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In-door positioning on RoRo vessels

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A feasibility study initiated and sponsored by Lighthouse 2017

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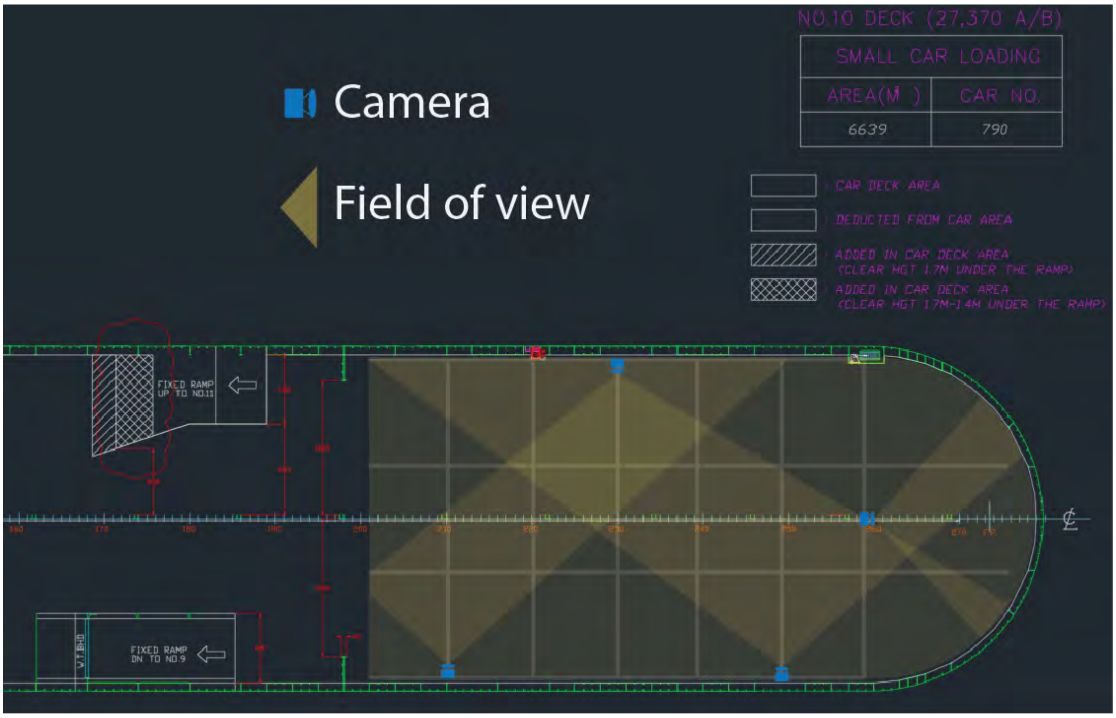

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Summary

Digitization is an enabling technology that facilitate automatic information exchange between connected devices. In-door positioning of goods on-board RoRo ships is an excellent example where automatic identification of goods can be aggregated through digitization, it may create a valuable overview of the cargo to be loaded/unloaded as well as the current situation of the cargo on-board the ship. This project explores the possibilities and viable solutions to achieve high positioning accuracy of in-door positioning inside RoRo vessels.

By engulfing the possibilities that high accuracy in-door positioning enables along with digitalization and automation, the traditionally manually operation called tally (the process of keeping track of goods on-board ships) will have a much wider impact on the shipment of goods, than just keeping track on where goods A is stowed on Deck 3. To achieve this, different data sources have to be available in a, for the shipping industry, new manner. This is something that is already happening in other areas of transportation and logistics supply chains.

Lack of correct cargo data and updated stowage plans have caused severe incidents where vessels have lost stability (e.g. Hoegh Osaka, 3 January 2015[1]). Such accidents may be avoided by the introduction of a digitized cargo-handling and management system.

The increasing number of vehicles with alternative fuel (here after called AFV) has raised the need for a higher level situational awareness inside the ship. Digitalization of the cargo handling could be a way to mitigate the risk that is introduced with the combination of energy sources that rolls on-board our ships today. Used vehicles[2] is also a special case of cargo that may need special treatment while transported.

By implementing an automated on-board system that can exchange data with shore-based data sources such as booking systems, national vehicle registration databases etc. along with a high positioning accuracy in-door positioning system and finer granular stowage/load/stability software, the system would be able to give benefits such as:

- Less personnel that have to be exposed to hazards like emissions, particles, noise and the risk of being hit by rolling cargo during loading/unloading.
- The trim and stability calculation would be more accurate, that could lead to less use of ballast water and still keeping the stability intact. That would lead to less energy consumption and less emissions.

[1] https://assets.publishing.service.gov.uk/media/56e9a7afe5274a14d9000000/MAIBInvReport6_2016.pdf

[2] https://www.gov.uk/maib-reports/fire-caused-by-electrical-defect-on-main-deck-of-ro-ro-cargo-ferry-corona-seaways-in-the-kattegat-scandinavia#accident-investigation-report-172014

- The use of digital sensors (such as cameras) could also lead to faster detection of hotspots on the cargo, it would also increase the safety and situational awareness in case of a fire.

In a larger perspective, the demands on the shipping industry is to become more and deeper integrated with data driven supply chains such as with the cargo owners that constantly want to keep track of their goods. Other stakeholders such as governments, customs and end customers are also interested in the status of the goods.

The overall scope for the concept of high accuracy in-door positioning is based on five specific areas:

- Connectivity to shore/booking system
- Identification of the vehicle
- Tracking of the vehicle on the vessel
- Positioning of the vehicle on-board
- Visualisation of vehicles currently on-board

Several technologies have been evaluated and identified as a way forward and there may be different solutions within different areas.

Today, there is no existing off-the-shelf solution. However, technology for the different parts exists and how these should be combined will have to be assessed and further explored.

This concept will implement new processes and technologies and will require research, development and close cooperation with all involved stakeholders, including customers.

The proposed automated solution does not only address the AFVs matters, it will also improve the overall operational efficiency and reduce manual intervention. It also provides information in a platform enabling future development of new services to stakeholders.

Today the number of AFVs is limited but the trend is that this will increase drastically in the coming years.

Additionally, in a wider scope (not covered in this report), incorporating other technologies from the automotive industry, like Weigh-In-Motion (WIM) would give accurate weights and loads on-board the ship.

Sammanfattning

Digitalisering är en möjliggörande teknologi för att underlätta automatiskt informationsutbyte mellan uppkopplade enheter. Inomhuspositionering av gods ombord på RoRo fartyg är ett utmärkt exempel på hur digitalisering kan användas för att automatiskt identifiera gods och på så sätt skapa en värdefull överblick av godset som lastas samt var godset finns ombord på fartyget. Detta projekt undersöker möjligheter och lösningar som kan användas för att åstadkomma noggrann inomhuspositionering ombord på RoRo fartyg.

Genom att ta vara på möjligheter som noggrann positionering skapar tillsammans med digitalisering och automation, så kommer den traditionella manuella tally-processen (som innebär att man håller reda på godset) att bli viktigare och få större betydelse än att bara hålla reda på att gods A finns på Deck 3. För att få dessa fördelar behöver datakällor göras tillgängliga på ett, för branschen, nytt sätt. Att tillgängliggöra data är något som redan pågår inom andra transportområden och logistikkedjor. Brist på korrekt data om godset och korrekta lastplaner har orsakat allvarliga olyckor där fartyg har tappat stabilitet (t.ex. Hoegh Osaka, 3 januari 2015). Sådana olyckor skulle kunna ha undvikits om godshanteringen och godsövervakningen varit digitaliserad.

Den ökade andelen fordon med alternativa bränslen (AFV) har ökat behovet av att skapa högre situationsmedvetenhet ombord på fartyg. Digitalisering av godshanteringen kan vara en möjlig metod för att minska risker som skapas då fordon med olika bränsletyper blandas ombord på fartyg idag. Begagnade fordon är också ett specialfall som idag kräver manuell hantering. Genom att implementera ett automatiskt system som ombord som kan utbyta information mellan land-baserade datakällor, såsom bokningssystem, fordonsdatabaser, etc., och system som kan identifiera och noggrant positionera godset ombord kan följande fördelar uppnås:

- Färre personer behöver utsättas för risker i godshanteringen som t.ex. avgaser, partiklar, buller, och risk att bli påkörd av gods under i- och urlastning.
- Fartygets trim och stabilitet kan beräknas noggrannare vilket kan resultera i mindre ballast, med bibehållen stabilitet, vilket i sin tur leder till mindre bränsleförbrukning och reducerade utsläpp.
- Kamerabaserade sensorer kan också leda till detektering och dokumentation av riskfyllda situationer i lastprocessen, det skulle också öka den generella säkerheten ombord vid t.ex. en brand.

I ett större perspektiv, ökar kraven på sjöfarten och dess värdekedjor och godsägarna vill få bättre möjlighet att ha kontroll på sitt gods. Andra intressenter, såsom myndigheter, tull, och slutkunder är också intresserade av att veta var godset befinner sig. Det övergripande konceptet för noggrann inomhuspositionering av gods är uppdelat på fem områden.

- Uppkoppling till land/bokningssystem

- Identifiering av fordon
- Följning av fordon när det kör i fartyget
- Positionering av fordonet när det parkerat
- Visualisering av fordon som befinner sig ombord

Flera teknologier har utvärderats och identifierats som möjliga vägar framåt. Beroende på inom vilken miljö som tekniken ska användas i, kan det finnas olika lösningar. Idag finns ingen färdig lösning som skulle passa ombord på RoRo fartyg. Men det finns dellösningar och hur de ska integreras behöver studeras vidare. Det föreslagna konceptet kräver nya processer och teknologier och kommer behöva mer forskning, utveckling och nära samverkan mellan de olika aktörerna, inklusive kunder. Det föreslagna automatiserade systemet adresserar inte bara AFV, det effektiviserar hela godshanteringen och minskar manuell hantering. Det möjliggör även en platform där gods och fartygsinformation finns tillgänglig som kan användas för vidare tjänsteutveckling.

Idag är antalet AFV begränsat, men trenden är att dessa fordon kommer öka drastiskt de närmsta åren. I en vidare kontext (inte behandlat i denna rapport), så kan ytterligare teknoligoier från fordonsbranshen inkluderas som t.ex. *Weigh-In-Motion (WIM)* för att få noggrann viktangivelse av lasten på fartygen.

