D27.1

Dynamic Dispatching – Cartography

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1. Executive Summary

Overall objective of WP 27 is to identify, coordinate and describe dynamic dispatching requirements and constraints that are specific to last-mile operations in terminals/yards, such as terminal operations, optimized loading and unloading in relation to real-time traffic restrictions and resource availability and constraints, order data management and transfer, dynamic slot management, dynamic task management, digital check-ins of containers/goods, etc. in an harmonised way in order to reduce knowledge barriers for operators and freight forwarders to access any terminal and to share status information in real-time to relevant stakeholders, implement real-time monitoring requirements. The description needs to be coordinated by the joint parties and with strong demand management from the multimodal industry, involving a substantial part of market stakeholders in multimodal freight and in strong alignment with all relevant technical enablers.

This description than formulates the basis of the envisaged implementation of real-time interfaces and the demonstration of their advantages.

14 Partners and affiliate entities have joined their forces with almost 130 Person months of effort, to jointly develop 5 use cases across Europe. All use cases aim to show what a positive effect dynamic information exchange can have in Terminals and Yards. Developments are ongoing for the mock-ups and demonstrators that will reach TRL 4-8.

The 5 use cases are not integrated in one single TOS but rather show the various best practices and shall demonstrate benefits. The interaction in between the different use cases to even further increase benefits are envisaged to be elaborated with in the second wave.

Especially the continuous customer and stakeholder engagement is encouraging us, indicating that we are on the right track.

But the use cases have also the objective to highlight current boundaries, that could not yet be tackled. Most of these boundaries are less technical issues rather than data availability and especially commercial constraints.

2. Abbreviations & Acronyms and Glossary

Abbreviation / Acronym	Description
EDICT	Enhanced Data Interoperability for Combined Transport stakeholders
ETA	Estimated Time of Arrival
GDPR	General Data Protection Regulation
ILU	Intermodal Loading Unit, *containers, swap-bodies and semi-trailers*
IM	Infrastructure Manager
InGa-Z	Intermodales Gate der Zukunft (intermodal gate of the future)
IVG	Intelligent Video Gate
LSP	Logistics Service Provider
LU	Loading Unit
OCR	Optical Character Recognition
RNE	Rail Net Europe
RU	Railway Undertaking
TAF TSI	Technical Specification for Interoperability relating to Telematics Applications for Freight Services
TMS	Terminal Management System
TMS	Traffic Management System
TO	Terminal Operator
TOS	Terminal Operating System
UIC	Union Internationale des Chemins de fer
YCS	Yard Coordination System
YDS	Yard Dispatching System
YMS	Yard Management System
YO	Yard Operator

Glossary

Term	Definition
Intermodal Operator	A transportation modality which uses standardized cargo units (such as containers, swap bodies and semi-trailers) that can be easily moved across different modes of transportation (such as ships, trucks or trains) to be brought to destination.
Combined Transport Operator	Intermodal transport chain with the focus on the road for the first and last mile.
Railway Undertaking (RU)	A company or entity that operates services and transportation of passengers and/or freight by rail.
Infrastructure Manager (IM)	An entity responsible for the management, maintenance, and development of the railway infrastructure, which includes tracks, stations, signalling systems, bridges, tunnels, and other facilities necessary for the safe and efficient operation of trains.
Intermodal	The movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes. By extension, the term intermodality has been used to describe a system of transport whereby two or more modes of transport are used to transport the same loading unit or truck in an integrated manner, without loading or unloading, in a [door-to-door] transport chain.
Multimodal	Carriage of goods by two or more modes of transport. It extends the intermodal option and is a prevalent method for transporting freight. In multimodal transport, goods are transported door-to-door using at least two modes of transport. Unlike intermodal transport, there is a possibility of reloading when changing modes. Importantly, the number of branches in the transportation route does not affect the number of transport contracts; it remains one.
Intelligent Video Gate (IVG)	Consists of a gate system installed at relevant railway nodes and equipped with cameras and RFID readers for automatic identification of wagons and intermodal loading units.

Intermodal Loading Unit	A standardized container or cargo unit designed for seamless transportation across different modes.
Container	A standardized cargo unit used for the efficient transportation of goods (20-foot or 40-foot lengths).
Use case	One distinct application of a system/function.
Use Case Environment	Geographical area in which the implementation of multiple use cases leads to a development of dedicated systems/functions and where these developments will be demonstrated.
Long-Term Planning Period	Means a period of time usually limited by the moment when it is possible to establish and make changes to objects such as transport, train and its resources with sufficient lead time before implementation.
Short-Term Planning Period	Means the time period bounded above by a long-term time period and ends a few hours, maximum 1 day before the realization.
Real-Time/Operational Period	This period starts a few hours before the beginning of the transport, through the actual running of the train, until the end of the transport.
Artificial Intelligence (AI)	Technologies to make machines think and act more like humans.
Common Data Model	A common data model aims to standardize that logical infrastructure so that many related applications can operate on and share the same data.
Cybersecurity	A Method of protecting computer systems, networks, and digital information from unauthorized access, attacks, and damage to ensure confidentiality, integrity, and availability of data.
Timetable	A scheduled plan with organized information about the arrival and departure times of trains at various stations along a railway network.
Train Path	A scheduled time slot on a railway track allocated for the movement of a specific train.
Dispatching	Dispatching in Terminals and Yards is understood as the prioritization of actions and tasks in order to lower downtimes and make the maximum use of infrastructure.
Terminal	A location where trains begin or end their journeys and where various operational activities take place. They play a crucial role in the transportation network by facilitating the

	loading/unloading processes and transfer of passengers or freight between different modes of transportation.
Yard	An area where trains are assembled, disassembled, sorted, and stored.
Hump yard	A specific type of rail yard designed for classifying or sorting railcars based on their destination.
Flat yard	A type of rail yard where railcars are classified and assembled using flat switching (railcars are moved horizontally between tracks).
Track-Time-Slot	Specifies at which track and at which time a train should be served, e.g. for loading or maintenance.
Corridor	A Rail Freight Corridor (RFC) is a designated rail route between two or more countries in the European Union that connects two or more stations along a main route.
TRANS4M-R	Transforming Europe's Rail Freight – The overall goal is to establish rail freight as the backbone of a low-emission, resilient European logistics chain which fulfils end-user requirements to full satisfaction.
Functional Requirement	Functional requirements define what a product/system must or should be able to do.
Non-Functional Requirement	Non-functional requirements define how a system should function. They typically tell us something about the performance of the system.
Milestone	The status or geographic position of a train, wagon set or loading unit in the transport process.
Block train	A dedicated and direct freight train in most cases for one customer operating from origin to destination with the aim of keeping lead times short.
Intermodal train	Freight train that carries *Intermodal Loading Units.*
Single Wagon Load train	Freight train transporting individual, mixed class of wagons carrying smaller, diverse shipments from different shippers.

3. Dynamic Dispatching

Introduction

The objective of dynamic dispatching is to implement a harmonised real-time interface between Railway Traffic Management System and the yards and the terminal management systems, in order to dynamically adapt planning and tasks in yards and terminals according to real-time evolution of traffic and availability of assets. The overall objective is to enable harmonised yard operations and terminal operations across Europe to further ease interaction between different yards or between different terminals or in between yards and terminals.

It was the collective effort to investigate the current boundaries in the intermodal ecosystem which is hindering more freight on rail. Within the Workpackage 27 community, extensive stakeholder engagement took place, involving partners, their affiliate entities and the customers of both. This interaction led to a list of requirements, that the group transformed into features with which we want to collectively tackle these requirements. All requirements have been collected in Project Place and will be transferred to Polarion. The requirements have been prepared and harmonised so that they are “Polarion ready” with the aim, to show, that we tackled all requirements with the mapping features and to therefor check for achieved optimizations.

These requirements and features have than been mapped to the different envisaged use cases. The objective was to have different use cases in different countries and surroundings, with a focus on yards and terminals. In general, the Work Package 27 aims for a relatively high TRL (6-8). Almost all use cases are working with real customer data and in real environments. Some use cases are nevertheless at a lower TRL due to innovative nature of them or contain elements that are at a lower TRL level, as they are tested if they can really bring an operational additional benefit before developing them to TRL 8 or above.

Objective

As of today, the usage of Rail in Freight is still around 20 % only. This has many reasons, but one factor is the lack of real-time information and therefore not optimal decision-making process in yards and terminals.

The group of Workpackage 27 has focused on 5 different Use Cases to demonstrate the advantages of how seamless real-time data exchange can accelerate process and stimulate for more freight on rail.

The first Use Case focuses on a dynamic terminal operating system, dynamic task adaptations thanks to real-time data from the traffic management system and sophisticated intermodal prediction.

The second Use Case demonstrates how the interaction with real-time data from video gates can enhance operational procedures.

The third Use Case elaborates on how the dynamic information from traffic management systems and intermodal prediction can support a decision support functionality for the various tasks and conflicts in a yard.

The fourth Use Case demonstrates the booking of marshalling yard services in order to analyze the impact of change requests by reordering activities in the last mile, terminals and Marshalling yards with the support of dynamic scheduling.

The last Use Case focuses on the prolongation of the promising works that have been accomplished during the Shift2Rail project YCS around dynamic dispatching requirements for yard coordination system in Malmö, Sweden.

All Use Cases want to demonstrate as a Key Performance Indicator how processes could be accelerated with a before and after comparison, with or without dynamic data to help make processes and decisions faster and more accurate.

All Use Cases are focused on real applications, in order to avoid theoretical work, that finds no application in the real intermodal world. But the focus of the Use Cases is to demonstrate the benefits in order for them to become blueprints for the European intermodal sector.

The project work concerning each use case is aimed at increasing the technology readiness level (TRL) of a corresponding module, either as a development of an existing system or by establing a new system. The table below summarizes the TRL goals of the modules within the Trans4M-R project.

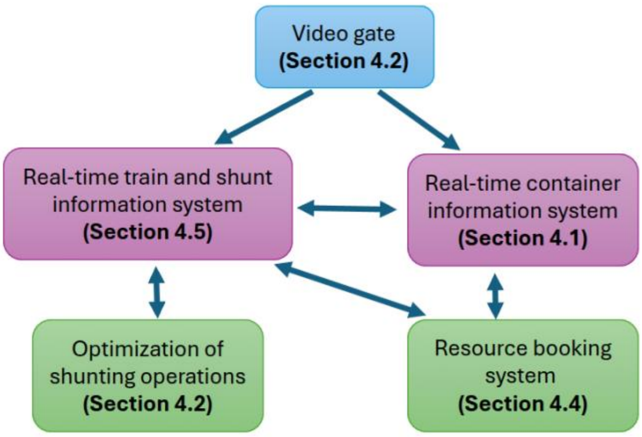
Table 27.1.1 Use Case overview with TRLs

Use case	System	Existing TRL	Goal TRL
Dynamic Dispatching in an Intermodal Terminal in Germany (Section 4.1)	Terminal Operating System	5	8
Dynamic Integration of the Terminal Operating System with Intelligent Videogate (Section 4.2)	Terminal Operating System	5	6/7
Decision support for shunting operations and yard dispatching at Alnabru (Section 4.3)	Yard Dispatching System	n/a (new system)	4
Booking system for Marshalling yards (Section 4.4)	Marshalling Yard System	n/a (new system)	7
Dynamic dispatching requirements for Yard Coordination System (Section 4.5)	Yard Coordination System	n/a (new system)	5/6

Overview of integration concept and data dependencies

For each of the five use cases, the cartography in the section below details the concepts and requirements for each system independently. The technical work of integrating these systems tightly through an overarching Terminal Operating System (TOS) is beyond the scope of the Trans4M-R project. However, the architecture concept for such an integration is illustrated in the figure below.

