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Optimised Real-time Yard and Network Management

Deliverable D2.1

Definition and selection of suitable methods for real-time data analytics

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EXECUTIVE SUMMARY

This deliverable summarises the current state of practice regarding the operating process with freight assets (trains, wagons, locomotives, static and dynamic resources), data collection and information management systems in rail freight yards and nearest networks.

Specifically, the outcome of the general analysis of operating processes with freight trains and the required data exchange showed, that handling freight trains in MYs is complex, where various stakeholders participate in order to fulfil the customers' needs best way.

Two case studies have been analysed (MY at Česká Třebová and München, Mannheim and Hallsberg). There are already several IT systems in MYs that support the operating processes with freight trains and the concerned personnel. These IT systems, though, are specific to each country and every company.

TAF TSI messages already support a wide variety of data exchange needs for processes in the freight rail sector. Each message consists of obligatory and optional information, what enables a flexible usage within different national IT systems but on the other hand secures a reliable data exchange.

The Rail Sector is already exchanging several million messages within the TAF/TAP TSI framework every month. TIS is a strong selling argument towards RU's customers: 'The RU knows the position of the train'.

The Česká Třebová MY and München, Mannheim and Hallsberg both operate a wide range of data formats for the data exchange between different software tools of the involved stakeholders. They are widely oriented towards the standard TAF TSI messages.

This deliverable looked a number of systems already fully TAF/TAP TSI-compliant, which currently handle data for around 1,6 million trains per year, some of these systems will be included in the feasibility and simulation test exercise of WP6.

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LIST OF ACRONYMS

AB	Allocation Body
ADAS	Automated Driver Advisory Systems
AIDC	Automatic Identification and Data Capture
API	Application Programming Interface
BI	Business Intelligence
BDRS	BD Rail Services
CDS	Central Data-management System
CI	Common Interface
CIM	Uniform Rules Concerning the Contract of International Carriage of Goods by Rail
CIT	International Rail Transport Committee
C-OSS	Corridor One-Stop-Shop
CSV	Comma Separated Value
CUV	Uniform Rules concerning Contracts of Use of Vehicles in International Rail Traffic
DIUM	Uniform Distance Table for International Freight Traffic, according to UIC leaflet 219
ECN	Electronic Consignment Note message
EDI	Electronic Data Interchange
ELTA	Estimated Latest Time of Arrival
ETA	Estimated Time of Arrival
ETCS	European Train Control System
ETD	Estimated Time of Departure
ETI	Estimated Time of Interchanges
ETP	Experienced Transport Plan
ERP	Enterprise Resource Planning
eWSM	enlarged Wagon Status Message
FTP	File Transfer Protocol
GNSS	Global Navigation Satellite System
GUI	Graphical User Interface
GPS	Global Positioning System

H30	Hermes application 30, according to UIC leaflet 404-2
HLA	High-Level Architecture
HOSA	HERMES Open System Architecture
HTML	Hypertext Markup Language
IM	Infrastructure Manager, based on TAF TSI: service provider for the allocation of paths, for controlling/monitoring the trains and for train/path related reporting
IoT	Internet of Things
ISR	International Service Reliability, RailData tool
ITS	Intelligent Transport System
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LoS	Level of Service
LRU	Lead Railway Undertaking, based on TAF TSI: single point of contact for the customer
LSP	Logistics Service Provider
MY	Marshalling Yard
NIS	National Information System
OCR	Optical Character Recognition
ORFEUS	Open Rail Freight EDI User System, RailData tool
PaP	Pre-arranged Paths
PCN	Paper Consignment Note
PCS	Path Coordination System, RNE tool
QR code	Quick Response code
REST	Representational State Transfer
RFC	Rail Freight Corridor
RFID	Radio Frequency IDentification
RNE	RailNetEurope
RTI	Run-Time Infrastructure
RTIS	Running Train Information System, RailData tool
RU	Railway Undertaking, based on TAF TSI: service provider for operating trains
SQL	Structured Query Language

SWL	Single Wagonload
SWOT	Strengths, Weaknesses, Opportunities, Threats
TAF	Telematics Applications for Freight subsystem of rail system
TAP	Telematics Applications for Passenger services
TCCCom	Traffic Control Centre communication
TD	Transport Description or Transport Dossier
TIS	Train Information System, RNE tool
TMS	Transport Management System
TPM	Train Performance Management
TSI	Technical Specification for Interoperability
VPN	Virtual Private Network
WIMO	Wagon and Intermodal Unit Operational Database
WS	Web Service
WSM	Wagon Status Message

GLOSSARY

Block	Wagon group bound for individual destination
Brakeman	Staff who assists in the train handling
Closing-up system	Facility enabling a closed-by position for non-powered rail vehicles into a ready-to-couple position
Coupler	Personnel who assists in the train handling
Coupling	Mechanism for connecting rolling stock in a train
Cut	A single car or a group of coupled cars that run down a hump
Hump	Where vehicles are pushed over to let gravity drive them or flat shunting into the classification tracks
Intermodal unit	May be moved from one wagon to another, often called container
Retarder	A trackside braking device used in gravity shunting to control cars running down a hump
Wagon characteristics	Classification of goods wagon, mass, length, axle count, destination, priority
Wagon list	Listing wagons with its position in train

1. SCOPE AND PURPOSE

This deliverable summarises the current state of practice on operating process with freight assets (trains, wagons, locomotives, static and dynamic resources), as well as existing methods of data collection and information management systems in rail freight yards and nearest networks.

The outcome from this deliverable will provide a foundation for further developments in the field as it will be included in the feasibility and simulation test exercise of WP6.

This deliverable includes a discussion on the current state of the art, where a number of past and ongoing EU funded projects are discussed. Specifically, we look at: TIS ETA Pilot, Corridor Rhine-Alpine, ELETA, SMRTRAIL, ARCC, ViWAS, C4R and eToger/Tiger DEMO. A presentation of operating processes with freight trains at marshalling yards is offered followed by analyses of data exchange practice and standard data exchange formats with XML files. We looked at TAF TSI messages, railML and RailTopoModel. A number of systems already TAF/TAP TSI-compliant have been discussed and their full potential revealed. Next, a number of case studies have also been collected and studied to further show recent developments in real time data management. A very strong case is demonstrated by Olin Bécancour, who implemented an OsiSoft system with On-Site Event Management (OSEM- SAP) for monitoring the rolling stock in real-time.

2. INTRODUCTION

Data collection, data analytics and data management are the means to achieve a better understanding of the operating processes in the yards and in the rail network, and hence achieve a better utilization of rail assets. As a result, a better control over the rail operation will be established, punctuality of the service delivery will be improved, operating times and dwell times will be reduced, and additional significant capacity will be unchained. These positive impacts will lead to a more competitive and flexible freight railway.

Digital technology will make it possible for us to manage and control freight trains and single wagonload operations better by providing accurate and targeted information about the rail freight network and operation in real time. This will improve the decision-making process currently in place. By gathering the accurate data in real time and processing it in no time to deliver a better decision-making we create a single view, which helps us understand how different components of the rail freight operating process interact (e.g. yards and lines, lines and terminals, yards and networks).

Real–time data analytics should provide instant responses. That is why it is very important for data to immediately become available. When it happens, this will allow us to instantly respond and react to critical situations in real-time, which involve delays, failures, disruptions, operations with sensitive and priority freight as well as dangerous goods. The flow of data through the terminal, yard and network needs to be captured, processed in real-time and utilized to form a single view. The data formats need to be consistent and compatible.

3. STATE OF THE ART: PAST AND ONGOING EU PROJECTS

We review past EU projects to better understand what sort of data and in what format information is being collected by rail freight yards. Specifically, we look at targeted information and data that have been gathered and used in real- time rail freight operations and management.

The review also captures, to the extent possible, data describing the operating processes with freight trains approaching and leaving the rail freight yards.

3.1 eTIGER/TIGER DEMO

3.1.1 Project objective, aims and outcomes

In the Tiger/Tiger demo project a concept of an e-port was developed where all necessary elements concerning the links origin/destination, the available capacity would be consolidated around a physical hub being in connection with various deep-sea ports. The data were to be provided by the ports to the web manager and processed by the operator of the physical hub in order to offer smooth connections to a large number of destinations by train correctly filled in.

3.1.2 Operating process described

Main objective of Tiger was to develop rail transport solutions in competitive and co-modal freight logistics chains. These solutions was implemented in four demonstrations (Genoa Fast Corridor, Mariplat and Innovative port & hinterland operations intermodal network) in order to address objectives such as improved services in terminals, efficient interfaces between transport modes, organisation of continental shipping, new generation of European freight train systems, development and use of co-modal IT transport solutions, operation of green corridors and best practices for transport, sustainability effects of new logistics and manufacturing systems transport impacts, transport forecasting and globalisation.

Tiger demo project objective was the demonstration of innovative technological and management solutions, capable of optimising the containers traffic flows to/from major European ports outlined on Tiger project.

3.1.3 Data and information management methods

The process includes a study, plan, engineer and implement a new logistics concept to be applied to each demonstration's work process and procedure. Consequently, logistics organisation re-engineering of port layout was developed including operational engineering and design of rail signalling and control systems. ERP intelligent system management and E-Customs control was analysed as well as signalling and safety train operation (on non RFI railway tracks) and container and train tracking & tracing (E-Customs/security services)

For Tiger demo four TIGER pilots into a full-scale demonstration was created for subsequent market uptake commercial exploitation.

3.2 CAPACITY4RAIL

3.2.1 Project objective, aims and outcomes

In Capacity4Rail (C4R), which was a EU funded project setting out step changes for the whole rail industry in the EU, the developments follow the direction of the Tiger project, and look at innovative research in order to prepare rail for the future taking into account results from previous research projects and programs.

New concepts for low maintenance infrastructure was analysed, using standardised and 'plug-and-play' concepts was proposed. Non-intrusive innovative monitoring techniques or self-monitoring infrastructure was investigated, allowing low or no impact on train operations.

One of the most interesting development by Capacity4Rail project linked to data collection and transfer was the automated brake test recommended as the immediately profitable innovation. It has already been implemented by SNCF.

3.2.2 Operating process described

The equipment with sensors of various types followed the same principle. The intervention of IoT enabled to have automatic alarms from the critical parts of the wagon transferred by short distance radio to the concentrator on each wagon. Then this concentrator could use the Mesh technology to reach the locomotive or directly the ground base in case the wagon would be disconnected from the train.

3.2.3 Data and information management methods

Positioning the wagon by GPS or less accurate solutions reducing the energy consumption were described. Other key elements are the follow up of the wear and tear to open the door to feed predictive maintenance plans, the temperature control of the bearings, and the status of the brake shoes.

The really new element was the description of extremely low frequency networks enabling to regularly transfer a very small quantity of data at a very long distance and economically. Automatic permanent capture of information leading to big data to be processed to enhance operational efficiency, safety, to reduce maintenance costs were the targets.

3.3 ViWaS

3.3.1 Project objective, aims and outcomes

(SWL) transport is still a major component in numerous European transport systems and in the logistics of different economic sectors such as steel, chemical, and automotive. However, changing framework conditions and increasingly demanding market requirements have led to dramatic market losses and even to complete shutdowns of SWL business in some countries. As this business segment has been evaluated as important for specific transport modes in a European co-modal transport system and also in the future, significant improvements are needed.

The success of SWL depends mainly on two issues:

- a viable SWL system is highly dependent on the critical mass. Thereby all options have to be considered to secure a high utilisation of the trains operated on the trunk lines, including a combined production with intermodal loads;
- only comprehensive and complementary measures can sustainably improve and preserve the European SWL systems in accordance with increasingly demanding market requirements.

3.3.2 Operating process described

The ViWaS project follows a comprehensive approach, aiming at the development of:

- market driven business models and production systems;
- security of the critical mass needed for SWL operations:
- new ways for last mile infrastructure design and organisation with the introduction of the innovative solution of the rail-road locomotive reducing last mile costs up to 40% and already certified outside private sidings in Germany;
- raising cost efficiency;
- adapted SWL technologies;
- improving flexibility and equipment utilisation;

- advanced SWL management procedures using ICT;
- raising quality, reliability, and cost efficiency.

The applicability of these solutions and their effects will be proved by demonstrations on the basis of pilot business cases. In doing so, important findings will be gained for a European wide implementation of the developed solutions.

3.3.3 Data and information management methods

In the ViWas a wagon was equipped with a variety of sensors, a concentrator of information and a long life battery to send the data to a ground base. This was developed by Eureka in order to follow the work of the wagon for a predictive maintenance, to have the positioning of the wagon to ease the commercial discussion with shippers and consignees, to measure the gross weight of the wagon to insure safety. There was also a little energy harvester for extending the battery life. This was the first automatic data collection per wagon.

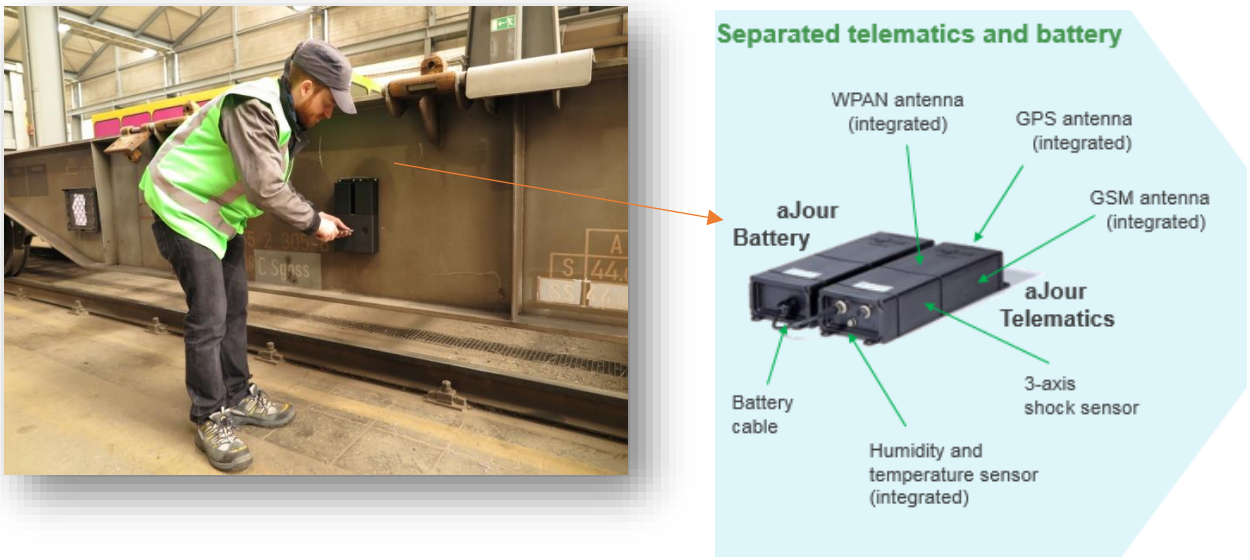


Figure 1 A wagon equipped with a variety of sensors (ViWas)

3.4 ARCC

3.4.1 Project objective, aims and outcomes

Automated Rail Cargo Consortium (ARCC) project (ARCC WP2, 2017) investigate rail freight automation scientific studies in order improve quality, efficiency and cost effectiveness in European rail freight operations. Significant positive impacts for rail freight has been identified when automation of tasks and digitalisation processes are exploited in a more appropriate way (e.g. increased efficiency on the main railway lines and nodes, reducing lead time and energy costs) The analysis was conducted at three different Marshalling yards:

- Mannheim/ Germany;
- München-Nord/ Germany;
- Hallsberg/ Sweden.

Beside the everyday plans of yard workforce and their continuous monitoring (assessment of actual times and planned times), a number of data for controlling and tracking operational procedures comes from a variety of IT-Applications, which is analysed in section 4.4.

3.4.2 Operating process described

Mannheim Marshalling yard

Main characteristics of the Mannheim Marshalling yard are described below.

- Infrastructure Owner and Manager: DB Netz
- Yard Operator: DB Cargo
- DB Cargo
- Overall track length: 240 Kilometres
- Switches: 550
- Starting trains (March 2017): 2.261 trains per month
- Terminating trains (March 2017): 2.275 trains per month
- Trains in transit (March 2017): 352 trains per month (Remove or add wagons from/to the train in the yard)

Table 1 Number of tracks and available marshalling capacity in Mannheim MY (ARCC WP2, 2017)

	System West/East	**System East/West**
Receiving yard	15 tracks	12 tracks
Classification bowl	41 tracks	42 tracks
Departure yard	16 tracks	30 tracks
Available shunting capacity over the hump	150 wagons per hour	154 wagons per hour
Average of marshalling wagons over the hump	110 wagons per hour	

Based upon on the timetables for arriving and departing trains, present yard infrastructure, necessary process steps and provided resources, the daily tasks of the yard personnel are organized in detail. This plan covers the chronological sequence of the activities to be performed such as brake tests, coupling/uncoupling activities, transfer trains and support in train building processes.

München-Nord Marshalling yard

Main characteristics of München-Nord Marshalling yard (Figure 2) are described below:

- Infrastructure Owner and Manager: DB Netz
- Yard Operator: DB Cargo
- FOC: DB Cargo, ARS Altmann, Lokomotion, RBH

- Overall track length: 120 Kilometres
- Switches: 356
- Starting trains (March 2017): 1.379 trains per month
- Terminating trains (March 2017): 1.441 trains per month
- Trains in transit (March 2017): 504 trains per month (Remove or add wagons from/to the train in the yard)

Table 2 Number of tracks and available marshalling capacity in München-Nord MY (ARCC WP2, 2017)

	München-Nord MY
Receiving yard	14 tracks
Classification bowl	40 tracks
Departure yard	13 tracks
Available marshalling capacity over the hump	250 wagons per hour
Currently average of humped wagons	110 wagons per hour

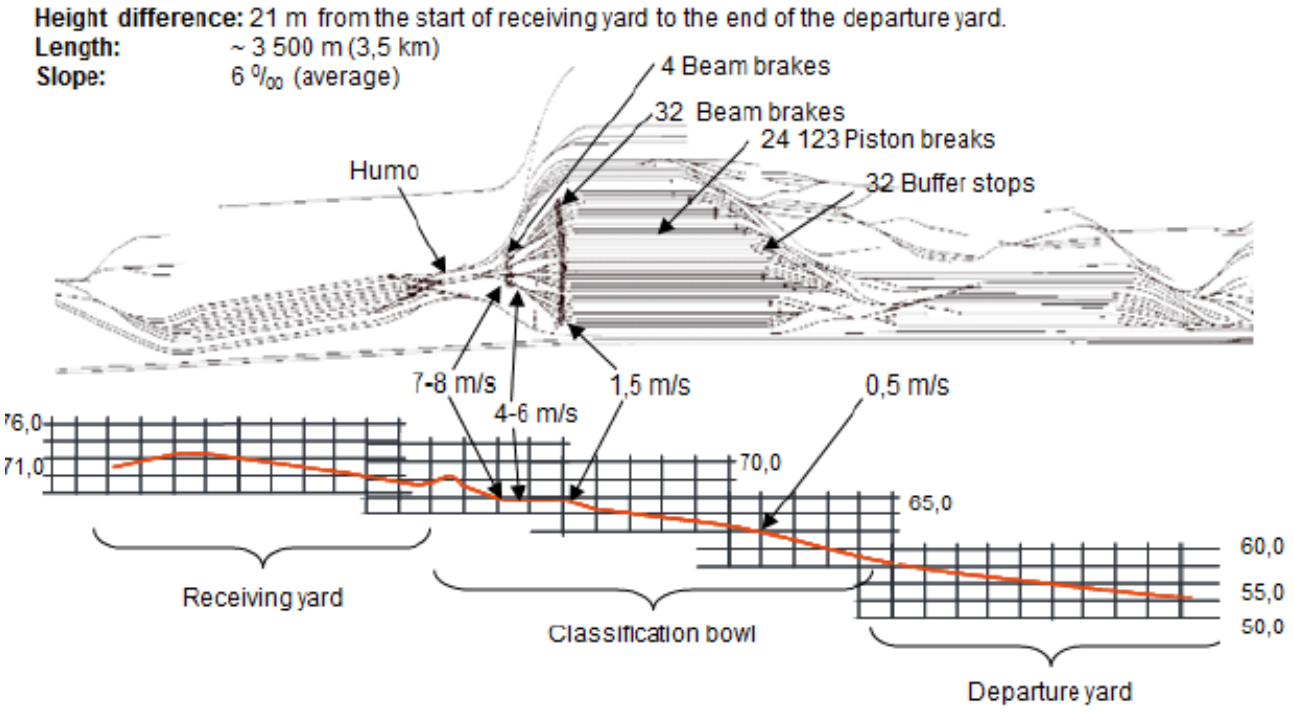


Figure 2 MY layout of München-Nord (ARCC WP2, 2017)

Based on the timetables for incoming and outgoing trains, existing yard infrastructure, required process steps and available resources daily activities of the yard staff are also planned in detail in advance similar to Mannheim.

Hallsberg Marshalling yard

Main characteristics of the Hallsberg Marshalling yard are described below.

- Infrastructure Owner and Manager: Swedish Transport Administration (Trafikverket)
- Yard Operator: Green Cargo
- FOC: Green Cargo, Hector Rail
- Overall track length: 60 km
- Switches: 170
- Capacity: 500 000 wagons / year
- Shunted volume: 305 000 wagons / year
- Beginning trains T161 (364 days in period): 13928
- Terminating trains T16 (364 days in period):: 14361
- Trains in transit T16 (364 days in period): : 2848

Table 3 Number of tracks and available marshalling capacity in Hallsberg MY (ARCC WP2, 2017)

	Hallsberg
Receiving yard	8 tracks
Classification bowl	32 tracks
Departure yard	12 tracks
Available marshalling capacity over the hump	167 wagons per hour
Average of marshalling wagons over the hump	102 wagons per hour

3.4.3 Data and information management methods

This topic is discussed together with the activities at a MY in section 4.4.

3.5 SMARTRAIL

3.5.1 Project objective, aims and outcomes

BDRS and their partners track the movements of wagons by using QR codes attached to the side-frame of the wagons. When the code is scanned at an origin, destination, or at an intermediate point, an automated email is forwarded to the customer informing them about the current location of the wagons. While the system is appropriate for the current level of service, it has to evolve in order to take account of a larger number of clients, commodities, wagons, and routes. This development will contribute to ensure a consistent implementation and efficient use of resources.

Required info:

- Real Time Information – most notably the Train Position;
- multiple primary information sources (e.g. independent ones as GPS units, RFID tags);

- primary data from the traffic control processes of the IM;
- fleet management systems of the RU;
- Location of the wagons, Track & Trace of individual wagons, which can be used for prioritisation for loading and unloading trains (e.g. weight, high value products, client request);
- ETA, ETD – the key data items for the operative planning.

3.5.2 Operating process described

In the context of the Smart-Rail project, the various working streams have to produce various inputs to be able to offer the level of services requested. The user story is directly connected to the processes as described in the Business Process Management (BPM) – and shared between all users – and "consumed" APIs. With this said, new APIs have to be defined. For example, the process to calculate the ETA of a wagon using the RailData ISR is specific (see also section 5.6.2). Most often, the ETA of a particular transport leg is required to optimally plan and execute, or cancel and re-plan the next leg. ISR has a specific implementation based on the use of Experienced Transport Plans (ETP). Once a day transport descriptions are checked to see which transport legs have been completed in a normal way, free of interruption events. From each closed transport description one more ETP is generated. This included gathering together all the transport criteria, the first and last transportation event or each intermediate and the last transportation event. Another project request is to collect pieces of information not available in the existing systems. The ETA calculation could require other sources to avoid the so-called "black box situation". The following stakeholders are involved:

- A LSP providing data of for example containers on a train;
- A RU operating a train consisting of wagons with containers of one or more logistic operators;
- An IM providing paths on its infrastructure;
- A shunting yard belonging to an IM. Normally, a shunting yard will use data belonging to the IM, but on some occasions a shunting yard can act autonomously;
- A terminal as the end point of wagons of a train. To optimal manage a shunting yard; data of cargo being carried on wagons is required. This included in particular data of dangerous cargo. This data is required for the overall safety in a shunting yard.