Abbreviations

AFV	Alternative Fuel Vehicle.
API	Application Programming Interface.
BV	Battery Vehicle.
EDI	Electronic Data Interchange.
EV	Electrical Vehicle.
FOC	Fleet Operation Centre.
HMI	Human Machine Interface, sometimes referred as Man-Machine-Interface.
IMDG	International Maritime Dangerous Goods code.
LOC	Logistic Operation Centre.
RoPax ship	Ship designed for rolling cargo and passengers, not considered as a passenger ship.
RoRo	Roll on Roll off.
RoRo ship	Ship designed rolling cargo with no more than 12 passengers.
VMS	Video Monitoring System.
VIN	Vehicle Identification Number.
WIM	Weigh In Motion, a technology to capture rolling goods weight on the move.
WWL	Wallenius Wilhelmsen Logistics.

1. Introduction

Based on previous incidents on-board RoRo vessels, there is a demand for a more online and accurate solution for tracking and monitoring the cargo on-board RoRo/ RoPax vessels. To achieve full situational awareness there are several issues that needs to be addressed such as interchange of data of the cargo and more precise data of the cargo. The recent implementation of the SOLAS Container Weight Verification Requirement[3] is an example of this. If data about the rolling cargo is not known, there are several new solutions that can solve the basic volume and weight data by laser scanning and weighting of vehicles (WIM) as they roll on-board.
But the challenge of what type of energy source that is used for specific vehicles is harder to obtain with external sensors. This type of data could come be provided by the manufacturer, the national vehicle database or the booking system, and is communicated to an on-board system.
Combining all these sources of data and information, would increase the efficiency of the loading/unloading operation, mitigating risks for personnel, reducing time spent alongside and increase safety on-board the ship. All this could also lead to shorter turnaround times inside the port, higher punctuality and reduced emissions to air/water.

1.1 Scope and purpose of the study/report

This report presents the findings from a Lighthouse feasibility study regarding in-door positioning of rolling goods on RoRo vessels.

Background

This feasibility study is conducted by RISE Viktoria AB, Wallenius Wilhelmsen Logistics ASA and Stena Rederi AB.

There are several benefits with such an in-door positioning system that can track the cargo without physical interaction:

- Minimising the number of persons present at the cargo operations limits exposure to exhausts and the risk for personal injuries
- All human interaction with the cargo is combined with a risk for damage to the vehicle
- It is a time-consuming and labour intensive task

Automation and digitalization, as means of increasing safety at sea, is a Lighthouse focus area for the Maritime Informatics.

Goal

The objective for the project is to define a feasible concept for in-door positioning of vehicles on board RoRo vessels. It also serves as one building block for a larger initiative to archive the connected vessel.

[3] http://www.imo.org/en/MediaCentre/HotTopics/container/Pages/default.aspx

Method

The project has used three different approaches to fulfil the project goals. A state-of-the-art review is made to find the available technologies that may be used to solve the in-door positioning problem. A number of visits to RoRo vessels, interviews and discussions with experts in the domain have been made to thoroughly understand the theoretical and practical challenges. Finally, an analysis is performed and a concept is proposed for future evaluation.

Structure of the report

This document reports the findings from the three working packages performed within the project. The state-of-the-art lay out the foundation of the available technologies that are discussed and evaluated in the chapter - Concept. The facts and scenario descriptions made available in the report are found through the visits at the RoRo vessels along with interviews and discussions with domain experts. Technology providers have also made available valuable information about technologies that may be used to solve the problem at hand. Technical experts that have been involved come from e.g. the following companies: Axis, Securitas, Viscando, Cypherstone, Termisk systemteknik, Opticon, NAPA, SICK, FLIR, Kockums, Consilium and Autoship. Halmstad University was also involved while discussing identification and tracking of vehicles. The analysis has resulted in a chapter called "System for identifying and tracking objects"

1.2 Industrial project partners

Stena Teknik

Stena has a wide diversity of rolling cargo, stretching from bicycles to high and heavy types of goods. Stena also has different types of vessels, passenger ships with several hundreds of passengers to pure RoRo ships with the maximum of 12 passengers.

In some ports, mainly the passenger ferries, Stena is the owner of the infrastructure and operator of the terminal.

Stena Passenger and RoRo services in numbers[4]

- 7,3 Million passengers 2016 (20 routes)
- 31 Passenger ships
- 8 RoPax ships
- 17 RoRo ships

WWL Ocean services

WWL ASA supplies different types of services, in this study focusing on the flow of new/used vehicles and to some extent other cargo (high & heavy, break-bulk[5]) that is shipped on board the RoRo vessels.

[4] Stena AB Annual Review 2016

[5] Break bulk, relating to materials shipped in conventional individual packages and not containerized.

WWL ASA also offers inland transportation, overseas shipping and services around the vehicles, such as finalising the vehicle for the delivery to the end customer. In some ports, WWL is also a terminal operator.

In some cases, WWL is the only operator the manufacturer needs in order to ship its goods from door to door. In other cases, WWL is one among many actors in the supply chain.
To support such global flow of cargo/gods, high level of automation and data interchange is desired.

WWL Ocean services in some numbers

WWL[6]

- 3.7 million movements of autos, rolling equipment and breakbulk units per year: 1.7 million (ocean)
- More than 126 vessels, servicing 12 trade routes to six continents
- More than 550 sailings and 4000 port calls per year

EUKOR (Subsidiary to WWL)

- 4 million movements of autos, rolling equipment and breakbulk units per year
- More than 80 vessels

1.3 The vessels

As mentioned earlier, Stena and WWL are mainly operating in different segments of shipping, the common denominator for this study is that the ships handle rolling cargo and an increasing number of AFVs.

Stena

By nature, Stena Passenger, RoPax and RoRo ships have different layouts. In general, the ships have several decks, from tank top[7] to high up in the structure, usually with passenger & crew areas at the top. Some ferries have passenger and crew areas below the car decks.

Most decks are indoor but RoPax and RoRo vessels have an open weather deck, not all of the Passenger vessels have such deck arrangement. They also have different arrangements of hanging decks for flexible use of height.

Depending on the types of cargo, the loading and discharge operations are different.

[6] WWL Company facts & figures (Updated January 2017

[7] Tank top, the plating laid on the bottom floors of a ship, which forms the top side of the tank sections or double bottom.

For example, on a passenger vessel, hundreds of passengers swarm the deck during loading/unloading. Then the decks should be empty of passengers during the sea voyage.

Other vessels have mostly rolling cargo of lorries, trailers and semitrailers and also cargo loaded using different types of flat beds/MAFIs[8] loaded/offloaded using harbor tractors.

Some vessels also carry cargo in the shape of breakbulk that is rolled on-board (flatbed/MAFI) and then stowed individually.

On some vessels, there is a large weather deck that is exposed to the current weather situation.

1.4 WWL

The fleet of Pure Car and Truck Carriers (PCTC), Large Car and Truck Carriers (LCTC) and RoRo vessels are on the outside similar, some vessels have a side door with a ramp as well as their stern door and ramp. But there are several generations of vessels and several different interior designs of the vessels.

On the inside, there are many differences to mention just a few:

- There are vessels with one pillar row in the center, others have two rows and some have a combination of one and two pillars on different decks.
- Some vessels have a very flexible deck configuration with liftable decks and ramps, while others are more static designed with fewer combinations.
- The headroom distance between cargo and bulkhead/steel beams can be as small as 5 cm.

WWL also handles breakbulk, placed on different types of flat beds or rolling equipment.

All rolling cargo is stowed inside the hull, some breakbulk/containers could be stored on a weather deck.

[8] A type of carrier/wagon that are specially designed for carrying different types cargos on top of it.

2. Alternative Fuel Vehicles (AFV)

Alternative Fuel Vehicles (AFV) is a group name for vehicles that use either pure batteries (Electrical Vehicle, EV) or some type of gas such as: Compressed Natural Gas (CNG), Liquid Petrolium Gass (LPG), Liquid Natural Gas (LNG) and Hydrogen as primarily energy source, pure or in combination with other energy storage such as batteries or diesel/gasoline.

These vehicles that use gas are to be treated differently than hybrid solutions that combines diesel/gasoline with batteries.

2.1 Challenges during transport

Due to risk management AFVs are often parked at weather deck to lower the effects of a gas leakage, however the number of AFV vehicles is rapidly increasing and will soon be so many that parking them on a weather deck will not be possible since it is then competing with other types of cargo that has to be placed on weather deck due to stowage and segregation rules such as International Maritime Dangerous Goods code (IMDG)

The challenge that these AFV bring is that in case of a fire, the traditional means of firefighting system (mainly CO2 for the cargo hold) and firefighting equipment that the crew on board has at hand, needs to be complemented with new solutions.
The traditional tactics using CO2 to fight fires in the section of cargo space might, not, be sufficient when there is EV and battery packs that can go into a state of thermal runaway[9] or leaking gas, such as hydrogen. The issues with reignition is also more complicated with these new types of energy sources and therefore the crew on-board will need new tactics and new tools at hand, to handle fires on-board.

Recognizing and localising different types of vehicles inside the vessel, to select the appropriate firefighting system is a main challenge.

2.2 Requirements during transport

Internal Combustion Engine (ICE)

No new requirements on vehicles that uses gasoline or diesel as energy source, vehicles that uses gas are noted below and under special provisions when it comes to stowage on-board a ship.

Hybrid Electrical Vehicle (HEV)

Vehicles that use batteries in conjunction (hybrid) with petroleum based energy source are treated as regular diesel/gasoline vehicles.

Battery Electric Vehicle with Range Extender (EREV)

The range extender could be an ICE but there is also development of Fuel Cells as range extenders.

[9] Thermal runaway describes a process which is accelerated by increased temperature, in turn releasing energy that further increases temperature.

Gas – LPG/LNG/CNG and Fuel Cell Electric Vehicle (FCEV)

A vehicle running on gas such as LPG/LNG/CNG is traditionally using a combustion engine but these types of vehicles and fuel cell driven cars are under special provision due to the fact that they use gas as energy storage and it is the storage tanks and its auxiliary equipment that are the concerns regarding leakage.

