.5 Laser Scanners

Nowadays laser scanners are used for a variety of applications and projects such as robotics, rail and automotive transport, objects sorting and counting, bolts and washers’ quality control, small objects scanning and counting, large diameter pipes parameters control, welding control, 3D imaging and research applications.

In particular, in rail applications, laser scanners are not only used for rail track surveying but also for capturing objects alongside the track like buildings, tunnels, bridges or other objects which might cause a potential danger for rail traffic.

The high resolution surveying of objects like station platforms or tunnels is necessary for clearance analysis or analysing tunnel walls. When carrying oversized loads a preflight can be performed to detect narrow points.

There are mainly three types of laser sensors available, depending on the technologies used for the measurement process:

- Time of Flight
- Phase shift
- Triangulation

All the three above types produce a concentrated light beam of a certain limited wavelength called LASER. The first two are equipped with a detector for collecting the amount of light reflected back by the surface subject to measure.

In the Time of Flight case a very accurate internal clock is used to measure the time needed by the laser beam to hit the surface and turn back to the receiver. One of the main disadvantages of this technique is the accuracy requested by the internal clock, which should measure laser beam travel time performed at light speed.

![Figure 6-12: Laser Scanner – Time of Flight](image)

The phase shift sensors produce a periodic modulated laser beam signal and instead of measuring the time needed by the laser to hit the target and turn back, measure the phase of the laser return signal. The phase of the signal, being this periodic and compared with the phase of the emitted signal, can be transformed to travel time. No need for high timing accuracy is needed.
The third type makes use of a robust industrial camera to acquire the surface subject to measure, marked by the laser emitted beam. The laser beam in the acquired image is used by image processing techniques to perform distance measurements.

Laser scanners main parameters are the following:
- Laser wavelength and power (also eye safety classification)
- Scanning frequency (profiles per second)
- Points per profile
- Field of view
- Measurement accuracy
6.4 Selection process & selection criteria

A formal selection process is proposed in this section to be used for the definition of Intelligent Video Gate components. The very first step consists on the definition of a standard technical data sheet for each of the components, e.g. cameras, illuminators, etc. The data sheet will include components technical characteristics, better representing the component category and mainly impacting its functionality inside the Intelligent Video Gate.

Then a market study will be performed, selecting some of the most promising components available on the market. A technical sheet will be filled with the technical data of each of the selected components, providing a consistent and easily to compare bases for the further evaluation step. Indeed, commercial components already have data sheets available, but normally these are heterogeneous in parameters completeness and representation. A standard data sheet, tailored to the needs of the IVG, provides a better and faster comparison.

Subsequently a number of evaluator experts, chosen from the project partners, will be defined for the real evaluation step. Considering the technical data sheets filled before each evaluator will give a rating from 0 to 10 for each of the components. The final score of the component will be calculated as the mean of all evaluators’ scores. An additional point could be assigned to the components if this was in some way tested in laboratory or relevant environment, by a project partner or in an existing system. The final score of the components will then be a number ranging from 0 to 11.

The final step of the selection process consists in the publication of the final rating results, with the better evaluated components at the classification top level.

The idea behind the selection process is that of providing a formal methodology for selecting a component, but not that of selecting the definitive ones to be used by the Intelligent Video Gate. Indeed, to the best of our knowledge, the best suitable components will be evaluated for a theoretical scenario. Still, ongoing work on this project and on the following, will better test the components in laboratory and in relevant environment, highlighting unexpected positive or negative characteristics. Another important consideration is that also depending on the real Terminal characteristics, such as number of tracks, installation position, environmental conditions, etc., a different component may be preferred to another one, even if the latter had a better evaluation score for the theoretical scenario. The relative high speed with which the hardware market is evolving, proposing new improved components at a lower cost and setting out of production existing ones is a final consideration to be kept in mind. As a conclusion, the main objective of the selection process is the process definition itself, together with an exemplification on a theoretical scenario, providing indications to further testing and site rollout activities.

Below follows a more detailed description of the components technical sheets and the evaluation ones.

An empty wheel sensor technical sheet is presented in Figure 6-15. Producer name is defined as the first parameter, providing information on the company producing the wheel sensor, followed by model name and description. Wheel sensor type is defined as mainly electromagnetic or fiber optics, even though there could be other less common types, such as piezoelectric, accelerometers, etc. Mounting is a very important parameter, providing information on the point of the rail where to mount the sensor, and if drilling is necessary or not. Accuracy depends on the type of the sensor, and could be the proximity range for electromagnetic types, strain measurement for fiber optics, etc.
Then general characteristics, environmental, operational or power consumption related follow. Finally price and notes are provided if known.

<table>
<thead>
<tr>
<th>Sheet Number</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Producer</td>
<td></td>
</tr>
<tr>
<td>Model Name/SN</td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>Pixel technology</td>
<td>e.g. CCD/CMOS</td>
</tr>
<tr>
<td>Array Type</td>
<td>Linear/Matrix</td>
</tr>
<tr>
<td>Pixel size (um)</td>
<td></td>
</tr>
<tr>
<td>Responsivity</td>
<td></td>
</tr>
<tr>
<td>Line rate (kHz)</td>
<td></td>
</tr>
<tr>
<td>Dynamic range</td>
<td></td>
</tr>
<tr>
<td>Communication Interface</td>
<td>e.g. GigE, cameraLink, etc</td>
</tr>
<tr>
<td>Resolution</td>
<td></td>
</tr>
<tr>
<td>Data Format</td>
<td>bits/pixel</td>
</tr>
<tr>
<td>Dimensions</td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td></td>
</tr>
<tr>
<td>Operating Temp</td>
<td></td>
</tr>
<tr>
<td>Power consumption</td>
<td></td>
</tr>
<tr>
<td>Power supply</td>
<td></td>
</tr>
<tr>
<td>Dig Input Control</td>
<td></td>
</tr>
<tr>
<td>Lens Mount</td>
<td></td>
</tr>
<tr>
<td>Calibration</td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td></td>
</tr>
<tr>
<td>Notes</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6-15. Camera technical sheet