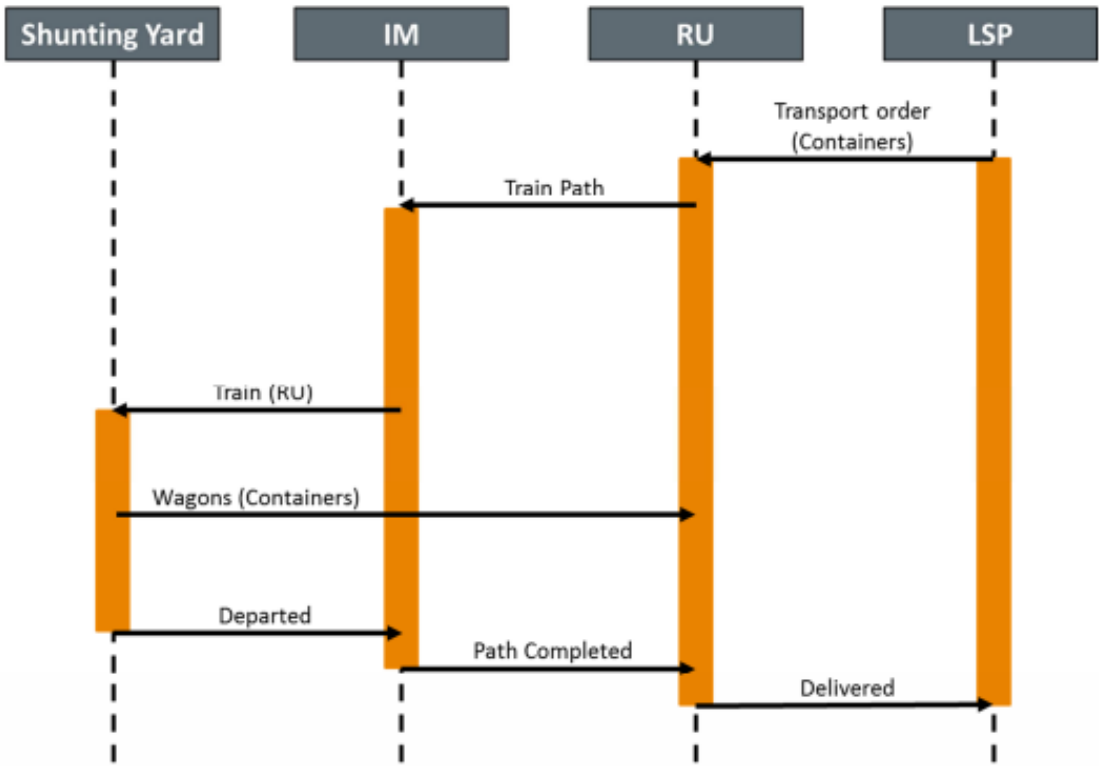


Figure 3 Example of data sharing (conceptually)

Figure 3 presents an (simplified) example of the data flow between various stakeholders. In this particular case, a shunting yard receives data on a train entering its yard from the IM. It can request additional data on the train composition and particular dangerous cargo from an RU, where this latter stakeholder has received the data from the LSP(s).

3.5.3 Data and information management methods

In practice, data on train paths and train positions can be retrieved from RNE's TIS (see also section 5.4). Data on wagonloads, which is required by IMs, can be retrieved from RailData for particular RUs. It is important to note that not all RUs are member of RailData, though. The Web services definition (API) has to be performed in a continuous exchange with the external providers.

Since 2010, H-Log InfoLogistics is a leading provider of logistics information throughout the supply chain. Supply chain needs more and more information to operate globally. The H-LOG group provides solutions that capture and digitize these pieces of information closer to its creation by the customer ERP or by Supply chain actors, and enrich them at each step: in production, in warehouse, during transportation or distribution, whatever the mode, and then manage the return logistics.

H-LOG develops innovative solutions in the field of cloud computing for logistics. These services are particularly well suited to this sector by providing a high quality of service, safety information and allowing almost instantaneous to a worldwide deployment. In line with the EU SmartRail project , H-LOG is the first contractor of the , which supports the re-emergence of rail as an alternative mode of transportation, or Class 2 Railway Undertaking (OFP), which combine loaders, road and rail companies or through the deployment of new rail Class 1 freight companies (as Europorte ECR).

Technical architecture and procedures that have already been developed through H-Log and ECOPMS can be adapted for use in Smart-Rail.

The overall application developed for ECOPMS has the internal name LogiCloud. The WSs of LogiCloud are accessible using RESTful; the WS answer is based on JSON. In the implementation, nine LogiCloud WSs have been defined to exchange information with TMS databases. The various parameters follow mainly references to Road transportation however, are used differently for train transportation. As part of ECOPMS, a specific WS for rail is being developed. Together with RailData common descriptions for everyday rail related elements are being developed. These include elements such as wagons, railway stations, slots, train numbers etc. Information that is collected includes the customer's number, the address of the origin and destination, carrier details, departure and arrival times, deviation from expected times etc.

Applications that conform to the REST constraints which are themselves based on: Performance, Scalability, Simplicity of interfaces, Modifiability, Visibility, Portability, and Reliability.

This will allow the end user to:

- Scan wagons at terminals, marshalling yards, or intermediary stops,
- Detect Issue waybills and
- Communicate via a web portal or by data exchange,

This further allows the user to utilise a specific tool to manage bookings, train loading, and orders relating to transport modes required later in the transport chain.

3.6 ELETA

3.6.1 Project objective, aims and outcomes

The project Electronic exchange of ETA information (ELETA) should encourage and facilitate the efforts developed by the sector, but also by Member States and the European institutions to overcome legal, operational and technical obstacles in the electronic exchange of ETA information. ELETA wants to demonstrate the practical value of streamlining exchange of ETA data on the basis of existing intermodal freight trains.

This section is mainly based of the project description at the UIRR website (UIRR, 2018) and several presentations held by Ad Toet. (Toet, ELETA project, 2017) (Toet, ELETA project, 2017) (Toet, ELETA project, 2018) (Toet, ELETA project, 2018)

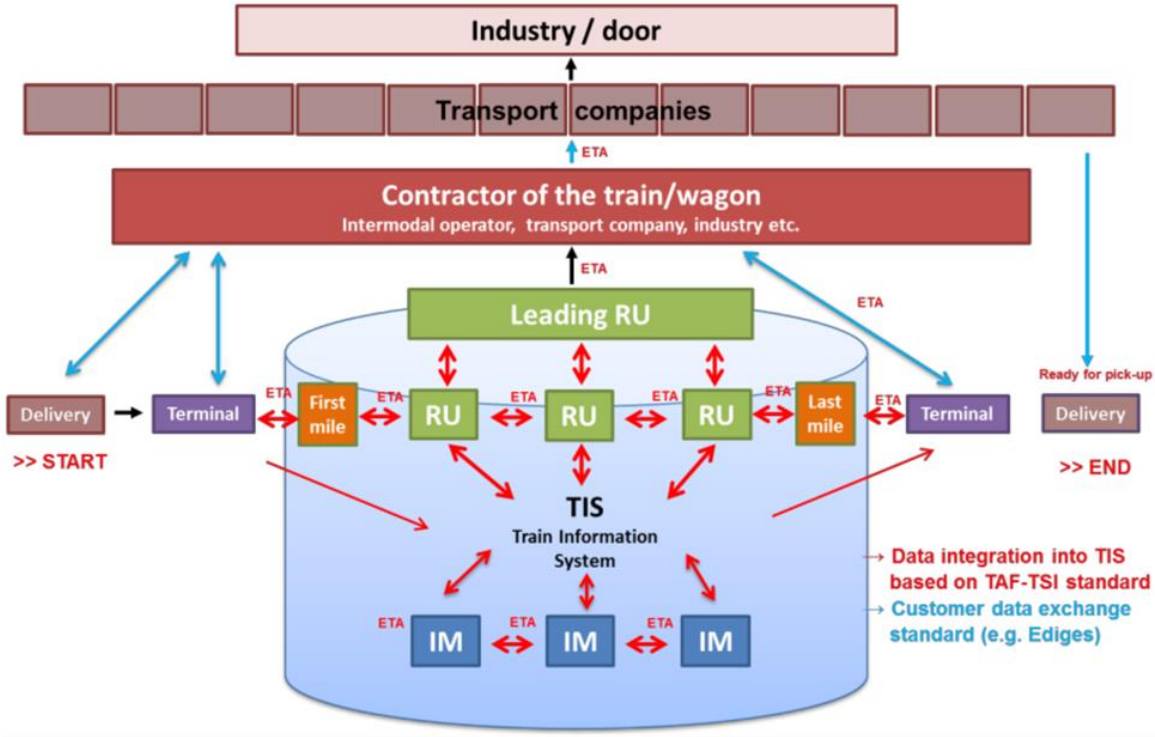


Figure 4 System overview for ELETA [6]

The ELETA project shall enable sharing of tracking information between all partners involved in a single train run, via RNE's TIS Train Information System ("Where is the train?"). It aims for offering estimated time of arrival data ("When will the train arrive?"). Furthermore, ELETA intends to achieve high quality output in order to assure reliable ETA communicated to the following partner of the train run. Therefore, all partners calculate their own part of the ETA. Moreover, RNE TIS shall be the common platform and measuring the quality of the ETA at defined points and directions. It compasses a step-by step introduction with volunteering RFCs, IMs, RUs, terminals, contractors for defined connections, and subsequent spreading to the network. ELETA system overview is shown in Figure 4.

3.6.2 Operating process described

The project defines a couple of work packages in order to achieve a maximum outcome:

- survey and system analysis of current situation (logistics and operations);
- survey of legal conditions;
- assessment and analysis of stakeholders wishes;
- assessment of customers' systems to be linked (ICT technology);
- elaboration of functional requirements and architecture;
- conceptual design of (smart) ETA application;
- programming of software applications;

- testing and evaluation of software applications in the transport operations;
- coordination / project management.

The earlier work packages of the ELETA project provide a basis for defining (enhanced) ETAs for terminals and for RUs at hand-over points. Intermodal operators in leading role shall support the project with their varied experiences. Thus, IMs, RUs and RNE are actively involved. A selection of already running intermodal shuttle trains is in favour for testing and evaluation. No new big database shall be installed, but interfaces to already existing TAF TSI (e.g. RNE TIS, see also section 5.4) information.

These goals may be described in two steps:

- Establishing the electronic data exchange link between all stakeholders in the chosen intermodal logistic chains.
- Feeding into the link valid data on ETA.

3.6.3 Data and information management methods

The description of the situation 'TODAY' helps for understanding the needs of the project:

- IMs provide ETA data based on simple time shifting.
- RUs do not feed data into RNE TIS.
- Data sharing is fragmented and non-standardised.
- Some RUs do not disclose tracking data with other RUs and the contractor of the train.
- The contractors of the train/wagon do not have access to RNE TIS. Only some terminals have, based on voluntary contracts.
- TAF TSI defines data exchange between RUs, IMs and wagon keepers. Terminals and Contractors of the train are excluded. (see also section 5.1)
- RNE TIS uses a reference number linked to a path; link to train gets lost in case of rescheduling.

When ELETA and cooperative projects earn success, the situation 'TOMORROW' may look like this:

- All partners involved in a train run have access to tracking and ETA data.
- All involved partners share train tracking data and ETA data.
- All partners involved in a train run feed their ETAs into RNE TIS.
- All partners plan ahead and share their ETA with the following partners, who can plan ahead as well.
- The LRU communicates tracking and ETA data to the Contractor of the train.
- The Contractor exchanges information with the terminal and communicates "ready for pick-up" to the transport company/industry.

ELETA already published the following preliminary findings:

- Permissions/authorisation for sharing data has to be solved. (RNE framework agreement)
- Intermodal operators and some terminals are not linked to RNE TIS.
- Change of train numbers at borders perturb the seamless train tracking due to the lack of unique train numbering.
- Terminals and their (common) user interfaces are not as standardised as needed. The sector has invested in costly workarounds.
- It's a challenge to show the whole train journey, not only the IM network or network entry point.

3.7 TIS ETA Pilot Rhine-Alpine Corridor

This section is mainly based on a presentation by Pascal Schnitzius at the Workshop on ETA development in 2018. (Schnitzius, 2018)

3.7.1 Project objective, aims and outcomes

The TIS ETA Pilot, Corridor Rhine-Alpine, was initially aimed with the following focus:

- RNE TIS displaying additional info on ETA in terminal and current data of train arrival in / train departure from the terminal,
- Shared manual data input (ETA/current dates) in RNE TIS by the shunting service provider and the terminal manager,
    - Incoming trains: ETA, current arrival, ready for unloading
    - Outgoing trains: ETD, current closing for loading, current departure

3.7.2 Operating process described

During the project runtime, the focus slightly changed to add the last mile train run to RNE TIS. Additional user accounts had to be created for each shunting service provider and the terminal, with individual user rights allocated.

The Pilot involved all relevant parties.

RNE

The following activities had to be done in RNE TIS regarding the pilot:

- Inserting additional line in TIS for terminal arrival
- Renaming existing line "arrival terminal" in "arrival hand-over"
- Training involved parties in TIS for inserting ETA "under the crane"

Terminals

The following activities had to be done by the terminals regarding the pilot:

- Selecting some pilot trains out of international freight trains on RFC Rhine-Alpine
- Registering in TIS and establish reporting point ("RICS code")

Shunting RU

The following activities had to be done by the shunting RUs regarding the pilot:

- Estimating train arrival in terminal “under the crane”
- Inserting ETA in TIS for selected trains

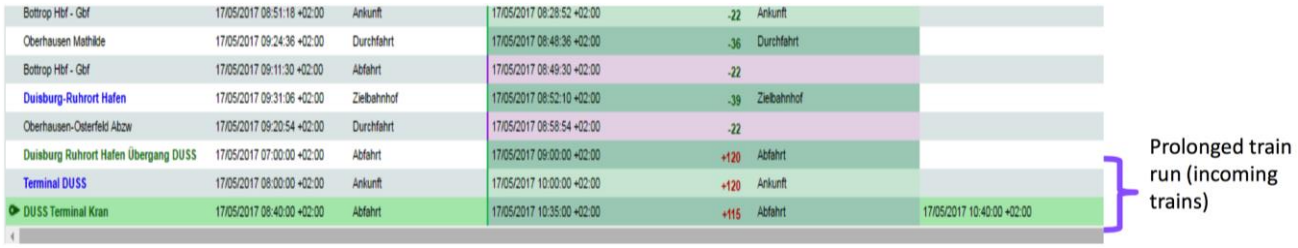


Figure 5 Screenshot of TIS handling for Pilot Rhine-Alpine-Corridor [7]

3.7.3 Lessons learned

The number of different stakeholders involved with their individual organizational structure and the shared responsibilities amongst them created an important complexity impeding good results.

- A quite important number of people had to be trained in RNE TIS.
- Shift work and changing teams in the operational centre hampered a continuous data input by the stakeholders.
- Stakeholders relied on each other regarding the RNE TIS data input what obviously did not work.
- Terminal and Shunting service provider are in contact with each other anyway. RNE TIS data input was considered redundant.

RNE TIS user interface for data input is probably too complicated considering the context mentioned afore.

3.8 CONCLUSIONS

The review of the current state of the art suggests that the development of new services has to be matched with developments in IT systems to take into account a larger number of stakeholders and a wider geographic scope. These have to be designed in a way so that Smart-Rail developments are user friendly and provide the relevant stakeholder with the relevant information at the right time. The basic information to do this exists through the products provided by RNE (TIS) and UIC (RailData), however a system has to be developed to bring these together in a meaningful manner. “If rail wants to be competitive in comparison with road, but doesn’t engage with digitisation, it will fall increasingly behind in productivity. But we want to inspire customers with modern technology.”

There is an imminent need for a data shared input. Two possible ways forward:

1. There should be just one stakeholder (“the terminal”) entering the data in TIS. Therefore, there is no direct data exchange, but it is relatively easy to implement. TIS frontend should be further developed. A more user user-friendly possibility for the data input should increase acceptance (max. 30 seconds per data entry).

2. There should be a direct information exchange via an IT interface of the individual production system (RU, Shunting RU, Terminal). This solution would be very efficient, but is costly, and thus a long-term solution.

4. RAIL FREIGHT OPERATION PROCESSES, TARGETED INFORMATION AND DATA

4.1 General Processes at a Marshalling Yard

After introducing a general layout of MYs, typical processes in the supply chain of a MY are described, followed by deriving the requirements of data exchange and carried out at the case study of Česká Třebová MY.

4.1.1 Overview of the general layout of a MY

In order to manage and control freight trains efficiently a significant number of activities need to be performed in the different parts of the rail yard. These activities are a basis for introducing different levels of automation, starting with a digital data transfer instead of current semi-manual process interactions.

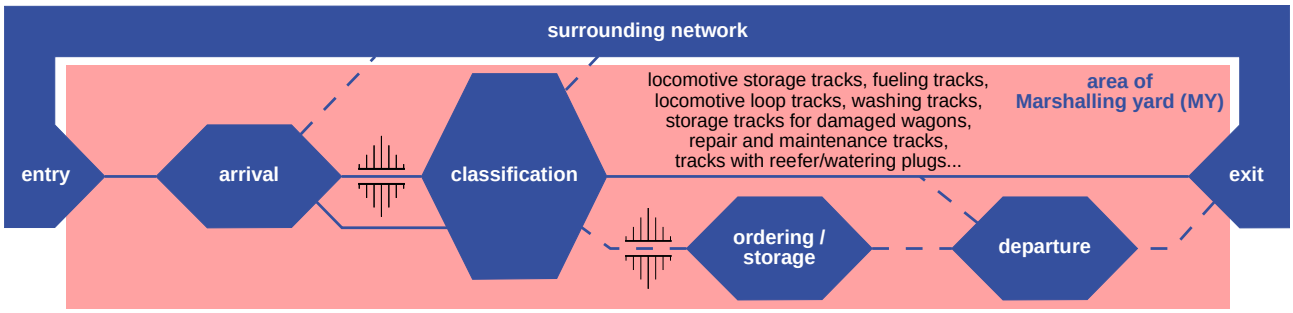


Figure 6 Generic MY layout

A MY is organized in several functional areas, as illustrated in Figure 6. These MY parts reflect the activities that must be fulfilled for the whole process of re-arranging freight trains in order to send the wagons efficiently to their different destinations.

The most important part is the classification part where the wagons or wagon groups are sorted into different outgoing trains using gravity starting from the hump or deploying flat shunting.

In some cases, MY parts are being decommissioned for reducing maintenance costs. They were built when less freight transport used road traffic, single-wagon shipments were common, and a steep growth rate in rail freight transport was estimated.

On the other hand, where there is less space for the MY in crowded situations, trains leave the yard from the classification part, and ordering and departure part are not built. Nevertheless, the necessary activities are done at the available parts of MY.

Dashed lines in the figure show optional track relations, which are available in some MYs, e.g. from arrival or classification part directly to the surrounding network. A second hump for ordering of wagons in an outgoing train is rarely built and still in use. But further storage sidings are sometimes needed for buffering wagons. In most cases the classified wagons are moved to a departure part for building the outgoing train which goes directly to the exit signal of the MY.

On some MYs further tracks for special handling of wagons and/or locomotives are provided: some of them are shown outside the various MY parts, but still inside the MY area. They are linked to the MY parts in different ways, or are even directly installed as a facility at selected tracks of MY parts.

In case of missing (general) MY parts, the activities must be done at the remaining parts.

Some MYs can only be operated in one direction, as it may be assumed for the overview in the figure. But in most cases, there are special tracks and switches that enable incoming trains from both directions to reach the arrival part. The same applies for outgoing trains running through the departure part reaching both directions of the surrounding network.

In order to simulate and automate processes at a MY, its topography, e.g. tracks (lengths…), switches, signals (possible aspects…), must be known. Furthermore, the current state of each MY element (means each facility) must be transmitted to the MY control centre.

MYs enable a flexible handling of wagons for different destinations, therefore a mostly determined sequence of activities must be fulfilled to swap wagons from an incoming to an outgoing train, as shown in Figure 7.

4.1.2 Processes in the handling order at a generic MY

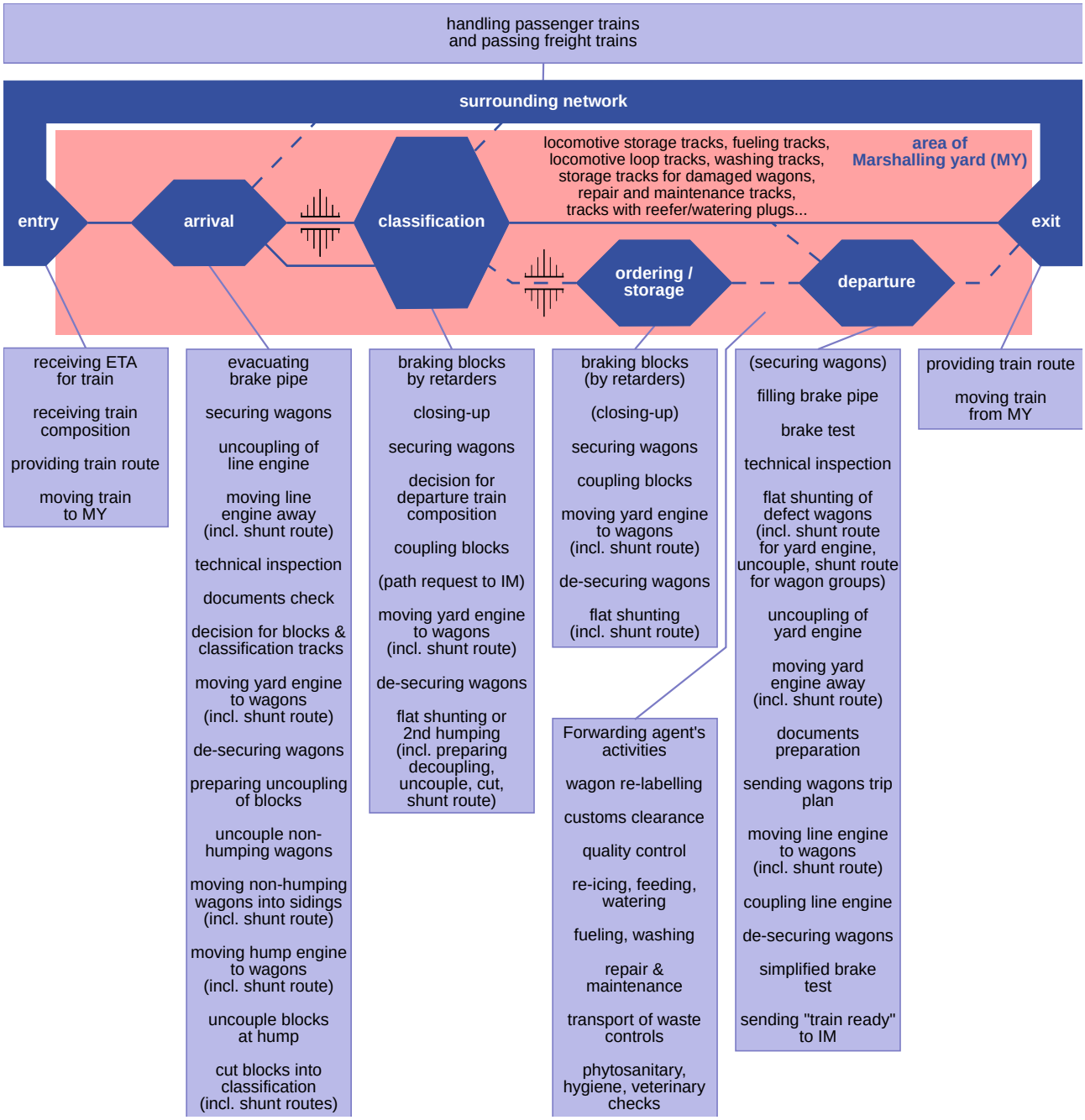


Figure 7 Processes at different areas of a generic MY

The following sections describe some aspects of the notices processes. The analysis is based amongst other sources on (UIC, 1991), (Gille, 2013) and (Pachl, 2016).

Entry part

Receiving ETA for incoming train

The IM informs the MY about an arriving freight train. The forecast time depends on the location of the MY and its surrounding network. Most freight trains run on a regular basis, e.g. they run every Tuesday, or Tuesday and Friday, or every two weeks on Wednesday etc. That means, the MY has a rough plan for the incoming trains on an hourly basis.

Receiving train composition

If the wagons of the incoming shall be changed at the MY, its planned composition is sent by the LRU to the RU at MY. Therefore, the local RU may provide this information to the MY in order to plan local resources, like staff, locomotives and track occupation. If the LRU is the same as the local RU at the MY, the data exchange is internal to the company, mostly in proprietary ways.

Providing train route

The MY has to provide a secured train route from the entry signal to a track at the arrival part, which is appropriate for its length and special treating, in case of dangerous goods etc.

Moving train to MY

When the signal aspect at the entry signal allows proceeding, the train entries the MY and runs to its given track at the arrival part.