IMDG Special Provision 961
"Vehicles and equipment are not subject to the provisions of this code if they are stowed on a roll–on/roll–off ship or in another cargo space designated by the Administration (flag State) as specifically designed and approved for the carriage of vehicles and equipment and there are no signs of leakage from the battery, engine, fuel cell, compressed gas cylinder or accumulator, or fuel tank when applicable."

At the moment, these vehicles have to be leak tested and labelled before they are allowed on-board the vessel. No other provisions apply for a complete vehicle as of today.

New buildings, keel laid after 2016, have new requirements on EX-classed equipment and ventilation. (Appendix B)

Electrical Vehicle - Battery Electric Vehicle (BEV)

As well as for vehicles using gas, battery driven vehicles do not have any special provisions for stowage and segregation on-board a vessel that is designed for RoRo

IMDG SP961
"Vehicles and equipment are not subject to the provisions of this code if they are stowed on a roll–on/roll–off ship or in another cargo space designated by the Administration (flag State) as specifically designed and approved for the carriage of vehicles and equipment and there are no signs of leakage from the battery, engine, fuel cell, compressed gas cylinder or accumulator, or fuel tank when applicable.

Marking of AFVs as of today

Stena
Registered vehicles are not as of today required to be labelled. Still, recreational or vehicles that have pressurised/containers for gas (CPG) must turn off the main valve and the cabinet/valve of the tank/container should be marked.

WWL
At the moment, the AFVs should be labelled so they can be identified, they are currently not under any restrictions regarding stowage and separation schemes. As for Stena, vehicles that have any gas for cooking etc., the system has to be shut off, leak tested and labelled before loading.

But nevertheless, AFVs with gas, as well as hybrid vehicles with batteries, require new firefighting techniques and/or equipment.

3. System for identifying and tracking objects

As background, the current procedure for handling cargo/vehicles in the port/terminal is presented, it should be noted that the procedure might vary significantly between different shipping companies/ports/terminals. It might also vary depending on the current situation during loading e.g. weather, obstructions in the port, type of cargo (height and weight) that is to be loaded/unloaded etc.

For comparison, the current situation is divided into three stages; Identification - Tracking - Positioning. During unloading, the sequence is Identification and Tracking, to allow supervision of what vehicles has been unloaded.
An overall monitoring system that handles the data exchange with shore systems such as booking and stowage planning as well as hosts the logic that is needed for the identification and tracking service/applications. A general term is Video Monitoring System (VMS).

3.1 Current process for handling AFVs

Handling AFVs is an all manual procedure, from booking, labelling, stowage planning to tracking of where the AFV is parked.

3.2 Current tally procedure

All cargo that goes on board and leaves the vessel are tallied (registered) more or less manually or by the use of hand barcode scanners. Today the vehicle/gods are tallied outside the vessel, close to the aft/side ramps during loading/discharged operation. The tally statuses are then sent to the centralised booking/documentation system.

In some ports, there is also a stowaway search in the vehicle before the vehicle/gods is loaded.

3.3 Current tracking procedure

Vehicles are not tracked by other means than that the drivers are instructed to take the vehicle/cargo to a certain deck. Occasionally vehicles end up on the wrong deck. If this is detected early, it only causes a slight delay in the loading process. However, there have been occasions when vehicles were blocked during loading, consequently the vehicles were delayed to the final destination. Another area of interest, is to make sure that cargo that is planned to be unloaded is not left on-board during unloading.

3.4 Current positioning procedure

During planning, vehicles are stowed in blocks of vehicles going to a specific port. Within these blocks, all types of different vehicles might end up. Only gas driven vehicles are separated and stowed together at designated areas on board.

3.5 Current situation identification - new cars from the manufacturer

Barcodes
At most ports, the cars are tallied by the means of tallymen using hand scanners and barcodes that are either placed; inside the car on a sheet of paper, a sticker on the

inside of the front window or on the rear window behind the driver seat (rear passenger seat).

2D codes
Some manufacturers use 2D barcodes such as Quick Response code (QR code).

RFID
During discussions with system suppliers, it has been mentioned that several manufacturers use RFID (Radio-Frequency Identification) tags to track the car inside the factories.

3.6 Current situation - used cars

Barcodes
Normally all types of cargo should be labelled, with text and barcode so that the cargo could easily be identified. The tags are typically placed either at the front window or on the window behind the driver's position.

RFID
Some newer used cars might have RFID tags on their chassis from the production line, see above.

License plates
Some new cars that are transported are already registered and may carry a license plate.

3.7 Current data exchange

WWL

Today data of new vehicles are exchanged from the manufacturer via EDI (Electronic Data Interchange) to WWL booking system.

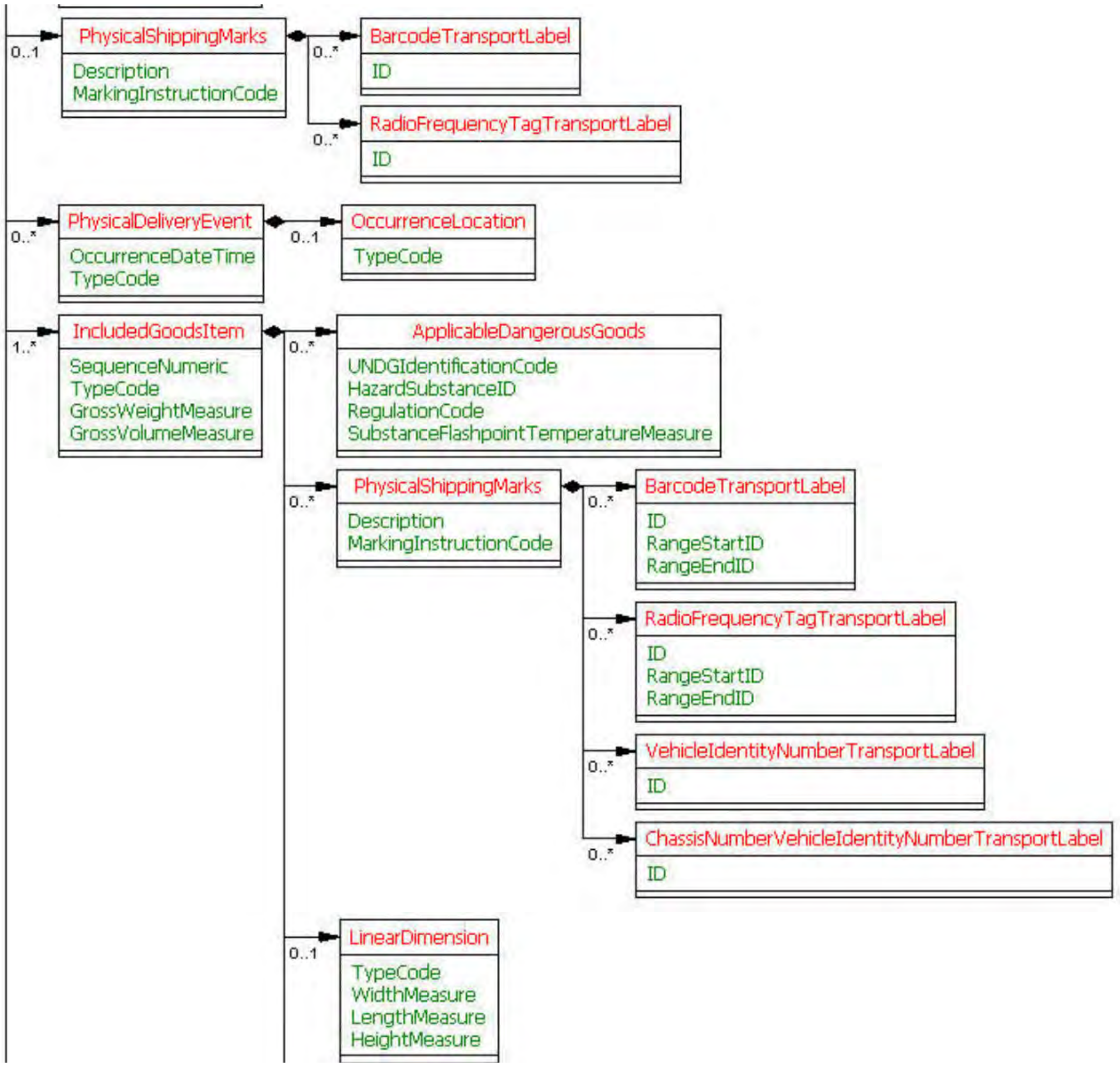

Figure 1. Data model of vehicle identification process.

In the current data model[10] (Figure 1) there is support for Barcode, RFID, Vehicle Identification Number (VIN) and Chassi number and if the cargo is categorised as IMDG.

There is also gross weight and size of the cargo.

The model lacks support for AFV and will be updated with this in near future.

For customers without the possibility for EDI exchange, an online booking is available.

[10] https://www.2wglobal.com/globalassets/edi/bookingmodel.pdf

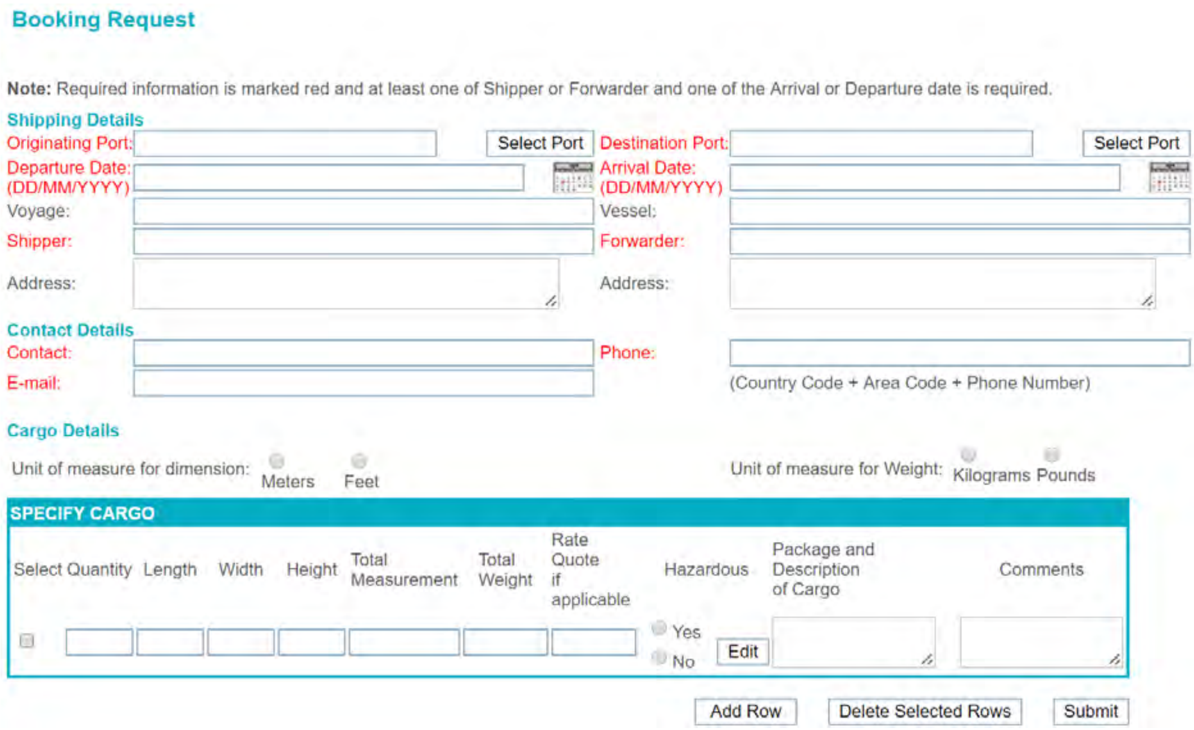

Figure 2. Illustration of the web-front-end used to book cargo in the EDI at WWL.