An illuminator empty technical sheet is provided in Figure 6-16. Producer name is defined as the first parameter, providing information on the company producing the illuminator, followed by model name and description. Illuminator type should be specified, even though mainly LED emitters will be preferred in the market selection process. Light source array size together with divergence provides the illuminated area. Wavelength spectrum together with emitted power gives information on the emitted light characteristics. Line rate is used only for impulsive illuminators, i.e. those turning on and off with a configurable or piloted frequency through the control interface. Then general characteristics, environmental, operational or power consumption related follow. Finally price and notes are provided if known.
A scanner empty technical sheet is provided in Figure 6-17. Producer name is defined as the first parameter, providing information on the company producing the scanner, followed by model name and description. Measurement principle, e.g. phase shift or triangulation, follows, together with emitted laser wavelength (in nm). Resolution parameters such as line rate (in Hz) and number of points for frame are provided. Communication interface is particularly important in the IT definition architecture. Follow some acquisition important parameters, such as acquisition range (min and max distance) and angle. Accuracy is the most important measurement parameter. Laser class is relevant for human safety operational requirements. Mounting repeatability and calibration are important parameters related to the measurement aspects. Then general characteristics, environmental, operational or power consumption related follow. Finally price and notes are provided if known.

<table>
<thead>
<tr>
<th>Sheet Number</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Producer</td>
<td></td>
</tr>
<tr>
<td>Model Name/SN</td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>Illuminator Type</td>
<td>e.g. LED</td>
</tr>
<tr>
<td>Light sources array size</td>
<td></td>
</tr>
<tr>
<td>Wavelength spectrum</td>
<td></td>
</tr>
<tr>
<td>Divergence</td>
<td></td>
</tr>
<tr>
<td>Emitted power</td>
<td></td>
</tr>
<tr>
<td>Line rate</td>
<td>may be fixed</td>
</tr>
<tr>
<td>Control Interface</td>
<td>e.g. GigE, CameraLink, etc</td>
</tr>
<tr>
<td>Dimensions</td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td></td>
</tr>
<tr>
<td>Operating Temp</td>
<td></td>
</tr>
<tr>
<td>Power consumption</td>
<td></td>
</tr>
<tr>
<td>Power supply</td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td></td>
</tr>
<tr>
<td>Notes</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6-16: Illuminator technical sheet
A wheel sensor empty technical sheet is provided in Figure 6-18. Producer name is defined as the first parameter, providing information on the company producing the sensor, followed by model name and description. Wheel sensor type describes the functioning principle, e.g. electromagnetic or fibre optics. The mounting type is important, especially if rail drilling is required. Follows measurement accuracy and control interface, e.g. electrical or optical. Then general characteristics, environmental, operational or power consumption related follow. Finally price and notes are provided if known.

An RFID antenna empty technical sheet is provided in Figure 6-19. Producer name is defined as the first parameter, providing information on the company producing the antenna, followed by model name and description. Read range is a very important parameter, defining the maximum sensitivity
of the antenna depending on distance from the reader. Frequency band together with RFID standard provide information about compliancy with RFID tags and installation environment. MTBF (Mean Time Between Failures) is a Life Cycle Cost and Availability important parameter to consider. Follow operating voltage and power consumption as relevant power supply parameters. Communication interface and antenna shape are followed by environmental characteristics. Finally price is provided if known and any notes.

<table>
<thead>
<tr>
<th>Sheet Number</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Producer</td>
<td></td>
</tr>
<tr>
<td>Model Name/SN</td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>Read range</td>
<td></td>
</tr>
<tr>
<td>Frequency band</td>
<td></td>
</tr>
<tr>
<td>RFID Standard</td>
<td></td>
</tr>
<tr>
<td>MTBF</td>
<td></td>
</tr>
<tr>
<td>Operating Voltage</td>
<td></td>
</tr>
<tr>
<td>Power Consumption</td>
<td></td>
</tr>
<tr>
<td>Interface</td>
<td></td>
</tr>
<tr>
<td>Antenna</td>
<td></td>
</tr>
<tr>
<td>Enclosure rating</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td></td>
</tr>
<tr>
<td>Dimensions (L x W x H)</td>
<td></td>
</tr>
<tr>
<td>Operating Temperature</td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td></td>
</tr>
<tr>
<td>Notes</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 6-19 RFID antenna technical sheet**

Figure 6-20 shows an empty evaluation sheet for the camera components. Camera models are listed at the left, while evaluators’ scores are provided for each evaluator. The technical score of a model is calculated as the mean value of all evaluators’ scores. An additional 1 point is added if the components is tested or not in some environment, such as laboratory, field or existing system. In the example below, two camera models are evaluated. The scores provided to both cameras by the evaluators are the same resulting in an equal technical score for both cameras. As only for the second camera some kind of testing has been made, the final score of the latter is 1 point higher than the prior.

**Figure 6-20: Camera evaluation sheet**

### 6.5 Market study

After the selection process was described in detail in section 6.4 a study of the market has been conducted to select the candidates for the components evaluation process. The technical sheets of
the market selected components are presented in Appendix I, while the final evaluation and ranking is provided in Fehler! Verweisquelle konnte nicht gefunden werden.

The most promising components have been selected for all the categories defined in previous sections, to the best of our knowledge at the moment of writing this deliverable.

6.6 Selection of components

As described in section 6.4 a technical components selection process has been defined for the IVG project, starting with the definition of technical data sheets and continuing with a first selection of the most promising components present in the market at the moment of writing this deliverable (refer to Appendix I). The components selected in this first stage were studied thoroughly and evaluated by a small group of technical experts, considering their suitability for the Intelligent Video Gate based on their technical characteristics. The expertise of the technical experts chosen is important because sometimes the most performing sensor is not necessarily the right choice, for example being overperforming (and too expensive) for the scope of the project.

For the camera, illuminator, scanner and wheel sensor components Roald Lengu and Giuseppe Gotelli from Ansaldo STS have been chosen as the experts with better expertise. This choice has been made unanimously by all the project partners.