Arrival part

In the Arrival part the train locomotive must be uncoupled after evacuating air in the brake pipe and securing wagons. In this step MY staff, e.g. coupler and brakeman, is required. The shunting route from this track at the arrival part either to a locomotive storage track or to the next site of operation for the train locomotive may be established in the meantime. After uncoupling the train locomotive, it can be moved away by the train driver. It might be required to split the train for practical issue (e.g. short arrival track), therefore the current status of topography data (e.g. arrival part, track lengths) are required.

The arrived wagons are on the one hand technically inspected and on the other hand commercially checked regarding its documents. Both processes require specially trained staff. In case of defect wagons, they must be handled specially and don't run over the hump, but are shunted by a yard locomotive to a storage track for defect wagons or even to a repair and maintenance track. Its current status must be transmitted to the LRU, which in turn informs the wagon owner for further decisions.

A wagon list with characteristics, like destination, load and priority, is required in order to support the decision for cutting the wagons into wagon groups – so called blocks – and moving the blocks into the classification tracks. This hump plan is broadcasted to the staff at the hump and at the classification part and to the hump command and control system.

A shunting route from the current location of the hump locomotive to the end of the current rest of the train must be commanded. Done that, the hump locomotive may be driven by the locomotive crew to the far end of the current train. Only the relevant couplings of the train are prepared for uncoupling at the hump by special staff following the hump plan. The remaining couplings stay closed. The wagons of the train must be uncoupled, in order to be moved by the hump locomotive to the hump.

In case of wagons that shall not be humped, they must be uncoupled and shunted by another yard locomotive and its driver. Therefore, special shunting routes must be provided for pulling up the locomotive and moving the shunting unit into the desired classification track.

The hump system must command the right route for each block along with several switches and retarders in order to stop at a certain position at a certain track at the classification part. Each prepared coupling is opened at the hump by a hump staff in order to cut the blocks along their commanded route into the determined classification track. Therefore, the hump system needs detailed information about the wagons, e.g. mass, axle count, and length. Furthermore, environmental data like wind speed and wind direction may be incorporated into the pulling speed for each block.

Classification part

When a block of wagons rolls from hump into a track of the classification part, groups of retarders attenuate the movement of the wagon group in order to stop at a certain position of the track. In most cases, the wagon groups stop with too much space between them, so that they don't get damaged, but the classification track is not effectively used, and the blocks might not be coupled. In order to put more wagons into this track and to enable coupling, the blocks are pushed together – called "closing-up" the blocks. Either they are pushed by a yard locomotive from the hump side or a closing-up system is installed and may be activated. The blocks must be secured, so they can't move away.

When there are enough wagons for a certain destination or the time is ready for an outgoing train, the train composition is fixed, that means, the train is planned with its ordered wagons. The time until the ready-to-run train may be forecasted. The following activities at MY are known and their time demand may be roughly estimated, in order to send a path request for a certain time for the outgoing train to the IM. On the other hand, MYs sometimes use pre-booked paths and don't need ad-hoc requests to the IM. Nevertheless, the desired train path needs to fit to the planned outgoing train regarding train length, train weight and brake characteristics.

In case of a regional freight train, the shunting operations along the route must be minimized, and this can be effectively achieved by an optimal ordering of its wagons. Ordering long distance freight trains at less frequented MYs may reduce the sorting effort at highly frequented MYs.

Therefore, the wagons at a certain classification track may be further shunted either by flat shunting with a yard locomotive and its driver or by a second hump which leads into an ordering part or by shunting back and second humping into the classification part.

Preparation of an outgoing train may be done either in the classification part, the ordering part or the departure part. Some actions are described in the following paragraph – the ordering part.

In case of a separate ordering part, a yard locomotive must be moved to the wagons based on a shunting route, it is coupled to the wagons, they are de-secured and moved to ordering tracks.

Ordering part

If the block were again humped into this part, they must be braked by retarders, afterwards closed up and secured. This part is often used as a buffer for quite ready outgoing trains, which wait according to their timetable.

When the wagons must be further handled in the next part of the MY, the yard locomotive has to be moved to wagons, including a shunting route from its current position. After de-securing the wagons flat shunting might be performed, including a shunting route, into the next MY part.

Somewhere at a suitable track

There are further activities that are sometimes done at MYs. In that cases, they must be done at special tracks according to the MY layout and responsibilities. For these activities, the wagons must be moved to these tracks by a yard locomotive and its driver based on shunting routes. Afterwards they must be further directed to the next MY part.

A local RU mostly does forwarding agents' activities, if the wagons must handled in a special way. Quality control is an example for such activities, which is targeted at the load and not the wagon itself.

The line locomotive may have to be refuelled; certain wagons may have to be washed. In case of defect wagons, they may be shunted to a repair workshop. On the other hand, certain wagons may be directed to a maintenance shop on a regular basis.

Wagon re-labelling may be needed in case of wagons just arrived from a nearby terminal.

Customs clearance is performed at MYs which head to country borders or at port MYs. Another administrative action on country borders is the control of waste transports. A state division also conducts Phytosanitary, hygiene and veterinary checks.

Departure tracks

After the coupled blocks arrived into departure part, the wagons must be secured for uncoupling the yard locomotive. The yard locomotive is uncoupled and moved away, based on an appropriate shunting route.

If the track provides brake test equipment, the brake pipes of the wagons may be coupled and then filled for a brake test (without locomotive), done by yard staff.

The technical inspection ensures, that there are no damaged wagons; no un-secure load and all wagons are tightly coupled. In case of defect wagons, they must be taken out and shunted by a yard locomotive to a storage track for defect wagons or even to a repair and maintenance track. Its current status must be transmitted to the LRU, which in turn informs the wagon owner for further decisions.

The commercial documents must be prepared based on the correct count and order of the wagons for the outgoing train. This data may be sent as «wagons trip plan» to the LRU, which in turn may spread this information to further MYs, wagon owners and its customers.

The train locomotive is moved to the wagons by the train driver based on a shunting route from its current position to the exit side of the departure track. It is coupled; including brake pipe. After filling brake pipes a simplified brake test has to be performed.

Now the «train ready» message can be sent to IM in order to get a route from the exit signal to the surrounding network in the desired direction. On the other hand, the MY has to command a train route from the departure track to the MY exit signal. When the signal at the departure tracks shows a proceed aspect, the outgoing train may be moved out of the MY.

4.2 DATA EXCHANGE REQUIREMENTS OF THE PROCESSES

4.2.1 Communication between IM and MY

Receiving ETA for incoming train

The actual forecast for the arrival of the expected train at the entry signal is sent by the IM in most cases, either on a TAF TSI basis (see also section 3.6) or in a proprietary data exchange protocol or even simply at a phone call.

Principally, the TAF TSI train running forecast message (see also section 5.1.4) is sent to the RU, which booked the path for current train. Based on an additional contract with RNE, this information may be served from IM to RNE TIS, too. That enables the MY to receive the data in RNE TIS. In case of additional contracts, the LRU may inform the customers. TAF TSI train running forecast message considers the whole train and does not contain any detailed information regarding the wagons.

Path request for outgoing train

When the train composition is fixed, that means, the train is planned with its ordered wagons, the time until the ready-to-run train may be forecasted. The following activities at MY are known and their time

demand may be roughly estimated, in order to send a path request for a certain time for the outgoing train to the IM.

On the other hand, MYs sometimes use pre-booked paths and don't need ad-hoc requests to the IM. Ad-hoc requests may be sent by the TAF TSI path request messages from RU/MY to IM (see also section 5.1.2).

Nevertheless, the desired train path has to fit to the planned outgoing train regarding its characteristics, e.g. train length, train weight and brake ability.

Sending « Train Ready »

When the outgoing train is ready to leave the MY after fulfilling technical inspection, brake test and documents preparation, the TAF TSI train ready message may be sent from RU/MY to IM (see also section 5.1.3).

Providing train route for incoming and outgoing train

Based on the train path the IM is informed about the train characteristics and its intermediate destination – the MY. Therefore, it provides a train route for the incoming train from the surrounding network to the entry signal of the MY. The same procedure works for outgoing trains from the MY exit signal to the surrounding network. No additional message exchange is needed between RU / MY and IM. The line locomotive driver follows the instructions resulting from the signal aspects.

4.2.2 Communication between LRU and MY

Receiving train composition for incoming train

This detailed data is not covered by TAF TSI train running forecast message but in TAF TSI train composition message (see also section 5.1.3), which principally has to be sent from the current RU to the next RU/MY. On the other hand, based on TAF TSI consignment orders regarding each wagon of the train (see also section 5.1.1), the RU/MY gets informed about all relevant data regarding each wagon of the incoming train and how it shall be handled at the MY.

Sending wagons trip plan for outgoing train

As the MY behaves like an RU (from the point of view of TAF TSI), it may send a TAF TSI train composition message regarding the outgoing train to the next RU or LRU. TAF TSI consignment orders have to be adjusted in case of any irregularities. This wagon data may influence the requested path for the IM, but will not be shared with the IM on that level of detail.

Movements at the MY

For each movement at the MY communication between different involved parties is required. The MY infrastructure manager must set a shunting route for moving a wagon unit or single locomotive. Typically, a yard locomotive is needed for pushing or pulling the wagons, sole exception is rolling down the hump where the wagon units are accelerated by gravity and braked by several retarders. A yard locomotive driver controls the locomotive.

The MY infrastructure manager must be informed by a RU staff, that a wagon unit is ready for the movement, accompanied by the local destination at the MY (e.g. track number). The local RU decides which yard locomotive with which yard locomotive driver will be sent to the requesting wagon unit in order to serve the movement. It therefore requests a shunting route for reaching the wagon unit or it acts in a zone, where switches are manually changed by either the locomotive crew or local MY staff. The communication between MY-IM and MY-RU staff is mostly realized with analogue or digital railway radio. The MY-IM decides which of all available routes is deployed for the requested movements.

The run from the MY entry signal to the arrival part and from the departure part to the MY exit signal is done at a higher secured level based on train routes, all the rest are shunting routes, which are limited to lower speeds. A train locomotive, commanded by the train locomotive driver, pulls both train runs. Yard locomotives and its drivers mostly serve all the rest.

Train locomotives may be either electric, or non-electric, or hybrid. In some cases, the MY offers electrified tracks from entry signal to arrival part and from departure part to exit signal. The movement from arrival part to the locomotive storage track and back to departure part may also be electrified or has to be served by a non-electric yard locomotive. Some new train locomotives offer a “last mile diesel locomotive”, so that no track electrification is needed. The rest of the MY tracks are mostly non-electrified and served by non-electric yard locomotives.

Splitting and joining wagon groups

Before starting a movement for a wagon group a coupler assists in opening relevant couplings, a brakeman assists in disconnecting the relevant brake couplings. The yard locomotive has to be coupled to the wagon group. Another MY staff assists in de-securing of the relevant wagons. Sometimes staff is trained to fulfil multiple activities concerning the wagons.

When the wagon group arrives at the intermediate destination track at the MY, a MY staff secures the wagons with brake shoes, a coupler assists in uncoupling of the yard locomotive.

At the arrival part all relevant couplings are already prepared for uncoupling at the hump, the brake pipes are uncoupled and the wagons are pushed to the hump by a yard locomotive at the end of the wagons. The relevant couplings are easily opened at the hump by using an uncoupling pole.

If there is too much space between wagon groups at a certain track, the wagons may be closed up by a yard locomotive or by a fixed closing-up-system. It is also a provision for coupling of wagon groups and connecting brake pipes as train preparation.

Special trained staff from the MY/RU must fulfil all these activities. They mostly communicate by analogue or digital railway radio. They are instructed by the MY dispatching centre.

«Paperwork» and related checks, inspections, tests

Technical inspection is undertaken at the arrival part for the incoming train as well as at the departure part for the outgoing train. The technical inspection ensures that there are no damaged wagons; no un-secure load and all wagons are properly coupled. It may influence the train characteristics for the outgoing train route in case of irregularities. In case of damaged wagons, the LRU and wagon owner shall be informed and they must decide to repair or to store the wagon.

The commercial documents are typically exchanged in electronic ways between the involved RUs. They contain consignment orders and characteristics, e.g. destination, wagon type, length, axle count, load, priority, for each wagon and have to be checked for the incoming train and prepared for the outgoing train. This is typically done by staff “at the ground” in close coordination with staff “at the tower”.

Brake test

In order to send a train to the surrounding network, a brake test shall ensure that the required brakes work correctly. If the MY is equipped with brake test facilities at the departure part, the already coupled wagons may be tested by a brakeman without any locomotive. Otherwise this brake test is done after coupling the train locomotive to the wagons. If the wagons were tested alone, a simplified brake test is needed after coupling the train locomotive to check the closed brake connection between the locomotive and the first wagon after the locomotive.

Disposition

On the one hand several human resources have to be effectively assigned to different activities at different locations. On the other hand, several infrastructure elements and mobile devices (locomotives) have to be effectively deployed. It results in very complex decisions that may be supported by experience but furthermore by modern simulation of the current situation and the near future.

Decision for blocks and classification tracks

A similar complex decision has to come for each block and its classification track in order to minimize further ordering movements. Modern simulation tools may also support that.

4.3 PROCESSES AND DATA EXCHANGE AT ČESKÁ TŘEBOVÁ MY

The Česká Třebová MY in Czech Republic is used as one case study in the frame of the OptiYard project. Therefore, their current processes and data exchange is analysed. As stated in Figure 8, the information flow at Česká Třebová is multileveled across different stakeholders in order to assure a smooth handling of freight trains throughout the MY.

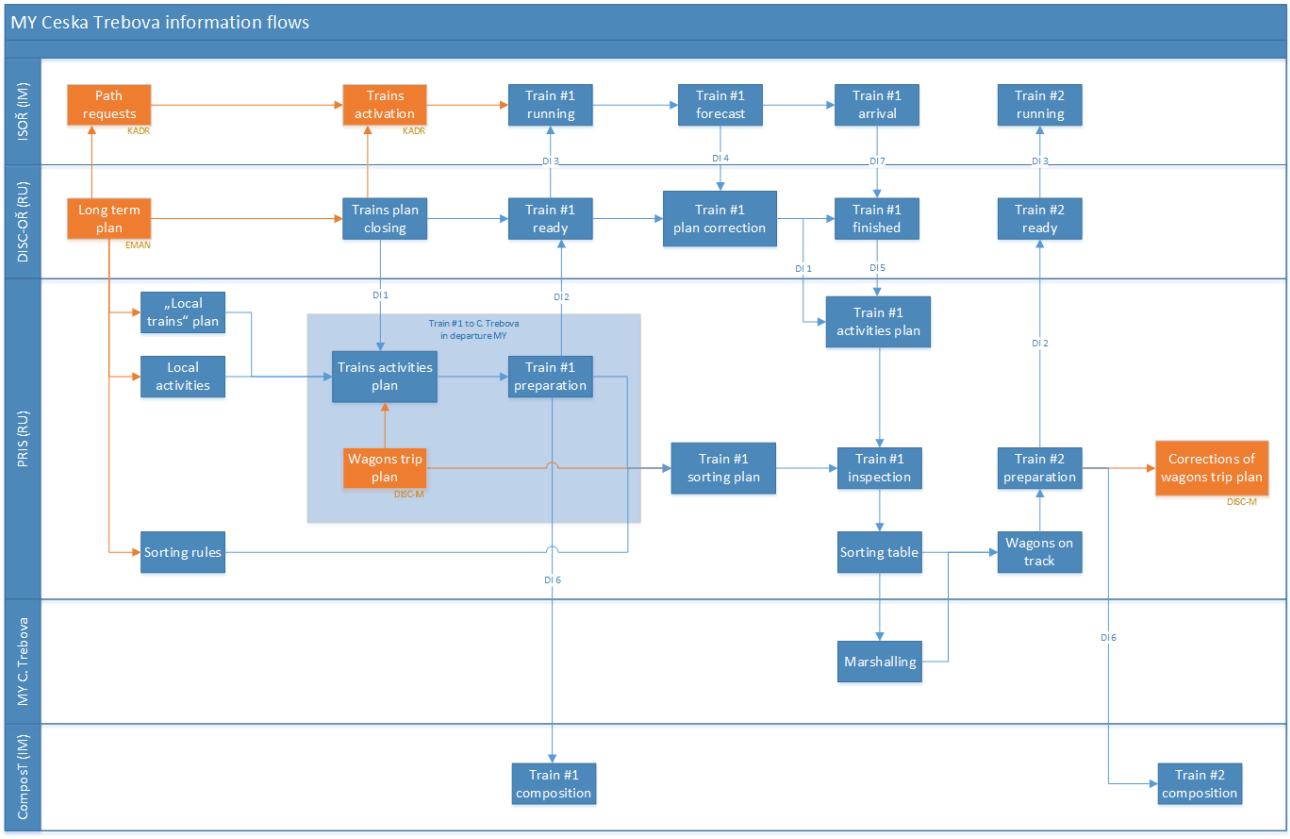


Figure 8 Data Exchange at process level in Česká Třebová

The horizontal lanes group different IT systems at the RU (ČD Cargo) or IM (SŽDC):

- KADR, used by SŽDC for path requests.
- ISOŘ, used by SŽDC for operational management of trains, e.g. TAF TSI train running and forecasting phase. It is loosely connected to signalling system.
- ComposT, used by SŽDC for train composition, e.g. TAF TSI train preparation phase. It is tightly connected with ISOŘ.

- EMAN, used by ČD Cargo for long term planning, e.g. trains, locomotives, local activities, sorting rules.
- DISC-OŘ, used by ČD Cargo for planning and operational management of trains, locomotives and drivers.
- DISC-M, used by ČD Cargo for planning and operational management of wagons movements, which is very similar to wagon booking, but based on sorting rules; it is tightly connected to DISC-OŘ and a black box for the user.
- PRIS, used by ČD Cargo for local activities, e.g. train inspections, train sorting and preparation, brake checking, wagon movement in stations, wagon status.
- GAC, used by the MY for sorting wagons which includes management of retarders and switches in the classification part.

The numbered interfaces between activities are explained in this document.

4.3.1 Interface DI1 – Train Plan Message

Interface DI1 enables the data exchange from the RU “responsible for the line operation” to the “RU responsible for the MY actions”. After the plan for a certain freight train has been finished, this message is sent. Furthermore, it is used, when an original freight train plan has been modified in order to inform the “MY-RU”. Therefore, no differences to the original plan are submitted, but the whole corrected train plan, which shall in turn replace the original one.

The Train Plan Message contains a rough train plan, which does not state each wagon with its destination and characteristics but handling details for the whole train. It encloses path information at the desired level for path requests to the needed IMs. The “MY-RU” may roughly plan its resources (personnel, locomotives…) for handling the incoming freight train at the MY.

Currently no TAF TSI message is used here, but a proprietary XML message. It already incorporates TAF TSI concepts (see also section 5.1), i.e. the Message Header and parts of the Path Identity.

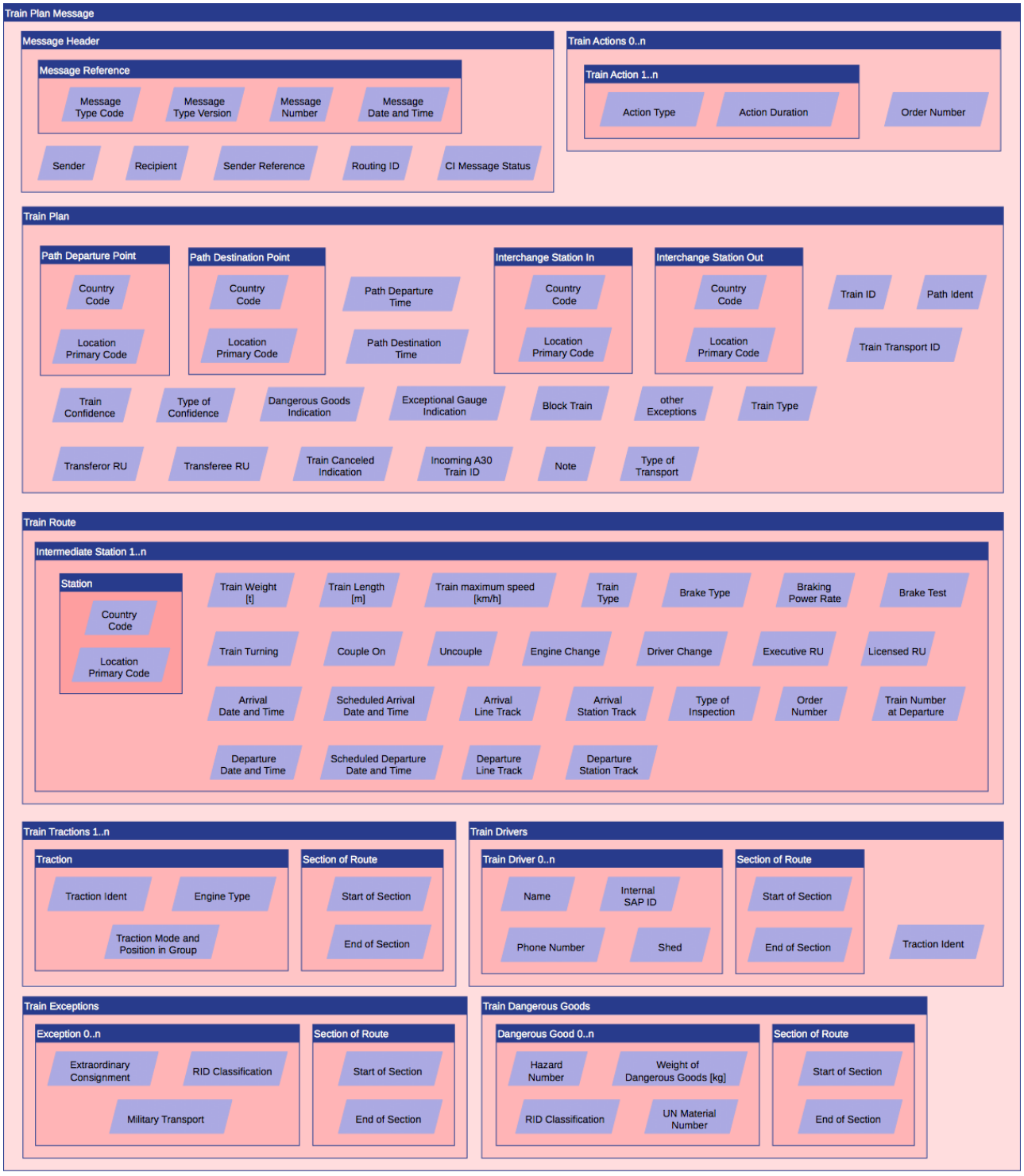


Figure 9 Structure of interface DI1 (Train Plan Message)

4.3.2 Interface DI2 / DI6 – Train Composition Message

The interface DI2 supports the data exchange from the “MY-RU” back to the “line-RU”. The same data format is deployed for announcing freight train composition to the IM, named DI6 in Figure 8. It forms an important basic for the Train Ready Message (see also the following section).

