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EXECUTIVE SUMMARY

This report is the first deliverable in Work package (WP) 5.1 "Optimisation of information and communications methods" of the Optimised Real-time Yard and Network Management (Optiyard).

In WP 5.1 research and innovation activities lead to the analysis, understanding and definition of optimized information and communication methods focused on Marshalling yards and the interaction between network/line management and the operation management in Marshalling yards and Terminals.

In chapter 2 "Technological aspects of optimizing the processes of marshalling yards and their surroundings" of this deliverable are described characteristics of surroundings, organizing of operation and sources of MYs. Sources of data and information to optimize the work of the Marshalling yard operator, infrastructure manager and railway undertaking are described in the second part of the chapter.

Chapter 3 "Interface design for inter-entity communication (Improved information and communication WP5.1" of the report deals with the basic characteristics of messages among stakeholders are described. In the next part of the chapter, interfaces for planning are stated. For clarity, we present several possible scenarios and their impact on communication between key stakeholders in the transport process.

WP 5.2 Improved decision support system on yard level is included in this report.

It can be expected, that proposed interface as a base of communication between participants in combination with an interacting optimization system will contribute to automation and efficiency of decision processes along the freight rail supply chain.

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LIST OF ACRONYMS

AP = arrival part data
CD = common data.
CP = classification part data
DISOM = Dispatcher information system of operational management
DP = departure part data
ES = entry signal
H = hump data
HL = hump locomotive data
IS = Information system
LL = line locomotive data
MY = Marshalling Yard
MYOS = Marshalling yard optimizing system
OIS = Operational information system
RU = Railway undertaking
TAF TSI = Technical Specification for Interoperability: Telematics Applications for Freight
YL = yard locomotive data

1. INTRODUCTION

As per a current established standard, and this project is no exception, accessing the information about the information systems themselves, their functions, necessary input and output data, data of formats and interfaces these systems use to communicate with each other is not a simple task. This is both the effort of companies to protect their sensitive data or knowledge, and the effort not to allow companies other than the ones established in the given place and time to participate in the development of data communications within the railway sector. This document dealing with the WP5 agenda is divided into several parts.

The first part deals with technological aspects of optimizing processes of marshalling yards and terminals and adjacent sections of railway lines. This chapter also includes aspects of information systems, data formats and interfaces used on the railway.

The second part deals with the design of the interface for communication between the railway network and the marshalling yard.

Non-interrupted data flow between marshalling yards and surrounding network as a base for optimized decisions is nowadays a very important issue due to delays caused by engineering works on railway lines and other disruptions, at least for Czech railways. This document concerns existing procedures, sources and duration of main activities in marshalling yards. Output of the analysis is a resume of inconveniences that should be eliminated in near future. The last part is focused on a proposal of a universal data interface for transferring information from network information systems to the considered yard management system.

Although the core of this part of the work package is the experience and knowledge gained in the environment of the Czech transport system, the principle of universality has been respected. The proposed interfaces have to be compatible with systems that are operated abroad. Czech marshalling yards and their processes are very similar to those in other European countries. For information systems, the situation is similar. As the Czech railway system is a pioneer in the implementation of communication according to the TAF TSI standard, and several information systems mentioned in the following text are already commonly used for communication of this standardised interface, therefore experience and proposed solutions are universally transferable and applicable everywhere else in the European rail system and thus fully respects the achieving the objectives of this project

2. TECHNOLOGICAL ASPECTS OF OPTIMIZING THE PROCESSES OF MARSHALLING YARDS AND THEIR SURROUNDINGS

System of single wagon load based on the system of trains that connect senders and recipients through dedicated stations commonly equipped with a hump and other special devices. These stations – marshalling yards are a crucial part of the system. To ensure reliability, speed and accuracy of transport per customer needs, it seems to be necessary to develop a new approach of information flow to and from marshalling yards. This new approach should be provided by the proposed TSI based interface, that will interchange data between the existing network information systems and the new considered marshalling yard (MY) operation (management) system, which should include a real-time decision module for optimized operational management of sources.

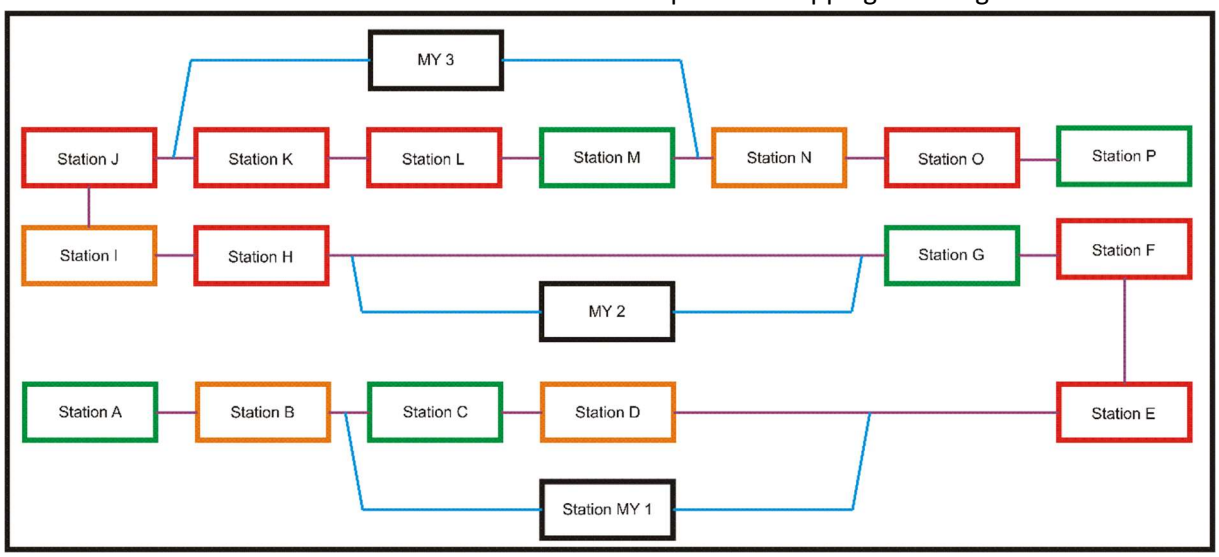
2.1 CHARACTERISTICS OF THE SURROUNDINGS OF MARSHALLING YARDS

For various reasons, operational situations that cannot be solved only by measures at the given station can occur in normal operation. It is necessary to use the capacity of the adjacent network. However, the adjacent network also has its restraints, which limit dispatcher's decision. The illustration is the starting point I for communication scenarios between the marshalling yard and the surrounding network, as shown in the following chapters of the proposal. The following illustration shows several station types that are color-coded.

Marshalling yards are marked in black. The main line is marked in purple. The interconnecting tracks between the marshalling yard and the main line are marked in blue.

Stations on the network which have sufficient length of tracks and thus an unplanned stop of a freight train would not interfere with the operation of other trains are marked in green.

Stations on the network which are limited for an unplanned stopping of a freight train are marked in



orange. Stopping is still possible without interfering with the operation of other trains following the timetable. Idling a train may require intervention in the operation of other trains — for example, changing

the scheduled track or changing the railway station. Restrictions may relate to track length, number of tracks, the need to change the operation of other trains or the length of the idling period.

Stations which are absolutely unsuitable for unplanned stops and idling are marked in red. They do not meet the requirements for track length, number of tracks or are busy in the given period.

Figure 1: Example of network in neighbourhood of MYs

2.2 CHARACTERISTICS OF ORGANIZING THE OPERATION OF MARSHALLING YARDS

Current situation in marshalling yards around Europe is heterogeneous. It is possible to describe some of the different cooperation models or use cases, but most cases are very specific depending on the country, station management system, role of a marshalling yard operator etc. Basic MY operation models are as follows:

- MY is operated by the railway undertaking (Table 1)
- MY is operated by the infrastructure manager (Table 2)
- MY is operated by both (some operations done by the railway undertaking, others by the infrastructure managers; table 3),
- MY is operated by a special operator who performs all activities associated with the train (this is a purely theoretical model, some container terminals can work this way).

Table 1: MY operated by RU

Item	MY	RU	IM
Permission for train arrival			X
Technical and commerce inspection		X	
Decoupling		X	
Shunting + shunting engine		X	
Hump service			X
Coupling		X	
Technical and commerce inspection		X	
Train documentation and permission to depart		X	
Permission for train departure			X

Table 2: MY operated by IM

Item	MY	RU	IM
Permission for train arrival			X
Technical and commerce inspection			X
Decoupling			X
Shunting + shunting engine			X
Hump service			X
Coupling			X
Technical and commerce inspection		X	X
Train documentation and permission to depart		X	
Permission for train departure			X

Table 3: MY operated by IM and RU

Item	MY	RU	IM
Permission for train arrival	X		
Technical and commerce inspection		X	
Decoupling		X	
Shunting + shunting engine	X		
Hump service	X		
Coupling	X		
Technical and commerce inspection		X	
Train documentation and permission to depart		X	
Permission for train departure			X

2.3 CHARACTERISTICS OF MARSHALLING YARD SOURCES

For comprehension of the processes, an overview of operations and facilities in the marshalling yard in Česká Třebová is given in this chapter. Although the described issues are based on Czech marshalling yards, the authors have taken into consideration the need for generality. Marshalling yard in Hallsberg, Sweden that is described in the project ARCC S2R-CFM-IP5-02-2015: Start-up-activities for freight automation, has a very similar layout to the station in Česká Třebová.

A marshalling yard is a part of the railway station complex in Česká Třebová. The station is of standard layout that is common in the European railway network for medium or big railway stations with mixed operation of passenger and freight trains. That means that the station consists of a passenger part, (intermodal container) a terminal, an industrial area with sidings, a locomotive depot with a maintenance area and a marshalling yard. The marshalling yard consists of an arrival yard, a hump, a classification yard and a departure yard. The hump and the classification yard are equipped by an automatic classification and braking systems (GAC and ARS GTSS). Planning in a long-term period integrates paths for arrival from the main line <–> shunting and marshalling of single wagons and groups <–> paths for departure to the main line.

In general, sources in the marshalling yard are as follows

- line locomotive and its driver,
- hump locomotive and its driver,
- yard locomotive and its driver,
- hump,
- arrival tracks,

- classification tracks,
- departure tracks,
- siding tracks,
- yard dispatcher of the infrastructure manager,
- yard dispatcher of the railway undertakings,
- head shunter,
- shunter,
- brakeman,
- coupler,
- transport agent,
- inspector,
- signalman.

There are three shunting locomotives in the marshalling yard in Česká Třebová. They are available 24 hours a day, 7 days a week.

- Arrival/Hump locomotive – receives commands over radio.
- Classification locomotive – receives commands over radio.
- Departure and siding locomotive – receives commands over radio and signalling.

The maximum length of the track is 933 m (arrival yard) and 829 m (departure yard). Average length of a train is 650 m. The classification yard consists of 33 tracks divided into 4 groups. Minimum empiric time for changing a locomotive is 10 minutes. Minimum empiric time from the arrival to the departure of a train is about 4,5 hours. Average marshalling time with an average train unit is about 6 hours. Average numbers of trains are as follows. There are 10 transit trains with some operations (e. g. change of locomotive) per day. There are approximately 30 trains that terminate their journey in the arrival yard per day. Four of them are local connecting trains. There are roughly about 27 trains that start their journey in the departure yard per day. Six of them are local connecting trains.