For the RFID component Gunnar Ivansson from Learning Well has been chosen as the main expert together with Roald Lengu from Ansaldo STS.

Table 6-2 presents the final ranking of the camera models considered for this project, with linear camera Spyder 3GigE Vision SG-14 outperforming the Linea models, because it is already tested in relevant environment. Indeed this camera model has been successfully employed in the Ansaldo TCCS product (see section 6.2.2). A problem that could arise in the future could be the availability in the market of this model, being it released several years ago. In that case Linea models, having slightly lower scores could be considered as good alternatives.

<table>
<thead>
<tr>
<th>CAMERA MODELS</th>
<th>Roald Lengu</th>
<th>Giuseppe Gotelli</th>
<th>Technical Score</th>
<th>Tested Not/Tested (0/1)</th>
<th>Final Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spyder3 GigE Vision 5G-14 Dual Line Scan Monochrome Camera-Teledyne Dalsa</td>
<td>9</td>
<td>10</td>
<td>9</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Lines™ 2K GigE Vision™ Monochrome CMOS Line Scan Camera-Teledyne Dalsa</td>
<td>9</td>
<td>5</td>
<td>8</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Lines™ 4K GigE Vision™ Monochrome CMOS Line Scan Camera-Teledyne Dalsa</td>
<td>6</td>
<td>8</td>
<td>7</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Gene™ Nano Cameras XL-Teledyne Dalsa</td>
<td>6</td>
<td>6.5</td>
<td>6.3</td>
<td>1</td>
<td>6.25</td>
</tr>
<tr>
<td>Gene™ Nano Cameras-Teledyne Dalsa</td>
<td>5</td>
<td>6.5</td>
<td>5.5</td>
<td>0</td>
<td>5.5</td>
</tr>
<tr>
<td>Vega HD</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 6-3 presents the final ranking of the illuminator models considered for this project, with LUL-350-1 linear illuminator outperforming LX150 and LX300 ones, because it has already been tested in relevant environment. Indeed this illuminator model has been successfully employed in the Ansaldo TCCS product (see section 6.2.2). The choice of a linear illuminator was also imposed by the selection of a linear camera just before.
Table 6-3 Illuminator Models final ranking

<table>
<thead>
<tr>
<th>ILLUMINATOR MODELS</th>
<th>Roald Lengu</th>
<th>Giuseppe Gotelli</th>
<th>Technical Score</th>
<th>Tested Not/Tested</th>
<th>Final Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>LUL350-1-European Advanced Technologies S.r.l.</td>
<td>8</td>
<td>9</td>
<td>8,5</td>
<td>1</td>
<td>9,5</td>
</tr>
<tr>
<td>LX310</td>
<td>LX300 Direct-Connect Linear Light- Smart Vision Lights</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>LDV1200-3R40 Outdoor Series- Smart Vision Lights</td>
<td>6</td>
<td>8</td>
<td>7</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>LMF500 Fluorescent Replacement- Smart Vision Lights</td>
<td>5</td>
<td>6</td>
<td>5,5</td>
<td></td>
<td>5,5</td>
</tr>
<tr>
<td>LLP X-H Series - Smart Vision Lights</td>
<td>5</td>
<td>6</td>
<td>5,5</td>
<td></td>
<td>5,5</td>
</tr>
</tbody>
</table>

Table 6-4 presents the final ranking of the scanner models considered for this project, with Scanner SPS outperforming LMS 5xx, because it has already been tested in relevant environment. Indeed this scanner model has been successfully employed in the Ansaldo TCCS product (see section 6.2.2). The main drawback with this scanner is that it is a top level performing in terms of accuracy and resolution, which is reflected in its final cost. A good alternative could be the LMS 5xx scanner from SICK.

Table 6-4 Scanner Models final ranking

<table>
<thead>
<tr>
<th>SCANNER MODELS</th>
<th>Roald Lengu</th>
<th>Giuseppe Gotelli</th>
<th>Technical Score</th>
<th>Tested Not/Tested</th>
<th>Final Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scanner SPS</td>
<td>7.5</td>
<td>7</td>
<td>7.25</td>
<td>1</td>
<td>8.25</td>
</tr>
<tr>
<td>LMS 5xx</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>LD MRS</td>
<td>5</td>
<td>6</td>
<td>5.5</td>
<td></td>
<td>5.5</td>
</tr>
<tr>
<td>CLV6x - Sick</td>
<td>3</td>
<td>4</td>
<td>3.5</td>
<td></td>
<td>3.5</td>
</tr>
<tr>
<td>CI-CI Series High Speed 3D Imaging with Ultra-High Resolution - Automation Technology Vision Sensors and Systems</td>
<td>3.5</td>
<td>3</td>
<td>3.25</td>
<td></td>
<td>3.25</td>
</tr>
<tr>
<td>LD-DWEM - Sick</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

Table 6-5 presents the final ranking of the wheel sensor models considered for this project, with Optosmart OS-WIM-S1 outperforming Frauscher RSR110d. The choice was mainly conditioned by the type of sensor, based on optical fiber technology. This has several advantages in terms of Electromagnetic Compatibility (EMC) and allows also the usage of the same sensor for performing other interesting measurements, such as wheel load, imbalances and defects.

Table 6-5 Wheel sensor models final ranking

<table>
<thead>
<tr>
<th>Wheel sensor MODELS</th>
<th>Roald Lengu</th>
<th>Giuseppe Gotelli</th>
<th>Technical Score</th>
<th>Tested Not/Tested</th>
<th>Final Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optosmart OS-WIM-S1</td>
<td>9</td>
<td>8</td>
<td>8.5</td>
<td>1</td>
<td>9.5</td>
</tr>
<tr>
<td>Siemens WSS</td>
<td>7</td>
<td>8</td>
<td>7.5</td>
<td>1</td>
<td>8.5</td>
</tr>
<tr>
<td>Frauscher RSR110d</td>
<td>7</td>
<td>6</td>
<td>6.5</td>
<td>1</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Table 6-6 presents the final ranking of the RFID Antennas considered for this project, with all antennas provided a very high score. There is indeed a huge number of potential RFID suppliers that can be used as long as they follow the given standards and the performance in reading capacity (reading distance, number of tags/sec etc. are not that different between suppliers). The main differences between readers are the formfactor, communication interfaces, I/O-ports, number of antennas, internal computer capacity and application SW and frameworks.