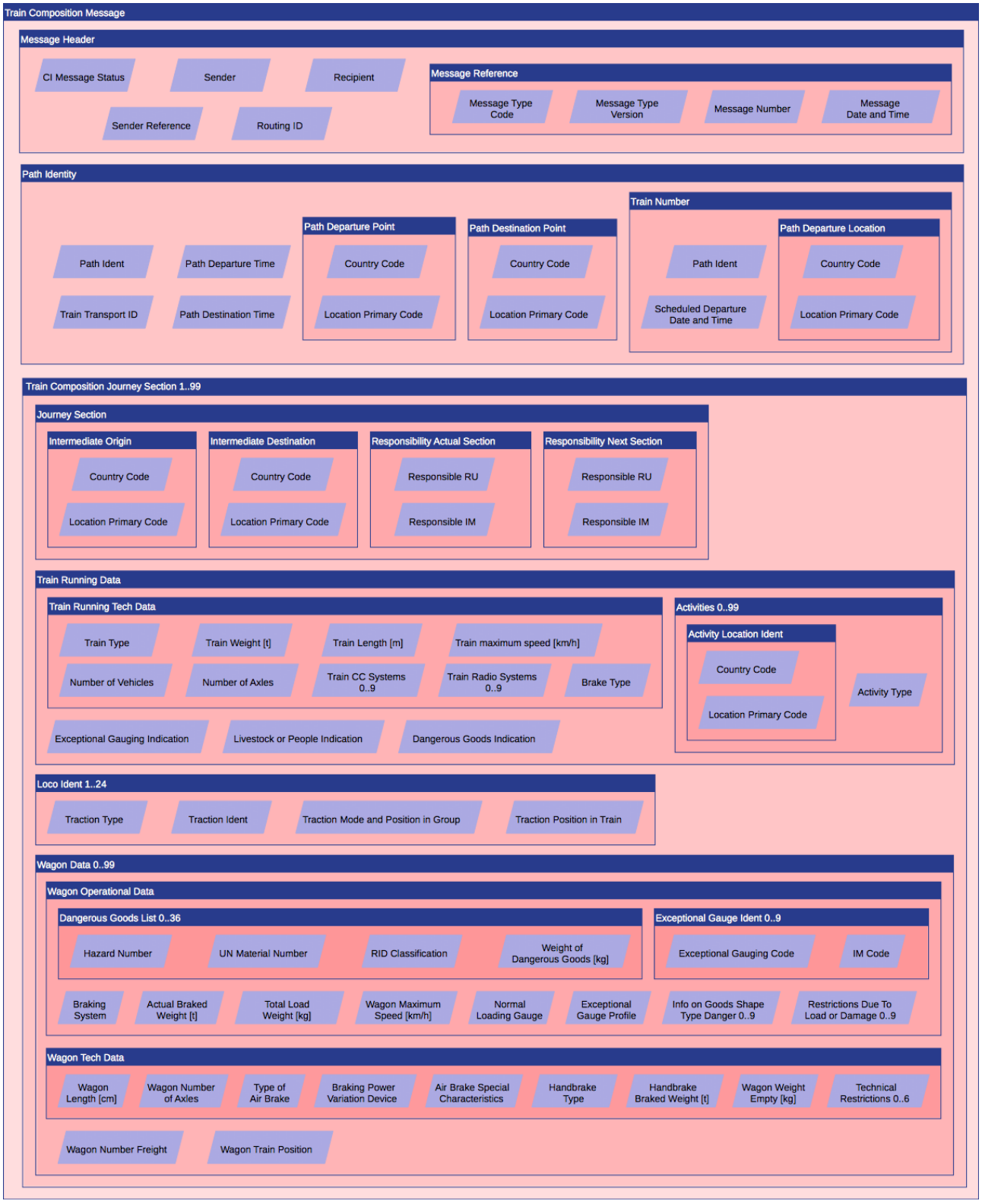


Figure 10 Structure of interface DI2 / DI6 (Train Composition Message)

This message contains detailed train and wagon data, which is needed in order to derive work plans at the MY, i.e. regarding track length and special requirements to the MY infrastructure.

Currently no TAF TSI message is used here, but a proprietary XML message. It already closely follows the TAF TSI TrainCompositionMessage (see also section 5.1.3).

4.3.3 Interface DI3 – Train Ready Message

The interface DI3 incorporates the small but very important Train Ready Message, which is widely used to indicate a ready to depart train to the IM. The IM itself may find and secure an appropriate route enabling the freight train to leave the MY from the departure part trough the exit signal in the desired direction onto the line.

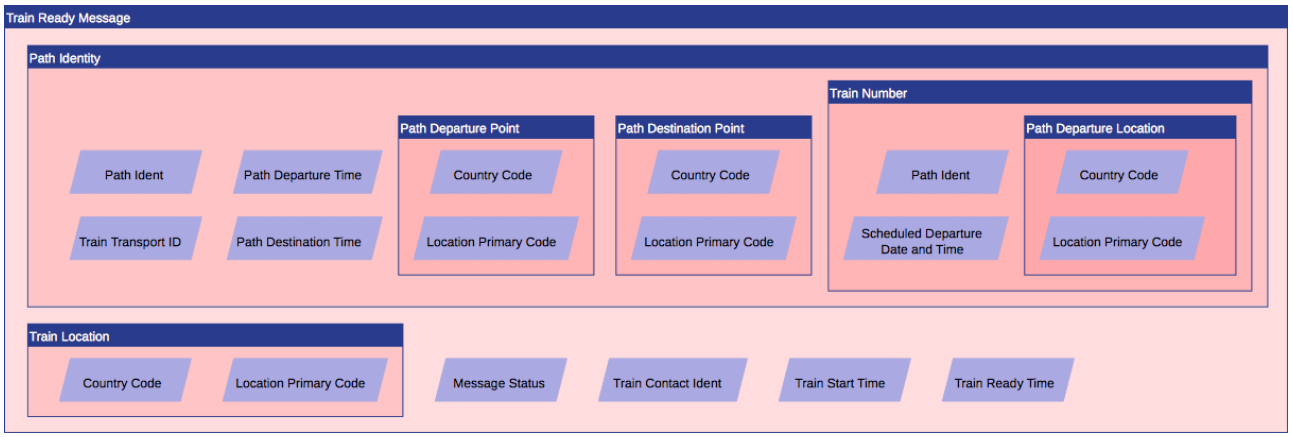


Figure 11 Structure of interface DI3 (Train Ready Message)

This small interface mostly contains identification information and the important train start and train ready times.

Currently no TAF TSI message is used here, but a proprietary XML message. It already closely follows the TAF TSI TrainReadyMessage (see also section 5.1.3).

4.3.4 Interface DI4 – Train Forecast Message

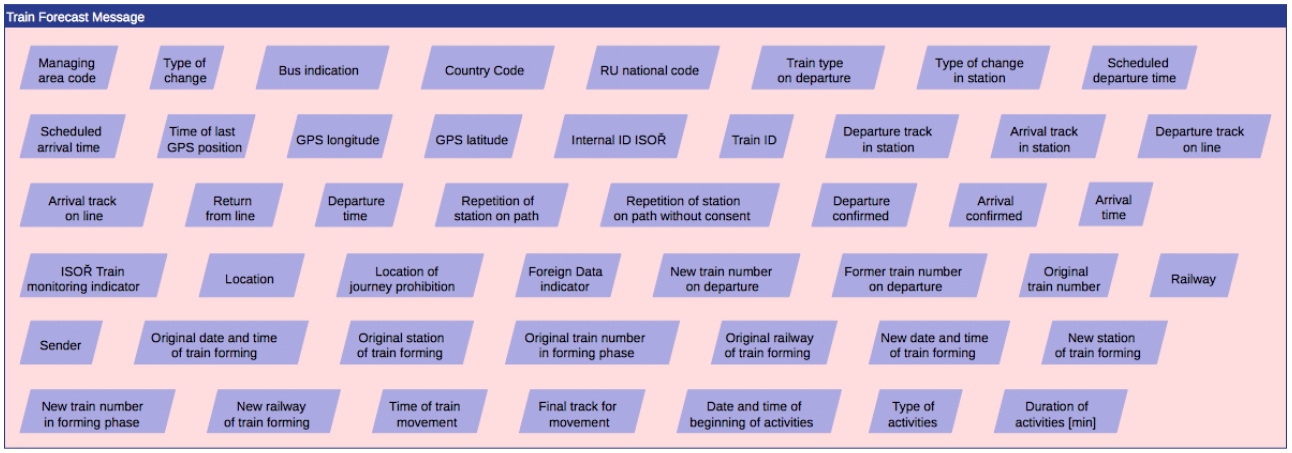


Figure 12 Structure of interface DI4 (Train Forecast Message)

The interface DI4 is used by the “line-IM” in order to inform the “line-RU” about the current position of the train and possible deviations from its original trip plan. It contains no detailed information about the train composition, the wagons, its load or destination. This message builds the basis for train plan changes, which in turn are communicated to the “MY-RU” within DI1.

It is a purely proprietary data format, not leaning from TAF TSI.

4.3.5 Interface DI5 / DI7 – Train Running Message

Through interface DI5 the “line-IM” informs the “line-RU” and/or the “MY-RU” about the actual train location and therefore builds a basis for MY-internal adjusting of work plans.

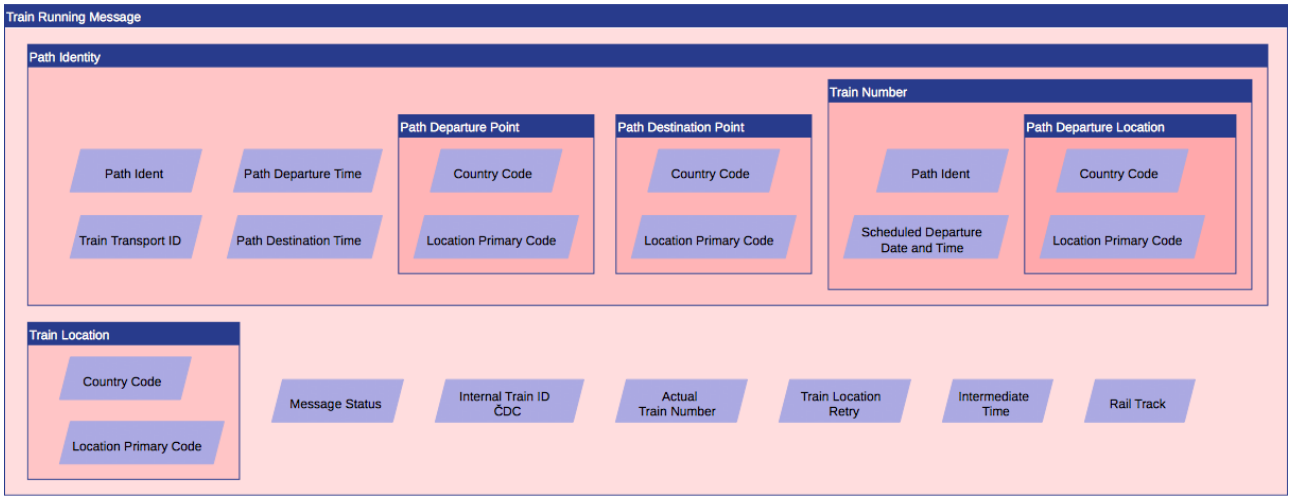


Figure 13 Structure of interface DI5 (Train Running Message)

This small interface mostly contains identification information and the important train location and time.

Currently no TAF TSI message is used here, but a proprietary XML message. It already closely follows the TAF TSI TrainRunningInformationMessage (see also section 5.1.4).

4.4 Processes and IT systems at MYs Hallsberg, München-Nord and Mannheim

These three MYs were analysed in the ARCC project (ARCC WP2, 2017) (see also section 3.4).

The operations of Hallsberg MY, as any MY with hump, can be categorised within the following activity groups:

Table 4 Activity groups of Hallsberg MY (ARCC WP2, 2017)

Activity group	Activities
Train arrival	Reserve time (based on braking prior to the signal) Driving Securing wagons and uncoupling them from locomotive Arrival inspection (1 min per wagon) Coupling to the shunting locomotive Towing, releasing brakes, waiting for signal Pushing wagons towards the hump (230+40 m with 1.2 m/s) Pushing over the hump
Hump operations	Pushing wagons towards the hump (230+40 m with 1.2 m/s) Pushing over the hump (32 wagons - 18 meters long and 1,2 m/s)
Classification	Coupling wagons and brakes (100 m/min + 10 s/wagon) Time for filling the brake system with air

Activity group	Activities
	Testing the brake system Refilling the brake systems after the test Brake test, hitting the brakes, controlling each wagon Releasing brakes Controlling that all brakes have been released Release buffer stops Activate brakes Time for driving the locomotive to the wagons and coupling it Releasing brakes Simple brake test Time for departure including path reservation Time for activating buffer stops, relays, reaction time
Train departure	Driving Uncoupling from the shunting locomotive Driving the shunting locomotive away Driving the train locomotive to wagons Coupling to the train locomotive Charging the brake pressure Simple brake tests Waiting for the signal Departing

Beside the everyday plans of yard workforce and their continuous monitoring (assessment of actual times and planned times), a number of data for controlling and tracking operational procedures comes from a variety of IT-Applications. The following tables give an overview over IT-Applications used for controlling and monitoring operational procedures.

Table 5 IT-Applications used at Mannheim MY and München-Nord MY (ARCC WP2, 2017)

IT-Application (Source of information)	Relevant Content	Owner
LeiDis – Leitsystem zur Netzdisposition	Pre-notification of incoming trains Monitoring of train runs	DB Netz

IT-Application (Source of information)	Relevant Content	Owner
	Causes of train delays	
TRACE – Train Control Europe	Overview of planned outgoing trains Timetable deviations of national and international train runs Overview of parked trains Overview of causes for train delays	DB Cargo
PVG – Produktionsverfahren Güterverkehr	Information about trains approaching the yard Administration of timetable and shipment information Train decomposition and wagon transfer/interchange Data interchange with the sequence control computer system of the hump Support of wagon inspection activities Information about wagons on tracks Treatment of outgoing trains	DB Cargo
TOM –Train Order Management	Planning of border-crossing special trains Cancellation and modification of international trains	DB Cargo
WIS – Wageninformationssystem	Wagon database	DB Cargo
IPL – Integriertes Planungssystem	Timetable of trains Trip plan for each wagon	DB Cargo
EDITH – Ereignisgesteuerte Personaldisposition im Transportbereich	Roster for yard staff Actual quantity taken for yard staff	DB Cargo
CDIF – Cargo-Disposition für Fahrzeuge	Operational schedule for locomotives	DB Cargo
Tf-Info – Triebfahrzeugführer-Informationssystem	Information about train driver assignment	DB Cargo

Table 6 IT-Applications used at Hallsberg MY (ARCC WP2, 2017)

IT-Application (Source of information)	Relevant Content	Owner

BRAVO – Bättre ResursAnvändning vagnstyrning Operativt	Client contracts and transport bookings Estimated departure and arrival times for booked transports Plans for all possibilities for transportation Wagon routes Wagon bookings on trains for each order Shipment and wagon information Wagon groups and ordering within trains Wagon disposition and control Planning of shunting activities Wagon Database Client alert system (delays, re-booking etc.) Trip plans for each wagon	Green Cargo AB
Körorder	Obtain train driving order	Trafikverket
Här och nu	Report that train is ready to depart (“K-rapport”) Monitoring train runs Report train delay causes	Trafikverket
Opera	Train composition Locomotive type Axle load	Trafikverket
GSM-MobiSIR and JIMO – Järnvägstjänster i mobiltelefonen	Radio system for communication Request access to train route	Trafikverket
Trainplan	Timetable planning	Trafikverket
Trafikbilder Ebicos 9000	Real time traffic information	Trafikverket
BP	Roster for train drivers and yard staff	Green Cargo AB
Loop	Simulation, optimization and tactical schedule for locomotives	Green Cargo AB
Platå	Operational schedule for locomotives and train drivers	Green Cargo AB
OP	Optimization and information about train driver assignment	Green Cargo AB

Increased digitalisation generates new data, which in turn can be used to automate processes and improve the decisions. The marshalling technology employed in Marshalling yards with humps varies depending on the importance of each yard and the traffic it serves.

Automatic and optimising decision support systems that can inform about the consequences of potential decisions are a good foundation for achieving enhanced yard capacity and efficiency and for the cooperation required at Marshalling yards.

Actually, many freight trains depart before their scheduled departure time and also plenty of trains depart after the scheduled time. This causes trains to run outside the planned timetable slots, and therefore many aspects of the transport have to be re-planned in the operational setting. As a consequence, there is a risk that the operational planning cannot be made in the same holistic planning perspective as the original tactical planning had been, leading to inefficient resource utilisation of infrastructure, vehicles and personnel. In particular, it occurs that when the freight trains approach the destination MY, this yard is not yet able to handle the arriving train due to limited arrival capacity. Then the freight train has to stop at some side track along the line, hindering other trains to use this side track, thus reducing the capacity of the rail line network.

4.5 CONCLUSIONS

The general analysis of processes and its required data exchange showed, that handling freight trains in MYs is a highly complex challenge, where various stakeholders participate in order to fulfil the customers' needs best way. The case studies Česká Třebová, München, Mannheim and Hallsberg showed, that already several IT systems support these processes and the concerned personnel. But these IT systems are specific to the country or even to the company. Each RU and/or IM has to develop its own IT assistance. Unfortunately, this has also to be stated for the data exchange protocols.

The next section looks at an alternative approach, applying standard interfaces and participating in sector specific groups and therefore utilizing available tools.

There is potential for further improvement through:

- Digitizing the data exchange by switching from manual to semi-automated processes,
- Making use of optimization tools for the whole MY management, not only for certain tasks,
- Closer cooperation between MY and IM of the surrounding network in order to dispose free capacity irrespective of planned slots.

5. STANDARDS AND TOOLS FOR DATA EXCHANGE IN RAIL

There are already some standards for data exchange of railway data and central tools for providing easy access to information. For the freight railway the TAF TSI have to be discussed and its tools for different stakeholders, namely RNE TIS for IM and RailData ISR for RU. In order to complete the picture of standard railway data formats, both railML and RailTopoModel shall not be missed.

5.1 TAF TSI

The purpose of the „Technical Specifications for Interoperability for Telematics Applications for Freight Subsystem of the rail system" TAF TSI (TAF TSI) is to ensure the efficient interchange of information by specifying the underlying technical framework. It covers applications for freight services, and management of freight connections with other modes of transport. TAF TSI is developed based on UIC leaflet 407, which sometimes is already used in old IT systems.

The TAF TSI covers (TAF TSI):

- Applications for freight services, including information systems, such as real-time monitoring of freight and trains;
- Marshalling and allocation systems, whereby train composition is meant;
- Reservation systems, whereby train path reservation is meant;
- Management of connections with other modes of transport and production of electronic accompanying documents.

For the TEN-T Corridors, the focus is on transparent and accessible information provision around path allocation and traffic management, thus achieving higher flexibility and increased capacity. This is realised by XML-messages that covers data concerning the following functions (Table 7):

Table 7 Categories of TAF TSI functions

RU only functions	Joint RU and IM functions
Consignment Note Data	Common Interface
Wagon & Intermodal Operating Unit Data	Reference Files
Wagon Movement	Train Running Information and Train Delay Cause
Shipment ETA	Train Forecast
	Service Disruption
	Train Enquiries
	Train Preparation
	Infrastructure Restriction Notice
	Ad hoc Path Request
	Train Transport Identifier

More specifiable the benefits of TAF TSI are:

- Simplifying the train/cargo handover processes. Simplified, seamless data exchange, i.e. simplified data handover, implies also an easier train or cargo handover. Through its unique representation and interpretation, the receiving side instantly recognizes the data, and therefore also the train or cargo may be accepted without unnecessary delay.
- Opening competition among Information and Communications Technology (ICT) vendors means also pushing down the prices of ICT. As the data exchange is not driven by proprietary, closed standards anymore (which are often hard to get documented from the original vendor), the new ICT systems and components may be purchased from an arbitrary vendor, only on the condition of the standards implementation.
- Shortening the handover and/or dwell times of the trains means less idle times and lower losses on dwell for the RU or operator (more efficient usage of train paths, vehicles, staff etc., and therefore increasing capacity and reducing costs).
- That way a better utilisation of the vehicles and other resources is achieved, which leads again to increased capacity and higher cost efficiency and pushing the prices for the end customer down.

Some of the XML data exchange formats are widely used, important for MY operation and therefore presented in more detail.

5.1.1 Consignment Note data

In fact, this message is called “Consignment Order message”. As shown in Figure 14, this message contains detailed information about the newly built freight train from the LRU perspective providing contacts, responsibilities, customs info, and handling orders, targeting at the wagon level.

It is a message, which is basically not transmitted from or to a MY. But in the context of combined terminals with MYs, it may be circulated from the terminal point of view, where trains are assembled and go on the journey.

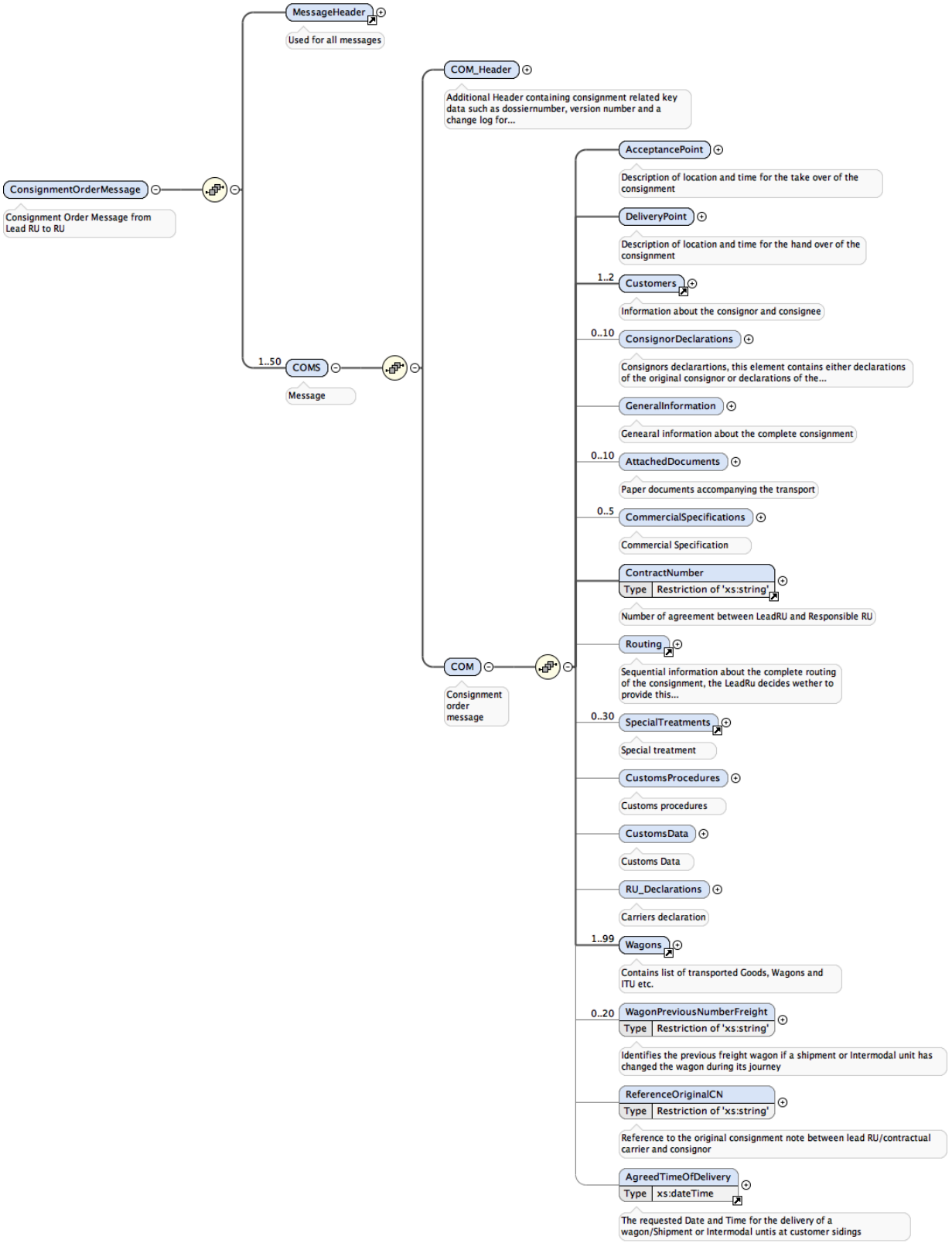


Figure 14 Overview over TAF TSI Consignment Order Message

5.1.2 Path request

In order to send a train along a certain line, it requires a path from the IM. This may be done by long-term planned, pre-booked paths, e.g. via “One Stop Shop” or in sections directly from each IM. On the other hand, a path may be requested ad-hoc, as sometimes done by MYs for outgoing trains.