Nowadays, all operations with a train arriving to or departing from the marshalling yard are performed according to a long-term plan, a medium-term plan, a shift and operational plan and commands. In the railway environment a long-term plan means a timetable and the amendments made to it that come into force in about every 3 months. Ad-hoc trains are served with no additional capacities of sources (there are some reserves in case more ad-hoc trains arrive). To prepare a long-term plan of operational processes in marshaling, the railway undertaking uses a software application. Namely, it is “Timetable of operational processes in a station” – TOPS. During the preparation of a train timetable, this application provides the train planner (railway undertaking's staff) with a basic tool for planning all procedures with a train. Activities of all necessary sources are included in the final plan of procedures.

2.4 PROCEDURES IN A MARSHALLING YARD

In this chapter, a simplified description of the operations performed with terminating and departing a train is given. Transit trains without required procedures are not included. Transit trains with only few operations (except for marshalling) – for example changing a locomotive - are also not included.

Measured values of activity duration that are stated in the next chapter are empiric – the measurement was done on 20 random days from 15th January 2018 to 15th March 2018.

All planned sources are matched to activities that are arranged to exact sequence. A common sequence is explained below.

The trigger of a procedure in a marshalling yard is the notification of train arrival that is provided by the “Dispatcher information system of operational management” information system – DISOM or by the

dispatcher of the infrastructure manager. The plan of activities is updated only “manually” by the railway undertaking's dispatcher based on train composition taken from the operational information system (OIS).

The decision about the sequence of trains to be processed (marshalled) depends on the railway undertaking's dispatcher who uses information from “Operational information system” – OIS to decide. OIS contains complete information about a train unit. OIS does not provide any optimal decision support. The quality of the decision depends on how skilled the railway undertaking's dispatcher is.

2.4.1 Inbound train and the marshalling procedure

The procedure begins with the arrival of the train (train head reaches the entry signalling). During the arrival the wagon, an inspector is watching the train unit and is searching for failures e. g. flat wheels. At the same time, a transport agent is waiting at the place where the forefront of the locomotive stops in order to take the train and shipment documentation. After arrival, the train unit is secured by a wheel chock or by tightening the wagons' hand brakes. Next, the line locomotive is uncoupled. Average time of this procedure is 3 minutes. Uncoupling is performed by the line locomotive driver. After that the line locomotive is shunted to the line locomotive sidings. A signalman sets up and locks the shunting route. Commands from the railway undertaking's dispatcher to the line locomotive driver are given over the radio and by signalling. The main activities of inbound train procedure are given in the table below.

Table 4: Inbound train procedure

Inbound train procedure	Time (min)	Performed by
Moving train from the surrounding network to the yard – arrival	X	X
Handing over the train and shipment documentation (loco driver hands it over to the wagon inspector)	1	Transport agent / wagon inspector
Braking the train unit with wheel chocks	1	Line loco driver
Tightening the hand brakes of the first five wagons	6	Line loco driver
Command to uncouple the line locomotive and to shunt	0.5	railway undertaking's dispatcher
Uncoupling the line locomotive	3	Line loco driver
Shunting from the arrival track to the line loco siding	3	Line loco driver

The hump locomotive driver gets the information about the track which the train unit is to be marshalled on. The hump locomotive is coupled to rear of the train unit. Screw couplings of wagons are loosened by the shunter and the head shunter in accordance with the sorting list. The hump locomotive moves the train blocks to the hump per commands from the signalman and the head shunter. Loosened couplings are taken off by a coupler using a special rod. If any of the wagons is not allowed to be humped, such wagon is decoupled and shunted to the siding track next to the hump during the process of pushing the groups of wagons to the hump. After all blocks are humped, the hump loco moves to the siding track with the non-humpable wagons, couples them and shunts them to the classification yard on a dedicated track. The main activities of the marshalling procedure are given in table below.

Table 5: Marshalling procedure

Marshalling procedure	Time (min)	Performed by
Notification to the hump loco about the track of the unit to be marshalled	0.5	railway undertaking's dispatcher
Notification about dangerous goods	0.5	railway undertaking's dispatcher

Marshalling procedure	Time (min)	Performed by
Shunting the siding loco from its track to the arrival track	3	Yard/hump loco driver
Coupling the train unit	3	Shunter
Loosening the wagon hand brakes	6	Shunter
Releasing the train unit (taking the wheel chock away)	0.25	Shunter
Preparing for humping (e. g. loosening the screw coupling)	25	Shunter
Command to shunt blocks of train	0.5	Head shunter
Shunting a block of train	5	Yard/hump loco driver
Cutting and humping blocks into the classification yard	30	Coupler, brakeman, signalman
Shunting the non-humping blocks into the classification yard	6 per shunting	Shunter / coupler, Yard/hump loco driver
Securing the train blocks against movement (wheel chocks and hand brakes)	0.5	Brakeman
Shunting broken wagons	10 per shunting	Shunter / coupler

2.4.2 Procedure before departure

After one of the tracks has been completed, the procedure to prepare the train to depart begins. The decision to begin this procedure is made by the railway undertaking's dispatcher. All operations on the departing train can be completed because the time norm has been reached, the weight norm has been reached, or there is no other wagon to be matched to the train in the dedicated direction. During humping, the brakemen push the wagons or blocks to one another and tightens the hand brakes of the wagons. Pushing the wagons is done manually by breakmen. If it is necessary to push blocks manually due to weight or bad weather conditions, the blocks are pushed by a yard locomotive. When the wagon shunting on the track is completed, brakemen couple the blocks of train together. Afterwards, the yard locomotive is coupled. Hand brakes of wagons are loosened and wheel chocks are put away. The brake system of the train unit is filled and a brake connection test is performed. According to the command of railway undertaking's dispatcher, the yard loco shunts the train unit to the departure yard.

The train unit is then again secured against movement on the dedicated track and a wagon inspector performs a technical and shipment inspection. From table 3 it is apparent that this activity takes the longest. It takes about 60 minutes and its duration, besides the number of wagons, depends on the type and the length of the wagon. Optimization proposal has to consider this attribute while calculating the necessary time for this activity. The listing activity of the train vehicles is performed by the transport agent and takes about 35 minutes. It is performed at the same time as the technical and shipment inspection. Then RU dispatcher gives the command to shunt and couple the line locomotive. The command is given over radio and signaling. Line loco driver and shunters release the wagon hand brakes and put the wheel chocks away. Next command given is to fill the brake system by compressed air and the line locomotive driver in cooperation with the wagon inspector perform a full brake test. Then the line locomotive driver receives the results of the full brake test verbally from the wagon inspector. After that, it is necessary to receive and sign relevant documents. The last activity performed is to send a “Ready to depart” text message by line locomotive driver to the DISOM system. Afterwards, in appropriate time according to the timetable and the situation on the surrounding network, the train leaves the departure yard. Departure is an activity managed by the infrastructure manager's dispatcher in coordination with the RU's dispatcher in the station and the RU regional network dispatcher. The main activities of outbound train procedure are given in the table below.

Table 6: Outbound train procedure

Outbound train procedure	Time (min)	Performed by
Pushing (manually + yard loco)	20	Brakeman, yard loco driver
Coupling train blocks	30	Brakeman
Shunting the yard loco	5	Yard/hump loco driver, shunter
Coupling the yard loco	3	Shunter
Filling the train unit brakes	4	Yard/hump loco driver
Shunting the train unit	5	Yard/hump loco driver
Technical and shipment inspection (in general)	60 (2 min per wagon)	Wagon inspector
Technical and shipment inspection (2/4/6/8 axle wagon)	1,5/2/2,5/3	Wagon inspector
Listing the train vehicles	35 (1 min per wagon)	Transport agent
Command to couple the line locomotive to train unit	0.5	railway undertaking's dispatcher
Shunting from line loco sidings to departure track	X	Line loco driver
Coupling the line locomotive to train unit	3	Line loco driver
Command to fill the pressure brake with air	0.5	railway undertaking's dispatcher
Loosening the wagon hand brakes	6	Line loco driver, shunter
Releasing the train unit (taking the wheel chock away)	0.25	Line loco driver
Placing wheel chocks beside the track	0.25	Line loco driver
Full brake test	30 (1 min per wagon)	Line loco driver, wagon inspector
Notification of full brake test results	0.5	Wagon inspector
Handing over the train and shipment documentation (car inspector hands it over to the loco driver)	1	Line loco driver, wagon inspector
Signing the international train braking report	0.1	Line loco driver, wagon inspector
Handing over commands for route	1	Line loco driver, wagon inspector
Signing the commands for train running	0.1	Line loco driver, wagon inspector
Train readiness to depart notification (text message)	3	Line loco driver
Departure	X	X

2.5 SOURCES OF DATA AND INFORMATION TO OPTIMIZE THE WORK OF THE STATION AND ITS SURROUNDINGS

The basic sources of data and information for optimal or suboptimal management of terminal or marshalling yard processes, which may even be a classic marshalling station, are currently information systems (IS) on, not only, the Czech railway. These are usually the information systems of the RU or the infrastructure manager. In exceptional cases, such as aforementioned terminals and marshalling yards within terminals or directly linked to these terminals, the information systems of the relevant operator may be the data and information sources.

As already indicated, types of information systems, which can be distinguished according to the following divisions, take part in the continuous flow of information, which is essential for the functioning of some optimization tool for process optimization in stations or terminals,

Based on the IS operator

- Railway undertaking's IS
- Infrastructure Manager's IS
- Terminal or station IS

Based on usage in time

- IS for long-term planning (for the whole year)
- IS for medium-term planning (with view in days)
- IS for short-term planning and ad-hoc plan changes (tens of hours)
- IS for operational management (hours, minutes)

Based on the nature of the managed area

- IS for managing traffic on the complete network
- IS for managing traffic on a selected part of the network
- IS for managing traffic at nodes and traffic points

Based on the type of managed capacity source

- IS for planning and managing wagon movement
- IS for planning and managing movement of locomotives and trains
- IS for planning and managing staff

In this project, it is necessary to deal with the characteristics of the systems listed above with the exception of the IS for managing traffic on the complete network and IS for planning and managing staff. All other types of systems should be involved either directly (in real-time decision-making) or indirectly (in particular information based on the long-term plan) in the preparation of an optimization tool for support of the decision-making of dispatchers.

The following text pays attention mainly to the information and information systems that have a direct impact on traffic management and decision-making in real time. The reason for this is the assumption that operational information systems work with input information that is already optimized during the preparation of long-term and medium-term plans. In other words, if actual traffic were to take place with high accuracy according to long-term and medium-term plans, there would be no need to make major decisions on the organization of operations in real time as the optimal solution had already been achieved in the said plans.

2.6 NETWORK INFORMATION AND MANAGING SYSTEMS OF THE INFRASTRUCTURE MANAGER

Dispatcher systems of managing railway traffic operate in real time. Their task is to collect, transmit, process, display and evaluate data on traffic in the railway system. Two basic information systems are mentioned in this chapter. The first is the GTN system, which receives data directly from the safety devices and processes them for immediate operation of the safety device. The second system is ISOM, task of which is to collect initial data mainly on the movement of trains from the GTN system and other systems of operational staff managing safety devices.

Both information systems closely cooperate with the dispatching systems of railway undertakings. They also communicate with the operation planning systems of both the railway undertakings and the infrastructure manager.