Table 6-6 RFID Antennas final ranking
### Table 6-6 RFID Antenna Models final ranking

<table>
<thead>
<tr>
<th>RFID Antenna MODELS</th>
<th>Gunnar Ivanson Learning Well</th>
<th>Road Lengu ASTS</th>
<th>Technical Score</th>
<th>Tested Not/Tested (0/1)</th>
<th>Final Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>TagMaster XT-3HD Reader</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>SICK AG RFU630</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>IMPPSU Speedway RAIN RFID</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Harting Technology Group Ha-VIS-RFID RF-R500</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>
7 Conclusion and Recommendations

This report summarizes the situation today, description of functional and technical requirements for the Intelligent Video Gates (IVG) and a presentation and selection of components for the IVG. The aim of this project is to initiate the next logical step to a higher automation of terminals and to reduce the lead time needed for the identification/verification process of train-sets by implementation of IVG. The IVG overall process is to support the general functions of the terminal operator to identify, verify and document the main steps within the transport chain due to the upcoming change of responsibility and liability for the freight, such as automatic identification of vehicles and load units as well as image documentation of quality and damages. Practical problems in the intermodal transport chain make the processes for the IVG more complex.

Some examples of common problems are:

- poor optical condition of numbers on wagons and load units for OCR-identification
- acceptance of non-standardized load units
- different load unit types and standards
- inappropriate positions of signs, markings etc.
- existence of transport/transhipment critical damages
- incorrect hazardous cargo status of placards
- breach of (customs) seals
- expired CSC-safety approval plates or load unit revision dates
- handling or shunting mistakes

The IVG must handle these issues and solve them in the best possible way to be able to provide correct and reliable information. As a technical system the IVG consists of structural components, technical components as well as logical components. The main technical components composing the IVG are:

- Cameras
- Illuminators
- RFID antennas and tags
- Scanners
- Wheel sensors

The set of IVG-components and functions must be selected and designed to fit into an overlapping framework of the terminals.

The idea behind the selection process is that of providing a formal methodology for selecting a component, but not that of selecting the definitive ones to be used by the Intelligent Video Gate. Still, ongoing work on this project and on the following one will better test the components in laboratory and in relevant environment, highlighting unexpected positive or negative characteristics. Another important consideration is that the design also is depending on the real terminal characteristics, such as number of tracks, installation position, environmental conditions, etc. A different component may be preferred to another one, even if the latter had a better evaluation score for the theoretical scenario. As a conclusion, the main objective of the selection process is the process definition itself, together with an exemplification on a theoretical scenario, providing indications to further testing and site rollout activities.
In the next part of this project a technical proof of concept will be done to test and adjust the components/concept. After that a rollout and implementation plan for a pilot site will be produced.
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Yoon et al. 2016

## Appendix I

**Camera models:**

*Teledyne Dalsa Linea 2K and 4K GigE Vision Monochrome CMOS Line Scan Camera*

<table>
<thead>
<tr>
<th>Model Name/SN</th>
<th>Teledyne Dalsa Linea 2K GigE Vision Monochrome CMOS Line Scan Cameras</th>
<th>Teledyne Dalsa Linea 4K GigE Vision Monochrome CMOS Line Scan Cameras</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Based on the most advanced CMOS line scan technology, the Linea GigE cameras employ a 2k or 4k single line 7.04 μm x 7.04 μm pixel array and a line rate up to 80 kHz using Teledyne DALSA’s TurboDrive and Sapera™ LT GigE Vision driver. With excellent sensitivity and speed, Linea surpasses the requirements of demanding applications—such as materials grading and inspection, transposition safety, and general purpose machine vision.</td>
<td>Based on the most advanced CMOS line scan technology, the Linea GigE cameras employ a 2k or 4k single line 7.04 μm x 7.04 μm pixel array and a line rate up to 80 kHz using Teledyne DALSA’s TurboDrive and Sapera™ LT GigE Vision driver. With excellent sensitivity and speed, Linea surpasses the requirements of demanding applications—such as materials grading and inspection, transposition safety, and general purpose machine vision.</td>
</tr>
<tr>
<td><strong>Array Type</strong></td>
<td>CMOS</td>
<td>CMOS</td>
</tr>
<tr>
<td><strong>Pixel size (μm)</strong></td>
<td>7.04 μm x 7.04 μm</td>
<td>7.04 μm x 7.04 μm</td>
</tr>
<tr>
<td><strong>Responsivity</strong></td>
<td>320 DN/ (nJ/cm²) in 12 bit at 1x gain</td>
<td>320 DN/ (nJ/cm²) in 12 bit at 1x gain</td>
</tr>
<tr>
<td><strong>Line rate (kHz)</strong></td>
<td>80 kHz, Sapera LT 52 kHz, standard</td>
<td>80 kHz, Sapera LT 26 kHz, standard</td>
</tr>
<tr>
<td><strong>Dynamic range</strong></td>
<td>&gt; 60 db</td>
<td>&gt; 60 db</td>
</tr>
<tr>
<td><strong>Communication Interface</strong></td>
<td>GigE</td>
<td>GigE</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>2048 pixels</td>
<td>4096 pixels</td>
</tr>
<tr>
<td><strong>Data Format</strong></td>
<td>pixel</td>
<td>pixel</td>
</tr>
<tr>
<td><strong>Dimensions</strong></td>
<td>62 mm x 62 mm x 46.7 mm</td>
<td>62 mm x 62 mm x 46.7 mm</td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td>&lt; 280 g</td>
<td>&lt; 280 g</td>
</tr>
<tr>
<td><strong>Operating Temp</strong></td>
<td>0°C to 65°C (front plate)</td>
<td>0°C to 65°C (front plate)</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>12 V to 24 V DC, HD15 connector (shared with I/O)</td>
<td>12 V to 24 V DC, HD15 connector (shared with I/O)</td>
</tr>
<tr>
<td><strong>Power dissipation</strong></td>
<td>&lt; 6 W</td>
<td>&lt; 6 W</td>
</tr>
<tr>
<td><strong>Dig Input Control</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lens Mount</strong></td>
<td>M42 x 1, Card F-mount adapters available</td>
<td>M42 x 1, Card F-mount adapters available</td>
</tr>
<tr>
<td><strong>Calibration</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Price</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Notes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Name/SN</td>
<td>Teledyne Dalsa Spyder 3 GigeVision SG-14 Dual Line Scan Monochrome and Teledyne Dalsa Genie Nano M4060</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
</tbody>
</table>