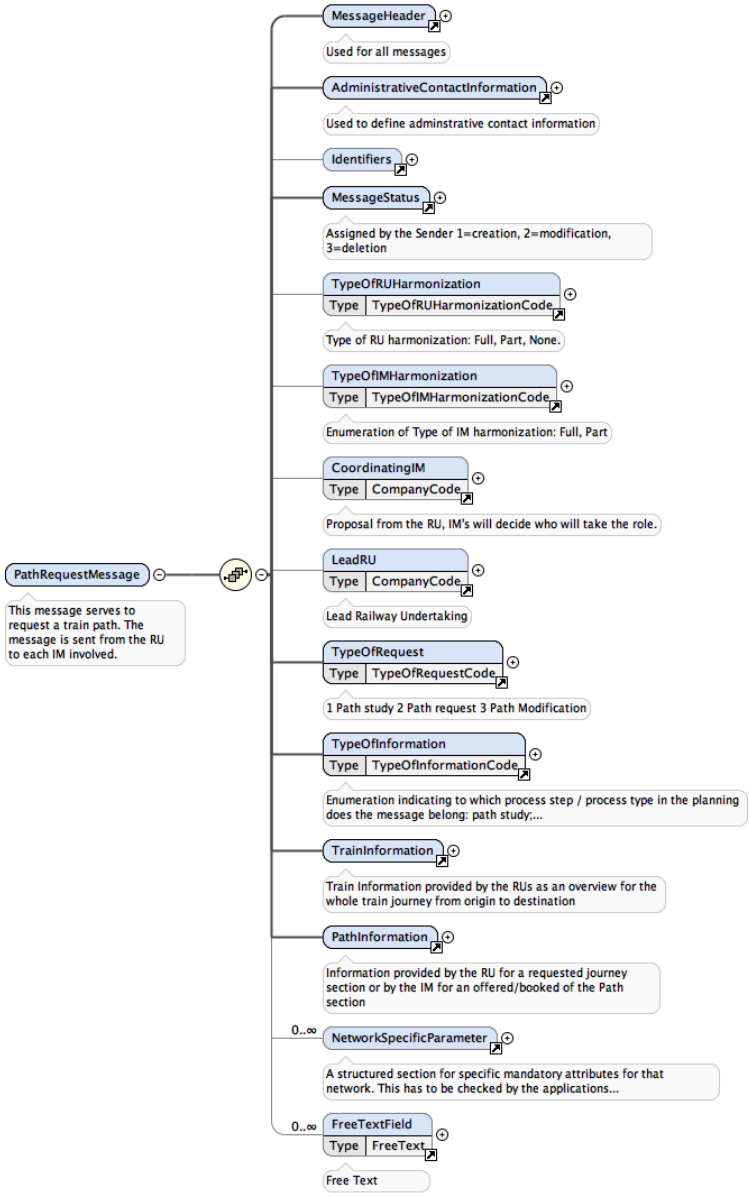


Figure 15 Overview over TAF TSI Path Request Message

5.1.3 Train preparation

Train preparation covers the train composition and train departure procedure. Both messages are of high importance for MYs. The train composition message (see also Figure 16) gives details about handling requirements at the wagons level. It shall be provided by the lead RU to the „MY-RU“.

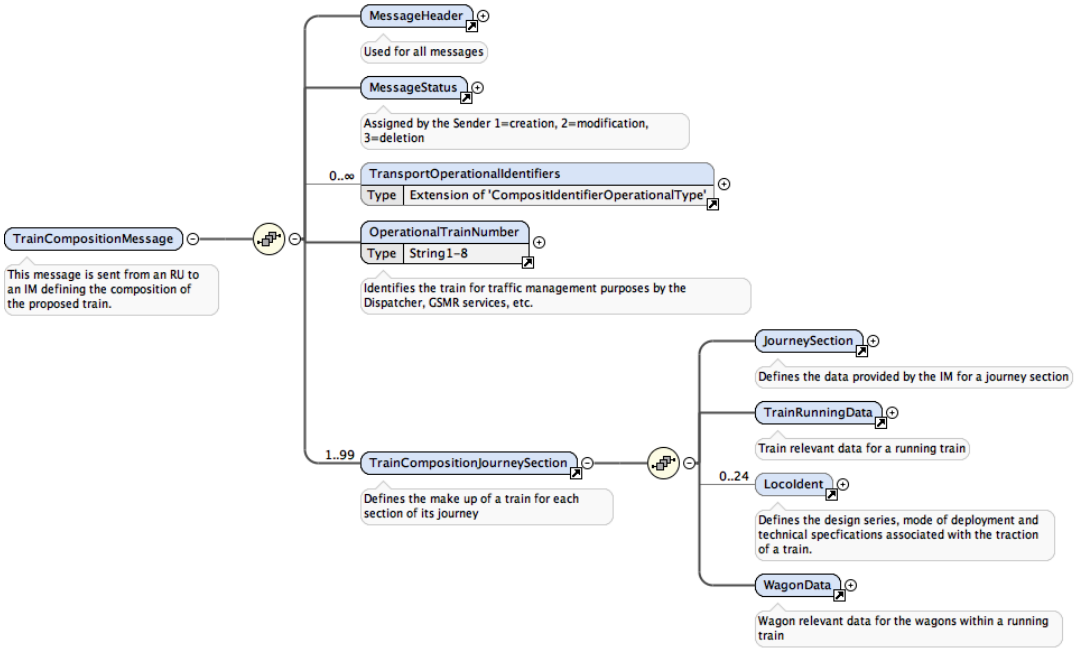


Figure 16 Overview over TAF TSI Train Composition Message

On the other hand, the train ready message (see also Figure 17) enables the IM to optimize the infrastructure capacity based on actual requirements. If there is not used capacity, a freight train may earlier leave the MY compared to its planned path, naturally only if it is earlier ready to depart.

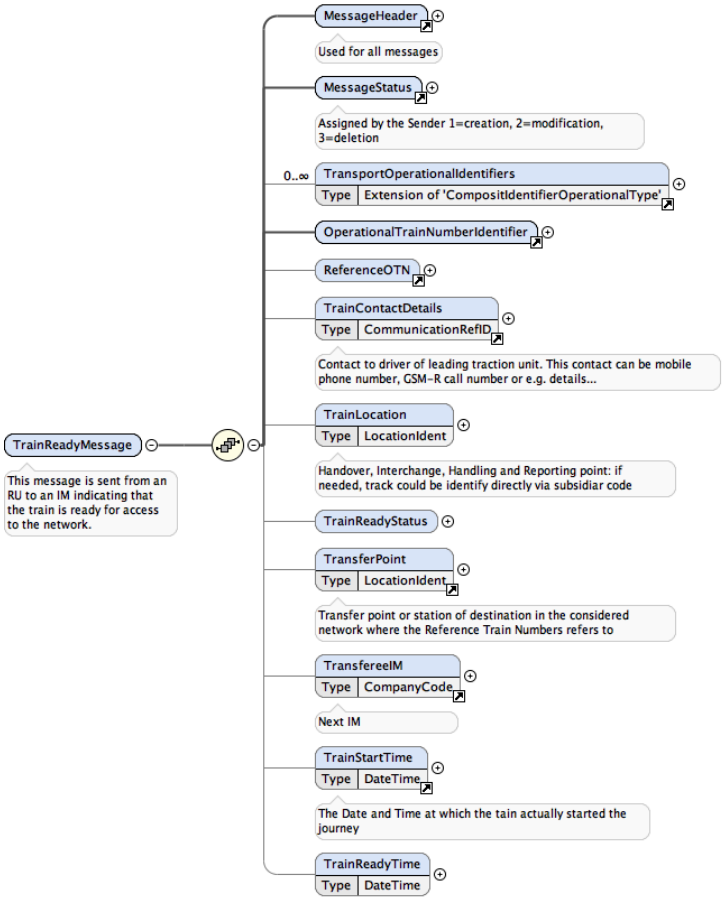


Figure 17 Overview over TAF TSI Train Ready Message

5.1.4 Train Running Forecast

The train running forecast encompasses the train running forecast message (see also Figure 18), the train running information message and the train delay cause message (see also Figure 19). This message bundle is of certain importance, as the MY early needs reliable information about the freight train arrival at the entry signal. It is issued by the IM to the RU, which booked the currently used path, and neighbouring involved IMs upon:

- Departure from departure point, arrival at destination,
- Arrival and departure at handover points, interchange points and at agreed reporting points based on contract (e.g. handling points).

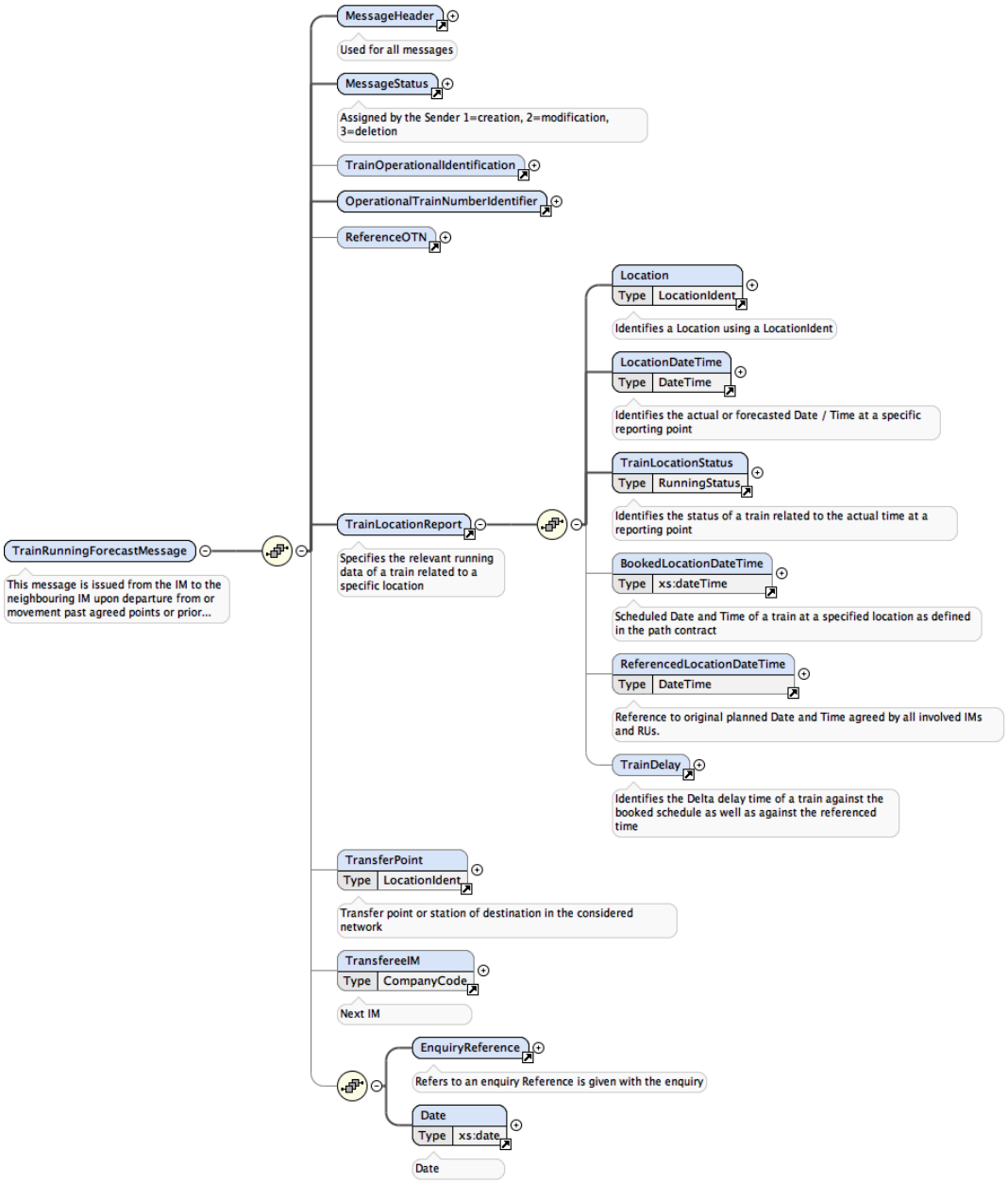


Figure 18 Overview over TAF TSI Train Running Forecast Message

Both messages, Train Running Forecast Message and Train Running Information Message contain basically the same data. They differ in its application between the various stakeholders, i.e. neighbouring IMs and concerned RUs.

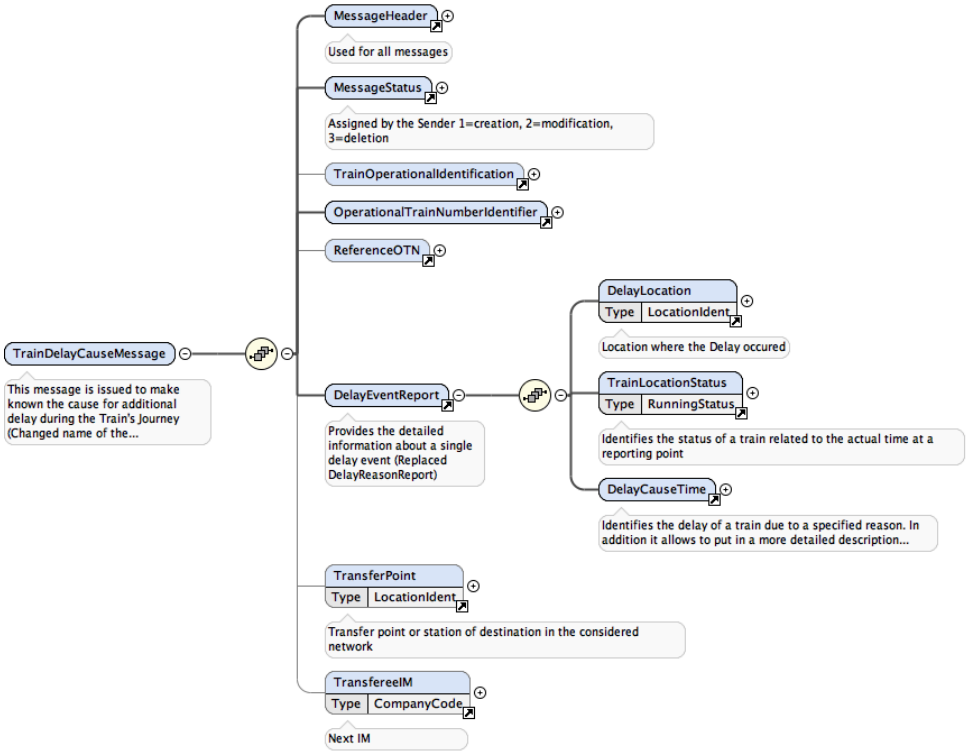


Figure 19 Overview over TAF TSI Train Delay Cause Message

5.1.5 Shipment ETI/ETA

The Shipment ETI/ETA message (see also Figure 20) may be used between RUs in order to inform about the predicted state of the operated wagons. Each concerned RU may get these data from the previous RU, deploys its own calculations on top of it and delivers the updated ETI to the next RU. The last RU sends its calculated ETA to the lead RU, which in turn may inform the customer.

The “MY-RU” may be informed about the predicted arrival of a wagon or wagon group at its entry signal as part of the RU chain independently from IM messages (train running forecast message). It may guess, in which train the wagon or wagon group is transported.

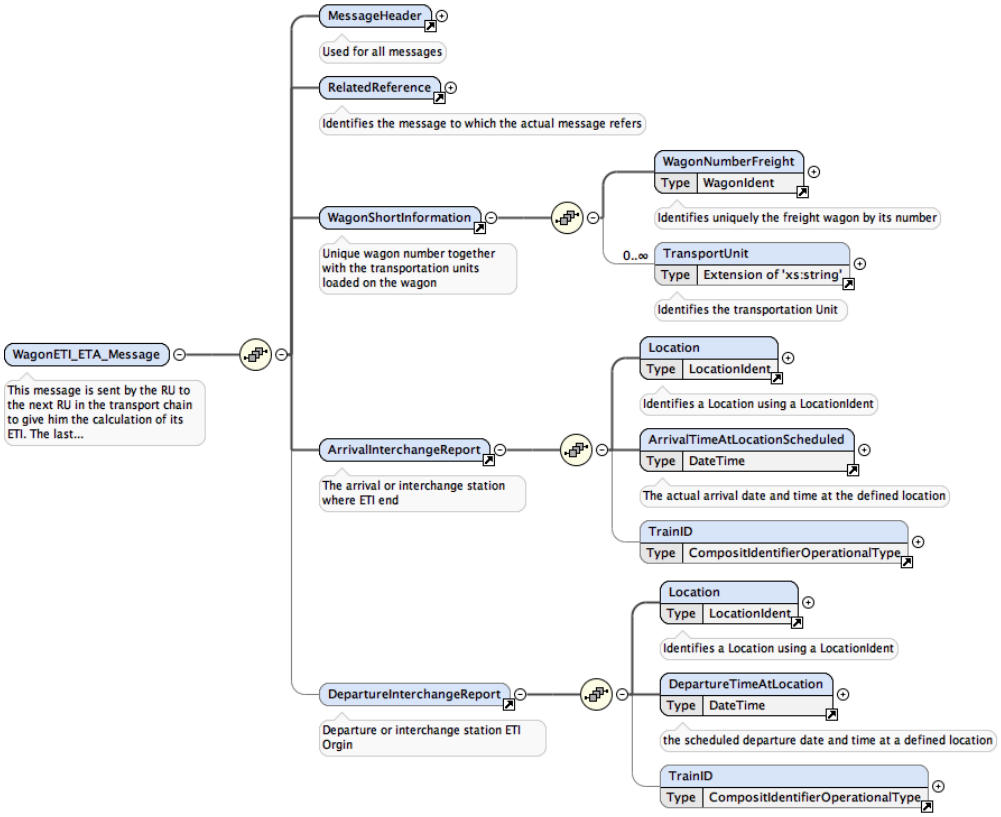


Figure 20 Overview over TAF TSI Wagon ETI/ETA Message

5.1.6 Wagon Movement

The Wagon Movement message bundle may be used to send information about the current wagon status from the current RU to the lead RU and from the lead RU to the customer. The following kinds of wagon movement information are pre-defined:

- Wagon Release notice
- Wagon Departure notice
- Wagon Yard arrival (similar to the Wagon Yard departure message)
- Wagon Yard departure (see also Figure 21)
- Wagon Exceptions message
- Wagon Arrival notice
- Wagon Delivery notice
- Wagon Interchange reporting

This message may be a basis for ETI calculation, but does not bring any new reliable information about freight train arrival or departure. In case of freight train arrival or departure this message shall be deployed for each wagon of the train to the responsible RU.

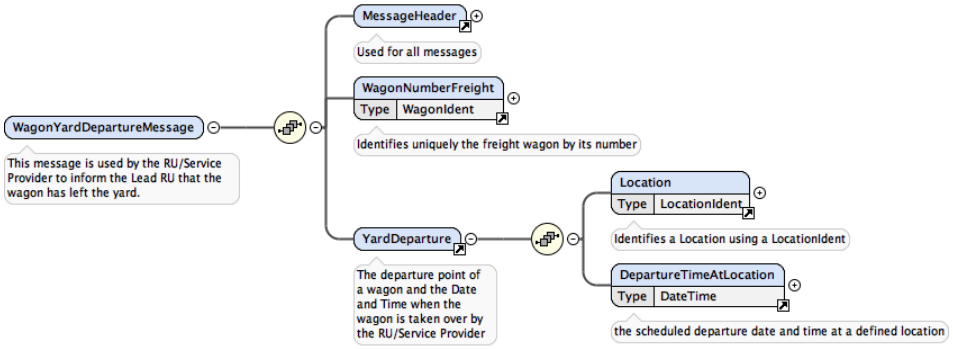


Figure 21 Overview over TAF TSI Wagon Yard Departure Message

5.1.7 Main Reference Data

TAF TSI describes various reference databases, which support the creation of TAF TSI messages.

The keeper of a rolling stock is responsible for the storage of the rolling stock data within a *Rolling Stock Reference Database*, which contains:

- Identification of rolling stock,
- Assessment of the compatibility with the infrastructure,
- Assessment of relevant loading characteristics,
- Brake relevant characteristics,
- Maintenance data,
- Environmental characteristics.

The *Rolling Stock Operational Data* provide the data representing the actual status of the rolling stock. This data shall include temporary data, such as restrictions, current and projected maintenance actions, km and fault counters, etc.; and all data that could be considered as 'status', e.g. temporary speed restrictions, brake isolated, needs for repair and fault description.

The *Wagon and Intermodal Unit Operational Database* (WIMO) is the most important one for the tracking of wagons and therefore for the communication between the RUs involved and the LRU. This database shows the movement of a wagon and of an Intermodal unit from departure through to final delivery at customer sidings with ETIs and actual times at different locations until the final delivery time ETA. The database also shows the different status of the rolling stock such as:

- Loading of the rolling stock, message from RU to IMs, and to other RUs involved,
- Loaded wagon on journey, message from IM to RU, and to other IMs and RUs involved,
- Empty wagon on journey, message from IM to RU, and to other IMs and RUs involved,
- Unloading of rolling stock, message from RU at destination to LRU,
- Empty wagon under fleet management control, required to get the information about availability of a vehicle of defined characteristics.

The *Wagon Trip Plans* must be stored by each LRU in a database.

5.1.8 Networking, Communication and General Facts

The TAF TSI data exchange is based on a common Information Exchange Architecture. A Common Interface has to be able to handle (TAF TSI):

- Message formatting of outgoing messages according to the metadata,
- Signing and encryption of outgoing messages,
- Addressing of the outgoing messages,
- Authenticity verification of the incoming messages,
- Decryption of incoming messages,
- Conformity checks of incoming messages according to metadata,
- Handling the single common access to various databases.

The Common Interface works like a transformer, which allows keeping national data and/or databases connected to national software tools, but to transfer standardized messages to the Central Repository.

TAF TSI states, that “other existing standards may be used for the same purpose if there is a specific agreement between the parties involved to allow the use of these standards in particular on the territories of EU Member States having a border with third countries.” Therefore, it may be worth to take a look at railML and RailTopoModel rather than to other national solutions.

The application of optional messages and optional data elements must be part of a contractual agreement between the involved parties.

TAF TSI does not cover the following topics:

- Payment and invoicing systems for customers or between various service providers such as RUs or IMs
- Long term planning of the timetables
- No direct data transmission from the subsystem TAF TSI into the train, to the driver or to parts of the Control Command and Signalling subsystem
- The physical transmission network is a completely different one from the network used by the Command Control and Signalling subsystem

TAF TSI messages already support a wide variety of data exchange needs for processes in the freight rail sector. Each message consists of obligatory and optional information, what enables a flexible usage within different national IT systems but on the other hand secures a reliable data exchange.

5.2 RAILML

railML is a data exchange format developed by a consortium of railway companies, academic institutions and consultancy firms. Formed in 2002, the railML.org project aims to continuously develop this format in order to facilitate its use in a wide range of railway applications. This analysis is partly based on (C4R WP3, 2015).

The project started as a partnership between the Fraunhofer Institute for Transportation Systems and infrastructure and the Swiss Federal Institute of Technology’s Institute for Transportation Planning and Systems (Nash, Huerlimann, Schütte, & Krauss, 2004), and is currently coordinated by a small independent

team. railML.org conferences are held twice a year and supplemented by specialized working group meetings. At time of writing the officially published versions of railML are 2.3 and 3.1beta. (railML.org, 2018)

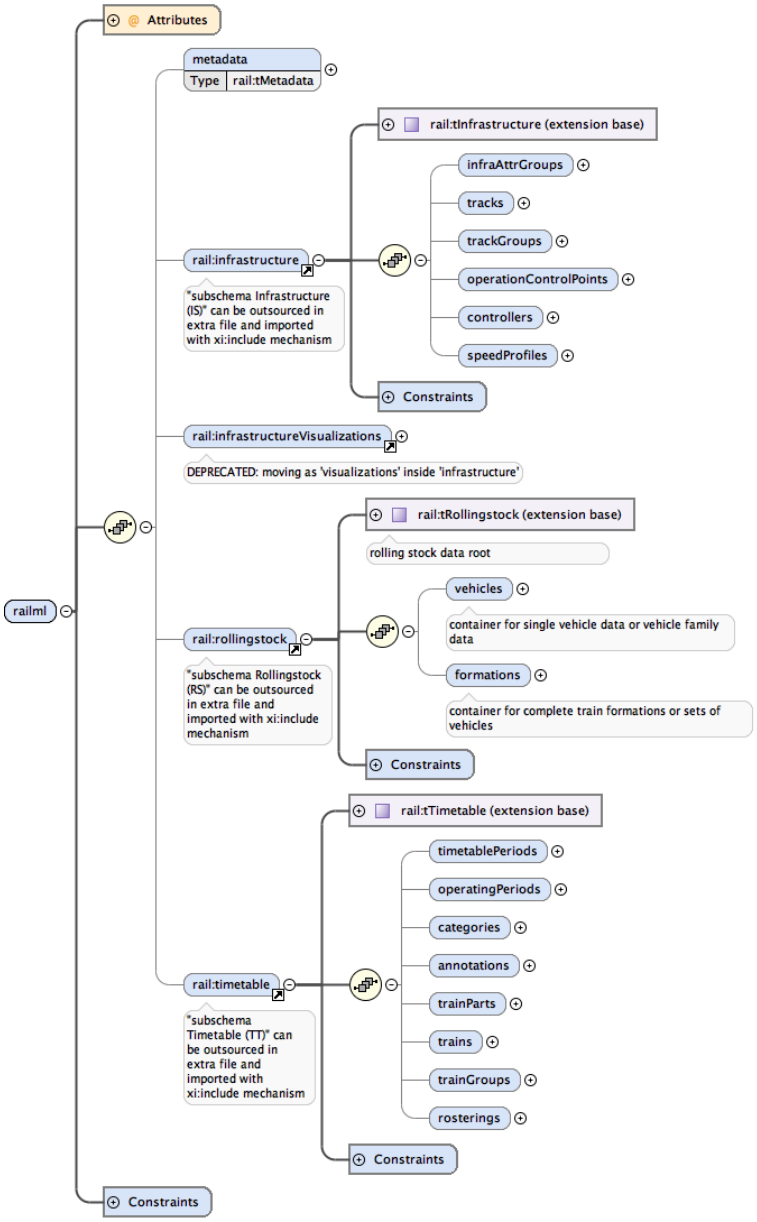


Figure 22 Overview of railML basic elements

railML is published as a series of XML schemas holding subschemas, each of which encompasses a particular field of railway application:

- Common concepts and objects (sometimes not mentioned separately);
- Timetable (TT);
- Rolling stock (RS);
- Infrastructure (IS), both macroscopic and microscopic;
- Interlocking, from railML 3 on.