2.6.1 Graphical-technological extension of interlocking system (GTN)

The introduction of modern interlocking system on the railway and their interconnection enables the transfer of large amounts of information between individual stations and both ways between dispatchers. Graphical-technological extension of a safety device is an information system that supports managing traffic processes on a defined section of the railway network. The basic input is the train number transferred from the interlocking system. GTN can be applied in isolated stations in addition to track sections.

Basic functions:

- real-time monitoring of the operation of the safety device;
- collecting the necessary data on the current state of operations in the controlled area,
- display and documentation of the actual implementation of operations on the line section and at individual stations (train record, fulfilled GVD, operator protocol),
- keeping traffic statistics for the allocated circuit,
- development of a prognostic model (continuous updating of train path position allows to immediately evaluate the course of the traffic process),
- enabling the organization of transport to be changed in the time forecast (transport planning),
- keeping an archive of the realized train transport
- transfer of actual traffic information to other railway system information systems,
- transfer of information on the shift plan and trains to the interlocking system.

The basic inputs are all information from the interlocking system. The GTN provides ISOM outputs of the infrastructure manager and the specified information is delivered to the DISOM system where it is a source of information on the optimal way of further train runs.

2.6.2 Information system for operational management (ISOM/PRIS)

ISOM is a central information system that serves the dispatching apparatus of the infrastructure manager for monitoring and managing all train transport in the area.

It is used to collect initial data mainly from systems with connection to safety devices. In addition, another task is to process the data, display the current and prospective state of the operation and then evaluate the quality of the railway operation management. As is evident, the system is operating continuously and communicates with a response within 3 seconds. Typical ISOM users are dispatchers (at individual stations) and operational dispatchers (responsible for given areas). The monitored and managed objects are as follows — trains, locomotives, drivers and operational restrictions.

The system provides system and technological functions

- receiving and generating data outputs for other systems
- user permissions,
- maintenance of core and operational data,
- presentation of outputs,
- dispatching operations planning,
- dispatching planning and monitoring of operational restrictions activities, excluded and occupied tracks;
- quality control of input data,

- evaluation of operational activities,
- replacement of manual documentation,
- long-term archiving of operational data.

The deployment of the system is concentrated in managing centers with remote work sites equipped with client applications of these centers. Workplaces supporting the collection of initial data and the use of the system data for the operational activities of the railway are deployed throughout the area of the railway network. The system can communicate with a standardized interface in accordance with TSI TAF/TAP.

The main ISOM software modules are:

- train traffic monitoring module that provides on-line tracking of trains with a graphical display of the current situation as well as the forecast of traffic situation — the timetable has been complied with.
- an information and query module that is protected by an access password for a defined stakeholder;
- a communication module that provides a continuous and rapid exchange of information between traffic control points,
- a monitoring module for operational restrictions activity,
- GVD analysis module
- module for monitoring the performance of selected railway stations,
- a special transport module.

Using the system eliminates cumbersome and potentially erroneous telephone communication and duplicate data acquisition, which supports fast and qualified decision-making. It provides extensive statistical outputs for better operational, medium- and long-term decision-making.

Inputs

- Trains and their properties from the long-term plan (EMAN).
- Trains paths ordered by the RU from the infrastructure manager KANGO and CAIN for both long and short periods of time — freight timetables, network data, code lists, train paths.
- APORT (Train analysis and train readiness before departure) and COMPPOST (Central application for receiving information on train composition) — Analysis of the train, readiness of the train for departure.
- CSV (central system of operational restrictions) — operational restrictions plan.
- DISOM — path activation, train analysis, train work plan (shift plan, agreement to run, train running, drive unit and driver deployed).
- TL (Traffic Log) — train running.
- GTN (Graphical-technological extension — managing and communication extension over remotely controlled safety device) — train running.

Outputs for information systems

- GRAPP (Graphic presentation of train position) — train position with additional data (drive unit, driver, etc.).
- OIS (OIS) — train running.
- COMPPOST (System designed to monitor train composition and readiness data) — train running.

- CSV — actual course of operational restrictions, interruption in service of a transport employee (VSDZ).
- DISOM — train running, shift plan agreement, agreement to run, train position with other data (drive unit, driver, etc.).
- DD (Travel Log) — automatic outputs, train work plan — shift plan, agreement to run, train analysis.
- GTN — automatic outputs, train work plan — shift plan, agreement to run, train position with other data (drive unit, driver, etc.).
- EVAL (Railway undertaking information system, application intended for RUs and forwarders — all data on wagons, locomotives and staff) — position of the train with additional data (drive unit, driver, etc.).

2.7 NETWORK INFORMATION AND MANAGING SYSTEMS OF THE RAILWAY UNDERTAKING

The DISOM/DISC OŘ system is a dispatch information system for operational management of the operation of locomotives, drivers and trains on the network. It serves the dispatching apparatus of the operational management of the RU for short-term planning of trains and preparation of a plan for the deployment of specific drivers for given performances (shifts), implementation of ad-hoc trains, management of diversion routes in the event of emergencies and unexpected operational restrictions. The DISOM system is a tool of dispatchers for making bookings and deploying drive units and driver on individual trains and their subsequent management and monitoring their running. The system books and assigns specific capacities regardless of whether they are trains running according to a long-term valid timetable (local service trains and relational trains between marshalling yards) or trains implemented entirely ad-hoc. For trains running in ad-hoc mode, DIOM serves as a tool for their complete planning and capacity assignment. DISOM is a part of the package of other operating systems of the RU and works closely (data exchange takes place) with the train management system on the infrastructure manager's network (ISOM). Through DIOM, requests are sent for approval and confirmation by the RU's scheduled shift plan for 6 hours with a prospect for another 6 hours. This is a floating 6 + 6 hours of continuous preparation of the operation — the shift plan. The systems are interconnected in such a way as to provide sufficient information to both the infrastructure manager and the operating systems of the RU. The RU's dispatcher directly decides on the deployment of a suitable drive unit on the train, while trains, available drive units and drivers are clearly displayed in DISOM at any moment.

First of all, the characteristics of the information system for operational traffic management of the RU is given — “Dispatcher information system of operational management” (DISOM). DISOM works in real time and, like the ISOM system, which serves the dispatchers of the infrastructure manager, displays the railway traffic status to the regional dispatchers of the RU.

Input information for the activities of the dispatch managing department:

- train running dynamics,
- occupancy of tracks at railway stations and passing points;
- the layout for the running of the train,
- disruption of the timetable.

The basic function is to ensure the updating of the actual train running and the recording of track occupancy in the completed GVD. Updating the train running dynamics can be performed by:

- automated receiving of train running messages from an electronic traffic logbook or GTN
- manual acquisition of a dynamic train running message,

- automatic updating of the expected train movement based on running time,
- manual acquisition of a report on the occupancy of tracks.
- instradation and monitoring of extraordinary shipments;

Inputs

- Contracted but not activated trains (business cases) and their characteristics.
- Trains and their properties from the long-term plan (EMAN).
- Trains paths ordered by the RU from the infrastructure manager KANGO and CAIN for both long and short periods of time — freight timetables, network data, code lists, train paths.
- Recording and tracking railway freight wagons and analyzing the train — OIS.
- APORT (Train analysis and train readiness before departure) and COMPPOST (Central application for receiving information on train composition) — Analysis of the train, readiness of the train for departure.
- CSV (central system of operational restrictions) — operational restrictions plan.
- APS (Automated Engine Driver's Workplace) — deployment plan — driving unit, driver.
- ISOM (Information system for operational management of the infrastructure manager, Central dispatch system module) — train running, agreement with shift plan, agreement with running, train position with other members (driving unit, driver, etc.).
- ISOM KAIN (track capacity ordering system) — path allocation

Outputs for information systems

- OIS (PRIS) — train running.
- COMPPOST (System designed to monitor train composition and readiness data) — train running.
- ÚDIV (Central Carriage Conducting) — automatic outputs.
- CSV — actual course of operational restrictions, interruption in service of a transport employee (VSDZ).
- APS — deployment of the driving unit and driver on a train.
- ISOM — path activation, train analysis, train work plan (shift plan, agreement to run, train running, drive unit and driver deployed).
- EVAL (Railway undertaking information system, application intended for RUs and forwarders — all data on wagons, locomotives and staff) — position of the train with additional data (drive unit, driver, etc.).
- TMS (Train Management System) — transportation information system for customers
- ISOM KAIN (track capacity ordering system) — path request

2.8 STATION INFORMATION AND MANAGING SYSTEMS

Operational information system (OIS/PRIS) is designed to support the activities of the RU's operations, in particular to cover all processes of marshalling yards, but also covers all operating activities of other stations, including activities related to technical and commercial inspections of wagons and trains. OIS is closely interconnected with the system for monitoring commercial processes of shipment (Central freight office) which enables to mutually use the data about wagons and shipments to optimize operational activities of both the wagon and the shipment. In addition, it enables monitoring local processes associated with the handover and acceptance of a wagon, the operational and technical condition of the wagon, its movement around the perimeter of the station, etc. Wagon Operational Database module, which provides the necessary

information about all vehicles that the RU can have at their disposal at the given moment, is an integral part of the system.

OIS is a basic information system designed for comprehensive coverage of processes and operational activities of the marshalling yard. In particular, it handles

- checking the train after arrival,
- creating a sorting list,
- actual load breakdown on directional tracks,
- train listing before departure,
- drawing up a work plan for service trains within the attraction circuit of the marshalling yard;
- supply and shunting of a wagon from the handling points,
- reporting and monitoring the work plan of the station
- instradation and monitoring of extraordinary shipments.

The system provides data on the wagons in the destination train set for physical inspection of the wagons and for the inspection of accompanying documents. It is also possible to add data, which are discovered in the track during rounds along the train. Initial sorting support, in particular, the creation of a numerical and occupational sorting list and its subsequent distribution to all the employees involved. It also allows finding out the actual sorting process — the completion of the implemented sorting board and subsequent archiving of all sorting lists.

In particular, the system is used for drawing up the report of vehicles of a default train, verifying and collecting data in the track during rounds along the train set. Drawing up train documentation based on the vehicle report and other necessary data (e.g. data on active locomotives) is another important function. Finally, the system transmits data about the departing train to other systems.

In addition to the basic requirements of the system, it is necessary to provide operational management of activities with an emphasis on their preparation and planning, operational interventions in the course of activities, evaluation and creation for subsequent breakdown of marshalling yard performance based on RUs, basic economic evaluation of marshalling yard processes and creation of data for monitoring capacity utilization (driving unit, staff), controlling, etc. The aim is to unify technological procedures and minimize exceptions to standard technology, which will make system expansion easier as well as its subsequent maintenance. Local conditions of individual stations are taken into account by setting parameters.

Inputs

- Trains and their properties from the long-term plan (EMAN).
- Recording and tracking railway freight wagons and analyzing the train — OIS/PRIS.
- APORT (Train analysis and train readiness before departure) and COMPPOST (Central application for receiving information on train composition) — Analysis of the train, readiness of the train for departure.
- DISOM — train running and drive unit

Outputs for information systems

- COMPPOST (System designed to monitor train composition and readiness data) — train running.
- ÚDIV (Central Carriage Conducting) — automatic outputs.
- DISOM (Railway undertaking information system, application intended for RUs and forwarders — all data on locomotives and staff) — position of the train with additional data (drive unit, driver, etc.).