Figure 2 illustrates the web-front-end that is used by WWL to register cargo in the EDI. There is currently no field for AFV in this system, thus there is a need to update the interface and current database with the AFVs data.

Stena

Registered vehicles owners are asked to state whether the vehicle is battery or gas powered upon booking. Breakbulk cargo, regardless of if it is stowed on a trailer or a flatbed, is under the IMDG provisions.

Authors observation regarding identification of vehicles during visits to vessels in the port of Gothenburg:

WWL

- There have been objects missing barcodes, some had printed papers lying on the dashboard with only text/numbers.
- The size of the barcodes varies.
- The quality of the printed barcodes varies.
- Some vehicles have had barcodes sitting in various angles (rotated).
- Some vehicles have covers, consequently, the barcode is behind a plastic window. This blurs the barcode and also causes light disperse/reflections.
- On some car covers the plastic window is open so that the barcode is properly displayed, on others, the plastic window is closed and obscures the barcode.
- Some vehicles have tinted window glass that makes it almost impossible to find (and read) the barcode.
- Many new vehicles have electrical heating of windows, this is done by a fine mesh of metallic wires in the window. This makes barcode reading

complicated and blocks out RFID signal from transponders placed inside the vehicle.

- Some vehicles only have their license plate as means of identification.

Stena

Passenger and RoPax vessels has a wide mix of vehicles, as mentioned earlier it ranges from bicycles, motorcycles to lorries and breakbulk loaded on flat beds/MAFIs. It also varies a lot with the seasons.

It is a more homogenous mix on the RoRo vessels where it is mainly trailers and breakbulk on flat beds/MAFIs. But on occasions all different types of rolling cargo are transported.

4. Concept

To mitigate the risks with AFVs and to obtain a real time situational awareness of the loading/unloading process, an on-board system that has knowledge of the different types of cargo and their final position on-board will be necessary.

Identification and tracking are two classical problems in computer vision and machine learning. In industry, automatic packet handling, quality control, and vehicle automation are among some of the common areas where this is used.

In this project, we divide the problem of identification and tracking into two processes on-board the RoRo vessel. When the vehicle is entering the vessel, it should be identified and while it is driving towards its final destination, it should be tracked - so that the system knows where every vehicle is parked.

4.1 Basic principles of the system

At the highest level, there is five systems;

1. Connectivity to shore systems such as booking/stowage/planning -systems
2. Identification of the vehicle
3. Tracking of the vehicle on the vessel
4. Positioning of the vehicle on-board
5. Visualisation of vehicles currently on-board

Loading sequence

Identification:

1. From the tag on the cargo, the ID (VIN or cargo ID) matched with the booking system ID.
2. This information is the critical starting point for tracking the cargo on-board the vessel.

Tracking:

1. A tracking system grabs the ID and “pins” it to the cargo as it moves inside the vessel.
2. Cameras with software that knows the layout of each deck (boundaries and ramps etc.) tracks the cargo in three dimensions X/Y/Z.
3. All cameras are connected to a Video Monitoring System (VMS) that can exchange data with all cameras at all times, allowing it to track and “hand over” data between different cameras. The VMS is also connected to the shore/booking system to allow enhanced cargo planning and tracking which in turn may be used for trim and stability control.

Positioning:

1. When the cargo is parked, the VMS “locks” the last known position of the cargo.

Visualisation:

1. The VMS system displays current operation; parked units, moving units in a live feed
2. It also features filtering/sorting/highlighting of different types of cargo (e.g. AFVs)
3. It can generate reports based on operator choices (e.g. show all AFVs, show EVs, show specific VIN or cargo ID).
4. Cargo that failed the identification is highlighted and can be manually corrected/updated.
5. All cameras are accessible to the operator for monitoring/surveillance purposes.

Internal cargo shifting

Tracking:

1. From the position of the parked cargo, the system picks up the tracking of the cargo as it starts to move.

Positioning:

1. When the cargo is parked, the VMS “locks” the last known position of the cargo.

Unloading

Tracking:

1. From the position of the parked car, the system picks up the tracking of the object as it starts to move

Identification:

1. When the cargo is discharged, the on-board system updates the booking system.

4.2 Identification automation

Today's labels whether it is license plates, barcodes or RFID tags, needs to be reviewed and adjusted to comply with preferred reading options and to allow machine vision.

Close cooperation with customers passengers/cargo owner/cargo forwarders is required, depending on the chosen solution.

License plate
Registered vehicles should have a license plate, unfortunately not all vehicles have a license plate at front. The size and placement of the plate varies and as well as the layout and the and number of letters/number/figures. On the trailers that are pulled on board, the license plates are at the rear of the trailers. It is not uncommon that the license plates are dirty and needs mechanical cleaning to be readable.

Barcode
As of today, it is not feasible to use existing barcodes for automation, this is due to several factors.

No conformity of labels

- missing barcodes
- size of barcodes
- placement on cargo

RFID
Some cargo/vehicles are as of today, tagged with RFID, and those tags could be reused, however the booking procedure has to have the functionality for this.

Automation using barcodes

Using stationary cameras or stationary laser scanners are probably the two most favourable solutions. This section describes details about configurations that may be worth to evaluate in a next step. The cargo has to pass through some kind of gate/filter or check point, at this location the barcode readers should preferably be located out of harm's way during loading/unloading. The challenge is the different size/types of vehicle, and the speed.

A good solution would not require the cargo/vehicle to stop during the scanning, slowing down could be fine.

Evaluation of camera positions and angles on board

Within the feasibility study, tests with cameras mounted at vessels were made to verify the general idea of the proposed concept. GoPro cameras were used at two different occasions and on different vessels. It was important to measure and compare different configurations, locations and orientations. After studying the videos captured during those visits we obtained important observations that are summarised below:

- Cameras facing down into a ramp are blinded by glare from the vehicle’s light and it will be very hard for the computer vision algorithms to extract the necessary features for tracking.
- The network of cameras will be used not only for tracking a vehicle from the entrance until its last position but also for a redundant tracking when occlusions appear.
- The field of view is considerably reduced for movable decks where there is a short distance between the ceiling of the deck and the roof of the vehicles.

- At the ramps, the best option for positioning the cameras out of harm's way, is to locate them flushed with bulk heads.

Below, six different configurations that may be evaluated in a follow up study are presented.

Weather deck

For the use of cameras on an exposed weather deck, the situation is a bit different compared to inside a cargo hold, partly by the fact that rain/snow/fog obscures the line of sight and light conditions may vary significantly. And the design of the vessels sets very specific configuration possibilities and challenges.

Configuration #1:

This configuration (Figure 3) offers a redundant field of view thanks to the large quantity of cameras needed for covering the whole space. This can also be seen as a disadvantage due to the larger investment in equipment, installation and maintenance. Since most cameras are aligned in the same orientation as the vehicles when parking, this configuration will suffer also from multiple occlusions which needs to be further studied if this configuration is chosen for implementation.

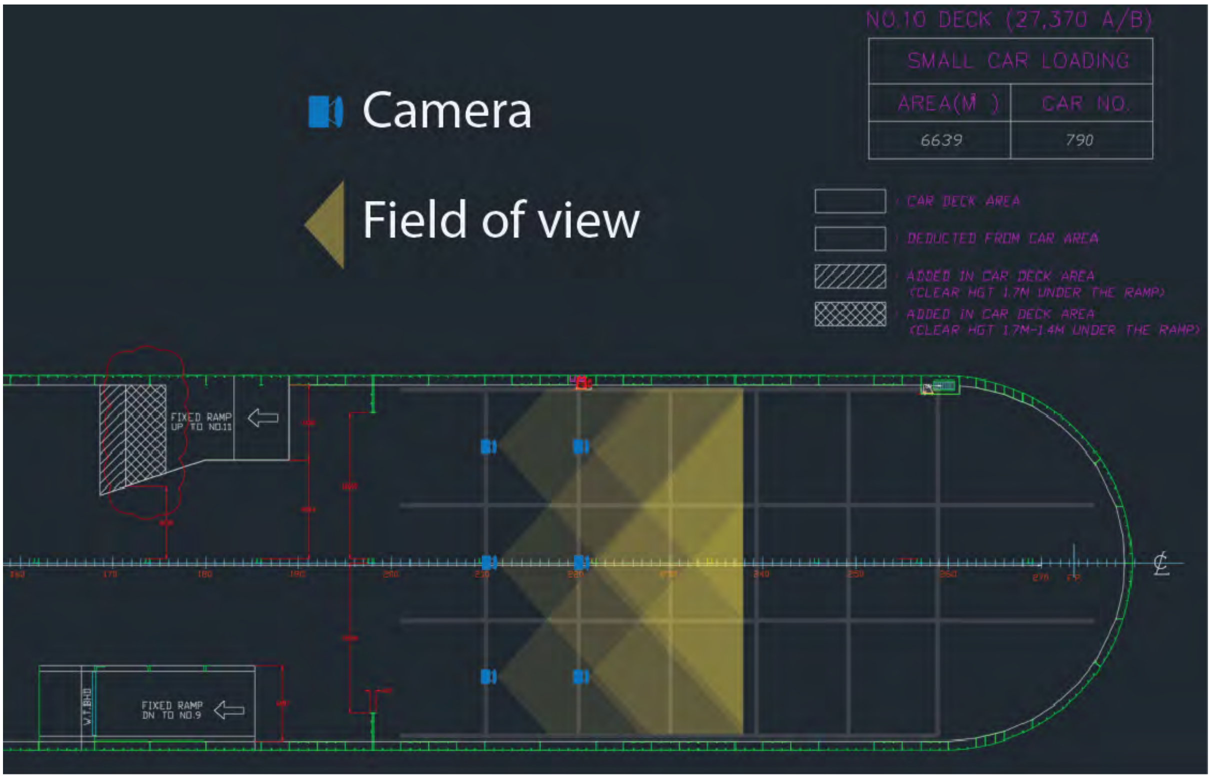

Figure 3. Configuration #1.