5.2.1 Common schema

The common schema allows the definition of metadata using the well-known Dublin Core vocabulary, e.g. information about the application, which generated the data set. Furthermore, author, date, identifier, and 'other' miscellaneous information may be given.

5.2.2 Timetable (TT) schema

The timetable schema supports various operational concepts, amongst others the coupling of trains. The rolling stock for a timetable has to be defined in the RS schema. All levels of granularity are supported by the same TT concept, allowing at minimum a name for the train material as well as defining a detailed combination of locomotives and wagons with track effort curves and seat places. This enables both passenger and freight transport services to be defined according to the same schema.

Time restrictions may be defined in a flexible way enabling both fixed and on-demand services. Cascading restrictions allow for general time periods for the whole timetable, further constrained at regular service level. Pre-defining holiday periods enables flexible pre- and post-holiday services that are required by freight trains engaged in multi-day journeys via closed terminals on those special days.

The TT schema is based on a railway infrastructure defined within the IS schema. At minimum operational points have to be provided, e.g. declaring its name. If more information is available, lines with mileages link those operational points. At the most detailed level, a fine-grained microscopic track network at switch level is offered. All those usage models are supported by the same timetable concept containing placeholders for detailed IS references if they are available.

5.2.3 Infrastructure (IS) schema

The infrastructure schema defines properties and structures for railway facilities. Key concepts are:

- Network topology with operational points and lines ('macroscopic' graph in railML);
- Track topology with switches, crossings and track sections ('microscopic' node and edge);
- Operation and control elements, such as signal, balise, axle counter, level crossing;
- Civil engineering structure, e.g. bridges, tunnels;
- Track capability in form of 'change point', e.g. line speeds, gradients, presence and kind of electrification;
- Further concepts to model infrastructure visualisation at simulator software.

railML 2.3 is intended to define macroscopic graphs the same way as microscopic nodes and edges. This concept built a robust foundation for a long time, where an infrastructure model is exchanged along with an appropriate timetable.

Since railway asset management moves into the focus of railML infrastructure development, the approach had to be changed in order to save both microscopic and macroscopic infrastructure data tightly coupled within one file. This movement is based on the platform-independent RailTopoModel and leads to railML 3 in form of XSDs for real XML file exchange.

5.2.4 Rolling stock (RS) schema

The rolling stock schema allows the representation of locomotives, multiple units, and passenger and freight wagons at various levels of detail. Factors such as propulsion type, braking ability, and mechanical

traction losses can also be captured along with many other attributes allowing trains to be physically modelled in great detail.

As a basic concept, each rolling stock unit that may be coupled outside of a workshop is defined as a single 'vehicle' or as instance of a vehicle family. A composition of 'vehicles' is called a 'formation' – best known as a 'train'. But in the railML context a 'train' is used for the timetabling perspective. The 'formation' is referred from within the timetable for each 'train'.

5.3 RAILTOPOMODEL

The RailTopoModel is being pushed by the UIC (International Union of Railways) in cooperation with the railML® consortium as a base topological model for railway infrastructure. railML 3 shall provide a reference implementation for RailTopoModel through an XSD schema enabling a standard data exchange. (DLR Institute of Transportation Systems; UIC ERIM working group;, 2017)

Many operational data formats for railways are legally mandated, e.g. RINF or INSPIRE. The design of each format primarily focuses on its specific requirements, with INSPIRE targeting mesoscopic data and RINF used for the more detailed microscopic data. Nevertheless, any data format requires qualified topological data for railway networks.

The model will help the railway sector to become a more competitive market, with the fast and efficient exchange of data between companies, their industrial suppliers, and railway regulation bodies and other authorities (UIC ERIM working group, 2014). Figure 23 illustrates this new situation.

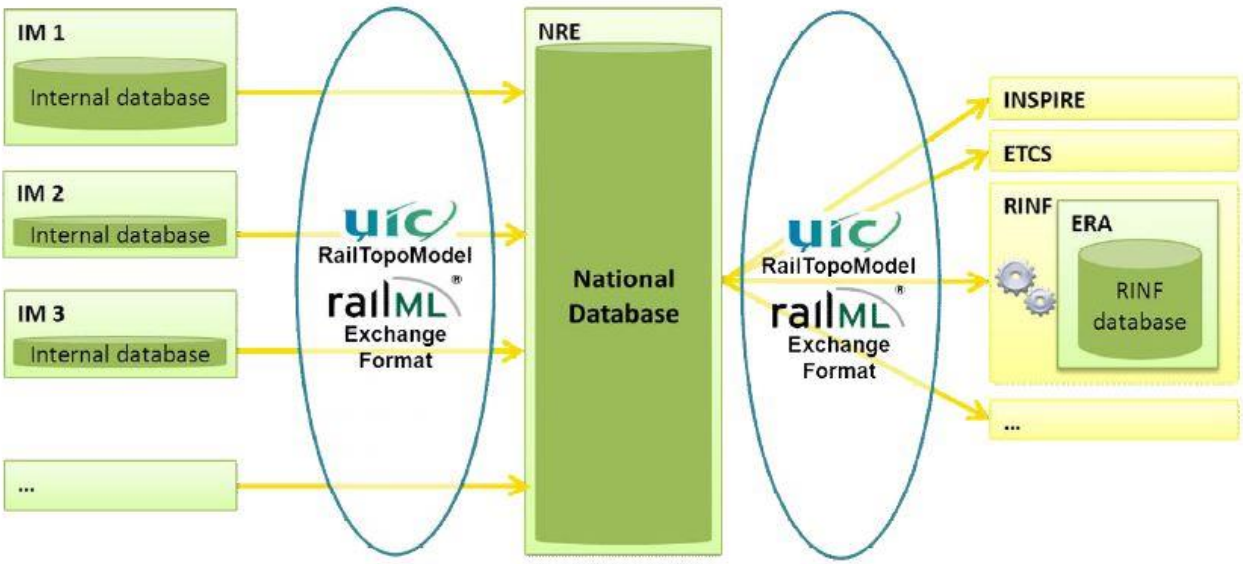


Figure 23 Ideal national situation with RailTopoModel and railML (DLR Institute of Transportation Systems; UIC ERIM working group;, 2017)

The RailTopoModel guarantees the ability to aggregate from the microscopic through mesoscopic up to macroscopic infrastructure data. These granularities may be flexibly combined with each other in one data set, offering flexible data handling for simulations based on detailed microscopic data in stations and less detailed macroscopic data on lines. (Gély, Dessagne, Pesneau, & Vanderbeck, 2010) This general concept may also be used for filling gaps with less detailed open data from different sources in case of missing detailed IM data.

5.4 TRAIN INFORMATION SYSTEM (TIS)

The RNE tool Train Information System (TIS) is a web-based application that supports international train management by delivering real-time train data concerning international passenger and freight trains. The

relevant data is obtained directly from the IMs' systems. This section is mainly based on (RNE, 2016), (RNE, 2018), (RNE, 2018).

The application was developed and taken over by RNE in 2007. Thanks to a basic refurbishment carried out in 2012, many user requests could be satisfied. The application is continuously being developed, based on business cases and feedback from the user community.

The system is already fully TAF/TAP TSI-compliant and currently processes around 1,6 million trains per year. Ca. 163 million TAF TSI messages (see also section 5.1) are exchanged per year. (Varga, 2018)

Several ongoing projects depend on TIS, i.e.

- European Performance Regime (EPR) – analysis of delays and their causes;
- International Rail Transport Committee (CIT) – refunding of passenger tickets – information about delays of international passenger trains.

TIS offers its users (RUs, IMs and RFCs) functions supporting Train Management and Train Performance Management, such as:

- Train Monitoring
- Data Exchange
- Reporting
- Traffic Management

5.4.1 Train Monitoring

This real-time information system is available for desktops and tablets through standard web browsers via public Internet. Train traffic information is visualised in the TIS graphical interface. Amongst others TIS comprises:

- Contracted timetable,
- Forecast,
- Running advice,
- Delays,
- Network overview,
- Space-time diagrams,
- Train run reports.

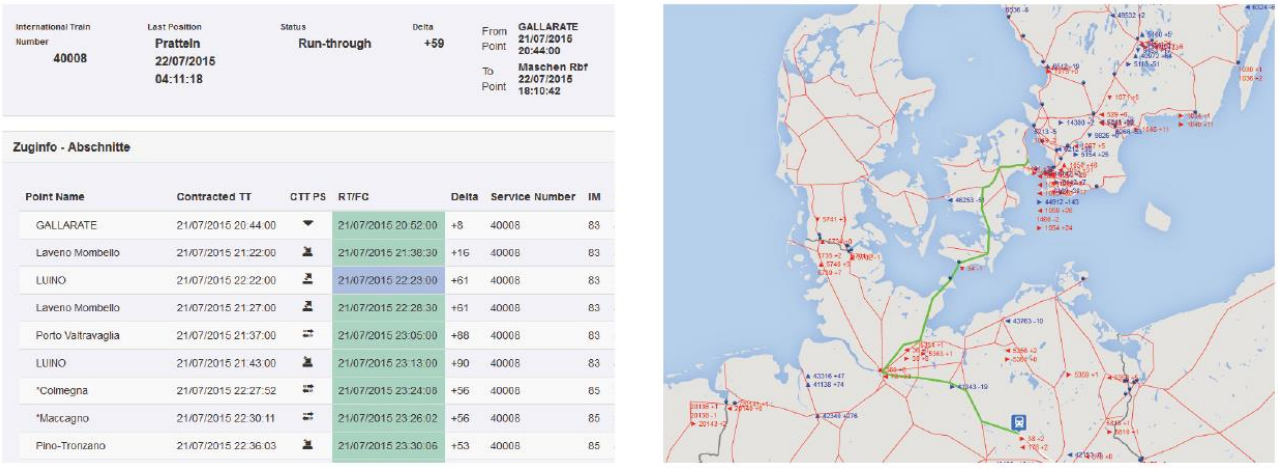


Figure 24 Screenshots of Train Monitoring in TIS (RNE, 2018)

In order to offer this service, TIS provides a platform for collection and exchange of railway traffic data from/with European traffic management systems.

TIS enables through these functions:

- Optimisation of train disposition,
- Optimisation of resource allocation, i.e. time, financial means, rolling stock, staff
- Steering of the logistical chain

5.4.2 Data exchange

This function deals with the raw data exchange based on TAF/TAP TSI messages between IMs and RUs. Large and internationally oriented RUs, such as SBB Cargo International, BLS Cargo, DB Schenker Rail, Eurostar have adopted this TIS interface. It served as TAF TSI pilot for the Common Interface (CI), means message exchange via CI. By sending messages to TIS, you can check if your messages have been correctly implemented in your legacy systems.

This TIS interface provides filtering functions to select the required information based on:

- Company, IM and/or RU;
- Mutual agreements between companies involved in the train run;
- Functional criteria, i.e. points, incoming trains, outgoing trains, delayed trains.

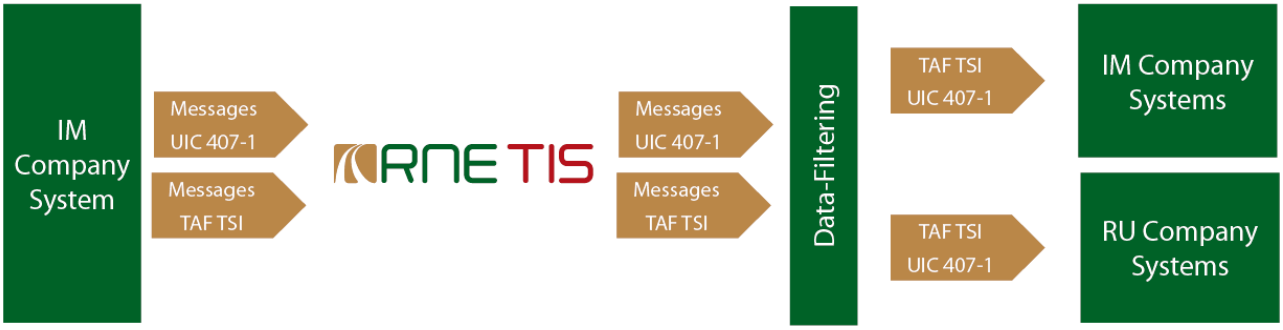


Figure 25 Overview over general data Flow with TIS (RNE, 2018)

5.4.3 Reporting

TIS reporting function is based on Oracle Business Intelligence (BI). It offers predefined and customizable reports and graphs, i.e. punctuality, delay causes. It serves as information source for international Train Performance Management (TPM).

TIS enables through these functions:

- Analysis of performance
- Identification of areas with bottlenecks, i.e. capacity problems or technical problems on networks
- Identification of appropriate corrective actions and feedback on their effectiveness
- Provision of statistical information about international traffic for management decisions

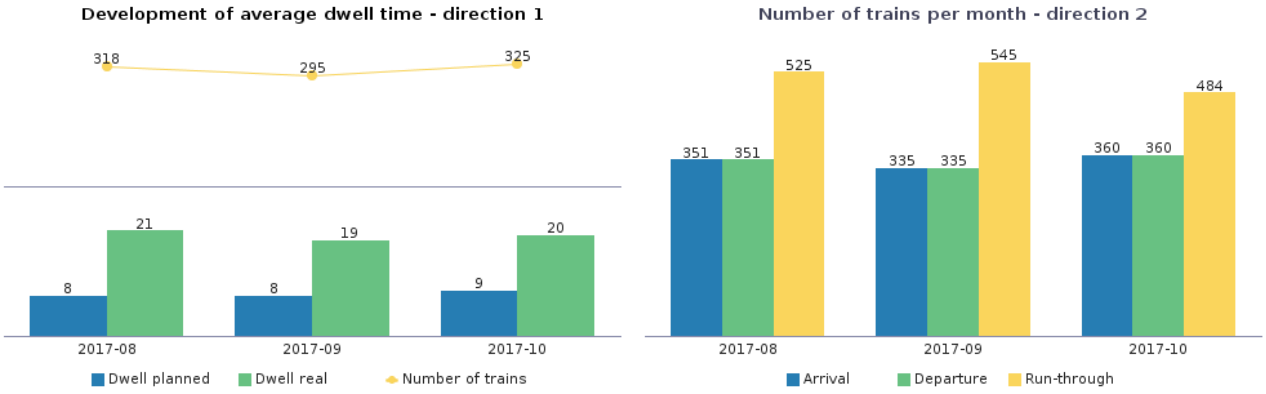


Figure 26 Screenshot of Reporting in TIS (RNE, 2018)

5.4.4 Traffic Management

Train Performance Management (TPM) including Performance Regimes enables scheduling of reports and graphs execution for both predefined and customizable reports and graphs. These functions are accessible online to defined users in a flexible and user-friendly application, which is based on Oracle Business Intelligence. Therefor it provides trustworthy information for international quality analysis for corridor-oriented train performance.

The TCCCom (Traffic Control Centre communication) serves as a babel fish by translating messages from a list of predefined messages into the recipient's language, where the tool runs in the browser.

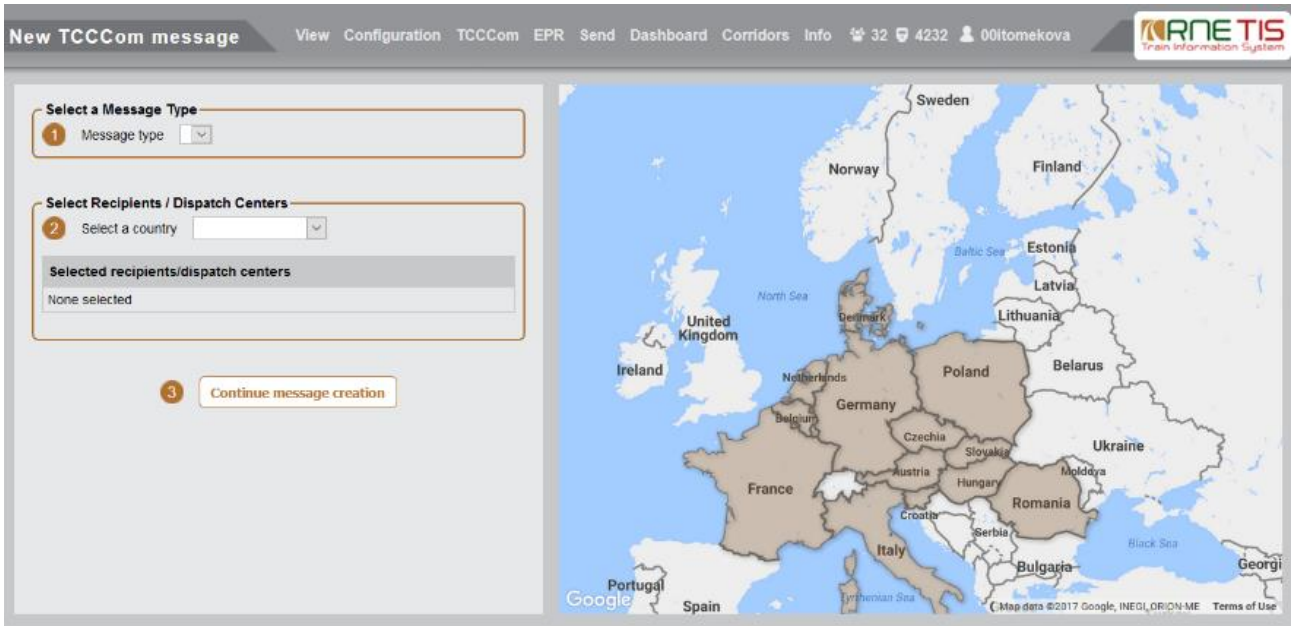


Figure 27 Screenshot of TCCCom interface in TIS (RNE, 2018)

The Park or Run tool is used to facilitate the dispatching of freight trains in case of capacity restrictions between multiple dispatching centres. It provides the following features:

- Automatic identification of trains and automatic notification of players affected by an interruption;
- Overview of all recorded interruptions and their impact, i.e. number of affected trains, number of trains to be parked, number of parked trains, location and time of parking;
- User-specific interactive list of affected trains, which serves as a communication tool regarding the treatment of affected trains;
- Tool and also e-mail notification available in the language chosen by the user;
- Optimising the usage of path capacity and resources, i.e. locomotives, drivers;
- Minimising the track occupation times in bottlenecks and speeding up border processes.

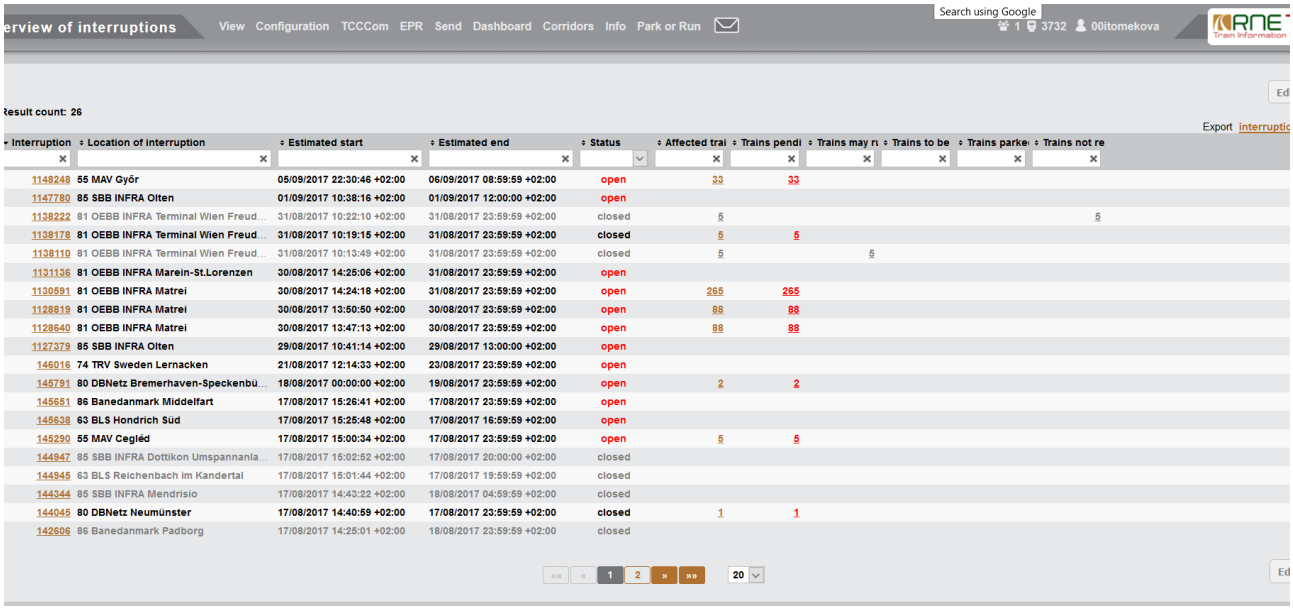


Figure 28 Screenshot of Park or Ride tool in TIS (RNE, 2018)

The Rail Sector is already exchanging several million messages within the TAF/TAP TSI framework every month. TIS is a strong sales argument towards RU's customers: 'The RU knows the position of the train'. The TIS is a very important tool for freight trains and shall play a central role in the recommendations for both case studies in the OptiYard project, Česká Třebová and Trieste Campo Marzio.

5.5 PATH COORDINATION SYSTEM (PCS)

The RNE tool Path Coordination System (PCS) is an international path request coordination system for path applicants, e.g. RUs, IMs and Allocation Bodies (ABs). This section is based on (RNE, 2018) and (RNE, 2018).

The internet-based application optimises international path coordination by ensuring that path requests and path offers are made in a harmonised way by all involved parties. Input for international path requests needs to be placed only once into one system – either into the domestic application or directly into PCS.

RFCs are responsible for pre-arranged paths (PaP) publication on their corridors at X-11 for the annual timetable. Minor corrections could be done on the capacity offer until X-10.5. For Late Path Request, RUs can use the remaining capacity from the annual process or the new capacity that is published by the RFCs at X-7.5. At X-2 each RFC publishes their reserved capacity for interim requests and some of them publish even real short-term capacity.