- TMS - Train Management System — transportation information system for customers

2.9 CONCLUSION OF TECHNICAL ASPECTS

Nowadays, there generally are no serious bottlenecks in marshalling yards except for extraordinary disruptions in the network that are naturally transferred to marshalling yards. That is why a marshalling yard can be used as a bumper in case of delays. However, this assumption does not apply for a marshalling yard connected to a port. Operational restrictions on the infrastructure and other events, and thus resulting big delays of freight trains are a problem for making a decision about order of trains to be marshalled.

As it was mentioned in the previous chapter, the OIS system, which provides information support to a dispatcher, has no optimization module. Decisions about which train should be served first based on the direction of shipments in it and based on the outbound train in dedicated direction became extremely difficult. In addition, the inbound train could be carrying shipment with “firm connection”. Firm connection means that the dedicated shipment (wagon or block of wagons) must be carried only by dedicated trains. For a railway undertaking's dispatcher, this information is the main base for making a decision. This rule can only be broken in extraordinary cases. Some operations mentioned in the previous chapter are dependent on each other and their correctness depends on providing correct information at the right time. In the mentioned situations, in which there are big delays and at the same time there are many inbound trains, it is almost impossible for the RU's dispatcher to calculate the time necessary for performing all the operations with trains in the marshalling yard and to make an optimal, or at least a good, decision.

The first operational problem for the dispatcher is, that even though the RU station dispatcher has precise information about the actual position of the inbound train, the supporting system DISOM is in many cases able to calculate the estimated time of arrival (ETA) only roughly. As a result of the operation of other trains on a given line, it often happens that the relevant dispatcher works with information that a freight train heading to a marshalling yard is really approaching and its arrival is likely in a certain time range — slot, rather than with a precise value of time.

The second operational problem is that there is no real-time support tool for calculating the necessary time to serve the inbound and outbound train according to a list of shipments and the type of wagons. That can potentially cause delays of outbound trains because a bad decision of train sequence has been made.

The third operational problem, which is connected to second one, is that it is not possible to calculate the estimated time of departure (ETD). For these three reasons, the railway undertaking's dispatchers and infrastructure manager of regional network dispatchers do not have the information whether a particular block train uses a particular ordered train path or whether another ordered train path will be used or if it will be necessary to order an ad-hoc train path. From the railway undertaking regional network dispatcher's point of view, it is very difficult for him to decide whether it is possible to use the train path of a particular delayed train for a different e. g. ad-hoc train.

As mentioned above in chapter “Technological aspects of optimizing the processes of marshalling yards and their surroundings“ and at the same time in the project ARCC S2R-CFM-IP5-02-2015: Start-up-activities for freight automation, WP2: Real time yard management, the role of the marshaling yard operator is dealt with differently in different European countries and is rarely clearly defined and implemented by a single entity. There are marshalling yards, where most of the processes are handled by the infrastructure manager (including the check-in of the train after arrival and before departure), as well as yards where the main particular RU (one or more) is the main process handler. However, these used models should not affect the operation of the marshalling yard. It is important that the implementation of these interfaces allows free access of the RU to the services of the relevant marshalling yard, thereby gradually freeing up the single wagon load market, which is important to the creation of competition of truck transport.

3. INTERFACE DESIGN FOR INTER-ENTITY COMMUNICATION (IMPROVED INFORMATION AND COMMUNICATION WP5.1)

This document describes the proposal of standards for communication of key stakeholders in the transport process in the single wagon load segment, i.e. between the infrastructure manager, the RUs and the marshaling yard operator. In European countries, the role of marshaling yard operator is not standardized in any way and is set differently in different countries. It is difficult for railway undertakings to do business in such environment, and that is why the single wagon load segment within the European Union is dying. This proposal seeks to define the role of the marshalling yard operator by means of communication interfaces and IT processes that the operator should provide. The proposal fully respects existing legislation and is based on existing standards — especially the European TSI-TAF Regulation.

The prerequisite of the proposal is that whatever model is used (models of operation of marshalling yards are described in the previous chapter) in a particular marshalling yard, it presents itself to the RU as one entity and the services provided are publicly known. It is therefore imperative to define and enforce the concept of marshaling yard operator within European railway legislation. Without this step, it is not possible to implement the proposal below.

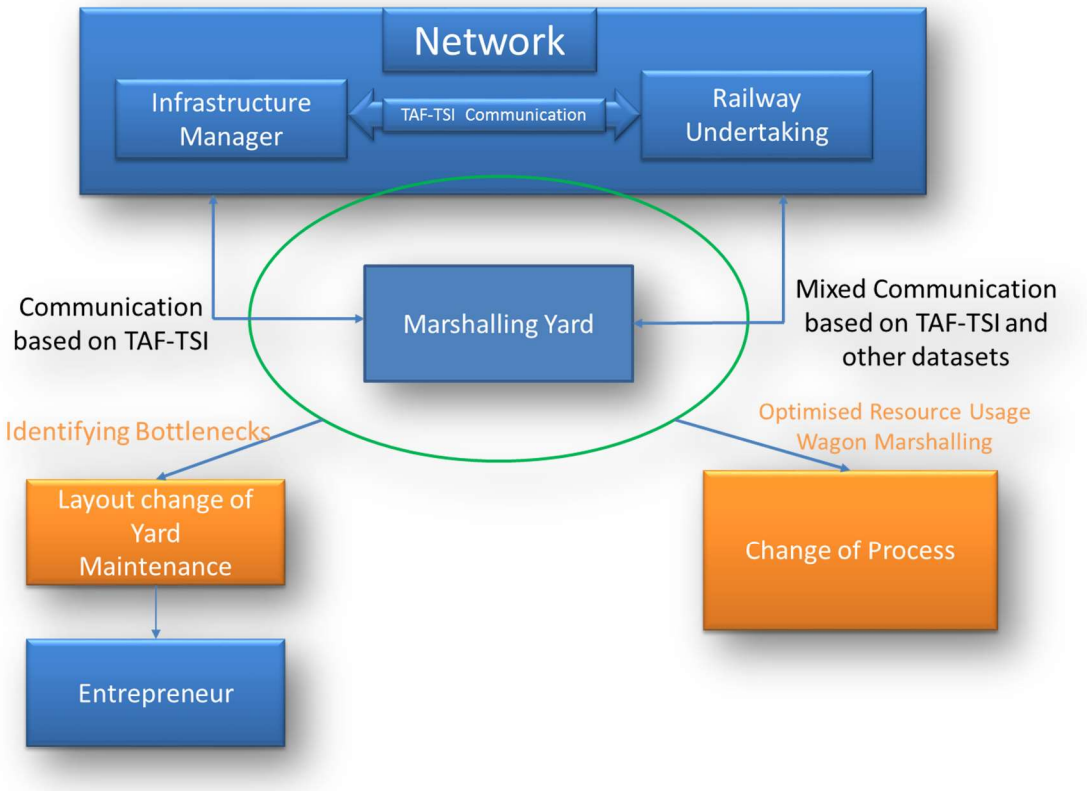


Figure 2: Scheme of communication between stakeholders

If we build on existing EU standards, it is necessary to respect the EU TSI-TAF Regulation in particular. This regulation precisely defines the processes in the planning and implementation of transport including

train running, but omits the area of train marshalling. This proposal defines the extension in the field of train marshalling and is very closely linked to TSI-TAF, specifically in the following areas:

- Path request
- Train preparation
- Train running forecast
- Information in case of traffic disruption
- ETI/ETA of the wagon
- Wagon running
- Exchange reporting

Because of possible existing data exchange formats it is appropriate to use any enterprise application integration as e.g. canonical data model.

One emerging data model for managing railway specific data is RailTopoModel (RTM), governed by UIC (International Union of Railways). While introducing time domain concepts, RTM is heading to harmonize with BIM's IFC Rail (Building Information Modeling / Industry Foundation Classes) and other standards, e.g. from OGC (Open Geospatial Consortium) and ISO's TC211 (International Organization for Standardization / Technical Committee). Extending RTM regarding command, control and signalling is pushed in the frame of the project EULYNX. The aim is to produce the digital twin of the railway system with focus on railway-specific infrastructure (leaving civil engineering, tunnel, bridge, road, station buildings, noise protection and real estate to other domains), energy, command, control and signalling. Operational and rolling stock data are covered by other models, e.g. railML. (UIC, 2018)

3.1 BASIC CHARACTERISTICS OF MESSAGES AMONG STAKEHOLDERS

While the MY optimization system is being developed, an interface to ensure transfer of information between "network" information systems and the considered marshalling yard system should also be in development. If we are considering only the solution of a problem in the marshalling yard, it is necessary to ensure uninterrupted flow of information throughout the whole marshalling process with connection to network processes.

Nowadays, it is possible to have available quite reliable information about ETA at least an hour before the arrival of a particular train into the marshalling yard. The cornerstone of this proposal is the interface between systems which interchanges information. After that it will be possible to develop a new "marshalling yard operation system" – MYOS that will be effective supporting tool for railway undertaking's dispatcher and for other marshalling yard staff as well. The proposal does not include the system but it is focused on the data that should be transferred through this interface.

The proposed types of interface data, or rather the attributes of the data, are divided into three groups given in the table below.

The first group consists of technical data, that represent the limits for RU dispatcher or IM dispatcher and MY workers. Maximum speed, power rate and braking power rate determine the time of approaching to and leaving the MY, and also the calculated time of arrival.

The second group includes technological data which depends on current situation in a particular case. A train with the same number can carry dangerous goods or priority shipment or any shipments requiring special care. Based on the current situation, a current plan for marshalling of trains and the calculated ETD will be prepared. The current situation is provided by the OIS system (operational system used for generating sorting lists) and the GPPS system (activity planning and assignment).

The third group consists of data used for train identification, train paths, and to contact the train driver. Some of proposed data is already available in RUs' information systems (e. g. DISOM, OIS etc.) Other

data (e. g. GPS position, maximum time of departure) is not available today. The data in the third group will be used for modelling an optimal procedure (e. g. planning train paths in the marshalling yard) and choosing the optimal train path for leaving of the train according to fluent travel on the network.

Table 7: Attributes of the interface

Technical data	Technological data	Information system data
Length of train unit	Wagon transfer (to which train)	Sender info (ID)
Braking power rate	Destination of wagon	Recipient info (ID)
Maximum speed	Wagon transfer (in which stations)	Train driver
Type of locomotive	Train ID number	Train driver's phone number
Length of wagon	Number of wagon	Equipped by a tablet
Number of axles	Order of wagons in train	Path ID
Weight of wagon	RID / dangerous goods	DISOM train number
Weight of shipment	Firm/priority transfer of wagon	Actual position (station)
Traction (in-/dependent)	Info for manipulation (limits/regulation)	Actual position (station, track, GPS)
	Planed activities (actual) e. g. arrival technical inspection	Executive railway undertaking
	Estimated time of arrival (to point e. g. MY)	Licensed railway undertaking
	Estimated time of departure (from point e. g. MY)	Available paths in direction
	Number of train unit (if present)	Available slots in direction
	Type of transportation (block train, single wagon load, special, military)	Available times for departure
	Maximum time of departure (each wagon) – railway undertaking requirement	Other notes
	Good faith in the first activities with the train	
	Origin station of wagon	
	Destination of wagon	
	Arrival track	
	Departure track	

Based on this data, the MYOS system should be able to calculate the time required to perform all the planned activities and thanks to that it will be able to estimate the time of departure for each train because the system will consider wagon transfers. In addition, this tool will help dispatchers to make optimized decisions about which train to accommodate and process first based on the possibilities to depart a connection train. Thanks to the complexity of the data gathered throughout the marshalling process, the process of train listing can be simplified.