Figure 27.1.1 Integration Concepts



The arrows in the figure above indicate messages that are passed between the modules. These messages are described in further detail in the table below. For each message type, the table lists the source and destination, naming both the system module and the stakeholder, i.e., Infrastructure Manager (IM), Railway Undertaking (RU).

Table 27.1.2 Message Types

Source		**Message type**	**Destination**	
System	**Stake-holder**		**System**	**Stake-holder**
Video gate	IM	Arrival of train	YCS	IM
Video gate	IM	Arrival of container	YCS	IM
External (TMS)	IM	Prediction of train ETA	YCS	IM
External	RU	Ad-hoc shunting request	YDS	IM
YDS	IM	Shunting plan	YCS	IM

4. Use cases derived from the cartography of requirements

The collection of requirements is the cartography of current needs of Terminals and Yards that are not yet fulfilled.

4.1 Dynamic Dispatching in an Intermodal Terminal in Germany (Industriestraße 1, 36269 Philippsthal (Werra))

The Terminal in Philippsthal (WKT) is operated by the company Werra Kombi Terminal which belongs to the Multimodal Operator Modal3. It is a classical intermodal Terminal almost in the geographic centre of Germany.

The WKT has a main customer that is located close to the Terminal which is one of the largest chemical companies in Germany (K+S).

Smaller to medium-sized Terminals such as the WKT have almost all a very similar requirement. They have a main customer, that is the commercial backbone of their operations. In order to diversify and grow profits they need to attract additional customers but without jeopardizing the backbone business with the main customer.

Therefore live information is a key factor to be able to mix the train with additional loads from other customers.

In WKT three trains per week are entering with waggons from the different ports of Hamburg. They arrive on Monday, Wednesday and Friday. The trains leave re-loaded with export Containers on the same day. Closing time for Trucks is 15:00 to guarantee a departure before 17:00.

As of today, the main concern of WKT is the daily disturbance of the planned traffic. E.g. trains not arriving before the terminal opens (05:45 a.m.) which leads to unproductive time of staff in the Terminal. Trains arriving unloaded or with a different waggon composition than announced by the rail undertaking company (DB Cargo). The train announcement comes a day before the arrival, so that disposition team can start to plan the unloading and re-loading operations.

Additional upside of real-time information is the reduction of administrative overhead works such as copy pasting excel lists for the train list as an input to the train checker.

This results into the following requirements which we transformed into features.

Table 27.1.3 Requirements Dynamic TOS

DYD1	The Terminal Operating System (TOS) must need to know in advance the waggon number and the waggon consist from the Traffic Management System
DYD2	The Terminal Operating System (TOS) must to send the final waggon numbers and the waggon consist to the Traffic Management System once train "is ready to depart"
DYD5	The Terminal Operating System (TOS) must need to know in advance the estimated time of arrival of approaching trains
DYD7	The Terminal Operating System (TOS) must need to be able to adapt task planning dynamically due to live data
DYD8	The Terminal Operating System (TOS) must need to be able to receive and process data from different sources in order to fill in necessary check in data for containers automatically
DYD9	The Terminal Operating System (TOS) must need to be able to record movements and distinguish between productive and non-productive movements
DYD10	The Terminal Operating System (TOS) must need to be able to receive also Truck ETA data if available
DYD11	The Terminal Operating System (TOS) must need to be able to treat a sophisticated multi tenancy, so several stakeholder from different legal entities able to access but with own restricted access

The objective of the Use Case 1 is to demonstrate the reduction of administrative tasks around a train-in and train-out, the reduction of unproductive moves in the Terminal due to real-time information of rail and ideally of road. And the most important objective is to increase the loading ratio of a train, thanks to the live information, respecting the restrictions around loading waggons with different containers types, weights, destinations etc.

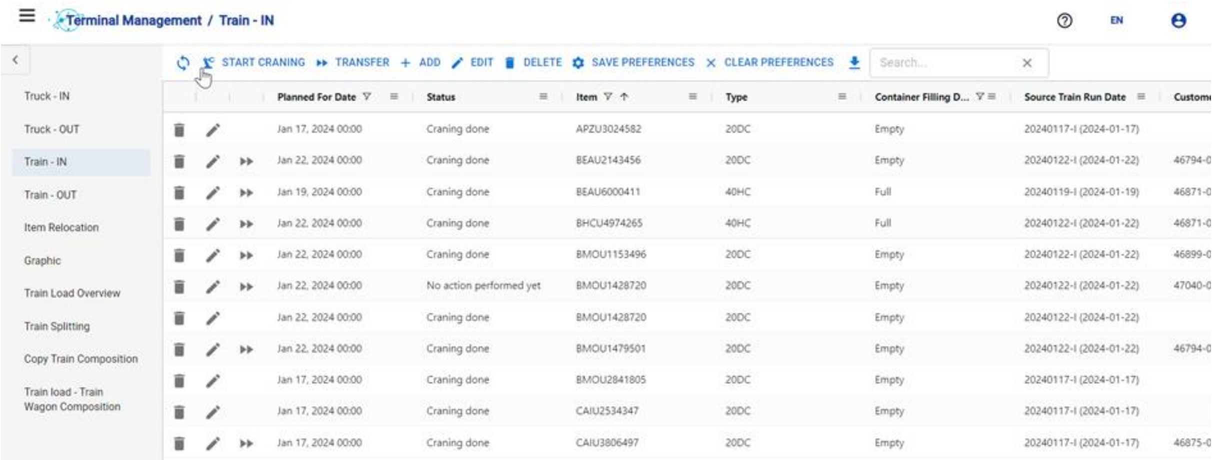
The stakeholders exchanging messages are the train operating company (DB Cargo), the network oeprator (DB InfraGo), the freight forwarder (modal3) and the terminal itself (WerraKombiTerminal). The main content is the waggon numbers, waggon type, train consist, loading units and the estimated time of arrival.

Main interfaces to be developed in accordance with Workpackage 32 are the interface to Traffic Management Systems of the Railway Network Operator to receive latest estimated time of arrival (ETA) and the final and correct waggon consist and loaded Containers information.

The interface to road information will be most probably a combination of order information from the Truck Operator (in order to know the departure time of a truck) and then live traffic information from providers like HERE.

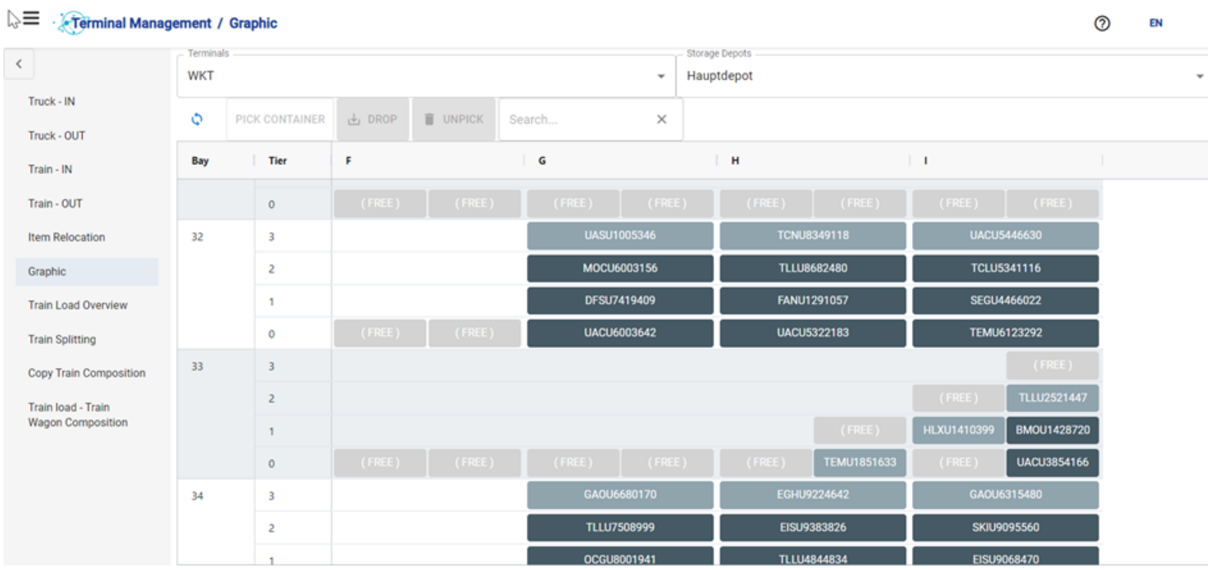
Planned craning tasks should update themselves automatically if new short-term orders arrive.

Figure 27.1.2 Task overview for a given day



The terminal overview should give visual guidance about all planned Containers to be loaded on the train. This will help to reduce unproductive moves e.g. not picking and dropping a Container in order to reach a Container below, although the lower Container is planned on the train as well.

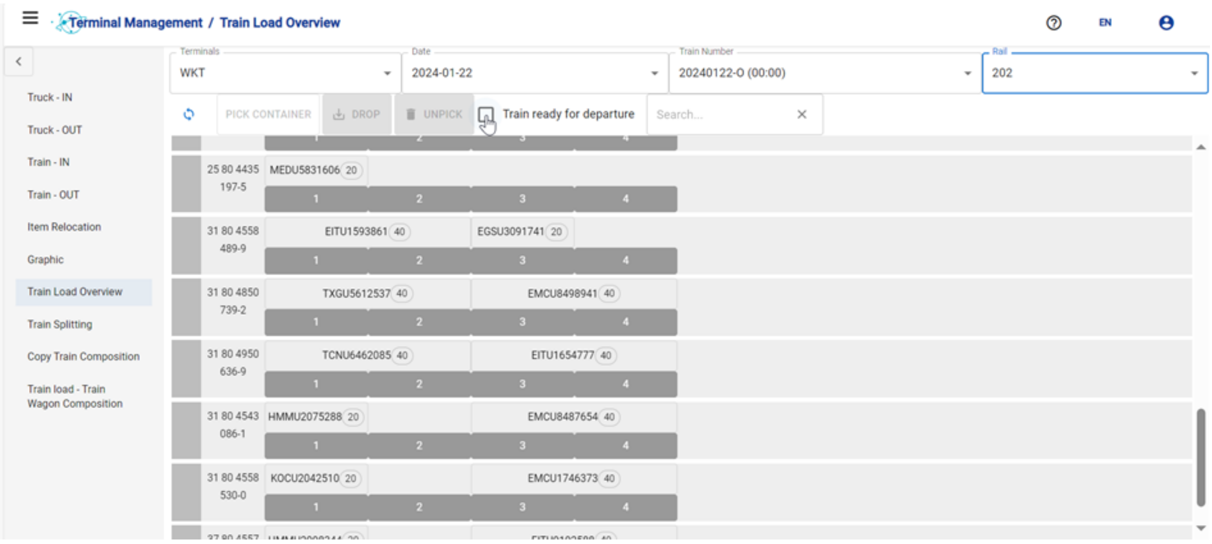
Figure 27.1.3 Terminal Management – Depot overview



Furthermore, the depot overview should help to search for possible Containers in the depot that could fill up gaps on not fully loaded Waggons. (e.g. search for Containers in the depot with already existing order to the same destination Terminal in Hamburg. (e.g. Highlight all Containers with a future train-out order and destination EUROKAI).