Configuration #2:

The configuration shown below, Figure 4, saves several resources in terms of equipment, installation and maintenance but there is a very high risk of suffering from occlusions. Cameras are located on the walls of the vessel and at the angle provided by their field of view. The main disadvantage with this setup is that it was very common to find large sized vehicles parked close to a wall, this would occlude the field of view of many cameras.

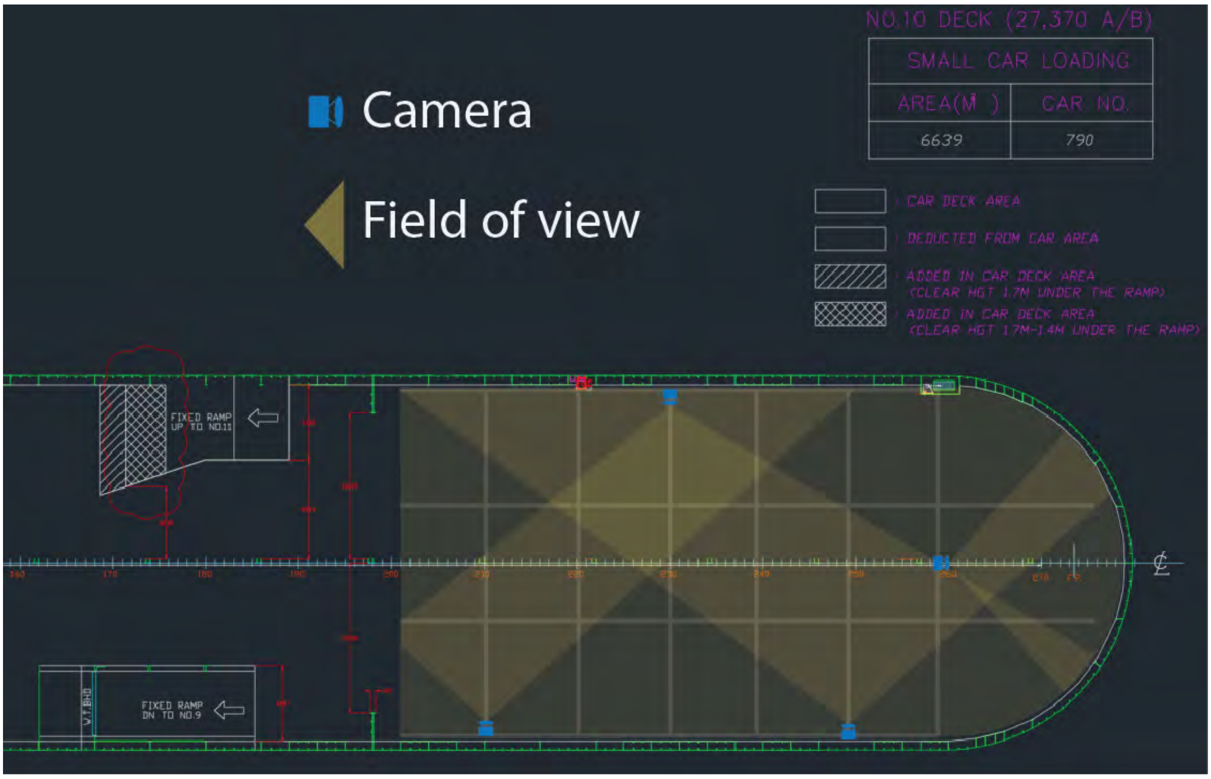

Figure 4. Configuration #2.

Configuration #3:

In this configuration, Figure 5, cameras are tilted and facing each other toward opposite walls. A shorter distance to the walls provides better resolution and redundant information from superposing cameras. The number of cameras and other equipment in general as well as the installation process is reduced in this configuration with respect to the first proposal. It will be necessary however to fine tune the tilt angles of the cameras to include vehicles driving through and parking in the central pathways.

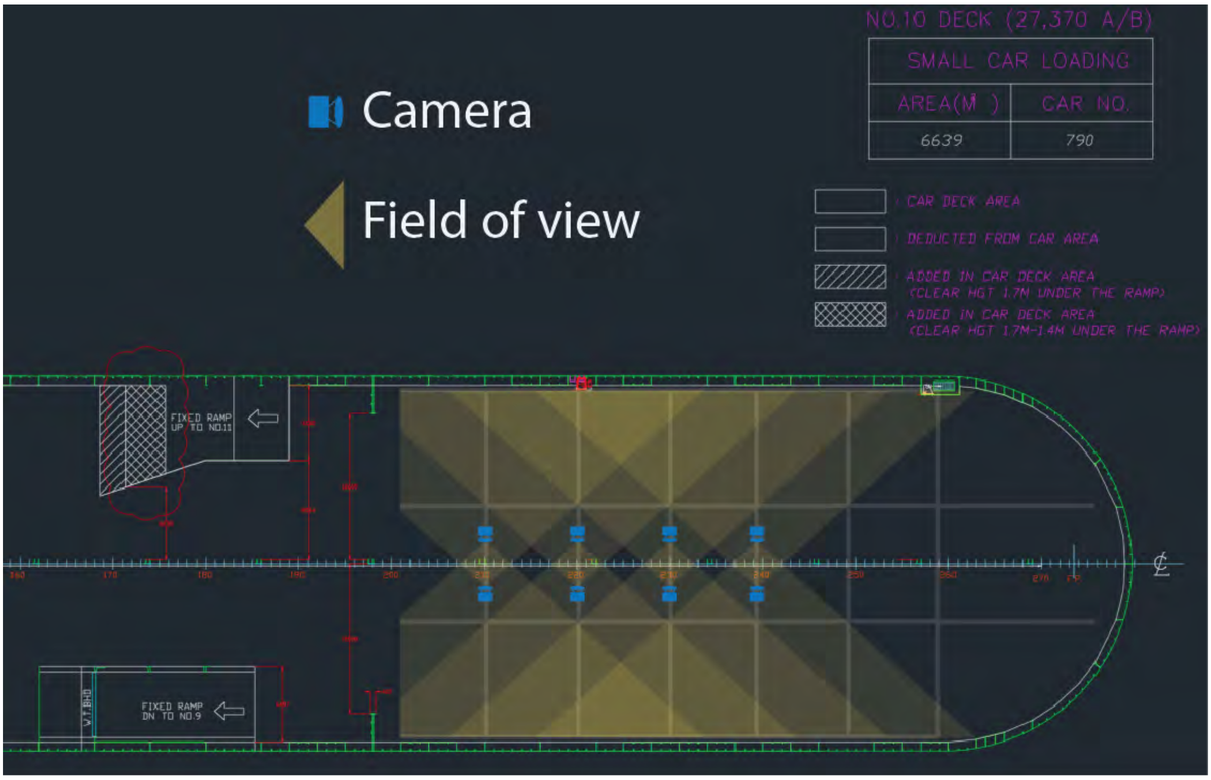

Figure 5. Configuration #3.

Configuration #4:

Cameras are installed on the ceiling of each deck looking downwards perpendicular to the floor. The main advantage of this configuration, Figure 6, is the avoidance of glare (that causes camera blindness) directly into the cameras but the main disadvantage is the reduced field of view. Cameras with large fisheye lenses could solve this problem and offer a better overlap between cameras.

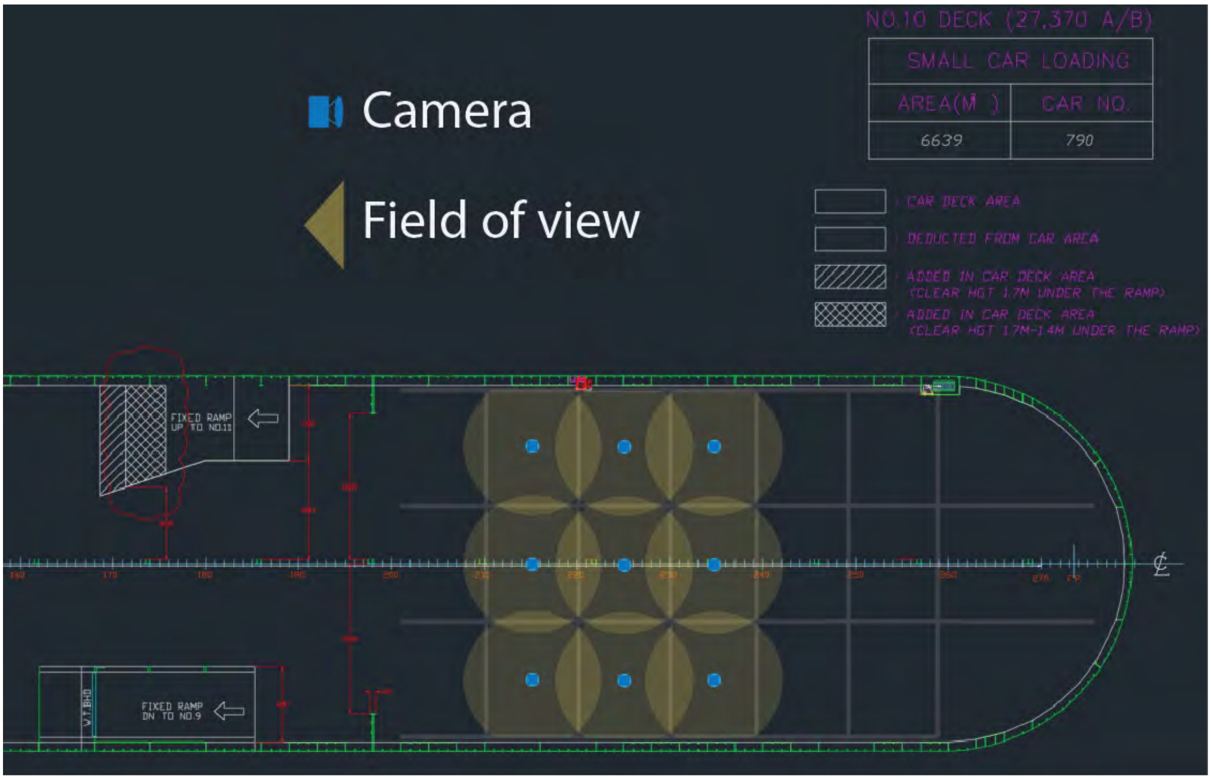

Figure 6. Configuration #4.