<p>| Description | The Spyder3 3GigE Vision (GEV) camera has a 3 times higher response capability than the Spyder2 linear scan camera. At the heart of the dual-line CCD technology that achieves unprecedented responsiveness. Spyder3 GEV is supported by SaperaLT and fully programmable offering precise control over key variables such as gain and offset. |
| Array Type   | CCD                                                                                           |
| Pixel size (μm) | 14 μm x 14 μm (1k and 2k) 10 μm x 10 μm (4k)                                                   |
| Responsivity | up to 2064 DN / (μJ/cm²) @ 0dB gain, 12 bit                                               |
| Line rate (kHz) | up to 60 kHz                                            |
| Dynamic range | Up to 1400 : 1                                                           |
| Resolution   | 1024 / 2048 / 4096 x 2 pixels                                                                   |
| Data Format  | pixel                                                                                         |
| Dimensions   | 72 mm x 50 mm x 65 mm , all models                                                           |
| Mass         | &lt; 300 g                                                                                      |
| Operating Temp | 0 °C to 65 °C                                      |
| Power        | +12 V to +15 V                                                                                 |
| Power dissipation | &lt; 9 W                                                  |
| Lens Mount   | M42 x 1 (1k and 2k) M58 x 0.75 (4k)                                                               |
| Calibration  | C and CS-Mount available                                                                 |
| Price        |                                                                                               |
| Notes        |                                                                                               |</p>
<table>
<thead>
<tr>
<th><strong>Model Name/SN</strong></th>
<th>Genie™ Nano XL M4090</th>
<th>Vega HD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturer</strong></td>
<td>Teledyne DALSA</td>
<td>Tatitle</td>
</tr>
</tbody>
</table>

**Sheet Number**

| **Description** | Genie Nano starts with industry-leading CMOS image sensors from 25-megapixel VGA and adds proprietary camera technology for exceptional speed, robust build quality for a wide operating temperature and a feature set like no other - all at an incredible price. | OCR Camera |
| **Array Type**   | CMOS                 | CMOS    |
| **Pixel size (μm)** | 4.5 μm |         |
| **Responsivity** |                      |         |
| **Line rate (kHz)** |                | 75 fps |
| **Dynamic range** | 55.2 dB             |         |
| **Communication Interface** | GigE | GigE |
| **Resolution**   | 4096/5120           |         |
| **Data Format**  | pixel                | bits/pixel |
| **Dimensions**   | 30 mm x 59 mm x 59 mm (no lens adapter or connectors) 30 mm x 59 mm x 59 mm (with lens adapter and connectors) | 299 x 127 x 225 (W x H x L) |
| **Mass**         | ~163 g               | 5.5 Kg |
| **Operating Temp** | -20 to +60°C (housing temperature) | from -40°C to +55°C |
| **Power**        | 10 to 30W or Power Over Ethernet (POE) | 50 W Max |
| **Power dissipation** | 6.5 W @ 24 Volt Aux. | 24 VCD |
| **Dig In/Out Control** | 5 Digital Inputs | 4 Digital Outputs |
| **Lens Mount**   | M42                  |         |
| **Calibration**  |                      |         |
| **Price**        |                      | 4,200 € |
| **Notes**        |                      |         |
**Illuminator models:**

*Smart Vision Lights LXH1200-SR40 Outdoor Series and LX150/LX300 Direct-Connect Linear Light*

<table>
<thead>
<tr>
<th>Control Interface</th>
<th>LXH1200-SR40 Outdoor Series</th>
<th>LX150</th>
<th>LX300 Direct-Connect Linear Light</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Producer</strong></td>
<td>Smart Vision Lights</td>
<td>Smart Vision Lights</td>
<td></td>
</tr>
<tr>
<td><strong>Sheet Number</strong></td>
<td>Developed for outdoor imaging applications and environments with large temperature swings, the LXH1200-SR40 is designed specifically for applications in homeland security and defense installations, intelligent transportation systems (ITS), and traffic and transportation applications.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Illuminator Type</strong></td>
<td>LED</td>
<td>LED</td>
<td></td>
</tr>
<tr>
<td><strong>Light sources array size</strong></td>
<td>6500°K WHITE; 625nmRED; 615nmRED-ORANGE; 590nmYELLOW; 530nmGREEN; 505nmCYAN; 470nmBLUE; 395nm, 365nmUV; 850nm-940nmIR.</td>
<td>6500°K WHITE; 625nmRED; 615nmRED-ORANGE; 590nmYELLOW; 530nmGREEN; 505nmCYAN; 470nmBLUE; 395nm, 365nmUV; 850nm-940nmIR.</td>
<td></td>
</tr>
<tr>
<td><strong>Wavelength spectrum</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Divergence</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Emitted power</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Line rate</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Control Interface</strong></td>
<td>PNP and NPN strobe input</td>
<td>PNP and NPN strobe input</td>
<td></td>
</tr>
<tr>
<td><strong>Dimensions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Operating Temp</strong></td>
<td>Tested -40°C to 50°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Power consumption</strong></td>
<td>24 Vdc</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Power supply</strong></td>
<td>24 Vdc</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Price</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Notes</strong></td>
<td>100000 cre (25°C - 24 Vdc)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Smart Vision Lights LHF300 Fluorescent Replacement and LLP X-H Series