The Terminal Software should support the loading of the wagons by restricting wrong loadings or proposing suitable wagons based on variable criteria. #

Figure 27.1.4 Train load overview



In order to measure unproductive moves and therefore to allow to the Terminal Operator to do lessons learned analysis of past operations days, the system should also record replacements in the depot without a customer order, as an unproductive move.

A before and after comparison will result later in the project in the Key Performance Indicators.

In addition to the above, which will reach TRL 8 and is currently in TRL 6-7, the partners of Workpackage 27 want to develop a simulation tool. Based on the dynamic inputs received, parameters will be set. Those parameters shall than be simulated with the craning tasks of a train to be loaded and their actual location in the depot. This with the objective to elaborate on an optimal loading sequence to reduce unnecessary distance travelled by the reachstackers.

The objective is time saving and reduction of energy consumption as well as maintenance intervals. The simulation will not exceed TRL 4 as it is at this stage a first elaboration if really of benefit to be implemented.

The dynamic dispatching problem is represented by means of Discrete Event System (DES) simulation model [cite BANKS] aimed at assessing and optimizing some key performance indicators, with particular reference to the total travel distance of the container reachstackers and the total loading time.

In the next subsection, the flowchart representing the main dynamics of the system and the main information flow is first described. Then, the flowcharts of specific dynamics and controls is provided. In doing so, the needed data requirements are also presented. In the end, the specific simulation tool and models are described.

Finally, in the last subsection, the optimization model and the relevant results are presented and discussed

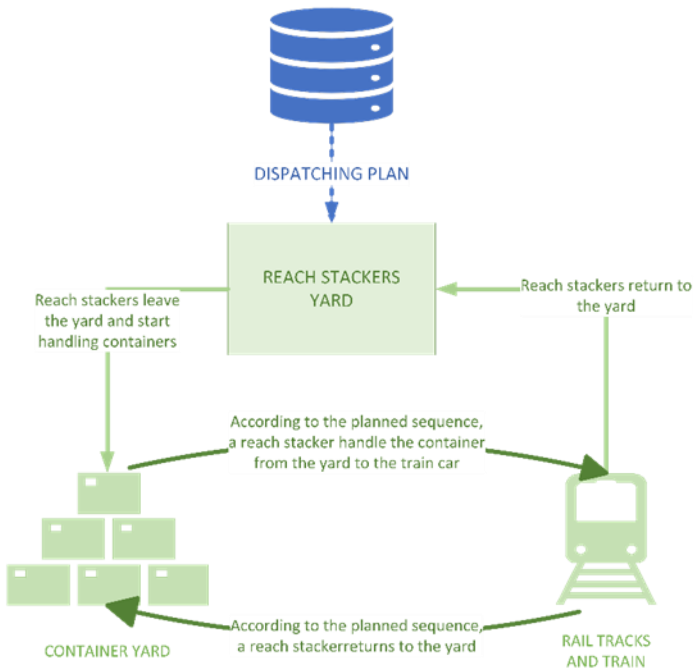
4.1.1 The simulation model

The basic dynamic of the considered dispatching system is reported in Figure 1, where the blue block, arrow and label indicate information storage and flow, where the green ones indicate physical locations and operations.

In this implementation, the *dispatching plan,* is assumed to be available. Such a plan provides, for each piece of the handling equipment (such as a reachstacker), the sequence

next container → specific car where to place the container

Figure 27.1.5 Basic dynamic of a generic terminal with dispatching operations



The operation workflow is then represented, for each piece of handling equipment (hereafter indicated as reachstacker (RS), by the following sequence of operations:

1. Initialization: set the container counter

2. The RS leave the handling equipment inventory and reaches the location of container
3. The RS picks up the container and moves to the train car
4. The RS loads the container on the train car
5. If the container is the last in the plan, the RS returns to its storage yard, otherwise
6. Set and return to 2

Note that, given the above sequence, the terminal layout and the handling equipment average travel speed (load or empty) and load/unload operation times, it is possible to determine by simulations the following KPIs:

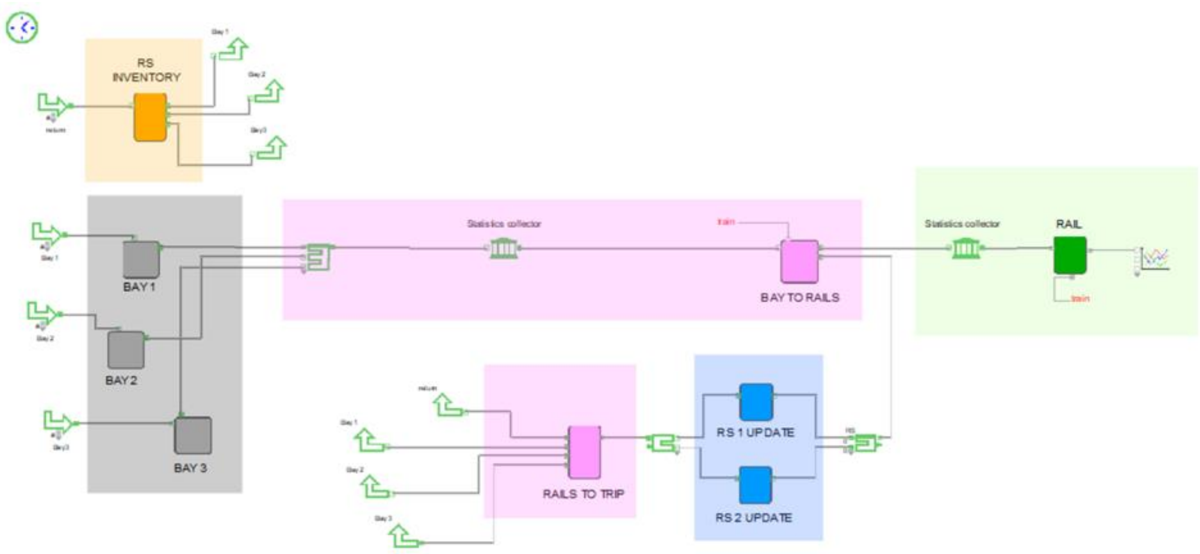
- Total travelled distance travelled in the yard by the reachstacker;
- Total load time to execute the dispatching plan.

4.1.2 The considered simulation tool and the detailed model

The simulation model is developed with ExtendSim which is a graphical tool that allows the user to focus on the relationship between the different modelled operations, the item routing, and the information flows, avoiding the details of the code representing each specific operations which, in any case, is accessible and customizable.

The basic example of a terminal characterized by three bays where containers are stored, two operating reachstackers that can be parked in a specific area when not operating, and a rail yard is reported in Figure 2.

Figure 27.1.6. Example of a simple three-bays/two reachstackers terminal



In such a model it is possible to identify 5 main modules representing the following terminal operations:

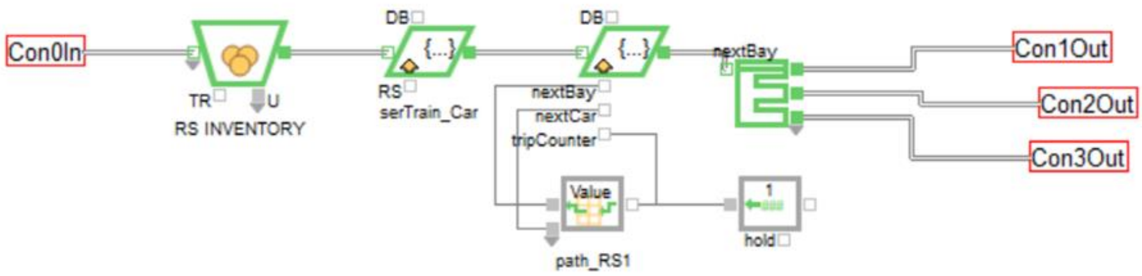
1. **The RS parking area (orange module):** this module collects and gathers all the RS that are not operating. It is logically connected to the bays and the rail yard so that RS stacker can move between them.
2. **The bays area (grey module):** this module contains several similar blocks, each representing a single bay and, therefore, characterized the specific set of containers stored as LIFO queues (with access from the top container) to be loaded on the train.
3. **The container movement from bays to rail and from rail to bays (pink module):** these modules represent the movement of loaded RS from the bays to the rail yard, and more specifically to the train car that represent the container destination, and vice-versa for the empty RSs. From each pair (bay, car) the distances represent the travel distances from the bay to the car, and from the car to the bay.
4. **The loading operations on trains (green module):** this module models all the train cars where containers are loaded. Such a module provides to the RS controller, the information about the train presence on order to allow/forbid container movements from the bays to the rail yard when a train is present/not present.
5. **The RS operation planning update (blue module):** such modules, each associated to a single RS, provide the routing instructions. In this connection, it is worth saying that any RS knows, for any operation, only the origin bay and the destination train car so that, after each container delivery, it must be updated with the next pair according to the dispatching plan.

Each block represented with darker colours in Figure 2 consists of a *hierarchical module* which gathers the detailed models of each operation as described in the following sections.

The RS parking area

The model depicted in Figure 3 and in particular the block "RS INVENTORY", represents the RS inventory. In such a model, it is interesting to note that the blocks "Con0In" and "ConOut", which provides the interface with the higher hierarchical level, provides the arrival of RS to the inventory, i.e., after completing the loading plan, and their exit towards a bay, respectively. Other blocks to note are the grey ones that provide the sequence of operations to each RS, implementing the dispatching plan indicated in Figure 1.

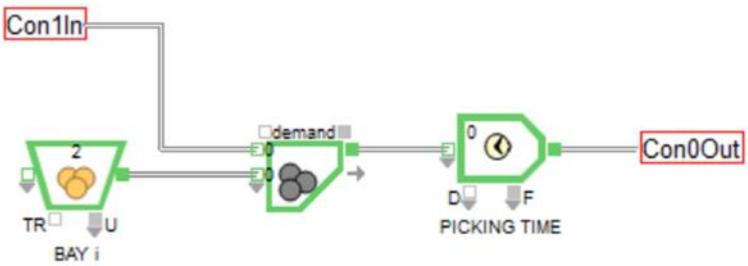
Figure 27.1.7 Details of the RS inventory block



The bays area

The bay area is constituted by a set of bays whose detailed model is reported in Figure 4 which is simply represented as the buffer "BAY i" and a batch block that pair a RS, entering from Con1In. After the container/RS pair is done, with a timing determined by the "PICKING TIME" block, the loaded RS leaves the bay via Con0Out.

Figure 27.1.8 Bay model



The container movement from bays to rail and from rail to bays

The handling of containers from bays to rail track, and vice-versa, is represented in Figure 5 and Figure 6 that represent the direct and return trip respectively. These two models include the plan implementation by means of the grey block which identify the RS pasting through the blocks and assign the proper route. Note that the block "LOAD ENABLER/DISENABLER" allows or blocks the RS flow thus permitting of forbidding the train load and is commanded, as mentioned in the following, by the presence of the train via the input in "Con3In".