3.2 INTERFACE FOR LONG-TERM PLANNING

The process of preparing a long-term plan is, from the point of view of communication between subjects, a process of making a long-term path request. For the completeness of the whole plan, the RU (or the cooperating RUs) creates a network of sessions covered by their plan. By sessions it is understood from where and to where the wagons will be transported. The network comprises of trains or rather of paths and transitions between them. And it is the transitions between train paths that represent so-called routing tables, which is actually a requirement for the capacity of a marshalling yard.

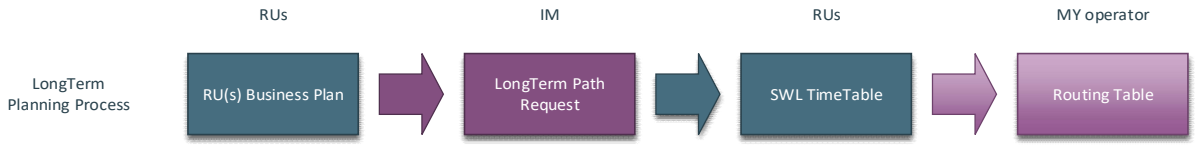


Figure 3: Long-term Planning Process

The biggest problem of defining a suitable interface for forwarding a routing table is the definition of the object that is the carrier of routing. Not all RUs use a train or its path as a carrier. In some cases, the carrier is still a session, and only then a train is assigned to the session. For the work of the marshalling yard operator, the difference is that in the latter case the RU does not determine the specific train (departure) of the wagon during transfer in case of multiple outflows from the train station in the given direction in 24 hours.

The proposal assumes that the definition of train check-in requirements upon arrival and before departure is a part of the path request process, and not the actual wagon transfer request.

Table 8: Definition of a routing table interface

Attribute	Description	Data Type	Size	Mandatory (Y/N)	Validation	Note
PlanTrainMessage						
MessageHeader				Y		
CIMessageStatus		AN		Y	1, 2, 3	1 new, 2 update, 3 delete
MessageReference				Y		
MessageTypeCode		AN		Y		New type by EUAR
MessageTypeVersion				N		
MessageNumber		N		Y	1..999999	Created by sender
MessageDateTime	Date and time of message creation	DateTime		Y		
Sender		N		Y		e.g. 2154
Recipient		N		Y		How to identify MYO(s)
SenderReference				N		
RoutingID				N		
Routing Table				Y		
PathIdentIncomingTrain		AN	6	N		
GroupOfWagons				Y		
WagonGroupOrigin	Location of Wagon or Consignment Dispatch or location of wagon coupling on train			N		
CountryCode		AN		Y		e.g. IT
LocationPrimaryCode		N		Y		
PathIdentOutgoingTrain		AN	6	N		
WagonGroupDestination	Location of Wagon or Consignment Delivery or location of wagon uncoupling from train			Y		
CountryCode		AN		Y		e.g. IT
LocationPrimaryCode		N		Y		

3.3 INTERFACE FOR SHORT-TERM PLANNING

The process of preparing a short-term plan is very similar to the long-term plan, only the motivation for its launch is usually a specific request for transport. The process can be both a refining of the long-term plan through knowledge of specific requests, and an input for a new request that has not yet been planned. The new request can be both a new train (for MY both on arrival and departure) and an unplanned transfer of a wagon between trains.

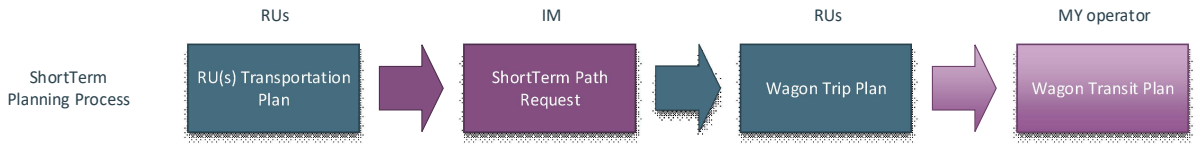


Figure 4: Short-term planning process

In this case, it is already assumed that the schedule of the transfer of the wagon in the station is determined by the arriving and departing train. A variant without a determined train is not permissible. WARNING! A wagon transfer plan does not have to be created for a particular wagon, as it may not be specified at the time.

The proposal assumes that the definition of train check-in requirements upon arrival and before departure is a part of the path request process, and not the actual wagon transfer request.

3.4 INTERFACE FOR ACTUAL TRANSPORT

The process of transport realization is a process of specifying the requests for wagon transfer from a particular train, including specifying the required activities on the train, if offered by the marshalling yard. The wagon transfer is specified when the train forecast is updated and in case of failure to comply with the conditions of the plan (e.g. loss of the connecting train, ordered wagon transfer with an impact on the delayed departure of a follow-up train).

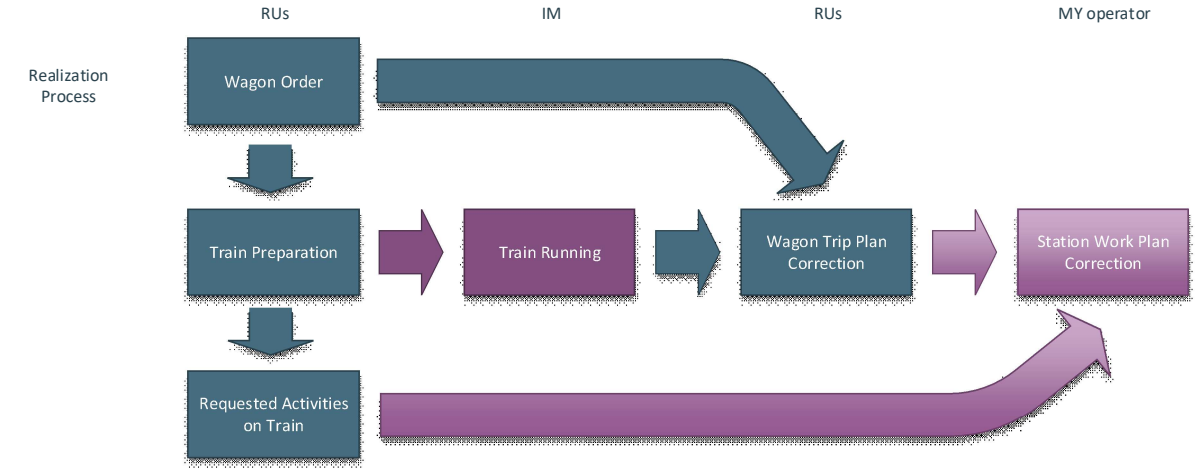


Figure 5: Process of performance

This process assumes the following communication interfaces:

- Wagon transfer in the station (update - RU > MYO)
- Required activities on the train (RU > MYO)
- Train composition (RU > MYO and vice versa)
- Train ready for departure (MYO > RU)

The last two interfaces already exist. It is only necessary to edit the header for forwarding the message to MYO. The definition of the interface for wagon transfer in the station is given above.

3.5 SCENARIOS OF COMMUNICATION BETWEEN IM, RU AND MY

For clarity, we present several possible scenarios and their impact on communication between key stakeholders in the single wagon load shipment process. Individual scenarios have been selected based on operational experience and represent a basic set of situations and communication proposals in these situations. The individual scenarios are as follows:

- train running without interruption,
- inability to reach the marshalling yard at the scheduled time, unloading on route,
- train delayed on arrival at the marshalling yard, the wagon transfer ensured,
- train delayed on arrival at the marshalling yard, the wagon transfer is not observed,
- non-compliance with the wagon transfer schedule on the part of MY,
- change in routing of the wagon or change of operations with the wagon during the marshalling in MY.

Scenario “Inability to depart from the MY to the network at the scheduled time” is not included because it is solved by information systems DISOM and ISOM.

3.5.1 Trouble-free trip

The first scenario describes a trouble-free trip of a wagon with no delays and other disruptions. This scenario considers a situation, in which operation in MY and on the adjacent network is carried out according to the timetable with minimal disruption. In this scenario, the train terminating in the marshalling yard is running on time, the marshalling yard ensures wagon transfer to other trains as scheduled, and the default freight trains leave the MY to the network according to the timetable. It is clear that this is a scenario in which the proposed communication is quite simple.

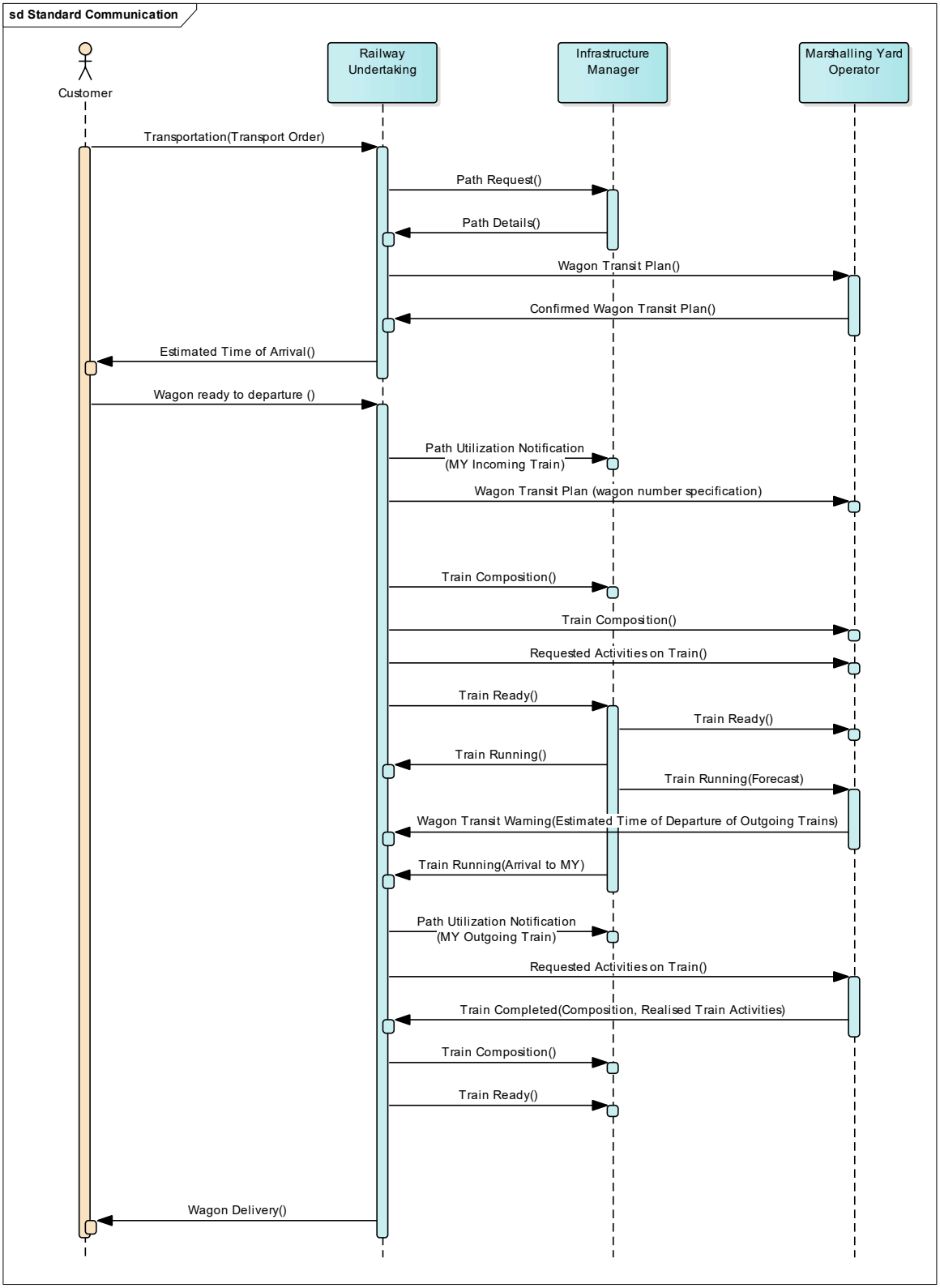


Figure 6: Communication in case of trouble-free trip

3.5.2 **Inability to reach the marshalling yard at the scheduled time, unloading on route,**

The second scenario describes the overfilling of the entrance track of the MY and the stopping or idling of arriving trains at stations before the MY. The limits for this scenario are described in chapter “Technological aspects of optimizing the processes of marshalling yards and their surroundings“.