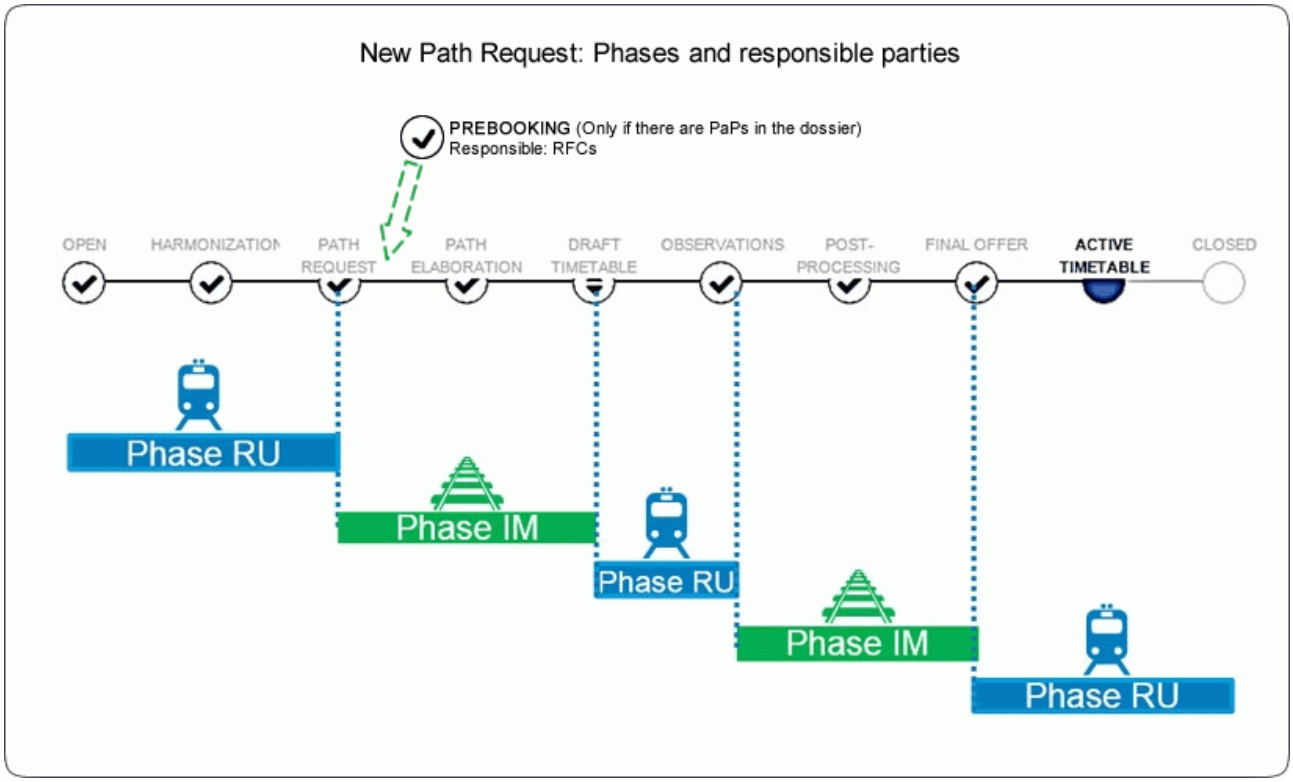


Figure 29 Simplified timeline for path booking with PCS (RNE, 2018)

PCS supports various process types for dossiers (path requests). They are defined in order not to mix up the terms with the rest of the dossier types. PCS processes differ to what purpose they serve. There are supported 3 processes for RUs for placing real path requests:

- New Path Request
- Late Path Request
- Ad hoc Path Request with some options:
    - Fully Harmonized
    - Partially Harmonized
    - With pre-accepted offer

There is one more process for checking the feasibility of ideas and aims of RUs (Feasibility Study). Two further processes serve as a possibility for updating of an agreed path, either from RU side (Path Modification) or IM side (Path Alteration). The last two processes (Catalogue and Pre-arranged Path) are for IMs and C-OSS (Corridor OSS on RFCs) only. They allow them to prepare their offered paths for RUs.

According to Mickael Varga (Varga, 2018), PCS exchanges about 2600 path dossiers in TAF TSI messages per year.

The PCS shall be recommended for the OptiYard case studies, Česká Třebová and Trieste Campo Marzio. From the real-time data exchange point of view, this tool does not play any role.

5.6 International Service Reliability (ISR)

The International Service Reliability (ISR) is an information system developed and operated by RailData. It offers to RUs a central platform for concentration and exchange of information about movements of freight

wagons in international traffic based on events reported by RUs' operational systems and partly by RNE's TIS (see also section 5.4). It makes possible to track both loaded and empty freight wagons and consignments across significant part of Europe.

This section is mainly based on (RailData, 2018).

Besides basic information about actual status and position of the wagons, ISR also offers additional information services:

- Records and shows the wagon movement history (for about 2 months),
- Estimates time of arrival based on experience of same past transports,
- Calculates estimated wagon mileage (km done) based on different sources,
- Integrates transport descriptions from commercial systems (from ORFEUS),
- Monitors wagons during the train run (using train movement information from TIS),
- Offers manual input of information (community cloud for data capturing).

The RailData members use the ISR data for several purposes, mainly for:

- Customer information,
- Wagon Tracking,
- Trip Analysis,
- Transport tracking (as forwarding, transit or destination RU),
- Wagon Usage Planning,
- Wagon performance measurement (estimated km done),
- Single wagon performance analysis (via Xrail, http://www.xrail.eu/).

5.6.1 Basic ISR functions

Information systems of connected RUs monitor wagons in their own trains and send movement information to the central ISR message broker. In opposite direction they may receive (and process) movement information from other ISR members, forwarded by the central message broker (CDS).

Central message broker ensures reception of messages, their validation, storage as well as format conversion and distribution. All data like the wagon movement events and the transport descriptions are stored in the central ISR database for the transport duration.

The ISR website allows to search in the stored data and to display different views on them. It enables for queries on wagons with many different query parameters, e.g. wagon numbers, consignment numbers, train numbers, countries/stations of origin and destination, dates. Due to strict filtering rules, RUs can access the ISR database, depending on their role within the transport. The relationship with the customers remains within each RU.

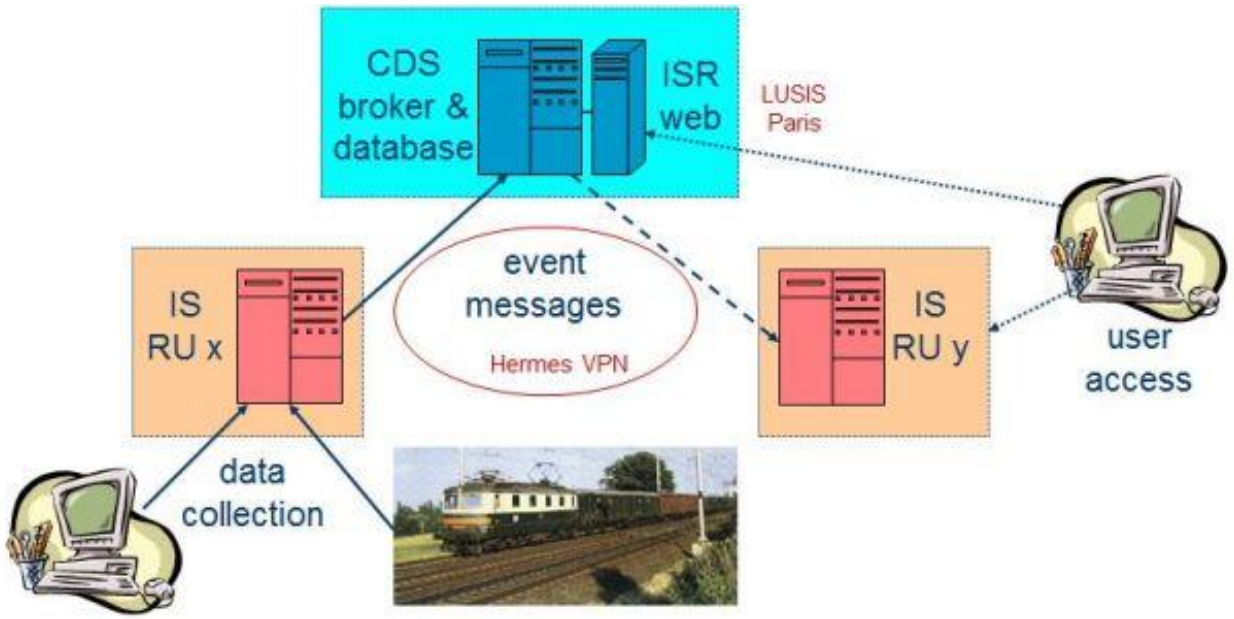


Figure 30 Overview over ISR architecture (RailData, 2018)

Member RUs can report to the ISR the following wagon event types:

- NoteCreated - consignment note completed (event reported directly, currently exchanged events are as near to the reality as possible depending on the ability of the production system of each RU)
- ReadyToPull - wagon can be pulled from customer
- Pulled - wagon pulled from customer
- LeftOrigin - wagon departed from shipping station
- Arrival - wagon arrived to intermediate station (typically MY)
- Departure - wagon left from intermediate station
- PassedThrough - wagon went through a station with train without stop or processing
- HandOverAdvice - planned border crossing (event reported via copy of H30 Train Pre-Announce)
- HandedOver - wagon given by the previous carrier to the next one
- TakenOver - wagon taken over (accepted) by the next carrier
- WagonRefused - wagon rejected by the next carrier, to be returned to previous one
- WagonDamaged - technical problem occurred on the wagon, is out of service
- WagonRepaired - wagon is restored, it can go again
- ReachedDestination - wagon arrived to destination station
- Delivered - wagon / goods is delivered to the customer
- FreeForDisposition - wagon is unloaded and ready for disposition

However, most of the national information systems are able send and receive only some (larger or smaller subset) of the event types and no member provides all event types yet.

5.6.2 Enhanced ISR functions

A subset of the *consignment note data* is taken over from ORFEUS (see also section 5.7) to match the events to a Transport Description (TD). TDs allow matching movement events belonging to one transport together. TDs can be created, updated or deleted via ORFEUS reporting. Another method for TD delivery is the WSM message with type NoteCreated.

After a transport has finished, a part of the TD as well as the first and last event is used to create an *Experienced Transport Plan* (ETP). So for new transports running under the same conditions (same origin, destination, and departure weekday) the expected last event as well as any deviations can be displayed.

ISR is also the main information source for the Xrail application, which calculates *Estimated Latest Times of arrival* (ELTA's) based on trip plans for specific relations. Xrail can also send ELTA to ISR to be forwarded to relevant RUs.

Few member RUs *calculate mileage* with their own tool and send results to ISR. For others, ISR calculates estimated distance ran by the wagon. ISR therefore uses and maintains a set of reference tables, e.g. production stations, DIUM stations, border crossing points, handover points. ISR can send the calculation results to interested members for their wagons using the WSM message in version 5.

RUs provide wagon movement events for ISR, but these events happen mostly in stations where the wagon start or terminate the transport or is taken- or handed-over from/to other partners. That means that after departure of a wagon in a long distance train there could be a long period without any information. To better the situation for wagon monitoring, RailData has realised *Running Train Information System* (RTIS).

RTIS provides an advanced wagon tracking based on the real time position and deviation from the timetable of the related border crossing trains while running. This feature has been realised thanks to a specific integration between the TIS run by RNE and the tracking and consignment information provided by the participating RUs within RailData systems.

5.6.3 Messages, communications and distribution channels

The ISR central system receives messages using the CDS message broker. Several formats are allowed:

- Short XML wagon status message (WSM v 01),
- Enlarged XML wagon status message (eWSM), versions 02, 04 and 05,
- Hermes application 30 message (H30), for planned border crossing (XML versions 1.01, 1.03, 1.04b and 1.04cs)

ISR uses the FTP (RFC 959) for transmission of messages. For the specific needs of the ISR application, each connected system needs to install specific FTP client to communicate with the CDS. Exception are the copies of the H30 messages (border crossing) transmitted using the HERMES Open System Architecture (HOSA) FTP clients. The communication infrastructure used is mostly the HERMES IP VPN provided by Hit Rail (http://www.hitrail.com/).

ISR offers three different data distribution channels

- ISR web site: This site offers access to the ISR information through several search criteria. Results are displayed as HTML pages or can be downloaded as CSV files.

- Forwarding: This function does automated distribution of received information to concerned RUs. The message used is the WSM format and from historical reasons, also the Edifact IFTSTA message.
- Web services: This option allows providing an own web interface with local language and added features.

5.6.4 ISR and TAF TSI

Two important TAF TSI functions are covered by the ISR application for its members:

- WIMO (Wagon and Intermodal Unit Operational Database, see also section 5.1.7)
- Train Running (functions on the RU side, see also section 5.1.4)

Between RNE's TIS and RailData's RTIS a TAF TSI compliant message is exchanged and routed via the RNE Common Interface (CI). According to Mickael Varga (Varga, 2018), ISR currently handles about 144 million train run messages per year.

The events in ISR map perfectly towards the TAF TSI Wagon Movement function (see also section 5.1.6). There is a high overlap between the data elements in ISR and TAF TSI. If RailData RUs send required information to ISR, they are TAF TSI compliant. (Červinka, 2018)

TAF TSI Train Composition (see also section 5.1.3) is not enough for RUs. Hermes application 30 (H30) contains a train pre-advice about freight train consist according to UIC leaflet 404-2. It is industry standard, it covers all RU needs, following RailData's evaluation. RailData suggests approving H30 v.2 as TAF TSI compliant message, and to use a subset of it also for RU-IM-communication as alternative to the Train Composition Message. (Červinka, 2018)

RailData's ISR is an important tool for RUs in order to calculate ETAs for wagons and trains and hand-over them to each other. Therefor it may significantly improve the reliability of the estimation of train MY arrivals. Thus, the processes and its required resources at the MY may be better planned and allocated. In addition to the already analysed TAF TSI messages, it may be worth to have a look at the H30 message.

5.7 Open Rail Freight EDI User System (ORFEUS)

Open Rail Freight EDI User System (ORFEUS) is an information system developed and operated by RailData. It ensures the exchange of railway CIM consignment notes and CUV wagon notes data between the co-operating RUs using a Central Data-management System (CDS).

This section is mainly based on (RailData, 2018).

Handling of paper transport documents is very costly and presents serious technological limitations for the railway transport. With the intention of paperless technology, major European RUs deployed information systems to collect and process data about their consignments. Next logical step was to interconnect these companies' systems to exchange consignment information of international transports. For this purpose, central system called ORFEUS was developed and currently handles around 2,5 million consignment note messages per year. (Varga, 2018)

Data is delivered by the forwarding RU to ORFEUS and from there distributed to other RUs involved in the transportation. Based on CITs legal and functional specifications for the Electronic Consignment Note message (ECN), RailData developed the technical specifications for the ECN exchange.

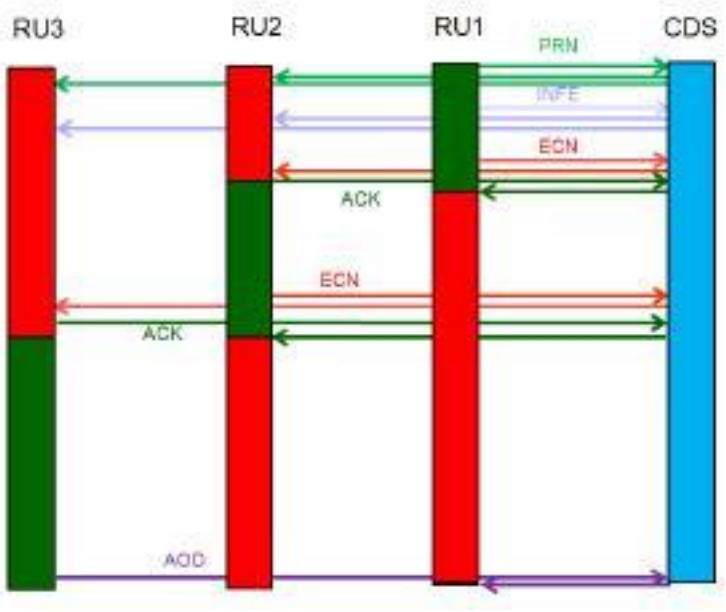


Figure 31 Message exchange for Consignment Notes (RailData, 2018)

The CDS acts as a message broker for collection and distribution of information, including specific logic and verifications. The CDS exchanges data of the CIM/CUV notes with the NISes using several message formats:

- CTD (version 2) XML message is former standard message format. It is used for creation (CTD) and update (UTD) of the transport dossier (TD). The CTD message is considered as obsolete and is not maintained since end of the year 2016. Anyhow it is used by few members still, who did not migrate to a newer format yet.
- ECN XML message is capable to carry 100 % of consignment note data and matches the requirements of the ECN defined by the CIT. Actual versions in use are 1.31, 1.4. and 1.42. This message format is used for several functions (ECTD, INF, ECN, ACK, NACK, CANCEL, DEL...) depending on the event and message flow type.
- Frachtbriefe XML message (designed by Rail Cargo Austria) version 4.13 is alternative for some RUs.

Since the members use different types of message formats, ORFEUS ensures conversion between these formats (where possible) in both directions.

ORFEUS uses FTP (RFC 959) for transmission of messages. For the specific needs of the distributed application, special FTP modules were developed. Each connected national system needs to install specific Lusis FTP client to communicate with the CDS. The communication infrastructure used is mostly the Hermes VPN provided by Hit Rail.

Specific web-based tool linked to the CDS allows to observe the traffic as well as to do on-line queries about specific wagon or consignment numbers. These services are open to authorized staff of the member companies only.

5.8 CONCLUSIONS

If RUs are members of RailData and the required IMs have cooperation with RNE, then they already meet important prerequisites for early and reliable ETAs of trains at an intermediate MY. TAF TSI messages support the deployment of RNE's and RailData's tools. railML and RailTopoModel may assist in filling the gap between the pre-defined messages and further national data requirements.

6. CASE STUDIES ON DATA ANALYTICS

We collected case studies with the purpose of gaining a better understanding of what other methods and techniques for data gathering, processing and management exist outside the rail domain and the EU. We wanted to identify suitable ones that could potentially be applied for managing data in yards and closest networks and hence to assist in making real time decisions. We looked at identifying suitable methods for data analytics that ingest and analyse large volumes of high velocity data to efficiently detect potential conflicts in a yard operating process and quickly trigger predetermined responses to such conflict in real-time.

We aimed to study a variety of Automatic Identification and Data Capture (AIDC) and RFID technologies suitable for semi and fully automated operations in rail freight yards and networks.

We aimed at looking to understand the challenge of obstacle detection in rail freight yards and networks which needs significant attention if automation in rail freight is to be introduced widely in Europe.

6.1 REMAS

The REMAS project presentes a platform for cooperation and sharing information for all interested parties, though the development of a new data model for provision of real time data and inter-organisational coordination and support of trips and drive manoeuvres of networked and automated vehicles in urban areas.

Date of Implementation (if applicable): NA

Project started in 2015

For the purposes of this case study we are interested in Resource management system for automated driving, (based on an interview with Mario Krumnow).

6.1.1 Location:

Germany

6.1.2 Challenges and motivation before initiation of case study:

The project evaluated new ADAS hindering through economic and safety risks, making simulation permissive before rollout (automated driving); and changing juridical and bureaucratic conditions. The project concluded that a concept to foster the development of new ADAS is needed.

6.1.3 Problem formulation:

The nature and dimensions of the ADAS make the identification of appropriate solutions very challenging due to the presence many different data sources, many different players, different data sinks (coming along with different needs for data presentation) and Integration of software as well as hardware.

The complex model involves components and transport protocols as well transport media that have to be simulated accurately. Therefore high level architecture was needed.

6.1.4 Objectives:

In order to deal with these requirements, the project aim to enable unbroken integration of resources and activities for development, test and operation of IST applications for all players. Additionally, it looked at

interlocking of scientific, technological, infrastructural, traffic related, organisational and operative perspectives. Finally matching of ADAS development with economic, juristic, psychological or societal research with the inclusion of the whole life cycle of an ITS application was required.

6.1.5 Methodology:

By providing interfaces and functionalities for registration and monitoring of test vehicles and their interaction with the ITS infrastructure, all functionalities and needed infrastructure are built in a proof-of-concept approach to evaluate their practicability. The publication of data and acquired knowledge in a "virtual showroom" allow partners to integrate their subject specific components and to test it using the Saxon ITS pilot system and definition of the content for the required standards (check, what else). RTI is used to allow various interested partners to publish/subscribe to data channels connecting simulations via an ambassador

6.1.6 Description of Technology:

Technical characteristics:

System design of REMAS with the RTI as Simulation Middleware is shown in Fig 32 and includes:

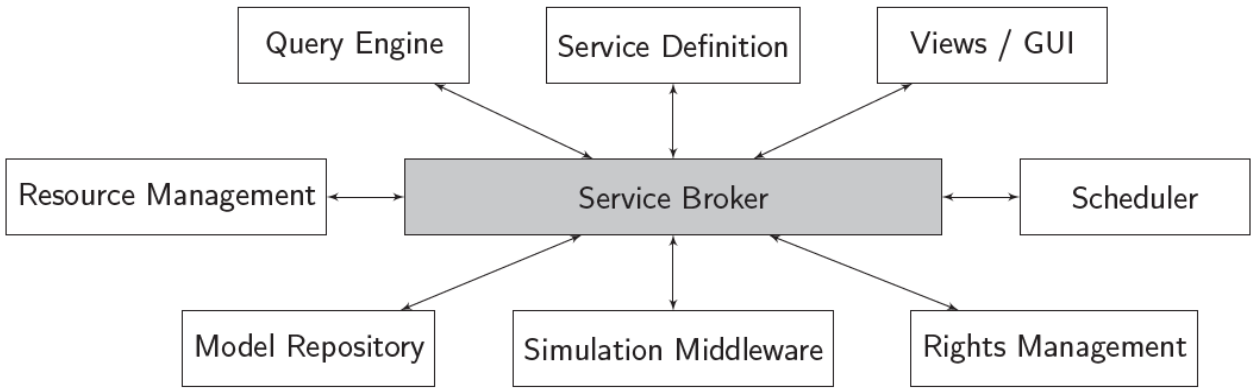


Figure 32 REMAS System

- Broker service to connect other components
- Views (GUI, Wiki-like, RESTful services over HTTP, JSON)
- Manoeuvre catalogue (typical test cases)
- Scheduler (find real roads/situations to test cases in reality)
- Query locomotive (to access data of test rides)
- RTI: HLA - Simulation Middleware based on the IEEE standard 1516 (1)
- Communication is done via Ethernet protocol

The software works as distributed application, because licence and non-disclosure issues where large obstacles to building a prototype running on one machine. See Fig 33.

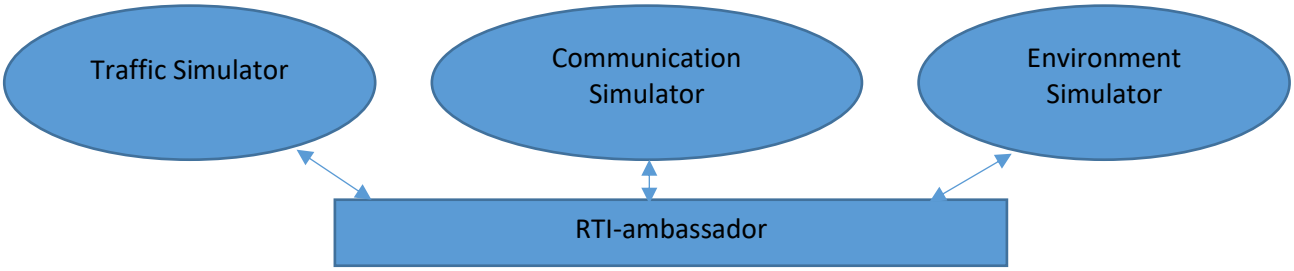


Figure 33 REMAS Software structure

Operational characteristics: RTI-Ambassador makes data structures and transport protocols used by the simulators transparent. It translates the data structure, but may also include functionalities e.g. for data merging, each subscriber to the RTI services can be every interested party; access has to be restricted and secured. External Clock is used; it has to be defined which part may act as clock, though.

6.1.7 If it is not a rail application, how can this technology be implemented in rail freight yards and networks?

The main concept of RTI may be used to connect network and yard simulators, however other simulators like communication simulators may be integrated as well e.g. to simulate communication network breakdowns, which is of particular interest for ETCS user cases.

6.1.8 Outcomes/Expected results:

The outcomes of the project includes a number of concepts and ITS solutions (development & simulation) for functional and technical integration and development of simulation software, development tools, and test racks. Specifically:

- Development of methods and tools to integrate applications in existing ITS infrastructures and in networked or automated vehicles (planning % integration)
- Development of processes and algorithms for planning and execution of trips and manoeuvres in ITS (real-time coordination & trip management)
- Development of processes for the validation of trips and manoeuvres and critical system properties (monitoring & validation)
- Development of a new semantic information model to enable the use of ITS related knowledge about systems, methods, and technologies (information & cooperation)
- Coupling of simulations has been enabled.

6.1.9 Description of Impacts:

Operational:

With the ongoing project new questions arose, application in development.

Commercial:

For the university they used the research field to enable new PhD studies to enrol.

In “industrial rollout”, the system may be commercialised in near future.

6.1.10 Lessons Learnt/Conclusions

Latencies on data channels may sum up to a delay of the combined simulation, so the needed simulation speed and needed minimal data frequencies have to be carefully designed and ensured. Methods to cope with larger latencies have to be set up to avoid latencies that are caused by high frequencies the concept of

data thriftiness should be applied as much as possible. The step width of the simulation has to be chosen and adjusted carefully.

List of References (if applicable):

(Krumnow, 2016)

List of Interviewees (if applicable):

Mario Krumnow

Chair of Traffic Control and Process automation

Institute of Traffic Telematics

Technische Universität Dresden

Others (if applicable)

6.2 VAMOS

VAMOS - Verkehrs- Analyse-, -Management- und Optimierungs-System, is a cyber physical system wherein the traffic state is measured using different detector techniques in real time. The measured data is evaluated in a real time process, too and integrated in the traffic model. This is basis of the control of actuators and thereby the manipulation of the physical traffic system.