Figure 27.1.9. Direct trip "Bay to rail Track" and loading operation block

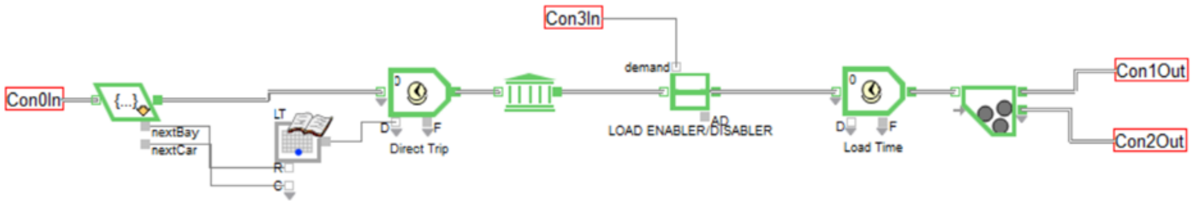
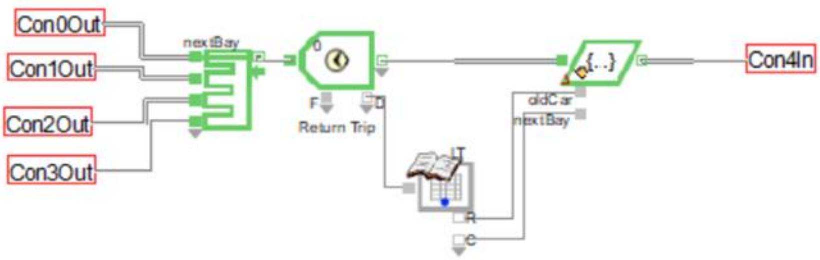


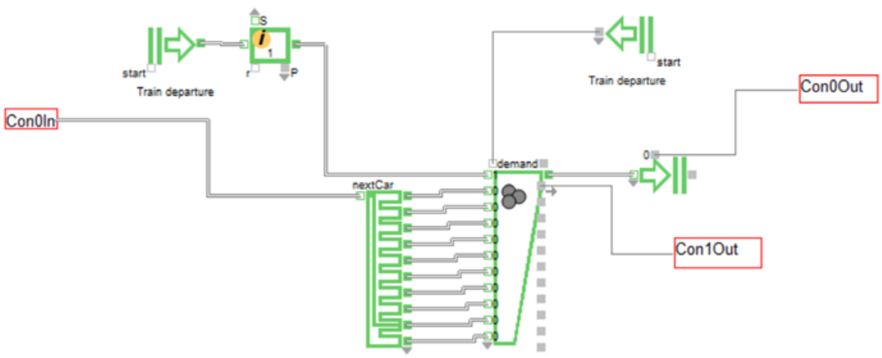
Figure 27.1.10. Return trip "Rail track to bays" block



The loading operations on trains

The model reported in Figure 7 represent the train to be loaded. Such a dynamic is modelled by batching a train, whose arrival and departure are represented by the indicated blocks, with the containers assigned to each car. Note that the departure signal forces the loading to stop.

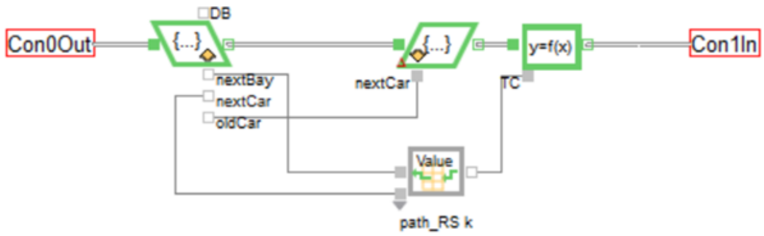
Figure 27.1.11. Details of the loading on trains block



The RS operation planning update

Finally, as regards the proper route assignment, the model in Figure 8 detects the reachstacker passing through it and, based on the last sequence (bay, car) assigned to RS, assigns the next one.

Figure 27.1.12. Details of the loading on trains block



4.2. Dynamic Integration of the Terminal Operating System with Intelligent Videogate

The main objective of this use case is to demonstrate the reduction of administrative tasks that are carried out daily by the terminals' resources, thanks to the integration with a physical system installed in the vicinity of the terminals, such as the intelligent video gate (IVG) that will provide real-time information on both the train and its composition.

Based on insights gained from Renfe, which operates multiple terminals in Spain, we have identified a significant administrative workload related to verifying train cargo upon arrival. Currently, once a train reaches the terminal, the information transmitted from the departure station regarding the equipment loaded on each platform must be manually verified on-site. After validation, this data is then entered into the Terminal Operating System (TOS). If the information captured by the Intelligent Videogate (IVG) could not only be transmitted—as is already done in Gothenburg—but also automatically registered in the TOS and used to update the theoretical records, manual validation would no longer be required. This would lead to a significant reduction in administrative tasks, improving efficiency in terminal operations, so an integration test to validate this assumption is relevant for the project.

The IVG is a physical system that captures useful data, using cameras, antennas, RFID, illuminators, and different technologies. It is an integral part of WP27 and can interact e.g. with the Use Case 4.1. in a second step.

One of the most relevant applications in the field of freight transport, by rail, is to provide as much information as possible to the terminals in advance about the train journeys and the compositions that they are going to receive by this means of transport, identifying the order in which the loads are arranged on each of the platforms that make it up.

By having advance information, the terminal has a view of the trains to be received and their cargo. So, the terminal can plan its resources and spaces in the courtyard with some time.

Currently, in Spain, the process of receiving this information can be facilitated in several ways. Normally, an operator at the terminal of origin (the terminal from which the train departs) must send a document indicating the platforms and the loads that each of them transport on the train journey. This document, in Spain, is called "Pie de tren", and contains a list of all the loads and all the platforms that make up the train. And on other occasions, the document that is received can be an excel or handwritten via email of the composition that is going to arrive at the destination terminal.

Both processes are carried out manually, they are not automated and, sometimes, discrepancies arise between the information received and what actually reaches the terminal physically. This means that when the train arrives at the destination terminal, a terminal operator must physically check the platforms and containers that have actually arrived, normally these operators do not use electronic devices, but paper and pen to identify discrepancies. This situation means that it is necessary to check and record again in the terminal management system (TOS), which containers have actually arrived, manually recording the discrepancies between the documentation received by the terminal of origin and what has actually arrived.

Considering the situation raised, the main objective of this use case is to demonstrate that by integrating the TOS system with the IVG physical system, it is possible to reduce the non-productive times of the Terminals' resources, and it will be possible to have more reliable information for the terminal in real-time, reducing manual tasks around the entry and exit of a train.

Regarding the Can Tunis Terminal, the different Intelligent Videogate (IVG) deployed would collect the necessary information and integrate all composition information into a single message with a unique ID (thanks to some kind in integration with the available TMS, to obtain the train ID to identify the whole train composition). Although the TOS is not officially planned to be included at Can Tunis demo, once all systems are in place, we will collect and make use of the information to validate how the TOS information helps automate the verification process of the train composition. This integration will be completed during this project.

It must be added to all of the above, that in the logistics transport of goods it is very important to detect and identify damage at terminal entrances, in order to then know who is responsible for the damage of an equipment. The IVG will provide images of the train, a user of the TOS system will be able to consult them, so that in case of doubt when it comes to knowing where the damage to the equipment may have occurred, before or after accessing the terminal by train, the user will be able to consult the images and rely on them.

4.2.1 TOS system: Requirements and function

The demonstration of this use case will be at the Can Tunis terminal, a strategic logistics centre in the Barcelona area due to the confluence with different important lines in the area, such as the access line to the port of Barcelona.

The TOS system will not only receive real-time updated information from the IVG's physical system in relation to a train journey, but will also have to interpret the data received and display it to the terminal system user (TOS) in an intuitive way in the user interfaces to be developed.

The requirements of the system are as follows:

Table 27.1.4 Requirements TOS

TOS-R1	The Terminal Operating System (TOS) must need to know in advance the waggon number and the waggon consist from the Traffic Management System.	Mandatory
TOS-R3	The Terminal Operating System (TOS) must need to know in advance the estimated time of arrival of approaching trains.	Mandatory
TOS-R4	The Terminal Operating System (TOS) must need to be able to receive and process data from different sources in order to fill in necessary check in data for containers automatically.	Optional
TOS-R7	The Terminal Operating System (TOS) must need to be able to treat a sophisticated multi tenancy, so several stakeholders from different legal entities will be able to access but with their own restricted access.	Mandatory
TOS-R8	The Terminal Operating System (TOS) must know waggon numbers, and container numbers in the exact order in which they are loaded in the train, by interacting with a CheckPoint. This information needs to be integrated in the Terminal Operating System and make it visible to the staff in order to facilitate unloading operations.	Mandatory

And the functions, with their related requirements:

Table 27.1.5 Functions TOS

TOS-1	The TOS shall be able to receive live data.	Mandatory	TOS-R8
TOS-2	The TOS shall be able to support loading of freight trains.	Mandatory	TOS-R1
TOS-3	The TOS shall enable real-time communication inside the Terminal directly within the system.	Mandatory	TOS-R7
TOS-4	The TOS shall be able to receive and send data of the trains to the Railway Network Operators and other relevant stakeholders.	Mandatory	TOS-R1; TOS-R2
TOS-5	The TOS shall prefill all possible data for Container Check-ins thanks to Interface data.	Mandatory	TOS-R4
TOS-7	The TOS shall enable different stakeholders to lively interact, with restricted user rights.	Mandatory	TOS-R7

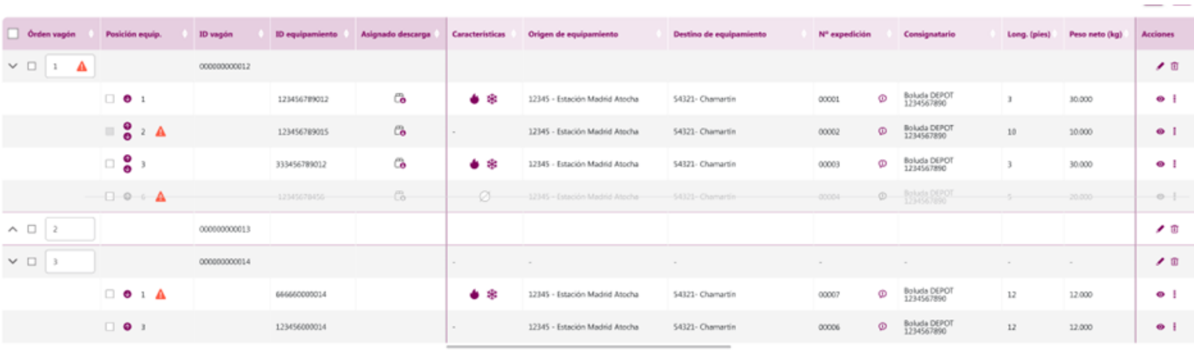
The Terminal Management System (TOS) will carry out the relevant checks by comparing the information received from the IVG with the theoretical and recorded information that the TOS system may have stored from other actors or systems. If the checks are satisfactory, the goods and rolling stock transmitted by the IVG will be recorded in the TOS, and in case of discrepancies between the information previously stored in the TOS system and that received from the IVG, it will be presented to users in the relevant interface.