Configuration #5:

An alternative solution to a static network of cameras is to design a system where very few cameras move along rails attached to the two central supports that cross the whole ceiling of each deck, Figure 7. Each of those cameras would follow a single vehicle when arriving to the deck and until it is parked at its final location. The total number of cameras required for this solution would be considerably less than that of the previous configurations, but instead of a plug-and-play system in terms of hardware it would be necessary to design and build a more elaborated mechatronic setup with servo-motors for linear and rotational motions. An added value would be the possibility to use specialised cameras for monitoring such as thermal cameras and use only a couple of them as a monitoring device.

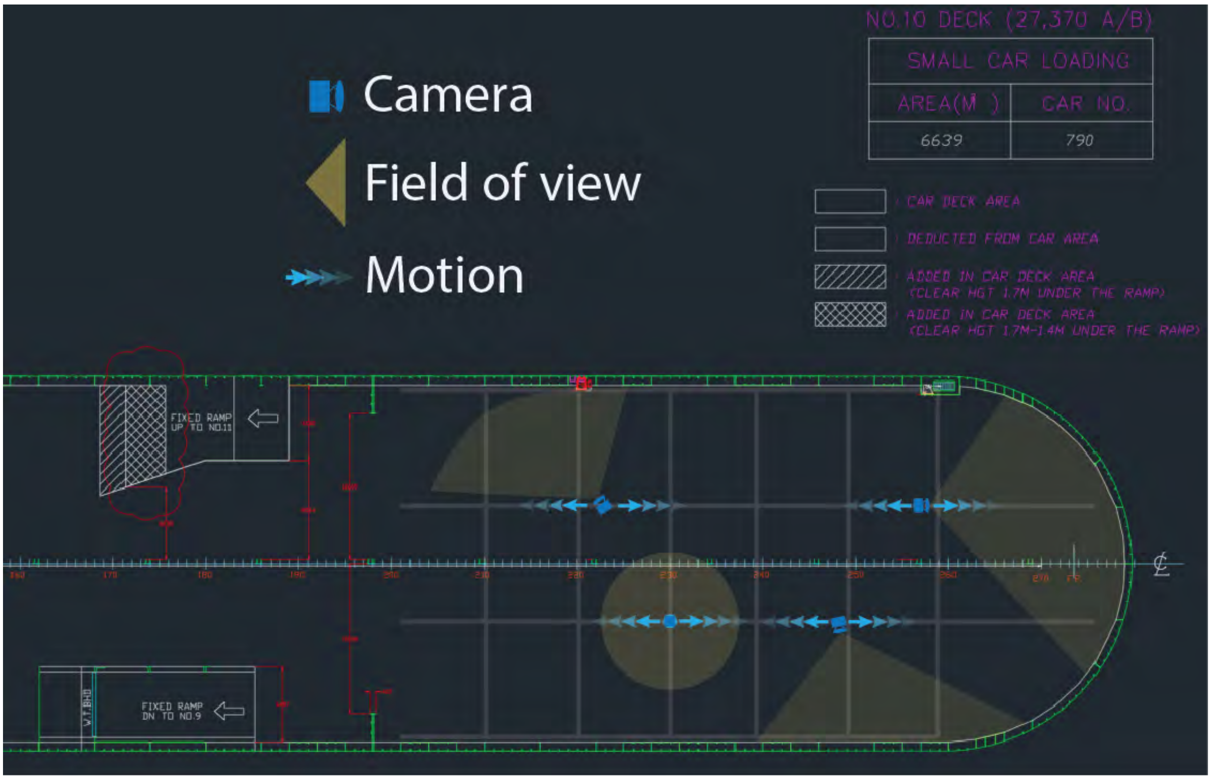

Figure 7. Configuration #5.

Configuration #6:

The use of flying autonomous drones could bring several advantages to this project, Figure 8. First, there is no need for extra installations of any kind since charging of batteries could be done at a central point on each deck where electrical wiring are already in place. This kind of drones could track and move easily in between vehicles for surveillance. The number of cameras will be also reduced largely compared to static solutions; and, like in the previous configuration, it could be possible to use few specialised equipment (e.g., thermal cameras) for surveillance. There are already commercial drones designed and built to protect both the environment and themselves, which is a necessary feature in this project.

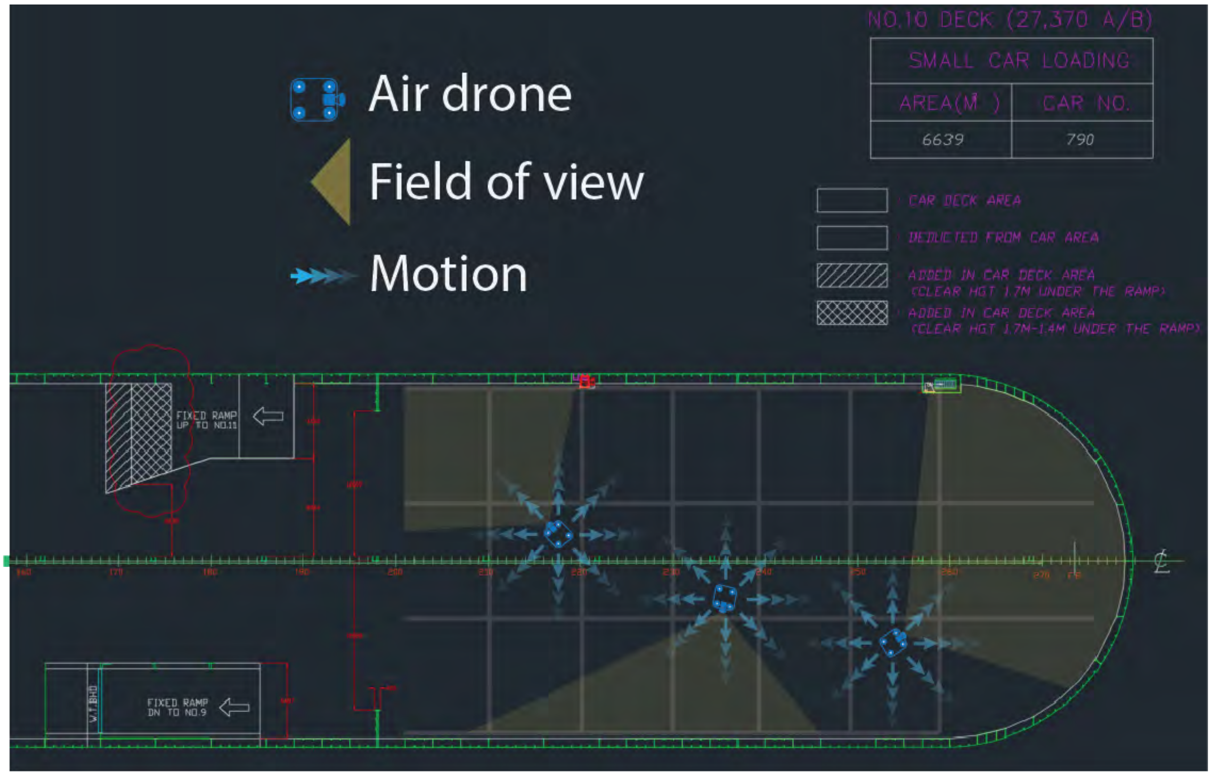

Figure 8. Configuration #6.

Configuration for coverage of ramps and blocked areas

To cover ramps, blocked areas (corridors, behind ramps, supporting walls) a hybrid configuration of cameras will be needed since there are several types of indoor landscapes on the vessels. Some series has two pillar rows, some series has liftable ramps, different series has different constellations of ramps between sections of the vessels.

5. Technologies

Below are three different tables indicating pros and cons of technologies used for Identification, Tracking and Positioning.

5.1 Identification

Based on state of art investigations the following technologies, presented in Table 1, were identified as being part of the solution to identify vehicles on-board RoRo vessels.

Table 1. Pros and cons of different technologies for identification

	Identification	
Technology	*Pros*	*Cons*
Camera 2D	Cheap	Needs light, high resolution, range limitation 0,5
Camera 3D	High accuracy	Needs light, high resolution, range limitation
Ultra Wide Band	High accuracy	Needs installation on vehicle, GSM/3G...
LED Light	High accuracy, cheap	Needs installation on vehicle
Barcode Scanner *Laser Class 1*	Cheap, high accuracy, no extra light	Range limitation (Short range, less than 0,5m)
Barcode Scanner *Laser Class 2*	Medium range (3-4m)	Expensive, needs to be placed so that drivers, crew, stewards are not able to look into the source “by accident”
QR Code Scanner	Cheap, high accuracy, no extra light	Range limitation, requires extra installation on vehicle
RFID	High accuracy, no extra light, high speed, direction (in/out)	Needs to be tagged to vehicle = high volumes, (Frequencies in different regions?)

5.2 Tracking

Based on state of the art investigations, the following technologies, presented in Table 1, were identified as being part of the solution to track vehicles on-board RoRo vessels.