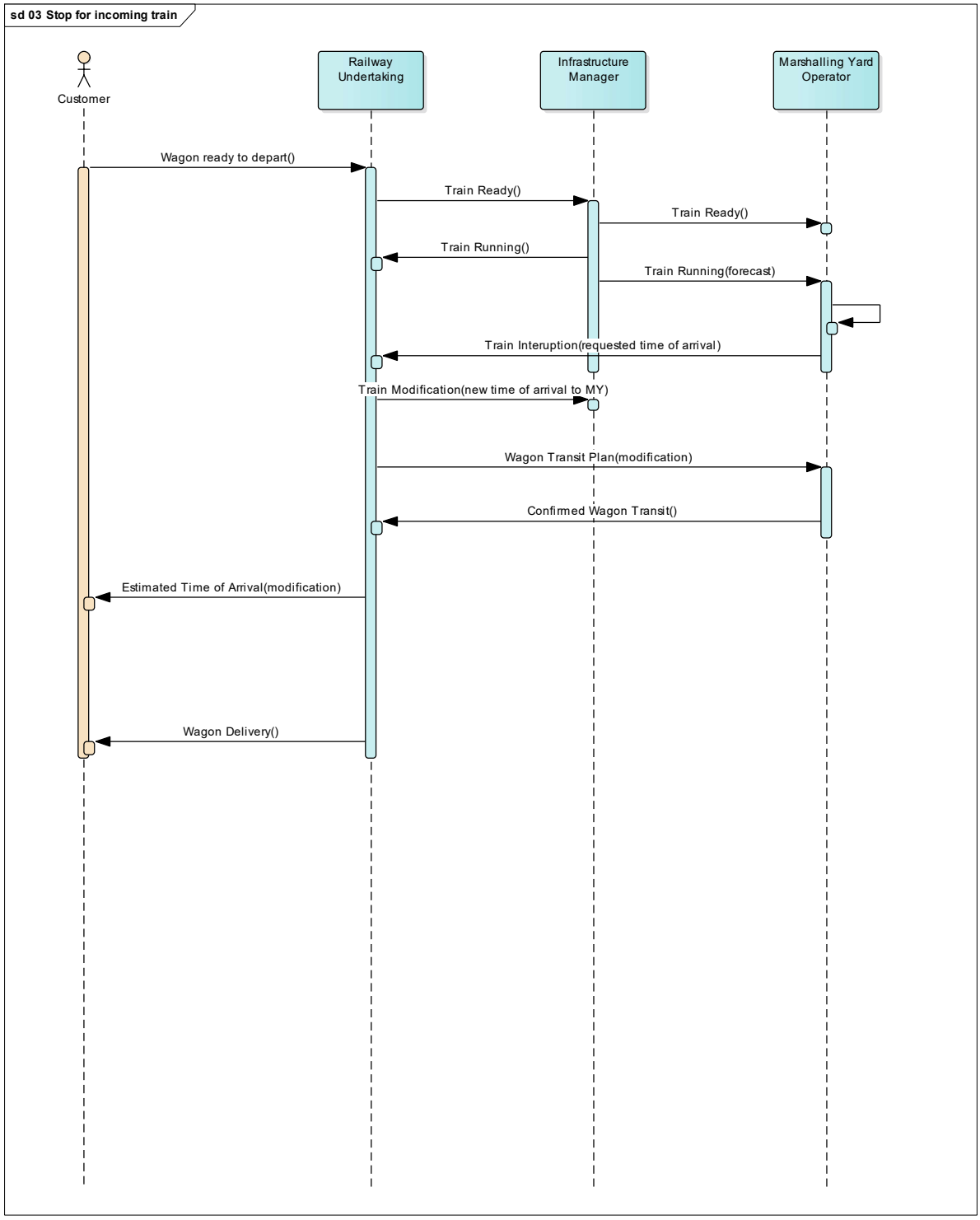
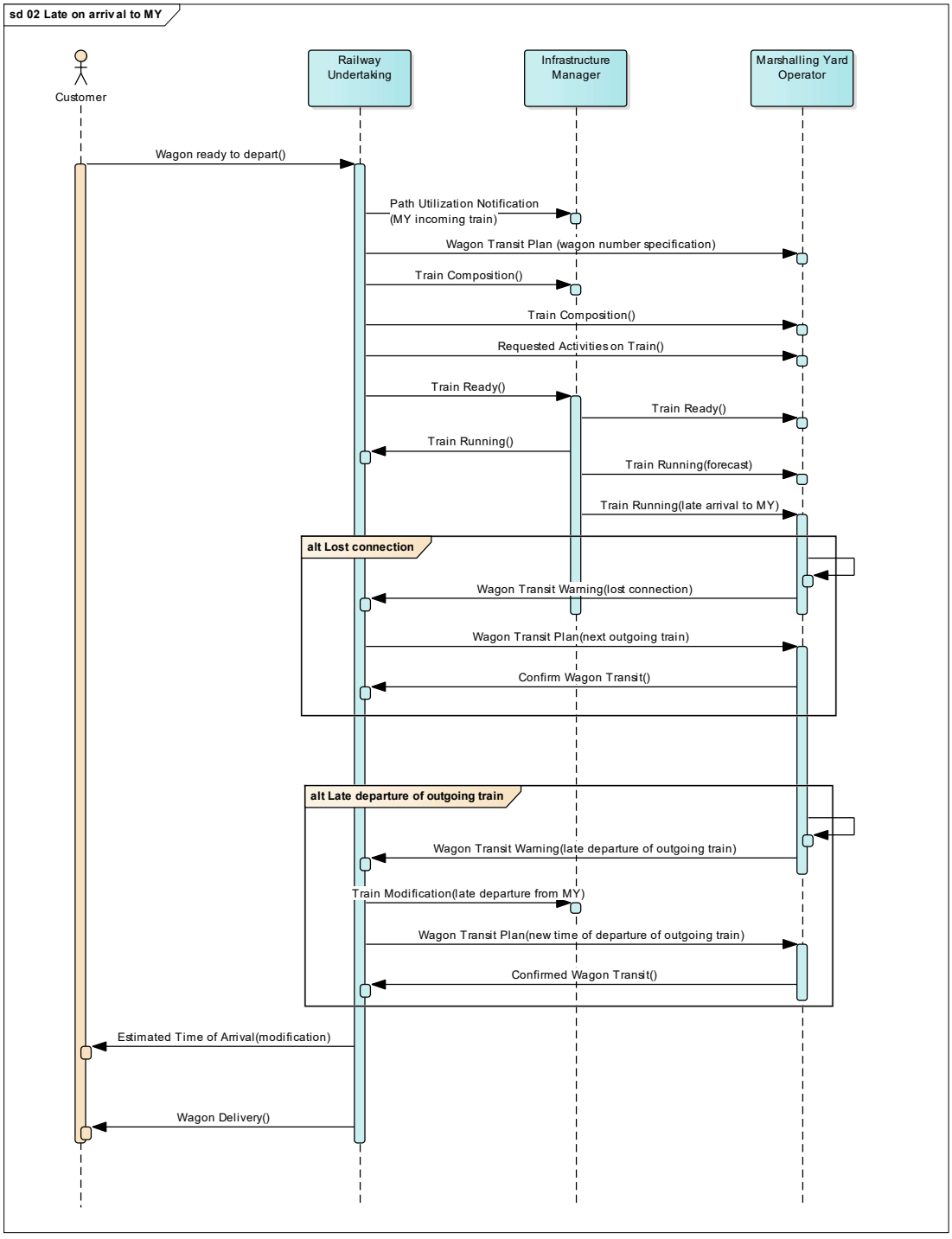


Figure 7: Communication in case of stop for incoming train

3.5.3 Train delayed on arrival at the marshalling yard

The third scenario describes the situation where the train arrives late at the MY for reasons beyond the control of the marshalling yard operator.

- wagon transfer ensured



- wagon transfer not ensured

Figure 8: Communication in case of late on arrival to MY

3.5.4 Non-compliance with the wagon transfer schedule on the part of MY

The fourth scenario deals with a situation where there was a non-compliance with the wagon transfer between trains during the processing of the wagon. This situation can occur, for example, when wagons are misplaced on individual directional tracks or when the MY is full.