4.2.3 Developments and interfaces to be implemented

The main interfaces that will be developed to achieve the identified use case are those that are related to integrating data related to the train journey and its associated composition, and also those interfaces necessary to record and visualize discrepancies in the composition as a result of integrating with the IVG physical system.

The aim is for the user to have an overview of the train journeys that are planned, and their associated compositions. This helps the terminal user to plan their tasks and those of their team. In addition, there will be an interface where the user will be able to visualize the incoming composition of the train as a result of the integration with the IVG Physical system, thus reducing the non-productive times of the resources minimizing administrative tasks mentioned in previous points.

Figure 27.1.13 Train journey overview

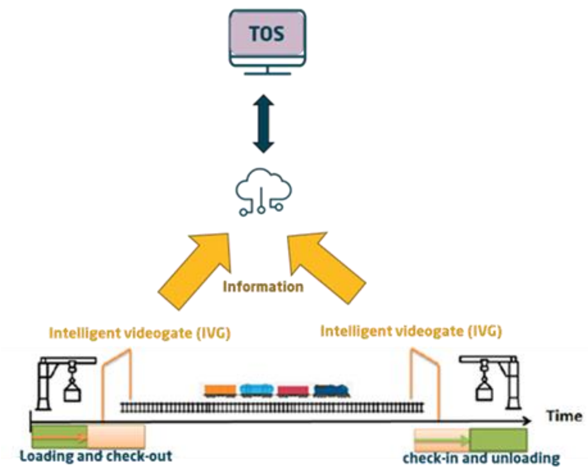


Órden vagón	Posición equip.	ID vagón	ID equipamiento	Asignado descarga	Características	Origen de equipamiento	Destino de equipamiento	Nº expedición	Consignatario	Long. (pies)	Peso neto (kg)	Acciones
1		000000000012										
	1		123456789012			12345 - Estación Madrid Atocha	54321- Chamartín	00001	Boluda DEPOT 1234567890	3	30.000	
	2		123456789015		-	12345 - Estación Madrid Atocha	54321- Chamartín	00002	Boluda DEPOT 1234567890	10	10.000	
	3		333456789012			12345 - Estación Madrid Atocha	54321- Chamartín	00003	Boluda DEPOT 1234567890	3	30.000	
	~~6~~		~~12345678456~~			~~12345 - Estación Madrid Atocha~~	~~54321- Chamartín~~	~~00004~~	~~Boluda DEPOT 1234567890~~	~~5~~	~~20.000~~	
2		000000000013										
3		000000000014			-	-	-	-	-	-	-	
	1		666660000014			12345 - Estación Madrid Atocha	54321- Chamartín	00007	Boluda DEPOT 1234567890	12	12.000	
	3		123456000014		-	12345 - Estación Madrid Atocha	54321- Chamartín	00006	Boluda DEPOT 1234567890	12	12.000	

The information that the terminal management system (TOS) will receive from the IVG is proposed to be as follows:

1. Train ID and direction of travel (incoming or outgoing).
2. ID of the wagons and the order in which they make up the train (train composition).
3. Identification of the containing plates, and the order in which they are found.
4. Identification, for each container, of the type of dangerous goods, if applicable.
5. Images to detect possible damage that each container may have.

Figure 27.1.14 Information Flow overview



It is important that before receiving the information from the IVG in the TOS system, data on the train journey and its composition have been previously recorded. The expected workflow would be as follows:

1. **Data registration**: An operator, with permits, or an external system enters the data of the train and its composition.
2. **Integration with the IVG**: Once the train has passed through the check point, the TOS system consults the data of the train journey and its associated composition.

3. **The TOS system collects related information**: Train, ATA, freight, and automatically reflects discrepancies on the previously recorded composition, if any.

The developments that are planned to be carried out are those that are related to the integration with the IVG Physical system to receive the data, and that the TOS management system can process them correctly in order to obtain the functionalities and objectives identified.

4.2.4. Possible limits or obstacles

To achieve the objectives of the use case and demonstrate that the KPIs presented can be achieved without limitations and obstructions it is important to obtain the data on train journeys and their composition and that this can be recorded in the TOS System before the train itself passes through the IVG check point. Terminals are sometimes reluctant to share certain information.

The next steps to take involve:

- Have conversations with certain terminals and the terminal of the use case itself.
- Define the functionalities and user stories to meet the requirements of the case to be demonstrated.
- Define interfaces, so that updated information can be displayed.
- Define the integration between systems to receive and consult data efficiently in real time.

This use case will not be integrated in one single TOS with the other use cases during this wave but rather show the various best practices and demonstrate benefits. The second wave of the 5th TRANS4M-R will allow for further development, testing , and the interaction in between the different use cases to even further increase benefits of the TOS.

4.3. Decision support for shunting operations and yard dispatching at Alnabru (Oslo, Norway)

The third use-case concerns how updated real-time information can be used to improve the planning of operations inside a yard. Changes in the train timetable, delays or other events affect not only the trains on the main line, but also local processes inside handover points, yards and terminals. A seamless transport by rail should ensure that data is shared between systems in a way which allows a dynamic adaptation in the planning of tasks according to the evolution of traffic.

In yards and terminals, several operators may work near each other and perform operations on sets of shared tracks. Trains are assembled and disassembled, loaded and unloaded, wagons are stabled, moved and maintained, cargo is carried and so on. When different shunting locomotives request to perform shunting simultaneously, the dispatchers must choose who to send first. Very often only one set of wagons can be transported at the time, leaving the other shunters waiting until their requested path is free. In this use-case we will focus on shunting operations that involve moving a set of wagons through bottlenecks in a yard and terminal, and thus situations with a high number of conflicting shunting requests. In these cases, dispatchers normally send trains by a "First Called First Served" principle. This is experienced fair and smart to do, however, there is no guarantee that this is the smartest sequence to choose, especially when real-time updated information is taken into account. Is there a way to gather, share and use available information so that shunting operations can be sequenced in a way which reduces delays in departure times from the terminal? If not, how can be developed a system which enables this in a seamless way?

There is already a large amount of research work and scientific literature on optimization of railway operations in general (Borndörfer, 2018). However, most existing studies of optimization of shunting operations in yards are typically (1) concerned with passenger train units or classification (marshalling) yards, and not container terminals, and (2) focused on non-real-time planning horizons (see e.g. Freling et al. 2005, Gestrelius et al. 2017). One recent report shows promising results suggesting that real-time container terminal shunting optimization is algorithmically achievable, although on a much simpler yard than Alnabru (Ambrosino et al., 2022).

Studies on real-time train re-routing and re-scheduling, especially applied to station areas, are relevant for their focus on frequent re-optimization using real-time data (see, e.g., Mannino & Mascis 2009). However, for complex container terminals, where multiple shunting locomotives are operated independently and are requesting ad-hoc shunting paths, there is an additional challenge in the intricate combination of communication needs and optimization needs. A student project performed at Alnabru in 2012 highlights the communication challenge between the dispatching operator and the shunting operators as one of the main causes of delays at the terminal (Endal et al. 2012).

There is currently no available commercial software for optimizing real-time dispatching of shunting movements in yard with ad-hoc requests. The unique combination of communication and optimization needs at Alnabru yard presents a challenging case study that will require new technological solutions combining user interfaces, data interfaces and optimization algorithms. Since Alnabru is both large and has multiple operator companies, the foundations of a successful system for handling dynamic dispatching here would be transferrable to most container yards across Europe.

4.3.1 The YDS System: Requirements and Functions

Through this use-case, demonstrated at the Norwegian Alnabru terminal, TRANS4M-R will inspect how functionalities of a Yard-Terminal Dispatching System (YDS) can enable dynamic dispatching in yards. This system will not just gather available information and receive updated real-time information, but also intelligently use this data for proposing sequences of shunting operations. This is a brand-new functionality completely unseen in commercial yard management systems for this operational purpose. This innovative nature has led us to a TRL level of 4 for this use-case, so we can demonstrate if the system can really bring an operational additional benefit and reach the KPIs.

The requirements of the system are as follows:

Table 27.1.6 Requirements YDS

YDS-R1	The YDS must store information about the yard topology and relevant safety regulations (minimum timelags, maximum speed etc.).	Mandatory
YDS-R2	The YDS must support computing a feasible shunting plan or notify that no such plan exists.	Mandatory
YDS-R3	The YDS must store information on trains' arriving and departing times as given in the train timetable.	Mandatory
YDS-R4	The YDS must store the assigned arrival and departure tracks in the yard from the track assignment plans.	Mandatory
YDS-R5	When shunting involves transportation to a terminal, the YDS must store the assigned loading or unloading tracks for each train.	Mandatory
YDS-R6	The YDS must store information about the trains (length, number of wagons etc).	Mandatory
YDS-R7	The YDS must store information about ETAs for the trains.	Mandatory
YDS-R8	The YDS should have information about preferred sequence of routes or tracks for shunting operations.	Optional
YDS-R9	The YDS should support computing not only feasible, but optimal shunting plans.	Optional

And the functions, with their related requirements:

Table 27.1.7 Functions YDS

YDS-1	The YDS must compute shunting plans that satisfy physical-, time- and safety-related constraints.	Mandatory	YDS-R1; YDS-R2
YDS-2	The YDS must present the computed shunting plans to the user.	Mandatory	YDS-R2
YDS-3	The YDS solver should return a minimal set of constraints that make the generation of a feasible shunting plan impossible.	Optional	YDS-R2
YDS-4	The YDS must present information about train's scheduled and estimated arrival and/or departure times.	Mandatory	YDS-R3; YDS-R7
YDS-5	The YDS should use the information about known arrival/departure tracks when computing shunting plans.	Optional	YDS-R4
YDS-6	When relevant, the YDS should use the information about known loading/unloading tracks when computing plans.	Optional	YDS-R5
YDS-7	The YDS must ensure presented shunting plans use the correct information, e.g., on train length, wagon compositions etc.	Mandatory	YDS-R6
YDS-8	The YDS should present the user with updated ETAs/ETDs.	Optional	YDS-R7
YDS-9	The YDS must support re-optimization of a schedule when ETAs/ETDs change.	Mandatory	YDS-R7; YDS-R9
YDS-10	The YDS must support re-optimization of a schedule when input data changes.	Mandatory	YDS-R9
YDS-11	The YDS should compute shunting plans that respect the preferred routes and tracks.	Optional	YDS-R8
YDS-12	The YDS must compute a feasible shunting plan for a given set of trains with known arrival- and departure times and required operations.	Mandatory	YDS-R2
YDS-13	The YDS should compute an optimal shunting plan for a given set of trains with known arrival- and departure times and required operations.	Optional	YDS-R9

The goal with the YDS is to present dispatchers with shunting plans that dynamically adapt to updated information about shunting requests and incoming and outgoing trains. The use-case wishes to demonstrate the following KPIs:

- Reduce lead times for shift including waiting times for track access;
- Reduce the number of track conflicts;
- Increase the punctuality of departing trains from the terminal;
- Reduce the time spent by dispatchers to resolve track conflicts.