<table>
<thead>
<tr>
<th>Control Interface</th>
<th>LHF300 Fluorescent Replacement</th>
<th>LLP X-H Series</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Producer</strong></td>
<td>Smart Vision Lights</td>
<td>Smart Vision Lights</td>
</tr>
<tr>
<td><strong>Sheet Number</strong></td>
<td>The LHF300 Series of lights was designed as a direct LED replacement for standard fluorescent lighting. The plug-and-play design of the Direct-Connect Linear Light Series gives users tremendous flexibility without the concern for additional wiring.</td>
<td>The LLX-H series is the second generation Smart Vision Lights of the LLP-H light panel that allows for greater intensity with the same ease of assembly. With its new optically clear interior light dispersion grid and the matt white finish backing plane, a greater amount of light is reflected upward and outward through the diffusion acrylic.</td>
</tr>
<tr>
<td><strong>Description</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Illuminator Type</strong></td>
<td>LED</td>
<td></td>
</tr>
<tr>
<td><strong>Light sources array size</strong></td>
<td>LHF300 array utilizes 30 high-intensity LEDs</td>
<td></td>
</tr>
<tr>
<td><strong>Wavelength spectrum</strong></td>
<td>6500°K WHITE; 625nmRED; 615nmRED-ORANGE; 590nmYELLOW; 530nmGREEN; 505nmCYAN; 470nmBLUE; 395nm, 365nmUV; 850nm-940nmIR</td>
<td></td>
</tr>
<tr>
<td><strong>Divergence</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Emit power</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Line rate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Control Interface</strong></td>
<td>control the pulse of the light</td>
<td>PNP and NPN strobe input</td>
</tr>
<tr>
<td><strong>Dimensions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td>2.5/3.8 Kg</td>
<td></td>
</tr>
<tr>
<td><strong>Operating Temp</strong></td>
<td>-40° - 50° C</td>
<td></td>
</tr>
<tr>
<td><strong>Power consumption</strong></td>
<td>306x306 = 19.2 – 28.8W / 459x459 = 29 – 43W</td>
<td></td>
</tr>
<tr>
<td><strong>Power supply</strong></td>
<td>24 Vdc +/- 5%</td>
<td></td>
</tr>
<tr>
<td><strong>Price</strong></td>
<td>IP50</td>
<td></td>
</tr>
<tr>
<td><strong>Notes</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## European Advanced Technologies LUL-350-1

<table>
<thead>
<tr>
<th><strong>Control Interface</strong></th>
<th>LUL350-1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Producer</strong></td>
<td>European Advanced Technologies S.r.l.</td>
</tr>
<tr>
<td><strong>Sheet Number</strong></td>
<td>LUL IS a compact, robust IR LED line light designed specifically for machine vision system to deliver extreme brightness for linescan application.</td>
</tr>
<tr>
<td><strong>Illuminator Type</strong></td>
<td>IR LED</td>
</tr>
<tr>
<td><strong>Light sources array size</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Wavelength spectrum</strong></td>
<td>850 nm</td>
</tr>
<tr>
<td><strong>Divergence</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Emitted power</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Line rate</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Control Interface</strong></td>
<td>124 x 124 x 550mm</td>
</tr>
<tr>
<td><strong>Dimensions</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td>10kg</td>
</tr>
<tr>
<td><strong>Operating Temp</strong></td>
<td>-20/50 °C</td>
</tr>
<tr>
<td><strong>Power consumption</strong></td>
<td>150VA</td>
</tr>
<tr>
<td><strong>Power supply</strong></td>
<td>24VDC</td>
</tr>
<tr>
<td><strong>Price</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Notes</strong></td>
<td>IP 67</td>
</tr>
</tbody>
</table>
Scanner models:

Automation Technology Vision Sensors and Systems C5-CS Series High Speed 3D Imaging with Ultra-High Resolution and Fraunhofer IPM Scanner SPS

<table>
<thead>
<tr>
<th>Model Name/SN</th>
<th>C5-CS Series High Speed 3D Imaging with Ultra-High Resolution</th>
<th>Scanner SPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer</td>
<td>Automation Technology Vision Sensors and Systems</td>
<td>Fraunhofer IPM</td>
</tr>
<tr>
<td>Sheet Number</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>CS compact sensors (CS) scan objects by means of the laser</td>
<td></td>
</tr>
<tr>
<td></td>
<td>triangulation method. This occurs through a projected laser</td>
<td></td>
</tr>
<tr>
<td></td>
<td>line that migrates along the surface. By scanning the laser</td>
<td></td>
</tr>
<tr>
<td></td>
<td>line the 3D profile of the object is captured in the sensor</td>
<td></td>
</tr>
<tr>
<td>Measurement principle</td>
<td>triangulation</td>
<td>phase shift method</td>
</tr>
<tr>
<td>Laser Wavelength (nm)</td>
<td>1500 nm</td>
<td></td>
</tr>
<tr>
<td>Line rate (Hz)</td>
<td>up to 25kHz</td>
<td>8kHz</td>
</tr>
<tr>
<td>Points for frame/resolution</td>
<td>Up to 4096 Points/Profile</td>
<td>angular resolution 6.01 deg</td>
</tr>
<tr>
<td>Communication interface</td>
<td>GigE Vision and GenICam Compliant</td>
<td></td>
</tr>
<tr>
<td>Acquisition range</td>
<td>measurement ranges of up to 1060mm (width) and 800mm (height)</td>
<td></td>
</tr>
<tr>
<td>Acquisition angle</td>
<td>70 deg</td>
<td></td>
</tr>
<tr>
<td>Accuracy (or measurement error)</td>
<td>10mm</td>
<td></td>
</tr>
<tr>
<td>Laser class (for eye safety)</td>
<td>2M, 36, 38</td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>17 kg</td>
<td></td>
</tr>
<tr>
<td>Operating Temp</td>
<td>-20 ... +55°C</td>
<td></td>
</tr>
<tr>
<td>Power consumption</td>
<td>10 - 24V DC</td>
<td>24VDC</td>
</tr>
<tr>
<td>Power supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dig Input Control</td>
<td>Opto-isolated input (2x) / Outputs (2x),</td>
<td></td>
</tr>
<tr>
<td>Mounting repeatability</td>
<td>Laser Safety, Trigger, Encoder (RS442)</td>
<td></td>
</tr>
<tr>
<td>Calibration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notes</td>
<td>IP67</td>
<td>IP68</td>
</tr>
</tbody>
</table>
### SICK CLv63x and LD-OEM