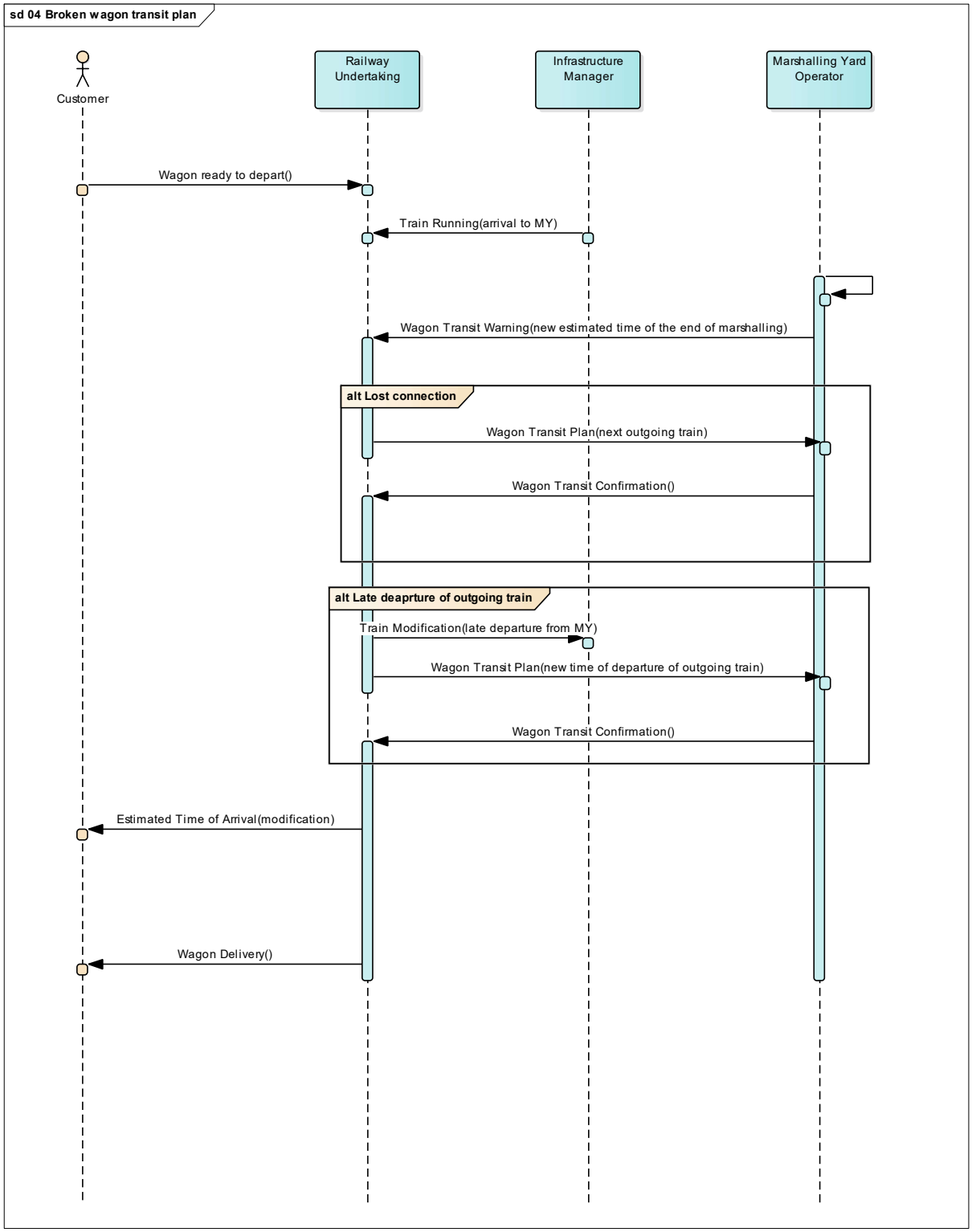


Figure 9: Communication in case of broken wagon transit plan

3.5.5 Changing the wagon transfer during marshalling in the MY

The fifth scenario describes a situation where a change in the wagon transfer is requested by the RU (another departure train, change of ordering of the departure train, etc.).

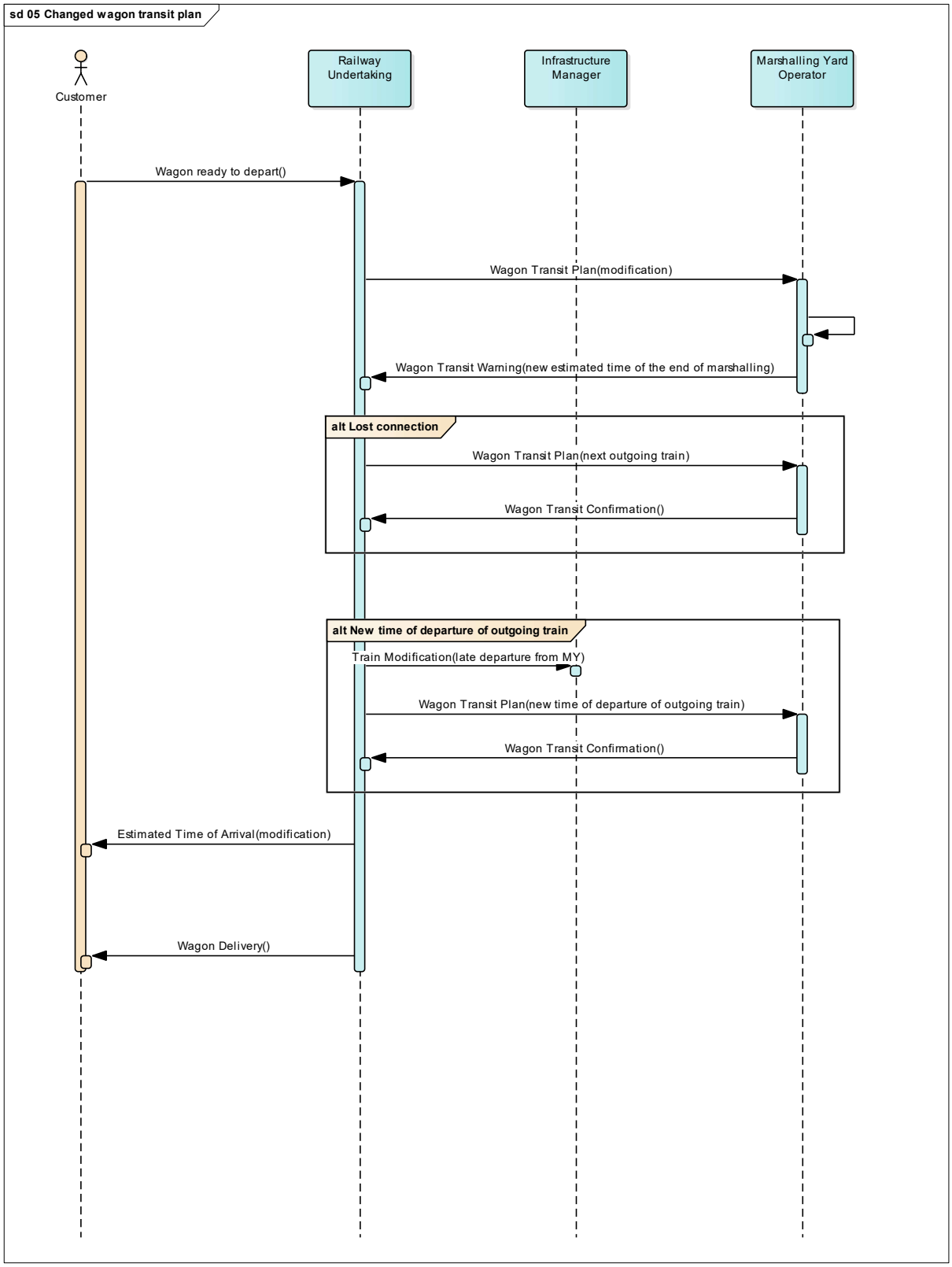


Figure 10: Communication in case of changed wagon transit plan

4. WP 5.2 IMPROVED DECISION SUPPORT SYSTEM ON YARD LEVEL

Partial issue of WP5 is optimization of processes with focus on IT technologies. The previous chapter contains the proposal of interface for connecting the currently used information systems with their current proceedings, or more precisely functions, and proposed real-time optimization system, which is also a partial outcome of WP5 mentioned in this chapter. The proposal of WP5.2 can be found in .xlsx document that is included.

The proposal of interface was partially based on the current processes, particular activities in processes and technologies used for ensuring marshalling operations, and the comparison of information systems used on railway networks and their functionalities in Sweden, Germany, and the Czech Republic. All process items of marshalling yard optimizing system proposal are based on the outcomes from WP2 and WP5.1. The proposal in this part of the document is only a draft of an optimization module on the micro-space level. That means that the proposal in this part of the document is focused only on the optimization of movements inside a marshalling yard.

Optimization of yard processes depends on the following information

- Monitoring of train running and delays.
- Information about real operational situation.
- Train composition – wagon groups and order of wagons in a train unit.
- Client contracts and transport bookings.
- Pre-notification of incoming trains.
- Wagon database.
- Wagon routes – direction of trains and wagons.
- Report of train readiness to depart.

The proposal is based on the information stated above and in previous chapters of the document. Main items of proposed MY processes

- Tasks.
- Main process steps.
- Sources used for marshalling.
- Required data.
- Code of required data.
- Source of required data.
- Generated data.
- Code of generated data.

A task is an item in marshalling yard process that includes one or more general process steps. Every process step commonly requires some sources to run. Necessary sources, marked with a cross, are given in the table.

Types of sources

- Vehicles (Line locomotive, yard locomotive, hump locomotive and wagon/block of train)
- Drivers (line locomotive driver, yard locomotive driver, hump locomotive driver)
- Yard staff (Coupler, Brakeman, Inspector)
- Yard equipment (retarders, closing-up systems, hauling facilities, tracks, switches, signals)

The optimization system requires some sort of input data and it also generates data. The source for such required data are other information systems. See table which is included in the attached .xlsx. Each data group consists of data to be interchanged by proposed interface. For example, the data group “wagon list with characteristics” consist of wagon number, length, weight, commands for handling, etc. These attributes are explained in the next chapter.

Each item of the data group has an allocated system code which is used to mark it. Some data groups contain only one item. The meaning behind the codes is explained below.

- CD = common data. These data groups are commonly used in cases when related tasks and activities are independent on the phase of the train marshalling process (e. g. topography of switches, decoupling needed, etc.)

Train, wagon data group

- ES = entry signal. This data is used in the phase in which the train is approaching the marshalling yard.
- AP = arrival part data
- H = hump data
- CP = classification part data
- DP = departure part data

Locomotive data

- LL = line locomotive data
- HL = hump locomotive data
- YL = yard locomotive data

Every single task, including the process steps in the chart, follow one after the other like a flow of activities with a train. The flow begins with the train entering the observed area on the railway network, passing through a marshalling yard or a terminal and then exiting the observed area. The network, considered an optimized surrounding network within this project, is smaller than the area from which the optimizing system needs to acquire data. The optimized area is limited to the railway line by a track entry signal to marshalling yard on one side and a first route signal on the line on the other. To optimize the activity plan in a marshalling yard, it is necessary to acquire data from a bigger area. The size of such area is the distance from the marshalling yard that the train can travel in one hour. The border of this area is variable based on the current state of the surrounding network, the timetable of each train, and the distance between the particular MY and the station in which some activities with the train are performed.

Examples of such are:

An observed train is running from the station, in which particular activities are performed and the time distance of which from the mentioned station/MY or the particular optimized MY is MORE than one hour. There are no activities planned between these stations. Network RU information systems OIS and DISOM send information from the last station (locomotive and train composition) or from a particular or a calculated point to the proposed marshalling yard optimizing system (MYOS). The particular point should be

calculated based on the current situation on the line (delays or deviations). If there are any deviations or unplanned events on the path of the observed train, the ETA is sent by DISOM.

The observed train runs from station where particular operations are performed and time distance from the mentioned station/MY or the particular optimized MY is LESS than one hour. There are no activities planned between these stations. Network RU information systems OIS and DISOM send information to the proposed Marshalling yard optimizing system (MYOS) from a particular or a calculated point, which is before the last station with planned activities and then from every station in the area, in which activities with this train are planned. The ETA to the optimized MY will be improved in every station thanks to such approach. Apart from ETA, more data, like actual train composition (OIS), is the base for optimized marshalling. Thanks to such approach and the information from MYOS, there is a complex package of information about train composition.

To help understanding and orientation in the chart given in the included .xlsx, there are examples provided below.

Example 1

The task “Moving the train from the surrounding network to the yard” consist of only one general process step. This process step is “Moving the train from the surrounding network to the yard”. Necessary sources used for this proceeding in this step are given in the table and are marked by cross. The line loco, its driver and wagons are necessary for this step. For the optimization process, the data group "Estimated time of arrival to the yard" is required. The required data can be found in the chart in the "Code of required data" column. The column next to the "Code" column - "Source of required data" - contains information about the source information system. In this case, the source of data is the DISOM information system. The proposed interface transfers information into the optimisation software.