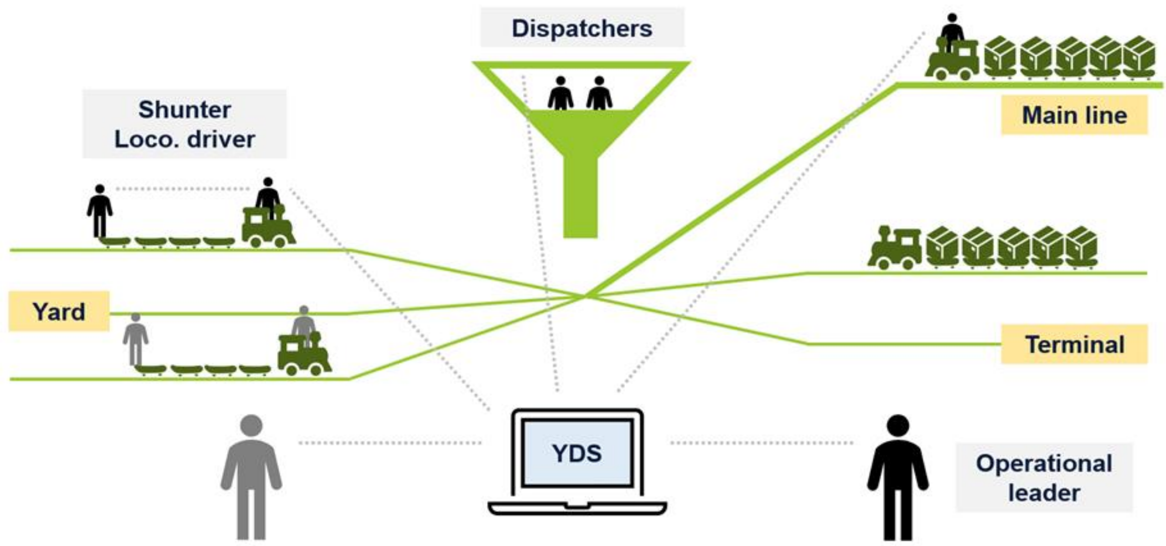
4.3.2 Developments, interfaces and architecture

The development of the YDS is a bottom-up approach where a significant effort has been put down to understand the operational processes that happens in a yard and terminal and thus determine the shunting requests. Through discussions with dispatchers, terminal operators and yard managers, the use-case has gathered requirements, functions, and designed intended interfaces towards other sources of data and information. The potential users of the system, its scope and level of use has been limited to ensure that the development phase leads towards a system that can actually be in operational use at a later stage. In addition, the intelligent aspects of the underlying algorithms for proposing plans have been narrowed and generalized to ensure easy adaption to other terminals and yards besides the Alnabru terminal.

4.3.2.1 YDS user-story

Today, shunting is often requested by (shunting) locomotive drivers who call the dispatchers and request to drive a path on-demand. There is little real-time coordination between shunters belonging to the same terminal operator, and if so, this happens through radio communication with the operational leader. There is no coordination between different terminal operators. With the YDS, we imagine to gather and increase the flow of information, requests and data as visualized in Figure 27.1.14.

27.1.15: The YDS receives information from different actors, computed and visualized a shunting plan



We denote by a "move" a shunting operation which involves moving a (possibly empty) set of wagons from one track (e.g. in the terminal) to another track (e.g. in the yard). The intended workflow of the YDS is as follows:

1. **Insert planned moves**: At the start of a shift, each terminal operator adds their planned upcoming sets of moves to the YDS. This is done by the operational leader and shunter. The moves can be dragged and dropped to represent the desired ordering of moves.
2. **Generate base plan:** The YDS receives the planned shunting from all operators and computes for the conflicting requests an optimal sequence.
3. **Operators update moves:** The terminal operator can change the desired sequence, add, update and remove moves as the situation changes.
4. **Real-time information:** The YDS receives updated ETAs according to the evolution of traffic on the main-line.
5. **Reoptimizing sequence:** Information received through 3) and 4) automatically triggers the YDS to re-optimize the sequence in the base plan.
6. **Shunting requests received:** A shunting locomotive will still call the dispatchers to request a specific move when it is ready to be performed. This request should equal the first move of that shunting locomotive in the base plan sequence.
7. **Yes/No shunting request answer:** The dispatchers consult the base plan to see if the requested shunting move triggers any conflicts, and if so, answers the

request while consulting the sequence suggested by the base plan. The dispatchers are, however, free to say Yes/No as they see fit.
8. **Shunting move in progress:** When a shunting request receives "Yes" from the dispatchers, the YDS locks the move at the first position in the base plan.

4.3.2.2 Interface and link to other systems

The YDS needs interfaces to other systems in order to access the data required by the underlying algorithms to compute feasible and optimal plans for the shunting movements. This involves the following information:

- **Train timetable:** It must be known, for each train arriving at or departing from the terminal, the planned times for this.
- **ETAs:** If a train is delayed, the updated ETA must be received. Potential systems: ETA prediction system (Hacon, WP28), main-line dispatching systems developed in FP1, other Network management systems.
- **Loading/Unloading plan:** The times and tracks where a train should be loaded or unloaded in the terminal must be known. Potential systems: The Track Assignment Optimizer (SINTEF, WP26).

Due to the huge variations in how terminal operators plan their shunting operations, and the systems they use for doing so (e.g. PickIt, Excel), we imagine the shunting moves to be put manually into the YDS though a simple, low-effort and user-friendly interface. Figure Y shows an example of how the computed base plan can be displayed to the dispatchers. Here, a move is represented as a row containing information about its path, (shunting) locomotive, the related train number and which type of move it is. Move types can be driving without wagons, shunting wagons to be loaded, retrieving a departing locomotive etc., and for each move type an associated duration is known. All moves belonging to a specific shunting locomotive get the same shade of colour, and the terminal operators have different colours. The locked moves have received "Yes" from the dispatchers and cannot be paused.

Figure 27.1.16: A simple UI for the base shunting plan displayed to the dispatchers through the YDS

Nr.	🔒	From track		To Track		Loco. id	Related train	Move type
1	X	*R42*	*N*	*C14*	*S*	*NP12553*	*41772*	*b.1.5*
2	X	*R34*	*S*	*C42*	*N*	*NP12642*	*5714*	*a.1.3*
3		C14	N	C13	N	NP12553	41770	c.2.8
4		C8	S	R24	N	OR5227	5813	b.2.0
5		R12	S	R13	S	BS11127	4841	d.1.0
6		R13	S	C32	S	BS11127	4841	a.3.1
7		C13	S	R42	N	NP12553	41770	b.2.4
8		C42	N	R34	S	NP12642	5713	a.2.5
9		R24	S	R25	S	OR5227	5813	d.1.3
10		R34	N	R35	N	NP12642	5713	c.1.8

4.3.3 Way forward

In order to achieve the use-case and demonstrate that the presented KPIs can be reached, several future steps must be taken. The YDS idea has been presented to some terminal operators at Alnabru in Norway, and some dispatchers. They raised concerns regarding system platform, who should input information and the frequency of this, and other aspects related to the operational use. However, most agreed that a system which automatically computes globally optimal sequences of shunting operations in times of conflicts is beneficial and desirable in order to minimize delays out from the terminal.

The next steps in the development phase of the YDS involves:

- Defining data structures for the yard and terminal, so that the geography can be implemented with a suitable granularity;
- Defining the optimization problem and developing an efficient algorithm for proposing the shunting sequences;
- Defining the interfaces towards other systems, to support that updated real-time information can be received in a proper format;
- Planning the demonstration activities and deciding how input should be gathered from the different actors in the laboratory environment.

The second wave of FP5 TRANS4M-R will enable the YDS to be further developed and tested. The UI will support more features and apply to more users, interfaces towards other systems with relevant data can be defined, the optimization algorithms made more advanced, and the testing performed on a higher TRL and in a more operational environment with live input. The operators at Alnabru are excited about the progress and future possibilities of this technical enabler.

4.4. Booking system for Marshalling yards

This is use case is a next demonstration how the complexity around intermodal services in the intermodal transport will be reduced thanks to WP27.

Booking of services provided by Marshalling yard operators is performed by Transport Planner – Assets Warehouse module/app. Based on requirements derived from analysis the Transport Planner application is designed for (small) freight RUs who do not need a robust information system for long-term transport planning. The system allows for easy planning and booking resource capacities (locomotives, drivers, other personnel, and eventually train sets) based on real customer/transport order requirements. It can also be used as a central resource warehouse for transport planning or other operations for sharing purposes among RUs. The application is designed as a server part with its own database (backend) and a user interface via a web page and communication services (frontend) and can be connected to the RU's internal systems using standardized data interfaces. For project purposes, the system is integrated into the systems of the freight RU ČD Cargo.

Requirements and Functions

The use-case is going to be demonstrated in Marshalling yard Nymburk operated by Czech infrastructure manager Správa železnic and railway undertaking ČD Cargo.

Fuctional and non-functional requirements are as follows.

27.1.8 Table: Requirements Marshalling Yards

AWH2	FR	The system must provide data about (un)successful resource reservation and its attributes to RU's dispatching management system.
AWH5	FR	The system must receive data of request for resources assignment to train from RU's dispatching management system.
AWH9	FR	The system must allocate resources (loco, driver, staff, service facilities) to services.
AWH11	NFR	The system operational rate (Service Level Agreement SLA) reaches 98% on a benchmark basis.
AWH13	NFR	The system needs to put the information into a common well-known format (for example REST API, WSDL).
AWH14	FR	The system works for defined resources (loco, driver, staff, path, service facilities).
AWH15	NFR	The system works 24/7 within the context of AWH11.
AWH26	NFR	The system has a maximum unplanned downtime of 525,6 minutes per year.
AWH27	NFR	The system shall require minimum maintenance to work.

The app will gather transport requirements, resource requirements and disposable resource and allocate, resp. book resources according requirements.

<u>User functions description</u>

User interface

A system control method that allows the user to assign (or link) objects (requirements and resources) to each other. To enable this resource assignment to requirements, all objects must be entered into the system. Objects can be entered manually or automatically loaded from other information systems. A requirement can be represented by a train object, to which resources (locomotives, drivers, etc.) can be assigned by Drag and Drop after being entered into the system. Individual objects may change over time (e.g., departure time may change), leading to overlaps – in such cases, it is necessary to change the assigned resources and adjust their operations, thus utilizing resource capacities.

Order Management

The application allows users to add and manage orders, including entering details such as weight, length, and type of transported goods. This functionality is crucial for efficient transport booking and optimization. Users can easily track the status of individual orders, adjust them as needed, and ensure that all customer requirements are met on time. For locomotive planning, this functionality is essential as it allows for accurate determination of required resources and their optimal use. Sharing this information among different RUs can lead to better coordination and more efficient use of locomotives, reducing costs and increasing transport efficiency. Each transportation/order is always clearly identified by a unique internal ID and by name at the same time.

Transport Planning

The application offers the possibility of planning transport at various time intervals and days of the week. Users can create detailed plans that consider various factors such as locomotive availability, track capacity, and customer requirements. This functionality is key to ensuring smooth and efficient operations. For locomotive planning, it is important to have an overview of all resource requirements and planned transports to optimally allocate resources and minimize downtime. Sharing these plans among different RUs allows for better coordination and use of locomotives, leading to more efficient operations and cost reduction.