<table>
<thead>
<tr>
<th>Model Name/SN</th>
<th>CLv63x</th>
<th>LD-OEM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturer</strong></td>
<td>SICK</td>
<td>SICK</td>
</tr>
<tr>
<td><strong>Sheet Number</strong></td>
<td>Integrated function keys, e.g. for the start of auto-setup or for the evaluation of the reading quality. Integrated bar graph. CAN, Ethernet TID / IP, PROFIM and Ethernet / IP on board. No additional Ethernet gateway required (with &quot;Ethernet&quot; connection). SMART code reconstruction improved. Highly flexible filtering and classification functions. Configuration with SOPIS, the parameterization tool for all new SICK products. High scanning frequency up to 1.2 kHz. Expanded remote diagnosis and network monitoring via Ethernet.</td>
<td>High operating distance even on dark surfaces. Eye protection laser technology. High angular resolution up to 0.12°. High insensitivity to sunlight and other infrared light sources. Synchronized monitoring up to four fields that can be defined as desired. Real-time emission of measurement data via Ethernet interface. Faultless sampling with uniform laser point in full 360 degree range.</td>
</tr>
<tr>
<td><strong>Measurement principle</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Line rate [Hz]</strong></td>
<td>400 Hz ... 1,200 Hz</td>
<td>5 Hz ... 20 Hz</td>
</tr>
<tr>
<td><strong>Points for frame/resolution</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Communication Interface</strong></td>
<td>EthernetCAT</td>
<td>Ethernet</td>
</tr>
<tr>
<td><strong>Acquisition range</strong></td>
<td></td>
<td>up to 250 m</td>
</tr>
<tr>
<td><strong>Acquisition angle</strong></td>
<td></td>
<td>360°</td>
</tr>
<tr>
<td><strong>Accuracy (or measurement error)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Laser class (for eye safety)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td>250 g ... 1.230 g</td>
<td>2.4 kg / 3.4 kg</td>
</tr>
<tr>
<td><strong>Operating Temp</strong></td>
<td></td>
<td>−25 °C ... +50 °C</td>
</tr>
<tr>
<td><strong>Power consumption</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Power supply</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Diag Input Control</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mounting repositability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Calibration</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Price</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Notes</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### SICK LMS 5xx and LD-MRS

<table>
<thead>
<tr>
<th>Model Name/IN</th>
<th>LMS 5xx</th>
<th>LD-MRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer</td>
<td>SICK</td>
<td>SICK</td>
</tr>
</tbody>
</table>

#### Description
- Powerful, efficient 2D LIDAR sensor for measuring ranges up to 80 m.
- Excellent performance even under unfavorable weather conditions due to multi-echo technology.
- Simultaneous measurements on up to 8 scan planes.
- Weatherproof thanks to multi-echo technology and IP69K enclosure rating.
- Lightweight, compact design: Approx. 0.77 kg / 1 kg.
- Wide temperature range: -40 °C to +70 °C.
- Low power consumption: 1 watts.
- Different angular resolutions in the scanning range are available.
- Integrated object tracking.

<table>
<thead>
<tr>
<th>Measurement principle</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser Wavelength (nm)</td>
<td>655 nm</td>
<td></td>
</tr>
<tr>
<td>Line rate (kHz)</td>
<td>1000</td>
<td>up to 50 ks</td>
</tr>
<tr>
<td>Points per frame/resolution</td>
<td>360</td>
<td></td>
</tr>
<tr>
<td>Communication Interface</td>
<td>Gigabit Ethernet and RS485</td>
<td>Ethernet, serial, CAN</td>
</tr>
</tbody>
</table>

| Acquisition range     | from 20 cm to 80 m | up to 50 m (10% reflectivity) |
| Acquisition angle     | from 5° to 180°    | 85° |
| Accuracy (or measurement error) | 1.9 mm | 100 mm |
| Laser class (for eye safety) | Class 1 | Class 1 |
| Mass                   | 3.7 kg            |  |
| Operating Temp         | -40 ... +70 °C    |  |
| Power consumption      | Max: 50W | Typ: 46W | 8W |
| Power supply           | 24 VDC           |  |
| Dg Input Control       | 4 Digital Inputs | 6 Digital Outputs |
| Mounting reusability   |                 |        |
| Calibration            |                  |        |
| Price                  | 4,500 €          |        |
| Notes                  | IP59             |        |
**Wheel sensor models:**

*Optosmart OS-WIM-S1 and Frauscher RSR110d*

<table>
<thead>
<tr>
<th>Sheet Number</th>
<th>Optosmart</th>
<th>Frauscher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producer</td>
<td>OS-WIM-S1</td>
<td>RSR110d</td>
</tr>
<tr>
<td>Model Name/SN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>STRAIN SENSOR FOR RAILWAYS APPLICATIONS</td>
<td>Two sensor electromagnetic systems for wheel detection including directional information</td>
</tr>
<tr>
<td>Wheel Sensor Type</td>
<td>fibre optics</td>
<td>electromagnetics</td>
</tr>
<tr>
<td>Mounting</td>
<td>under rail foot, no drilling</td>
<td>rail foot clamping, not drilling</td>
</tr>
<tr>
<td>Accuracy</td>
<td>2.5 ppm strain measurement</td>
<td>5 cm</td>
</tr>
<tr>
<td>Control Interface</td>
<td>F8G optics signal</td>
<td>Analogue interface</td>
</tr>
<tr>
<td>Dimensions</td>
<td>151 x 40 x 16</td>
<td>60 x 270 x 77</td>
</tr>
<tr>
<td>Mass</td>
<td>250 g</td>
<td></td>
</tr>
<tr>
<td>Operating Temp</td>
<td>-40 : 75°C</td>
<td>-40 : +85°C</td>
</tr>
<tr>
<td>Power consumption</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>Power supply</td>
<td>N.A.</td>
<td>8-33 Vdc</td>
</tr>
<tr>
<td>Price</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Siemens WSS**