Table 2. Pros and cons of different technologies for tracking

	Tracking	
Technology	*Pros*	*Cons*
Camera 2D	Cheap, known technology	May need careful mounting to avoid back-light
Camera 3D	High accuracy	Need extensive calibration
Ultra Wide Band	High accuracy	Needs installation on vehicle, difficult with reflection inside ship
LED Light	High accuracy	Needs installation on vehicle
Barcode Scanner *Laser Class 1*	Cheap, high accuracy, no extra light	Need Barcode installation on vehicles, range is limited and may need extensive number of sensors, may need several barcodes to be able to identify vehicle at all locations in ship
Barcode Scanner *Laser Class 2*	Short range	Same as for Class 1, with better range however exposure to class 2 is not acceptable.
QR Code Scanner	Cheap, high accuracy	Needs installation on vehicles, range is limited and may need extensive number of sensors, may require several QR Codes to be able to track everywhere
RFID		Only usable for status update when passing a certain "gate" with dual antennas it can also give direction

5.3 Positioning

Based on state of art investigations the following technologies, presented in Table 1, were identified as being part of the solution to position vehicles on-board RoRo vessels.

Table 3. Pros and cons of different technologies for positioning

	Tracking	
Technology	*Pros*	*Cons*
Camera 2D	Cheap, known technology	May need careful mounting to avoid back-light
Camera 3D	High accuracy	Need extensive calibration
Ultra Wide Band	High accuracy	Needs installation on vehicle, difficult with reflection inside ship
LED Light	High accuracy	Needs installation on vehicle
Barcode Scanner *Laser Class 1*	Cheap, high accuracy, no extra light	Need Barcode installation on vehicles, range is limited and may need extensive number of sensors, may need several barcodes to be able to identify vehicle at all locations in ship
Barcode Scanner *Laser Class 2*	Short range	Same as for Class 1, with better range however exposure to class 2 is not acceptable.
QR Code Scanner	Cheap, high accuracy, no extra light	Need installation on vehicles, range is limited and may need extensive number of sensors, may require several QR Codes to be able to track everywhere
RFID		Only usable for status update when passing a certain "gate" with dual antennas it can also give direction

5.4

5.5 Recommended solution

Laser - for Identification

It is important to note that not all vehicles currently have an attached barcode that enables identification; moreover, the barcodes attached to those vehicles that do have one, differ from each other in size and position on the vehicle, depending on the manufacturer. This heterogeneous way of identification puts hard constraints on the alternatives for an automated solution. Therefore, the recommended solution for the identification problem, with the system working as in the current state, is based on using scanners to manually read the already existing barcodes attached to each vehicle.

A homogeneous presentation of the information, where size and location of barcodes can be standardised and attached to all vehicles entering a vessel, would give us the possibility to automate the identification process. In this case, it could be possible to create a scanning station at the entrance of the vessel where vehicles wouldn't need to wait or stop for being identified. Again, in this case the recommended solution would be a barcode scanner fixed to the frame of the scanning station.

A further improvement to the previous solution would be to attach a standardised RFID tag to each vehicle entering the vessel. The main advantage of identifying a vehicle with this method is the speed at reading this type of tags which would be very important for reducing the loading time of the whole vessel and thus, reducing the time of being berthed at the port.

RFID - for Identification

From Table 1, it is found that RFID have the following features:

- \+ Fast, reasonable range, direction
- \- Needs different frequencies for different regions worldwide

Camera - for Tracking and positioning

The main difficulty with the kind of elements that need to be tracked and located in this project is the lack of individual features that could be useful for this purpose. There could be dozens and even hundreds of vehicles of the same size, colour and model without any physical feature that can be distinguishable. With these limitations, it is recommended to design and work with a deep learning solution that will consider not only physical features but also motion through time for learning, tracking and locating any element in space and time.

An end-to-end solution, using machine learning techniques is recommended for the tracking and positioning part of this project, due to the complexity of the input variables both in space and time. There are already efficient and robust implementations of tracking objects using a single camera, thus the major challenge will be the successful tracking across multiple cameras.

VMS Video Monitoring System

The VMS software takes input from both cameras as well as from external systems such as the booking system and stowage plans. It has functionality that “supervises” all the cameras/scanners used to gather data and tracking the vehicles as they transit inside the vessel.

It has visualisation capabilities for the operators so that they can follow the loading/unloading progress.

Each deck and ramps are mapped in the system so that all vehicles can have a unique position in X,Y,Z.

It can show the stowage situation down to each individual car.

The operator can also use direct video feed from the cameras to monitor the current situation.

The system tracks vehicles that are not tracked properly and flag them for later inspection, allowing post-loading correction of data (e.g. a vehicle that are not identified at the “toll gate” can easily be located and personnel can search-scan and identify the vehicle using manual handheld scanners. It could be visualised as a grey box among all other green (correctly identified and tracked) parked vehicles). When identified by the crew, the vehicle's ID tag is scanned and the location is ticked off in an “app” (similar to choosing your seat in an airplane).

The same handheld device and app could be used at the “toll gate” to capture ID’s of the cars as they roll on/off the vessel if there are problems identifying any vehicle at the “toll gate”.

“Toll gate” identifying the cargo

During loading/unloading, the vehicles have to pass a “gate” where several functions are executed:

Identifying the vehicle

- The ID-tag is either the vehicle VIN or a given ID from the booking system.
- Reporting to the vessels “VMS and Logistic system” that the car is being loaded or offloaded.

Added values

- The vehicle is “surveyed” for damages, this is done by taking photos/film of the vehicles as they pass the gate during loading and the procedure is repeated during unloading.
- All vehicles carrying gas have to be audited (leak testing) prior to loading and labelled/marked with a yellow triangular sticker. During the optical survey, this sticker could be identified. If the vehicle is “marked” as a vehiclecarrying gas containers in the booking system and the sticker is not detected, the car could be stopped (red light) from proceeding on-board the vessel.

Cameras with tracking software

A network of cameras will cover all places of a deck and its access ramps; and this will be implemented for every deck of the vessel. This network will have a common information hub "brain", which will be in charge of running a machine learning algorithm for tracking and positioning all vehicles in the vessel. Due to the similarity among vehicles, a traditional computer vision algorithm for classification is not advisable in this project. An end-to-end algorithm based on reinforcement learning on the other hand, has the potential for solving the challenges present in this application. The selected algorithm should allow us to extract static features that can be linked across multiple cameras and associated to the digital layout of the vessel. This learning algorithm should also allow us to associate temporal features such as a sequence of images and the objects inside those sequences. Finally, the algorithm should be able to track vehicles considering partial occlusion from other vehicles, people or beams between decks.

Once a vehicle has reached its final parking location, it will update the layout of the vessel now with all the vehicles that are parked in their final position. This information could then be shared for internal use and/or as an additional service with clients in the form of mobile applications.

6. Conclusion

This report has examined and evaluated feasible concepts for in-door positioning of vehicles on board RoRo vessels. The technologies also lay the foundation for improving the cargo planning and vessel utilisation through a connected ship infrastructure.

The proposed solution includes a camera-based system that identifies vehicles as they enter the ship. A camera based system that can track vehicles as they drive towards their final parking location on-board the RoRo ship. Finally, the tracking system can be used to verify the final parking location of the vehicles and this information can be stored in the shore/booking system to allow for a better control of where vehicles are located and if they are loaded or unloaded at the correct location.

Benefits with the recommended solutions are:

- Live monitoring of cargo operation
- Fire detection (early smoke, light)
- Live monitoring and tactical support for fire team crew/leaders
- Automatic detection of stowaways
- Quality control, documentation of vehicle/cargo as it is loaded/offloaded
- Change of destination for the vessel or its cargo, i.e. the system would give a possibility to determine where are these vehicles/cargoes are stowed, and how costly will it be to shift/relocate the cargo for the operator/customer.
- Optimized utilisation of cargo operation and hold.

6.1 Discussion and future work

The recommended solution may be implemented at a part of a RoRo vessel in order to evaluate the concept and reveal any unforeseen challenges. The first identified challenge is how the identification should be made in a cost-efficient way. Either by using high fidelity cameras that automatically reads the barcodes, or by either using existing RFID-tags, with the risk of different standards on RFID messages across brands, or installing new tags. The second challenge is to track vehicles while they move inside the vessel, and handling the handover between different cameras throughout the vessel.

Other tracks that should be given more attention, that may completely avoid any fixed installation, is the use of mobile/flying robots/drones. Such a feasibility would be highly relevant within this context. A droid with wheels that could autonomously navigate in the ship and automatically detect, identify and position parked vehicles would be highly cost efficient. The challenge is to navigate and to make the droid safe, so that it does not crash into any parked vehicles. Drones may also be an alternative if their operation can be made safe, so that no harm is made to the cargo if the drone crashes.

Another alternative that would be cost efficient in terms of installed cameras concerns a rail-system where moving cameras are mounted in the ceiling being able to move and capture images of more vehicles than if it had a fixed mounting.

With the mandate to connect all future vehicles proposed by NHTSA[11] in the US, there may be a possibility to use the internal communication of vehicles using DSRC (Dedicated Short Range Communication) to communicate vehicle ID from the vehicles. This is however not standardised, nor mandated yet. And it will take several years until all new vehicles have this type of communication installed.

Also, other types of cameras (e.g. Infrared, Ultraviolet, LIDAR…) and a combination of these could give the on-board VMS system fantastic capabilities, just to mention one, hot spot detection of cargo/vehicles that is “abnormal” much earlier than today's heat/smoke sensors on the vessel.

[11] https://icsw.nhtsa.gov/safercar/v2v/

8. APPENDIX

A. Regulations on vessels carrying EV/Gas driven vehicles

MSC.1/Circ.1471

MSC.1/Circ.1471

29 May 2014

RECOMMENDATION ON SAFETY MEASURES FOR EXISTING VEHICLE CARRIERS CARRYING MOTOR VEHICLES WITH COMPRESSED HYDROGEN OR NATURAL GAS IN THEIR TANKS FOR THEIR OWN PROPULSION AS CARGO

1 The Maritime Safety Committee, at its ninety-third session (14 to 23 May 2014), in adopting the amendments to SOLAS chapter II-2 to include requirements for vehicle carrier carrying motor vehicles with compressed hydrogen or natural gas in their tanks for their own propulsion as cargo, approved *Recommendations on safety measures for existing vehicle carriers carrying motor vehicles with compressed hydrogen or natural gas in their tanks for their own propulsion as cargo*, as set out in the following paragraphs.