Locomotive Tracking and Utilization Planning

The application provides an overview of the status and location of locomotives at different times. Users can track the current position of locomotives, their status, and availability. This functionality is crucial for efficient transport management and ensuring that all locomotives are used optimally. For locomotive planning, it is necessary to have up-to-date information about their status and location to quickly respond to changes and optimize transport.

Locomotive Planning

Locomotive planning includes not only their current use but also long-term deployment planning. The application allows users to create detailed plans that consider various factors such as locomotive availability, status, and location. This functionality is crucial for ensuring smooth and efficient operations. For locomotive planning, it is important to have an overview of all planned transports to optimally allocate resources and minimize downtime.

Locomotive Lifecycle Tracking

The application allows tracking the entire lifecycle of a locomotive, including external operations and maintenance. Users can record and track all important events in the locomotive's lifecycle, such as regular maintenance, repairs, and upgrades. This functionality is crucial for ensuring long-term reliability and efficiency of locomotives. For locomotive planning, it is important to have an overview of their technical condition and planned maintenance to minimize downtime and ensure that all locomotives are in optimal condition. Sharing this information among different RUs allows for better coordination and use of locomotives.

Driver Planning, Tracking, and Sharing

The application also allows for planning, tracking, and sharing of drivers. This functionality is very similar to the solution for locomotives, but with an emphasis on linking the driver's performance to a specific locomotive during a ride. Users can plan driver shifts, track their current location and availability, and ensure they are assigned to the correct locomotives and operations. For other operations not directly related to driving, the driver can be independent of a specific locomotive. This functionality is crucial for ensuring efficient operations and minimizing downtime. Sharing information about drivers among different RUs allows for better coordination and use of human resources.

Planning, Tracking, and Sharing of Other Personnel and Local Professions

The application also supports planning, tracking, and sharing of other personnel and station staff. This functionality is designed to enable efficient management of human resources needed to ensure transport operations. Users can plan shifts and tasks for various professions, such as inspectors, shunters, and other support staff. Tracking their availability and current status allows for quick response to changes and optimization of work processes. Sharing this information among different RUs and departments ensures better coordination and use of human resources. This functionality is crucial for ensuring that all necessary tasks are performed on time and efficiently, contributing to the overall reliability and efficiency of the transport system.

Facilities Planning and booking

Transport planner will allow for planning, tracking, and sharing the capacity of facilities that are particularly needed for operations in terminals or stations. Each facility will be defined primarily by its type, location, availability, and other specific characteristics typical for each facility. The facilities include:

- Tracks,
- Ramps,
- Loading docks,
- Cranes,
- Other loading and unloading equipment,
- Special tracks (cleaning, etc.),
- Track scales,
- Sensors (radioactivity),
- Fuel stations,
- Electrical connections,
- Sidings,
- Marshalling yard equipment (humps, track brakes, etc.).

Facilities Management and Sharing (booking) involves planning and coordinating the use and occupancy of various facilities. This process includes the following steps:

- Planning of Usage: Users can plan the use of facilities such as tracks, ramps, loading docks, and more through an online platform. This process includes booking facilities for specific time periods and ensuring that they are available for planned operations.
- Occupancy Monitoring: The system allows for real-time monitoring of facility occupancy and availability. This enables quick responses to changes and optimization of facility usage.
- Information Sharing: Information about the usage and availability of facilities is shared among different departments and RUs, ensuring better coordination and efficient use of resources.
- Usage Optimization: Based on monitoring and data analysis, the system suggests optimizations for more efficient use of facilities. This includes reallocating resources or adjusting plans to minimize downtime.

This approach ensures that all facilities are used efficiently and that all operations have the necessary facilities available at the required time.

Filters and Graphs

The application allows applying various filters and displaying data graphically for better overview and analysis. Users can easily filter data by various criteria, such as transport type, time period, or order status. Graphical data representation allows for quick identification of trends and anomalies, facilitating decision-making and transport optimization. For locomotive planning, it is important to have an overview of all relevant data and the ability to easily analyse it. Sharing these analyses among different RUs allows for better coordination and use of locomotives.

Basic operation description

Creating an Order

- **Adding an Order**: Click the + Add order button.
- **Filling in Details**: Enter the necessary information such as order name, status, weight, length, commodity type, and transport type.
- **Saving**: Click Save to save the order.

Figure 27.1.17: Transport planner – order overview

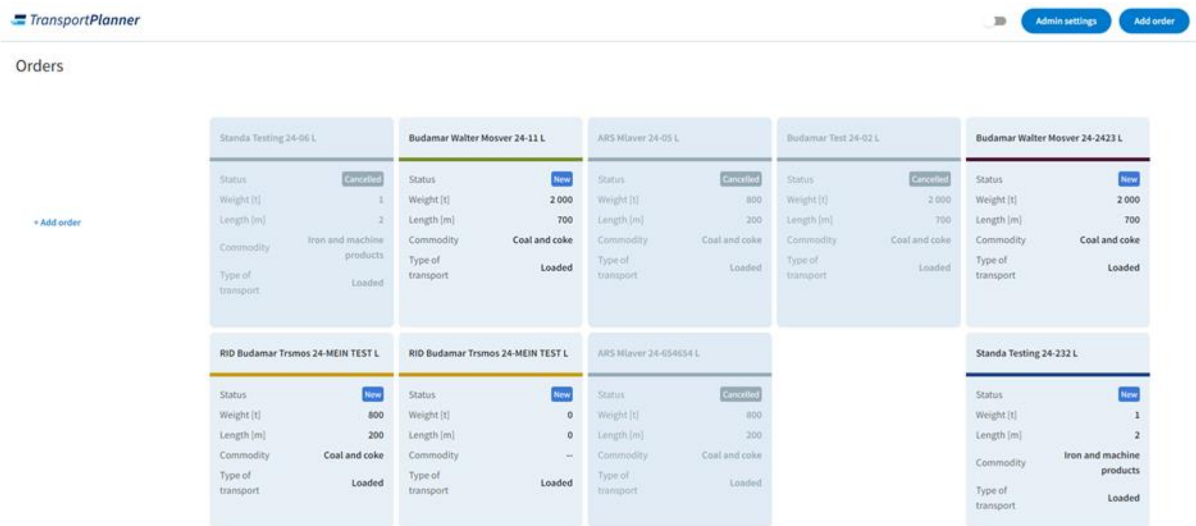


Figure 27.1.18: Transport planner – edit order business case

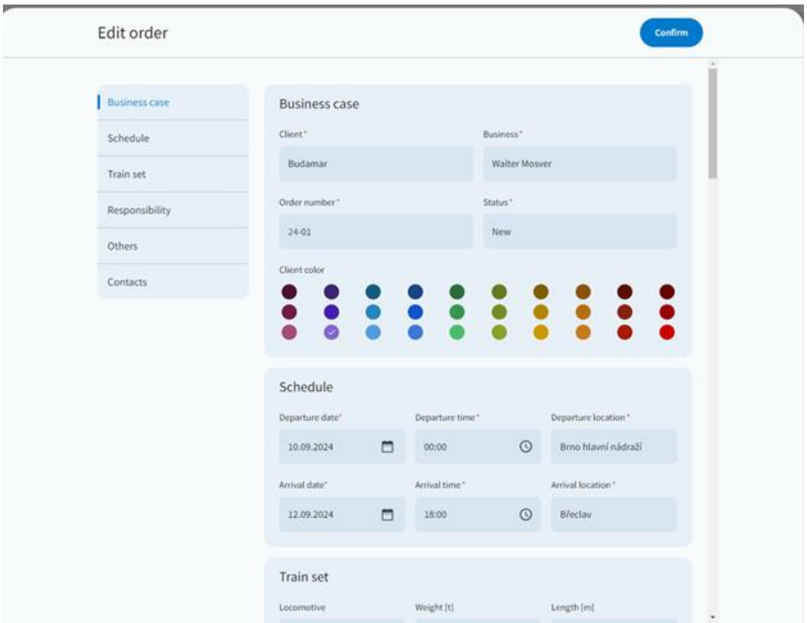
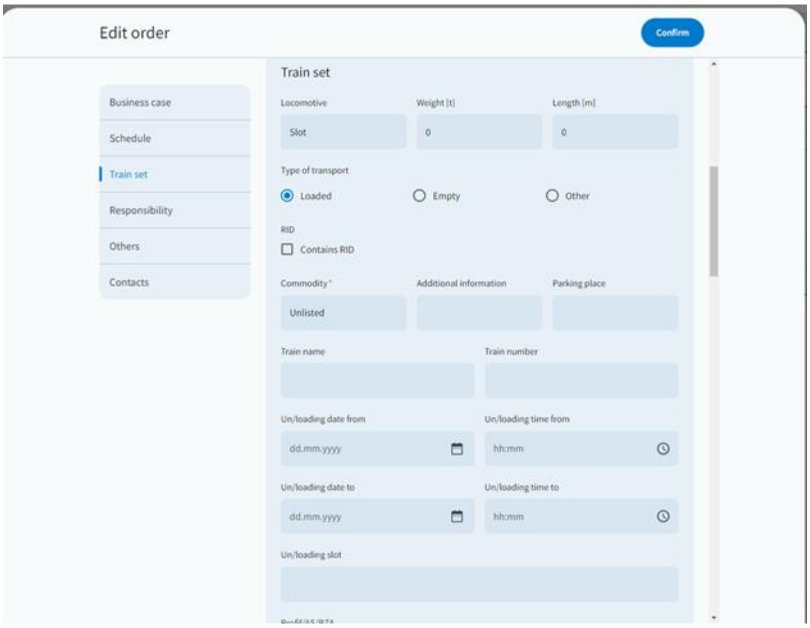


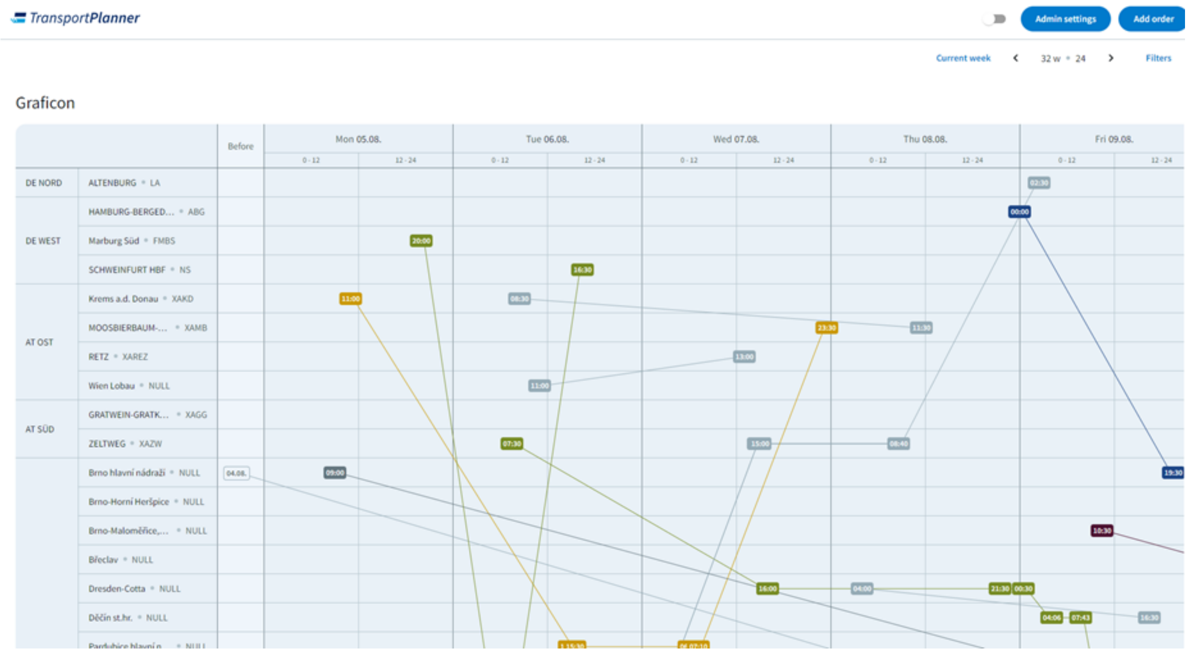
Figure 27.1.19: Transport planner – edit order train set



Work with the Graphical Timetable Display

- **Displaying the Timetable**: Select Graphicon from the main menu.
- **Filters**: Use filters to display specific time periods or days.
- **Edits**: Click on a specific time period to edit or add new information.