<table>
<thead>
<tr>
<th>Sheet Number</th>
<th>Siemens</th>
<th>WSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>The WSR (Wheel Sensor Relay) and WSS (Wheel Sensor Single) Wheel Detectors are electronic switches which respond contactlessly to wheel flanges. They are suitable as a replacement for the track-installed switching devices S44, MK, WSSS-Impulsgeber and RSE 45.</td>
<td></td>
</tr>
<tr>
<td>Wheel Sensor Type</td>
<td>electromagnetics</td>
<td></td>
</tr>
<tr>
<td>Mounting</td>
<td>rail foot clamping or drilling</td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Interface</td>
<td>Analogue interface</td>
<td></td>
</tr>
<tr>
<td>Dimensions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Temp</td>
<td>-40 : +85°C</td>
<td></td>
</tr>
<tr>
<td>Power consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power supply</td>
<td>18 Vdc</td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**RFID antenna models:**

*Sick AG RFU630 and Harting Technology Group Ha-VIS-RFID RF-R500*
<table>
<thead>
<tr>
<th><strong>Sheet Number</strong></th>
<th>RFU830</th>
<th>Ha-VIS-RFID RF-R500</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Producer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Model Name/SN</strong></td>
<td>SICK AG, Sensor intelligence</td>
<td>Harting Technology Group</td>
</tr>
<tr>
<td><strong>Description</strong></td>
<td>Read/Write device with integrated antenna</td>
<td>Read/Write device with external antenna</td>
</tr>
<tr>
<td><strong>Read range</strong></td>
<td>5 meter depending on the RFID-tag</td>
<td>Up to 16 meter depending on the RFID-tag and environmental conditions</td>
</tr>
<tr>
<td><strong>Frequency band</strong></td>
<td>UHF (860 MHz – 960 MHz)</td>
<td>UHF (860 MHz – 960 MHz)</td>
</tr>
<tr>
<td><strong>RFID Standard</strong></td>
<td>EPCglobal UHF Class 1 Generation 2, ISO/IEC 18000-6C</td>
<td>EPCglobal UHF Class 1 Generation 2, ISO/IEC 18000-6C</td>
</tr>
<tr>
<td><strong>MTBF</strong></td>
<td>14 years</td>
<td>Linux (Kernel 3.x.x)</td>
</tr>
<tr>
<td><strong>Operating Voltage</strong></td>
<td>18 VDC – 30 VDC</td>
<td>+24 VDC / power over Ethernet (PoE)</td>
</tr>
<tr>
<td><strong>Power Consumption</strong></td>
<td>&lt;20W with full transmit power</td>
<td>&lt;50W with full transmit power</td>
</tr>
<tr>
<td><strong>Interface</strong></td>
<td>Ethernet, Profinet, Serial, CAN, Profinbus, DeviceNet, USB</td>
<td>Ethernet, RS 232, RS 485, USB and USBport</td>
</tr>
<tr>
<td><strong>Antenna</strong></td>
<td>Integrated circular polarized antenna, additional 3 external antenna ports</td>
<td>4 external antennas with SMA connector</td>
</tr>
<tr>
<td><strong>Enclosure rating</strong></td>
<td>IP57</td>
<td>IP64</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>3.5 kg</td>
<td>2.0 kg</td>
</tr>
<tr>
<td><strong>Dimensions (L x W x H)</strong></td>
<td>239mm x 239mm x 64mm</td>
<td>260mm x 153mm x 70mm</td>
</tr>
<tr>
<td><strong>Operating Temperature</strong></td>
<td>-25 °C ... +60 °C</td>
<td>-25 °C ... +50 °C</td>
</tr>
<tr>
<td><strong>Price</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Notes</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Tagmaster XT-3HD Reader and IMPINJ Speedway RAIN RFID

<table>
<thead>
<tr>
<th>Sheet Number</th>
<th>Producer</th>
<th>Model Name/SN</th>
<th>Description</th>
<th>Read range</th>
<th>Frequency band</th>
<th>RFID Standard</th>
<th>MTBF</th>
<th>Operating Voltage</th>
<th>Power Consumption</th>
<th>Interface</th>
<th>Antenna</th>
<th>Enclosure rating</th>
<th>Weight</th>
<th>Dimensions (L x W x H)</th>
<th>Operating Temperature</th>
<th>Price</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>XT-3HD Reader</td>
<td>TagMaster</td>
<td>Read/Write device with integrated antenna</td>
<td>Up to 5 meters</td>
<td>UHF (865 MHz – 868 MHz) for Europe</td>
<td>EPCglobal UHF Class 1 Generation 2, ISO/IEC 18000-6 type C</td>
<td></td>
<td>+10 -- +30 VDC / power</td>
<td>&lt;15W with full transmit power</td>
<td>Ethernet, RS 232, RS 485, Wiegand/Mag-stripe interfaces</td>
<td>Internal antenna</td>
<td>IP66</td>
<td>2,3 kg</td>
<td>300mm x 300mm x 60mm</td>
<td>-40 °C ... +60 °C</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Speedway RAIN RFID</td>
<td>IMPINJ</td>
<td>Read/Write device with external antenna</td>
<td>Tag dependent</td>
<td>UHF (865 MHz – 868 MHz) for Europe</td>
<td>EPCglobal UHF Class 1 Generation 2, ISO/IEC 18000-6 type C</td>
<td></td>
<td>Power over Ethernet (PoE) or 24 VDC/2.1 A</td>
<td>&lt;15W with full transmit power</td>
<td></td>
<td>External antennas</td>
<td>IP52</td>
<td>0,7 kg</td>
<td>190mm x 175mm x 30mm</td>
<td>-20 °C ... +50 °C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>