2 The carriage of vehicles with compressed hydrogen or compressed natural gas in their tanks for their own propulsion should be to the satisfaction of the Administration, taking into account SOLAS regulation II-2/20-1 and SP 961 and SP 962 of the IMDG Code, as applicable.

3 The shipper should provide a signed certificate or declaration that the vehicle fuel system, as offered for carriage, has been checked for leak-tightness and the vehicle is in proper condition for carriage prior to loading. In addition, the shipper is to mark, label or placard each vehicle, after it has been checked for leak-tightness and that it is in proper condition for carriage. During loading, the crew should check each vehicle for the shipper's markings.

4 Member States are invited to use the recommendations above on a voluntary basis when approving the carriage of motor vehicles with compressed hydrogen or compressed natural gas in their tanks for their own propulsion as cargo on existing vehicle carriers and bring them to the attention of owners, operators and other parties concerned, as appropriate.

B International Maritime Dangerous Goods code IMDG

Vehicles and equipment are not subject to the provisions of this code if they are stowed on a roll–on/roll–off ship or in another cargo space designated by the Administration (flag State) as specifically designed and approved for the carriage of vehicles and equipment and there are no signs of leakage from the battery, engine, fuel cell, compressed gas cylinder or accumulator, or fuel tank when applicable.

Special provisions

B1 SP961

Exceptions:

SP961 applies to vehicles which are being transported on a vessel in an area specifically designed to contain vehicles such as Roll on, Roll off vessels and other vessels which have approved designed areas. These areas do not include storage areas for containers.

Such vehicles are not subject to any conditions of the IMDG code provide there are no signs of leakage from the battery, engine, fuel cell, compressed gas cylinder or accumulator, or fuel tank when applicable.

In addition when transported by vessel, vehicles and equipment when transported in cargo transport units which comply with the following are also not subject to the conditions of the code:

do not contain dangerous goods, flammable liquid or flammable gas fuel tanks are empty, the positive pressure in the tank does not exceed 2 bar, the fuel shut-off or isolation valve is closed and secured have batteries installed which are protected from short circuit
(Note: these exceptions are not applicable for lithium batteries installed in vehicles or equipment)

B2 SP962

SP962 applies if the conditions of SP961 are not met. Vehicles and equipment are assigned to Class 9 and must meet the following conditions:

Vehicles and equipment shall not show any signs of leakage from:
Batteries
Engine
Fuel cells
Compressed gas cylinders accumulators, or fuel tanks

If the vehicle or equipment is powered by a flammable liquid, the fuel tank may:
be up to ¼ full or, up to 250 L whichever is less.

For a flammable gas powered vehicle or equipment, the fuel shutoff valve must be securely closed. (Note: There is no limitation on the amount of flammable gas contained in the fuel tank).

All installed lithium batteries must be of a design type which successfully passed the United National Manual of Tests and Criteria, part III, subsection 38.3 or be approved by a competent authority and must be protected from damage, short circuit and accidental activation.

Additional dangerous goods such as fire extinguishers gas, compressed accumulators and airbag inflators are permitted as long as they are securely mounted in the vehicle or equipment.

If all of these conditions are met, then the marking, labeling and placarding provisions of the IMDG do not apply.

The documentation requirements apply.

B 3 From DNV GL on RoRo vessels keel laid after 2016

Excerpt

"Rules Ship Technology, Part 1 Seagoing Ships

Chapter 3 Electrical Installations

Section 16 Additional Rules for Ships for the Carriage of Motor Vehicles

Edition July 2015 Germanischer Lloyd Page 16–7

I Requirements for Spaces intended for Carriage of Motor Vehicles with compressed Natural Gas in their Tanks for their own Propulsion as Cargo

I.1 Electrical equipment and wiring
All electrical equipment and wiring shall be of a certified safe type for use in an explosive methane and airmixture [2].

I.2 Ventilation arrangement
I.2.1 Electrical equipment and wiring, if installed in any ventilation duct, shall be of a certified safe type for use in explosive methane and air mixtures.
I.2.2 The fans shall be such as to avoid the possibility of ignition of methane and air mixtures. Suitable wire mesh guards shall be fitted over inlet and outlet ventilation openings.
I.3 Other ignition sources
Other equipment which may constitute a source of ignition of methane and air mixtures shall not be permitted.
I.4 Detection
When a vehicle carrier carries as cargo one or more motor vehicles with compressed natural gas in their tanks for their own propulsion, at least two portable gas detectors shall be provided. Such detectors shall be suitable for the detection of the gas fuel and be of a certified safe type for use in the explosive gas and air mixture.

J Requirements for Spaces intended for Carriage of Motor Vehicles with compressed Hydrogen in their Tanks for their own Propulsion as Cargo

J.1 Electrical equipment and wiring
All electrical equipment and wiring shall be of a certified safe type for use in an explosive hydrogen and air mixture [2].
J.2 Ventilation arrangement
J.2.1 Electrical equipment and wiring, if installed in any ventilation duct, shall be of a certified safe type for use in explosive hydrogen and air mixtures and the outlet from any exhaust duct shall be sited in a safe position, having regard to other possible sources of ignition.
J.2.2 The fans shall be designed such as to avoid the possibility of ignition of hydrogen and air mixtures. Suitable wire mesh guards shall be fitted over inlet and outlet ventilation openings.
J.3 Other ignition sources
Other equipment which may constitute a source of ignition of hydrogen and air mixtures shall not be permitted.

2 Refer to the recommendations of the International Electrotechnical Commission, in particular, publication IEC 60079.

Source: http://rules.dnvgl.com/docs/pdf/gl/maritimerules/gl_i-1-3_e.pdf

C. Concept description

The concept should provide in-door positioning of vehicles on board RoRo vessels. An additional feature is to serve as a building block for a larger initiative to archive the connected vessel, with improved ability to plan the on- and off-loading, logistics etc.

Assumptions

1. We assume that all cargo has an identification that is visible through machine vision
    a. Cars have a VIN (Vehicle Identification Number) on either the left passenger back-seat window or, in the right part of the windscreen.
    b. Other cargo (including used-cars, boxes, chassis, construction equipment etc.) should have an equivalent visual ID-tag so that it can identified and mapped to the storage plan.
2. The systems should handle rolling cargo.
3. It is assumed that the cargo can be on-loaded on either the rear-ramp or the side-ramp.
4. The size of the cargo is limited by the ramp-door size e.g. typically maximum 7 m high and 12 meters wide.
5. The lowest roof height of where the cargo is stored is 1.70 m.
6. The lowest distance between the cargo and the ceiling is close to 5 cm.
7. The positioning accuracy of the parked cargo should be sufficient to give an accurate "grid" of where all vehicles are positioned (indicative resolution is 1.5 m).

Cargo operation

1. Generally, all vehicles are driven on-board by their own engine. Other cargo is assisted on-board e.g. towed/pushed in place (only the cargo should be registered).
2. The driver should make sure that the vehicle is identified before entering the cargo deck (e.g. remove obstacles, snow and drive in slow speed).
3. We assume that no extra tags/devices are attached to the outside of the cargo (minimising the risk of damaging the cargo).
4. The cargo is entering the ship ramp sequentially (not in parallel/pairs).
5. Cargo operation can occur at multiple decks and ramps, both loading/unloading in parallel.

Expected benefits

1. Identification
2. Tracking
3. Connection

- Improved stability control since the exact weight and location of cargo is known
- Improved safety since the VIN is known of the cargo, the drive-line is also known and where it is parked.
- An identification station is capable of documenting the physical status of the cargo - making it possible to track any damages.
- Since the exact location of all cargo is known, it is easier to re-schedule on- and off-loading.
- Via IR cameras be able to early detect “hot spots” and own personnel and unauthorised persons on deck (stowaways, passengers etc.)

Proposed solution

The concept builds on machine vision-based sensors that automatically identifies VIN by capturing barcodes from stickers placed on either the left backseat passenger window or the right windscreen of cars (vice versa for left steered cars). The system then tracks the cargo from the identification area/station to its final parking position.

Generally:

1. Identification
2. Tracking to final parking position
3. Connection to ship storage plan to enhance stability control, firefighting techniques for the particular type of cargo (different drive-lines requires different techniques for fire extinguishing)

Functional description

1. Identification
    a. For each on-off loading ramp, an identification station should be set up to identify the vehicles as they are entering the vessel. They should not be allowed to enter the cargo decks until it is correctly identified.
    b. Two methods for identification are recognized that can be used for automatic identification
        i. Camera-based where e.g. OCR is used to read the VIN from the ID-tags.
        ii. Laser-based scanners that reads the bar-code of the ID-tags.
        iii. RFID-based tags that may be printed at the same time as bar-codes are printed.
    c. If the automatic procedure fails, a manual backup system should be used. A handheld sensor should be used to scan the ID-tags.

2. Tracking
    a. When the cargo is identified it is allowed to enter the cargo decks. The ID of the cargo should be associated with its digital counterpart - captured by the tracking cameras.
    b. Sufficiently many cameras should be mounted to cover the complete cargo area, including ramps, since they may be used for stowage.

3. Connection
    a. Power supply is preferably covered by Ethernet network (Power over Ethernet)
    b. To process data and to track the vehicles, it is assumed that a central server connects all on-board cameras. Server rooms are available on-board the ship.
    c. To enable additional features of the system, described in the Section Expected Benefits, an API is set up to exchange data.

4. Visualisation

A local human machine interface (HMI) on-board should be used to monitor (in real time) the loading process and be able to identify any vehicles not being correctly identified or tracked. If any vehicle needs manual attention a mobile app could be used, with the visual interface reminding of a flight seat booking layout to mark any vehicle and then manually scanning or entering the correct ID.

With the HMI, it should be possible to gather statistics to create report of the system performance.

5. API Logistic/Trim & Stability

Interconnectivity with land and on-board systems that is used by Fleet Operation Centre (FOC) and Logistic Operation Centre (LOC)

Lighthouse gathers leading maritime stakeholders through a Triple-Helix collaboration comprising industry, society, academies and institutes to promote research, development and innovation within the maritime sector with the following vision:

Lighthouse – for a competitive, sustainable and safe maritime sector with a good working environment



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