Figure 27.1.20: Transport planner – timetable edit



Work with Resources

Locomotives

- **Adding a Locomotive**: In the Locomotives section, click + Add locomotive and fill in the necessary information such as ID, type, capacity, and current status.
- **Editing a Locomotive**: Click on a specific locomotive to edit its details, such as status, planned maintenance, or current location.
- **Sharing Locomotives**: The application allows sharing locomotives with other RUs or entities. Users can set access rights and share information about the availability and status of locomotives, enabling better coordination and use of locomotives.

Drivers

- **Adding a Driver**: In the Drivers section, click + Add driver and fill in the necessary information such as name, ID, qualifications, and current status.
- **Editing a Driver**: Click on a specific driver to edit their details, such as status, planned shifts, or current location.
- **Sharing Drivers**: The application allows sharing drivers with other RUs or entities. Users can set access rights and share information about the availability and status of drivers, enabling better coordination and use of drivers.

Local Staff and Other Professions

- **Adding Staff**: In the Staff section, click + Add staff and fill in the necessary information such as name, ID, qualifications, and current status.
- **Editing Staff**: Click on a specific staff member to edit their details, such as status, planned shifts, or current location.
- **Sharing Staff**: The application allows sharing staff with other RUs or entities. Users can set access rights and share information about the availability and status of staff, enabling better coordination and use of human resources.

Performance Editing and Transfer

- **Editing Performance**: Click on a specific performance in the Locomotives, Driver, or Staff section and edit its details, such as time, performance details, or other relevant information.
- **Transferring Performance Between Specific Resources**: Select the performance you want to transfer and choose a new location. The application automatically updates all related information.
- **Transferring Performance Between Slots (Unassigned Performances)**: If a performance is not assigned to any specific resource, it can be transferred or assigned to a slot for unassigned performances. From there, it can later be assigned to a suitable locomotive, driver, or other resource.

4.5. Dynamic dispatching requirements for Yard Coordination System (YCS) (Malmö, Sweden)

In this section, we present requirements related to a dynamic dispatching from a perspective based on the Yard Coordination System (YCS). YCS is a system aimed at coordinating the planning the arrival/departure bowl of a marshalling yard. YCS was first developed in Shift2Rail (FR8RAIL III, 2024; Shift2Rail IP5, 2024) and is further enhanced in EU-RAIL FP1 MOTIONAL (MOTIONAL 2024a, MOTIONAL 2024b) and in TRANS4M-R WP32, data interfaces and communication to and from YCS is enhanced. In TRANS4M-R WP27, the possibilities, potential and requirements of including aspects related to dynamic dispatching in YCS is investigated. The scope of this section is the derive functional requirements, while the specifications for the handling of the requirements in YCS is investigated in later deliverables. Any potential enhancements of YCS to include dynamic dispatching is foreseen in next wave of EU-RAIL.

The outline of the section is as follows: First, there is a short resume of the YCS-system and its main scope. Thereafter there is a description about what dynamic dispatching includes in the viewpoint of YCS, and the users of YCS could be affected. Finally, we present requirements and functions related to dynamic dispatching and YCS.

4.5.1 About YCS

The current scope of YCS is short-term (operational) planning of activities and resources at the arrival/departure bowl (A/D-yard) of a marshalling yard. The marshalling yard in Malmö, Sweden, is the case that is in focus for which the prototype is developed and evaluated. More details about Malmö marshalling yard are found in (FR8RAIL II, 2020; FR8RAIL III, 2022). The main considered resource is the tracks of the A/D-yard, as this resource is shared by several different actors from different organizations with different objectives. Therefore, there is an important coordination need in order to make the resource utilization efficient. Some more technical information about YCS is found in (MOTIONAL D4.1, MOTIONAL D11.1).

YCS is updated in real-time regarding the planning of other activities, e.g. estimated times of arrivals and departure are updated momentarily from the TMS-system. It is important highlighting that YCS is a system for short-term operational planning and not for execution of the plans, i.e., YCS does not control any signals and does not directly dispatch locomotives or personnel. YCS current user interface is illustrated in Figure 27.1.20.

Figure 27.1.21: YCS user interface.

4.5.2 Dynamic dispatching in YCS perspective

The general aim of including dynamic dispatching aspects in YCS is to capture operational aspects related to the movements of trains, locomotives and wagons that have an impact on how the operational plans in YCS can be performed. The plans in YCS may seem feasible, but considering, e.g., signalling system and dependencies between the routing of different movements, the plans in YCS should be adjusted to be possible to be executed efficiently. These kind of implications on the planning in YCS is what is considered as the dynamic dispatching aspects and is the aim of the investigations here.

There are several types of activities performed on the yard involving movements of equipment, for example:

- Train arrivals;
- Train departures, either from A/D-yard or directly from marshalling bowl or from terminal;
- Pushing wagons over the hump;
- Movements to and from the terminal;
- Movements to and from the harbour area;
- Movements to and from the postal area;

- Locomotive movements to and from stable to departing trains.

The dynamic dispatching aspects place restrictions on how these activities/movements can be performed simultaneously. These restrictions are very much formed of the combination of the detailed track layout of the yard and the signalling system. In fact, the exact track used for one activity, as well as other details, may place restrictions on other activities. Some examples:

- Pushing wagons over the hump from some tracks of the A/D-yard restricts arrivals of trains, while pushing wagons from other tracks of A/D-yard does not put restrictions on arrivals.
- Moving a loco from stable to a departing train from A/D-yard normally does not put restrictions on arrivals, but if there is a double-connect loco, it must take another route on the yard which puts restrictions on the arrivals.
- Departures from some tracks of the marshalling bowl cannot be made at the same time as wagons are pushed over the hump, while from other tracks it is possible.
- While moving wagons from the port, some tracks of the A/D-yard are blocked.

In summary, there are operations that can or cannot be performed in parallel, and this can depend on the exact tracks where activities start, end or use during the operation. This may have an impact on the planning of the A/D-yard made in YCS, and this is what we capture with the dynamic dispatching aspects in YCS.

If the dynamic dispatching aspects are not considered, the execution of the operational plans in YCS may be problematic. For example, start to push wagons over the hump right before a train departure, may cause the departing train to be delayed since – under some specific circumstances – trains departures cannot occur at the same time as wagons are pushed over the hump. Further, the duration of the pushing wagon activity can depend on the number of wagons and number of wagon groups in the train.

In conclusion, to understand the details of the restrictions on how different actions can be performed in parallel or have to be performed sequentially requires detailed knowledge about the yard operational requirements. The details are very specific to Malmö marshalling yard, and to its layout of tracks and signal system.

4.5.3 User perspective

There are three main actors/users to YCS:

- YCS Operator, that has the responsibility to plan and decide about the capacity of the A/D-yard (representing IM). The YCS Operator also controls both TMS and YMS.
- Yard Manager, responsible for the planning marshalling yard (representing marshalling operator).

- Terminal Manager, responsible for planning the intermodal terminal (representing the terminal operator).

Of these users, the YCS Operator is the one mostly affected by the dynamic dispatching aspects, since she/he is responsible for the overall coordination of movements and the signalling system.

When it comes to YCS and dynamic dispatching, the main idea is to capture when the dynamic dispatching aspects have, or may have, important implications on the possibilities to execute the plan without significant delays. To really determine all dynamic aspects will enforce a need to very detailed planning of e.g. all routes that movements on the yard will use. Since YCS is not an executing system, there is an important risk that too much detailed planning in YCS will be considered as an unnecessary burden that does not help. Thus, it is very important to find the right balance between the concepts controlling by planning and controlling by execution, the system should help the users finding important risks related to dynamic dispatching in the plan, but it should not force users to make unnecessary planning. Therefore, is it likely to assume that *all* details that are relevant for the movements in the yard will not be available to YCS.

Without all details, it might be problematic for the system to fully evaluate the operational plan in YCS and to conclude if the plan is feasible or not. The activities in the plan could therefore be evaluated in three levels:

- Conflict: The system evaluates that there are two activities that conflict with each other, and at least one of these have to be changed.
- Potential conflicts: The system foresees that there is a risk that two activities conflict with each other, but depending to the detailed performance of the activities, there may or may not be an actual conflict. The system does not have enough information to determine if the conflict will occur or not.
- No conflict: The system does not foresee any risks that activities are in conflict.

The conflict level should be automatically calculated by the system, but the user should be able to overrule the systems proposed level. In particular, the potential conflicts could be changed to status *no conflict* if it is resolved, to *conflict* if user thinks that some action should be performed or stay at *potential* conflict if user wants to keep it as a “heads up”.

4.5.4 Requirements

Table 27.1.9 presents some important requirements regarding the extension of YCS to include dynamic dispatching aspects.

Table 27.1.9: Requirements for YCS with respect to dynamic dispatching.

YCS-DD-R1	System shall automatically identify conflicts between activities which depend on dynamic aspects, like on which track operations start, end or are routed.	Mandatory
YCS-DD-R2	Dynamic dispatching conflicts shall be visualized in YCS user interface.	Mandatory
YCS-DD-R3	The user shall be able to override the conflicts.	Mandatory
YCS-DD-R4	System should propose solution(s) to the conflicts.	Optional
YCS-DD-R5	User shall not be forced to put “too many” operational details into the system so that the value of the system is perceived as smaller than the efforts to use it.	Mandatory
YCS-DD-R6	System shall function even if not every (in theory relevant) detail of every activity is known for the system.	Mandatory
YCS-DD-R7	User shall be able to add details regarding operations while using the system.	Mandatory
YCS-DD-R8	System should make plausibility check of manually entered values.	Optional

4.5.5 Way forward

Forthcoming work in WP27 regarding dynamic dispatching for YCS includes the following steps:

- User prioritization: Expert user should prioritize which dynamic dispatching aspects and cases that are most important and relevant to include.
- Level of detail: Expert user should help to define the relevant level of details that the system should handle to be a support for the users and not a burden.
- Data need and data availability: Investigation of data need and possibilities to capture data from other systems and/or manual.
- Evaluation: Expert user should evaluate the grade of importance that including dynamic dispatching in YCS would contribute with.
- Demands for wave 2: Proposed future development of dynamic dispatching in EU-RAIL wave 2 should be specified.

Continued work will be further reported in upcoming deliverable(s).

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