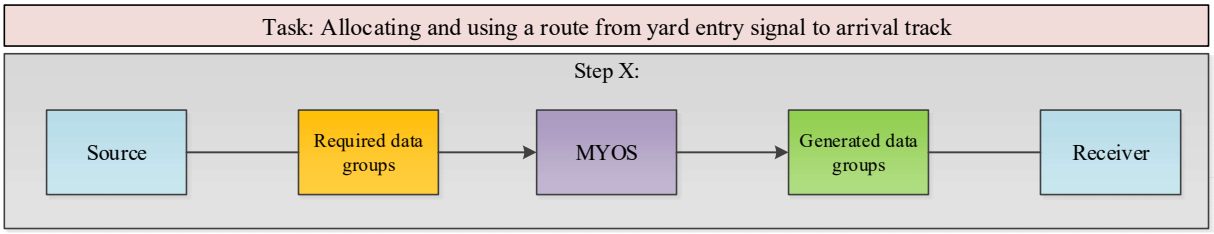


Figure 11: General scheme of task

The proposed optimization software processes this data and afterwards generates the following data:

- time stamp
- location (lat + lon) or station
- velocity
- direction of movement

In this case, the data is used as documentation of the approaching train, and for the following task of allocating and using a route from yard entry signal to arrival track.

Example 2

The task “Allocating and using a route from yard entry signal to arrival track” is divided to the following four general process steps.

- Search for possible routes from the yard entry signal to the arrival track.
- Decide the route from the yard entry signal to the arrival track.
- Lock the route from the yard entry signal to the arrival track.
- Main process steps in the task "Moving train from yard entry signal to arrival track".

The following data are required to perform the " Search for possible routes from yard entry signal to arrival track"

- ETA at yard entry signal (ES101)
- wagon list with characteristics (CD107)
- topography of tracks (CD107), switches (CD102), signals (CD103)
- track lengths (CD104)

The RU dispatcher system DISOM is a source of information related to time. The RU operation system OIS is the source of wagon lists. Information about topography of yard and network are taken from IM information system KANGO/CAIN.

Based on the described information, the optimization system generates the "Possible routes from yard entry signal to arrival track (ES102)" data group This data group contains data of technically possible routes between the yard entry signal and the particular arrival track. Marshalling yard optimization system (MYOS) calculates the appropriate technically possible (e. g. shortest with a catenary) route.

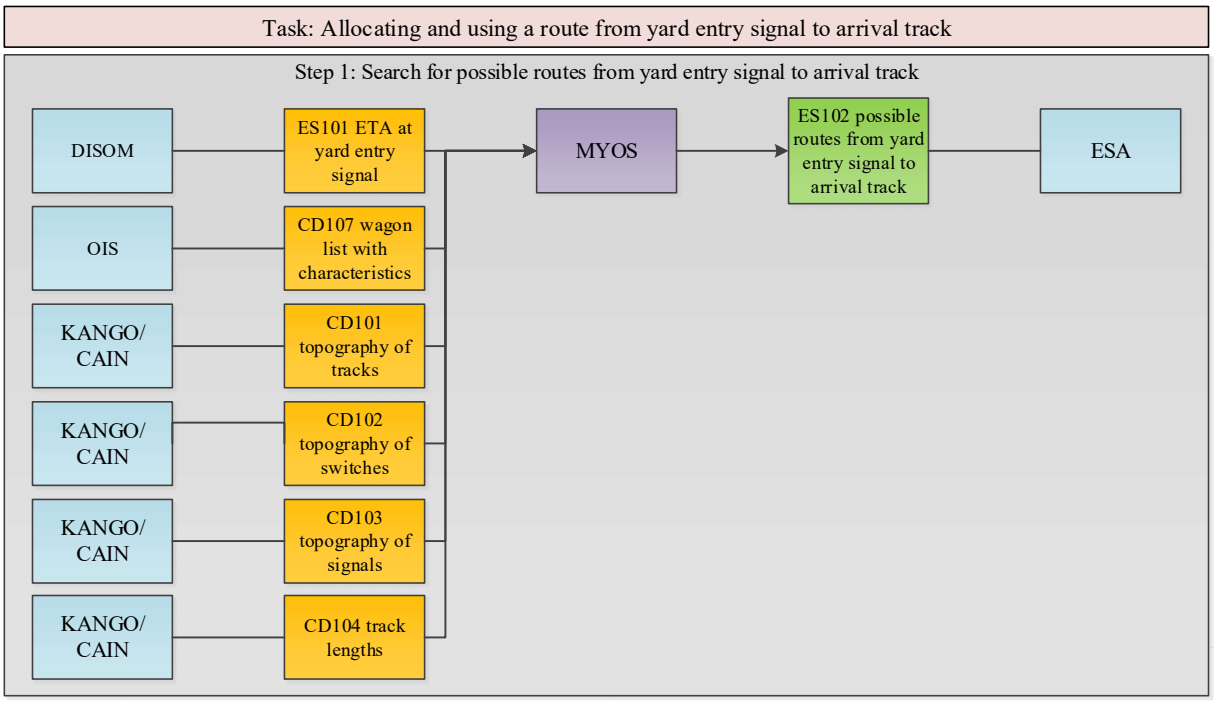


Figure 12: Search for possible routes from yard entry signal to arrival track

In the time when MYOS sends the request to IM interlocking system ESA (in simulation VILON), the second general process step “Decision for route from yard entry signal to arrival track” begins. The ESA (VILON) system processes this request and then either confirms or rejects the proposed route. MYOS receives the answer from ESA and calculates another route. Then it sends a request to ESA again. The algorithm is repeated until the ESA system confirms the route or there are routes to explore.

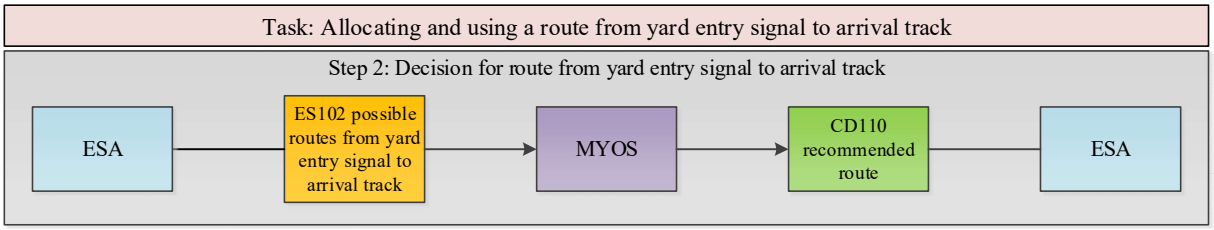


Figure 13: Decision for possible route from yard entry signal to arrival track

When the ESA system confirms the route, it is marked as “recommended route” (CD110). In this phase, the third general process step “Locking route from yard entry signal to arrival track” begins. MYOS confirms the recommended route as well (required data CD110) and generates data (command) for the ESA system – make the “route ready for use” (CD137). The ESA system locks the route and sends a confirmation that “available route from yard entry signal to arrival track” (ES103) to MYOS.

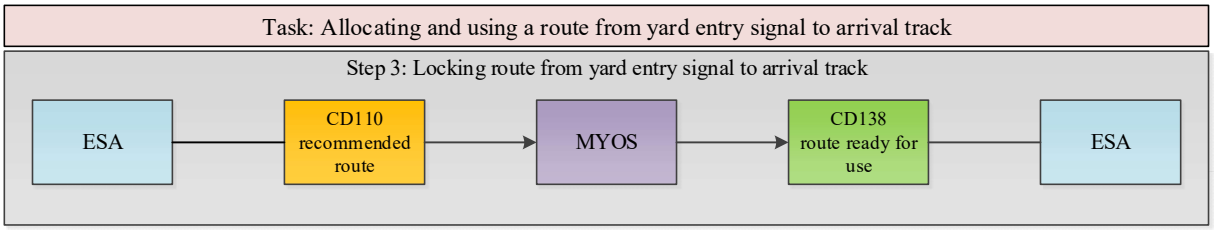


Figure 14: Locking of route from yard entry signal to arrival track

This data group is a part of the “Moving train from yard entry signal to arrival track” general process step. Afterwards MYOS generates the following data groups which are used for calculating times – ETA and ETD:

- real-time: time stamps (CD115),
- real-time: location (long + lat) (CD116),
- real-time: velocities (CD117),
- real-time: direction of movement (CD118),
- real-time: distances (CD119),
- real-time: track number (CD120),
- real-time: yard part (CD121).

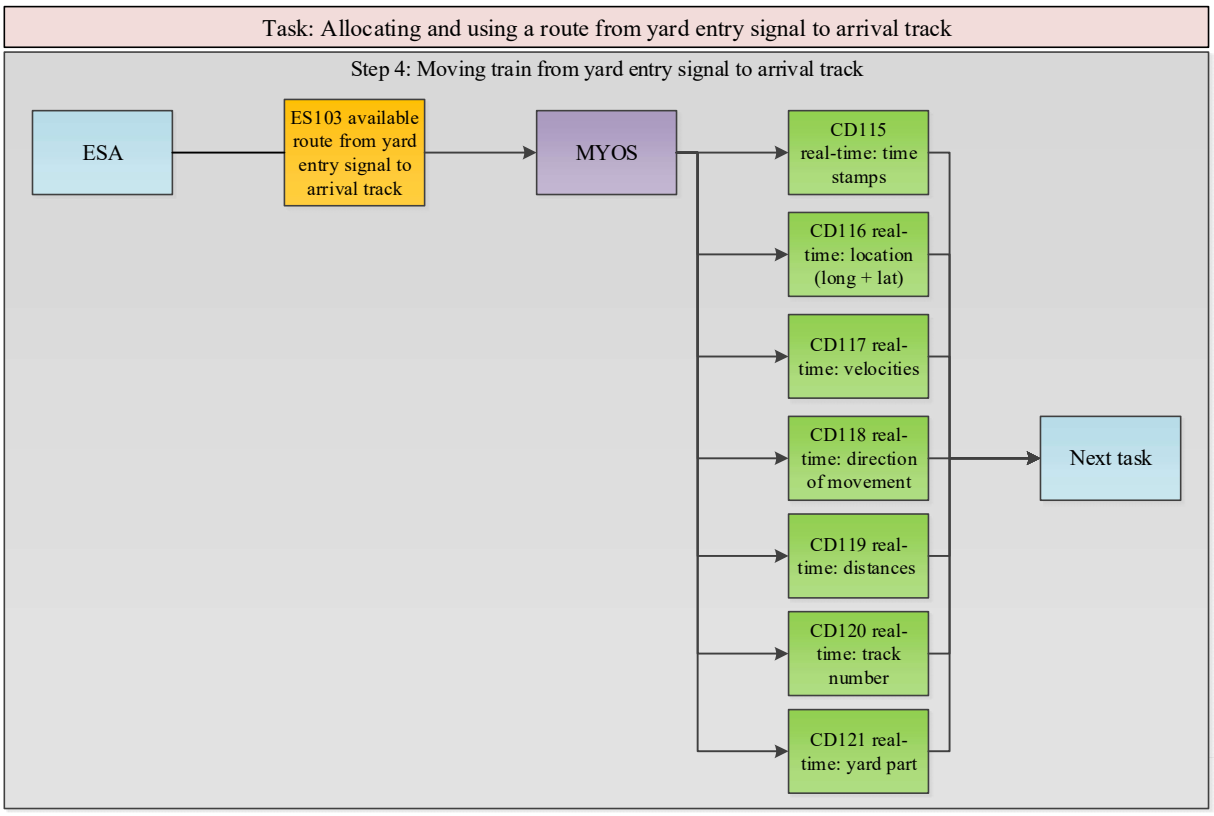


Figure 15: Moving train from yard entry signal to arrival track

5. BIBLIOGRAPHY

UIC. (2018, November 22nd). *RTM - RailTopoModel*. Retrieved June 24th, 2019, from http://rtm.uic.org/