(System for traffic analysis, management and optimisation)

Date of Implementation (if applicable): NA

Project started in 1999.

Continuous enhancements and updates.

6.2.1 Location:

Dresden, Germany

6.2.2 Challenges and motivation before initiation of case study:

The project has been motivated by the mobility in dense areas in the new federal states of Germany and changes came from large infrastructure investments in the region (motorway A4, car-park routing system, suburban line extension, railway station- and bridge building, airport terminal, tram line extension). The existing physical transport routes where supplemented with “data motorway” and telematics systems for intelligent usage of this infrastructure. As consequence of that fast motorisation, suburbanisation, economic structural changes, changes in way of living has been observed and well highly heterogeneous system with different types of sensors and actuators as well as interfaces to services/user access. It is a fast way to reach effectiveness in praxis while developing long term strategies.

6.2.3 Problem formulation:

The existing data about traffic state has not been available resulting in frequent traffic jams. Due the lack of system of traffic detectors design the need for develop a traffic control system has been identified in order to traffic and clarify the responsibilities of the parties concerning data owning, control measures, server operation.

6.2.4 Objectives:

The project aim is focused on how to avoid soil sealing by introducing an intelligent traffic control and propose optimal use of infrastructure with control of demand for motorised individual traffic raising attractiveness of public transport.

6.2.5 Methodology:

The objective of controlling the traffic is strongly connected to the need of measuring it. Therefore, numerous traffic detectors have been installed and dynamic detection techniques have been tested and brought to use. Traffic data from far more than hundred detectors gained in frequencies between 5 seconds and 1 minute is filed in a database and evaluated for the use in traffic prediction and control as well.

To control the demand of the motorised individual traffic different approaches have been combined. Infrastructural investments such as building new park-and-ride sites as well as operational reforms like adaptive routing advice have been introduced.

The focus of the management system lies in influencing the motorised individual traffic. Public transportation has been integrated as of late to unlock its potentials. In combination with individual traffic coordinated enhancements in traffic as a whole have been made. Actual developments even include bike traffic and address the needs of traffic participants in this area.

6.2.6 Description of Technology:

a. Technical characteristics:

The architecture is built as a High-Level Architecture (HLA) - Simulation Middleware based on the IEEE standard 1516.

The dynamic traffic model of VAMOS consists of different layers.

Layer a) lane specific net model (node-edge-model)

Layer b) model of turning relations (1 edge per direction, in nodes different edges without length are defined to model turning relations)

Layer c) aggregated traffic flow model (aggregation and distribution of available data to all layers, references between layers available, fusion with data of other layers)

Actuators

- Variable-message signs for dynamic route guidance
- Traffic information system (FIS-tabula)
- Dynamic parking information and control system
- Information system for Elbe bridges (EBIS)
- Quality balancing traffic lights QLSA system “Cosel”

b. Operational characteristics:

The system (VAMOS) is operated and taken care of at the TU Dresden. The office of road and civil engineering (“Straßentiefbauamt”) of the city of Dresden owns administrative rights and is responsible for

main decisions regarding the traffic control systems. The traffic control centre can be operated without permanent presence of personal.

- Delivery of sensor data is event triggered and stored per minute in a relational database (RDB)

- Internal services call for data of RDB using SQL requests, refine it and push the generated information into the “dynamic traffic model” (DVM) (which is a database as well)

- There, actual data is regularly updated and filed

- External and internal services may get the data delivered from DVM and decide about traffic control measures on top of this basis

- Services get connected more and more in a net-like structure

c. Functional characteristics

- Synchronisation of time stamps of data

- Attach Quality measure to each dataset

- Data fusion, computation of traffic state (quality), adding geographic reference, map-matching, enrichment with historical data

- Traffic Control measures, including coordination of different control measures

Computation of dynamic traffic measures

- Travel times

- Mean waiting time

- Traffic state (LoS)

6.2.7 If it is not a rail application, how can this technology be implemented in rail freight yards and networks?

Technologies of real time traffic observation and data evaluation as well as traffic control are needed for automated rail freight yard management.

Operational/functional concepts may be in many cases applicable, but concrete technical equipment may only be an inspiration of what types of traffic state monitoring facilities may be used.

6.2.8 Outcomes/Expected results:

The efficacy studies were not financed by the client, delivering higher percentage of travellers who are using public transport (DVB statistics).

The lower travel times observed, impact on higher satisfaction with traffic in general (public and private) and the distribution of emissions to low polluted areas.

Other expected results not checked includes retardation of suburbanisation process and the reduction of traffic demand.

6.2.9 Description of Impacts:

a. Operational:

- Massive building of traffic lights

- Tests of different traffic light control principles

- Until now, no environment zones needed in Dresden

b. Commercial:

- Good public transport and almost fluently working road traffic is soft criteria for enterprises as well as families to decide to live/stay/come to Dresden

- City of Dresden saves money for traffic investments in other traffic related infrastructure like building and maintaining of additional parking lots or multi-stories

- City is one of the lighthouse project cities for electro mobility because traffic management system and city councils are regarded as highly innovative

6.2.10 Lessons Learnt/Conclusions

- Uniform traffic condition available via an open interface as a basis for all interested parties/systems is an essential measure to avoid inconsistencies;

- Traffic control based on traffic conditions is more effective than if it is based on detector data;

- Homogeneity of areas for mining of sensor data of different control systems is needed to avoid inconsistencies;

- Event based system is preferable over a system with fixed frequency because latencies may sum up.

List of References (if applicable):

- https://www.dvb.de/de-de/die-dvb/nachhaltigkeit/soziales/ ;
- https://www.dvb.de/-/media/files/die-dvb/zahlen%20daten%202017_web.pdf
- https://www.dvb.de/-/media/files/die-dvb/jahresabschluss%202016.pdf ;
- https://www.dresden.de/media/pdf/umwelt/co2_emissionen_09.pdf ;
- https://www.tns-infratest.com/presse/presseinformation.asp?prID=3591 .

List of Interviewees (if applicable):

Dr. Ralf Franke

Chair of Traffic Control and Process automation

Institute of Traffic Telematics

Technische Universität Dresden

6.3 RFID-BASED TECHNOLOGY FOR WAGON IDENTIFICATION

ČD Cargo, as an RU performing marshalling operations, carried out a pilot on RFID (Radio Frequency Identification-based technology) systems for freight wagon number reading, which can prove to have a significant future and innovation potential in terms of automation of marshalling processes. (Jindra, 2017)

6.3.1 Location

This technology can be utilized in any marshalling yard, both gravity and flat shunting based, as well as in a simple train forming station.

6.3.2 Challenges and motivation

Automatic identification of wagon IDs can entail in faster, easy and more correct capture of elementary train composition data, i.e. wagon numbers, with direct impact on efficiency and accuracy of marshalling and train forming processes.

6.3.3 Problem formulation

The most time consuming and still very often manually performed activity within freight railway marshalling and shunting processes is the identification of the smallest elements of the railway technological process, i.e. identification of handled wagons.

6.3.4 Objectives

The project aims to review the possibility of implementing novel technologies, e.g. RFID for wagon identification in marshalling facilities, in the railway freight environment and understand the impact on the daily rail freight operation.

6.3.5 Methodology

SWOT analysis as well as a pilot testing was applied to evaluate the RFID based technologies in rail freight.

6.3.6 Technology

RFID-based technology has been used for freight wagon ID reading.

Technical characteristics

The wagon ID, coded in RFID tags fitted on several places of the wagon is recognized by an RFID device in the yard and is transferred into the RU's operational information system (to be converted into the wagon number in the back-off system).

Operational characteristics

The wagon ID recognized is transferred into the RU's operational information system (to be converted into the wagon number in the back-off system) instead of a manually captured wagon number. This overcomes the need of manual input and eliminates erroneous routines.

6.3.7 Implementation in rail freight yards and networks

The possibility of RFID utilization is twofold. The first possibility rests in stationary trackside devices firmly anchored in the ground or attached to an existing construction on a suitable spot in the yard, e.g. close to the entry signal/station gate, hump slope, classification or departure tracks for the automated processes of scanning of vehicles in motion. The second possibility relies on mobile (hand-held) devices used by operators in the yard track while breaking down and making up trains.

6.3.8 Outcomes/Expected results

The expected results are: faster and error-free capture of wagon identification and maximum elimination of manual input activity.

In case of all IT and processes working correctly, the technology would mainly act as an easy way of a "double-check" or a "higher level of supervision" of the system and process functioning, especially for

trains/wagons incoming in the yard/station. In the fully-fledged coverage of all processes, no re-entry of wagon IDs in a marshalling yard would be necessary. The systems would automatically exchange the wagons between tracks and yards within one yard and within the network.

Due to high complexity of shifting wagons between individual tracks of a yard or a station, movements of which could be followed only with difficulties in real-time even in case of wagons fitted with GPS devices (risk of inaccurate location when moving between closely adjacent tracks, etc.), the necessity of proper checkout of wagons of an outbound train will probably still be persistent even in the future. It means that either automatic or manual scan of the wagon ID may be unavoidable. However, the Galileo GNSS system with higher accuracy will have the potential to overcome this issue.

Another significant benefit of using this technology would materialize in the process of interchange of trains/wagons between successive carriers and/or the handover/pull-out to/from customer's sidings. This routine is yet not fully reliably covered.

6.3.9 Impacts

Operational

With RFID based technologies o manual data capturing will be necessary.

The implementation of RFID for wagon identification will result in faster check-in (clearance) of wagons to be processed/being processed/having been processed.

Potential savings of direct labour in the yard before (check-in of arriving trains/wagons) and after the hump processes (check-out of outbound wagons, clearance of the train after its composition has been finished, even in case of individual wagons being taken out from the train set during the departure clearance due to technical, commercial or transport reasons) can be expected, too.

Commercial

Fully-fledged coverage of railway wagon fleet would enable further steps towards elimination of paper-based transportation procedure and automation of marshalling operations and their full digitization.

Other

Automatic identification of railway vehicles is a natural prerequisite of fully automatic railway processes.

6.3.10 Lessons Learned/Conclusions

Except of costs for the stationary or hand-held devices, the RFID solution also requires initial costs for the RFID tags to be fitted in to the entire wagon fleet. The biggest disadvantage of this solution rests in the fact that unless all wagons arriving into the yard are equipped with this technology, the full-blown benefit will not be reached. It implies the necessity of a large-scale deployment of such technology within the Single European Railway Area to bring its full benefits.

However, this solution would act mainly as a "higher level of checking supervision" when all systems and processes work flawlessly (i.e. the primary data capture in the information systems is correct and the processes ensure correct data flow through the system, closely copying the life cycle of the wagons transportation and all wagon movements).

It means that the real financial benefit is not easy to be quantified at this stage.

Strengths	Weaknesses
Fast and error-free acquisition of data. Potential savings of direct labour in the yard before, during and after the hump process. Simpler and faster interchange of trains and wagons between successive carriers or handover/pull-out to and from customer's sidings. Wagon ID readable even in case the wagon number is dirty or illegible. Dual possibility of utilization, either stationary or hand-held devices.	Significant costs of the RFID device and fitting all wagon fleet with RFID tags, networking and power supply of the fixed readers. Adjustment of the interface with existing IT systems (only RFID code is transmitted which needs to be translated into the wagon number). In case of stationary reading devices, necessity of cooperation with the Infrastructure Manager. Reduced distance of effective reading in case of non-optimal position of the tag on the wagon, e.g. on a U-profile. Risk of theft or loss of the tag. Necessity to set up processes for handling of non-fitted wagons or in case of stolen or lost tags. Necessity of matching a new tag with the system. Equipment of the all-European freight railway wagon fleet with RFID tags can take a very long time. Until a fully flat deployment of the RFID tags, the utilization is considerably limited or even negligible.
Opportunities	**Threats**
Further steps towards elimination of paper-based transportation and automation of marshalling operations. Another improvement in effectiveness of single wagonloads in marshalling and train forming processes. Possibility to utilize this technology for stock-taking of individual parts of wagons and management of wagon components.	Inability to emulate the road transport flexibility despite rather high costs into fitting the wagons with RFID tags. Significant investments necessary for upgrade of existing systems based on different technologies not corresponding with their real benefits.

Figure 34 SWOT Analysis of RFID-based technology used for wagon identification

6.4 OCR-BASED TECHNOLOGY FOR WAGON IDENTIFICATION

ČD Cargo, as an RU performing marshalling operations, are interested in OCR (Optical Character Recognition-based technology) systems for freight wagon number reading, which can prove to have a significant future and innovation potential in terms of automation of marshalling processes. See also (CAMEA, 2016)

6.4.1 Location

This technology can be utilized in any marshalling yard, both gravity and flat humping based, as well as in a simple train forming station.

6.4.2 Challenges and motivation

Automatic identification of wagon IDs can entail in faster, easy and more correct capture of elementary train composition data, i.e. wagon numbers, with direct impact on efficiency and accuracy of marshalling and train forming processes.

6.4.3 Problem formulation

The most time consuming and still very often manually performed activity with train marshalling and shunting operating processes is the identification of the smallest elements of the railway technological process, i.e. identification of handled wagons.

6.4.4 Objectives

The activity aims to review the possibility of implementing novelty technologies in the freight railway environment, in the daily railway operation.

6.4.5 Methodology

SWOT analysis was applied to evaluate this novelty technology in rail freight.

6.4.6 Technology

The technology to be assessed is Optical Character Reading-based technology used for freight wagon number reading.

Technical characteristics

The wagon ID is recognized by an OCR device in the yard and is transferred into the RU's operational information system (to be converted into the wagon number in the back-off system).

Operational characteristics

An OCR device instead of a manually captured wagon number recognizes the wagon ID. This overcomes manual input and eliminates erroneous routines and accelerates the process.

6.4.7 Implementation in rail freight yards and networks

There is a dual possibility of the OCR utilization. One possibility rests in stationary trackside devices firmly anchored in the ground or attached to an existing construction on a suitable spot in the yard, e.g. close to the entry signal/station gate, hump slope, classification or departure tracks for the automated processes of scanning of vehicles in motion. The other possibility relies on mobile (hand-held) devices used by operators in the track yard while train decomposition and assembly.

6.4.8 Outcomes/Expected results

The expected results are faster and error-free capture of wagon identification and maximum elimination of manual input activity.

In case of all IT and processes working correctly, the technology would mainly act as an easy way of a "double-check" or a "higher level of supervision" of the system and process functioning, especially for trains/wagons incoming in the yard/station. In the fully-fledged coverage of all processes, no re-entry of

wagon IDs in a marshalling yard would be necessary. The systems would automatically exchange the wagons between tracks and yards within one yard and within the network.

Due to high complexity of shifting wagons between individual tracks of a yard or a station, movements of which could be followed only with difficulties in real-time even in case of wagons fitted with GPS devices (risk of inaccurate location when moving between closely adjacent tracks, etc.), the necessity of proper checkout of wagons of an outbound train will probably still be persistent even in the future. However, the Galileo GNSSS system with higher accuracy will have the potential to overcome this issue.

Another significant benefit of using this technology would materialize in the process of interchange of trains/wagons between successive carriers and/or the handover/pull-out to/from customer's sidings. This routine is yet not fully reliably covered.

6.4.9 Impacts

Operational

No manual data capture will be necessary.

Results in faster check-in (clearance) of wagons to be processed/being processed/having been processed.

Shows potential savings of direct labour in the yard before (check-in of arriving trains/wagons) and after the hump processes (check-out of outbound wagons, clearance of the train after its composition has been finished, even in case of individual wagons being taken out from the train set during the departure clearance due to technical, commercial or transport reasons).

Commercial

Fully-fledged coverage of railway wagon fleet would enable further steps towards elimination of paper-based transportation procedure and automation of marshalling operations and their full digitization.

Other

Automatic identification of railway vehicles is a natural prerequisite of fully automatic railway processes.

6.4.10 Lessons Learned/Conclusions

The OCR solution requires initial costs into the stationary or hand-held devices only. The biggest advantage of this solution in comparison to the RFID-based solutions rests in the fact that all wagons in operation are inherently marked with their digital identification written on the wagon body and frame.

However, this solution would act mainly as a "higher level of checking supervision" when all systems and processes work flawlessly (i.e. the primary data capture in the information systems is correct and the processes ensure correct data flow through the system, closely copying the life cycle of the wagons transportation and all wagon movements).

It means that as also in the case of RFID based technologies, the real financial benefit is not easy to be quantified at this stage.

Strengths	Weaknesses
Fast and error-free acquisition of data. Potential savings of direct labour in the yard before, during and after the hump process. Simpler and faster interchange of trains and wagons between successive carriers or handover/pull-out to and from customer's sidings. No additional costs or activities with fitting any additional equipment on the wagons. All wagons are marked with a digital ID. No significant adjustment of the interface with existing IT systems is necessary (no translation of an ID into the wagon number needed). Not only wagon numbers can be identified, but also other data written on the wagon body, frame or undercarriage. No risk of theft or loss of any additional equipment. Dual possibility of utilization, either stationary or hand-held devices.	Significant costs of the OCR reading devices and power supply of the fixed readers. In case of stationary reading devices, necessity of cooperation with the Infrastructure Manager. Sometimes not a fully reliable solution (in case of dirty/illegible or wrongly written number on the wagon body or frame).
Opportunities	**Threats**
Further steps towards elimination of paper-based transportation and automation of marshalling and train forming operations. Another improvement in effectiveness of single wagonloads in marshalling and train forming processes.	Inability to emulate the road transport flexibility despite rather high costs into the technology.

Figure 35 SWOT Analysis of OCR-based technology used for wagon identification

6.5 STM

STM (Societé de transport de Montreal) is the operator of public system (metro and bus) in Montreal and is the 2nd largest urban transit network in Canada. In order to improve the control over the fixed asset STM implement a pilot experience of real-time asset monitoring using PI System architecture (OsiSoft) for escalators.

6.5.1 Location:

Montreal-Canada

6.5.2 Challenges and motivation before initiation of case study:

The main challenges faced by STM were issues with generate reports and KPIs as well as equipment. The command centre was not designed for “easy to do” maintenance.

The main motivation was the customer experience improvements by monitoring escalators health in order to reduce potential faults.

6.5.3 Problem formulation:

Fault on escalator impact significantly on the customer experience potentially contributing to crowd stations, especially for customers with reduced mobility. The number of equipment issues was significantly higher due to a lack of data in real time. Then the reaction time of the maintenance teams to fix equipment faults varied stochastically.

6.5.4 Objectives:

Implement real-time monitoring system to improve reliability of the fixed assets.

6.5.5 Methodology:

Proof of concept of real time monitoring for escalators has been developed.

6.5.6 Description of Technology:

The technology used includes sensors and real time data with Matrikon (OPC-S8000 / OPC-Modbus-TCP) and PI interface for monitoring the escalators. Architecture of STM PI Structure is shown in Figure 36.

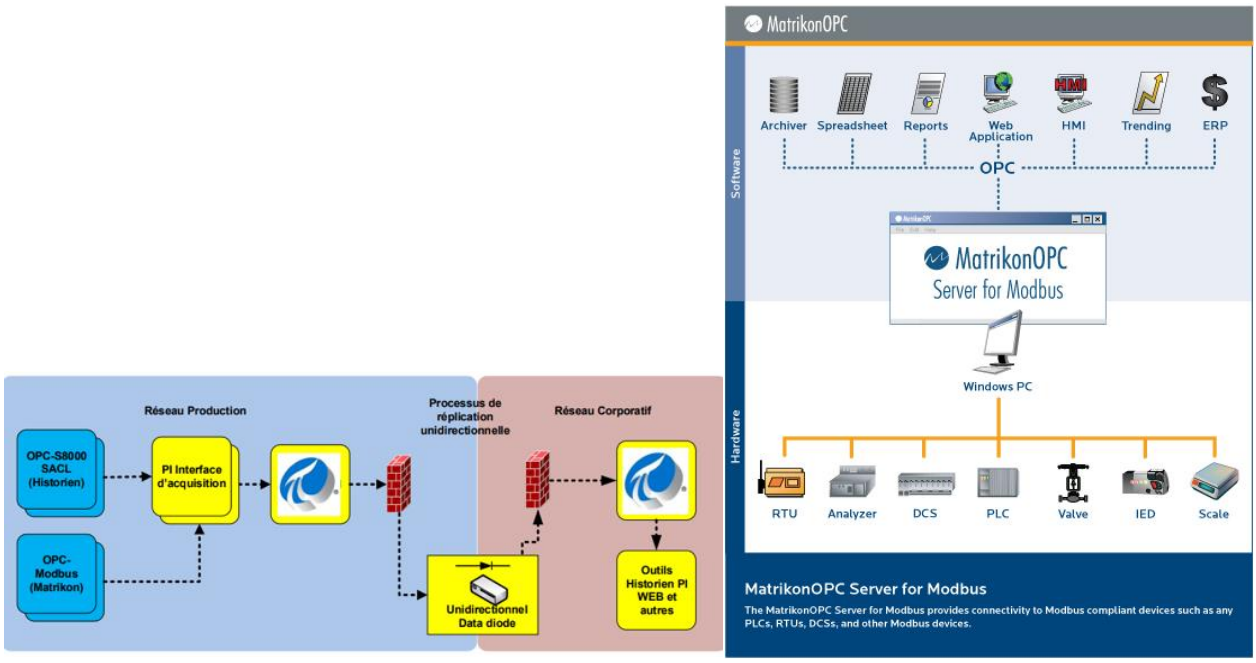


Figure 36 STM PI Structure

Technical characteristics:

- The system developed uses PI Interface connecting OPC-S8000SACL and OPC Modbus (Matrikon). The User Interface also uses PI package for visualisation.

Operational characteristics:

- The real-time asset monitoring using PI System architecture improving reaction time of the maintenance teams controls escalators.

6.5.7 If it is not a rail application, how can this technology be implemented in rail freight yards and networks?

Although the escalators' real-time monitoring system is not an implementation in rail freight the project was implemented by rail operator and the future initiatives of the STM includes real time monitoring of rolling stock (new fleet MPM10 Cars), ticketing and E-workers. Similar technology can be applied for monitoring rail yards to improve the reliability of the operation with freight trains.

6.5.8 Outcomes/Expected results:

Improved customer experience: Quicker time to action in station leads to improved customer experience.

- easy to remotely detect an anomaly.
- easy to determine whether a mechanic intervention is required.

6.5.9 Description of Impacts:

Operational:

- Considering the operational outputs, the maintenance costs reduction was the most significant impact observed.

Commercial:

- Considering the commercial impacts of the implementation, the customer experience improvement was identified as the main impact helping to increase the company image.

Other:

- Considering other impacts, the system helps to optimize performances and integrate date in real time while minimizing time and cost on passengers and Metro operator.

6.5.10 Lessons Learnt/Conclusions

The implementation of the OsiSoft packages has proven that an easy acquisition for data monitoring in real time is possible. There is a potential for implementation of the packages in other assets, hence maintenance costs (labour costs) will be reduced and the reliability of the asset improved. Difficulties at the beginning of implementation have been found, specifically when selecting most relevant KPIs. The centralisation of the information contributes to reducing operational failures.

Standardisation of communication considering the different assets manufactures (4 types of escalators) is an important lesson for OptiYard.

6.6 SNCF

SNCF Réseau: Operational data for future maintenance. Since 2014 SNCF have been using the OsiSoft PI System™ giving their workers more digital tools in the field of rail maintenance, enabling machine learning, and ultimately, allowing operators and maintenance personnel to catch equipment failure before it occurs.

6.6.1 Location:

France

6.6.2 Challenges and motivation before initiation of case study:

The main motivation for the implementation of the OsiSoft package was to reduce the impact of maintenance activities on rail traffic, improving asset surveillance and anticipating/preventing possible incidents.

6.6.3 Problem formulation:

Digital transformation with smart asset management create an opportunity for improving the rail operation. Corrective maintenance potentially has a significant impact on rail traffic resulting in disruption in the system.

6.6.4 Objectives:

The objective of the project was to optimize the maintenance of the network, by enabling to capture data from multiple technologies (cameras, sensors) in order to better manage data.

6.6.5 Methodology:

The methodology used includes predictive analytics and machine learning techniques to anticipate possible events.

6.6.6 Description of Technology:

The technology behind the system includes electric switch motor with power sensors (SCAG) installed on the rail switch (switch number 3017) as illustrated by Fig 37 and Fig 38.

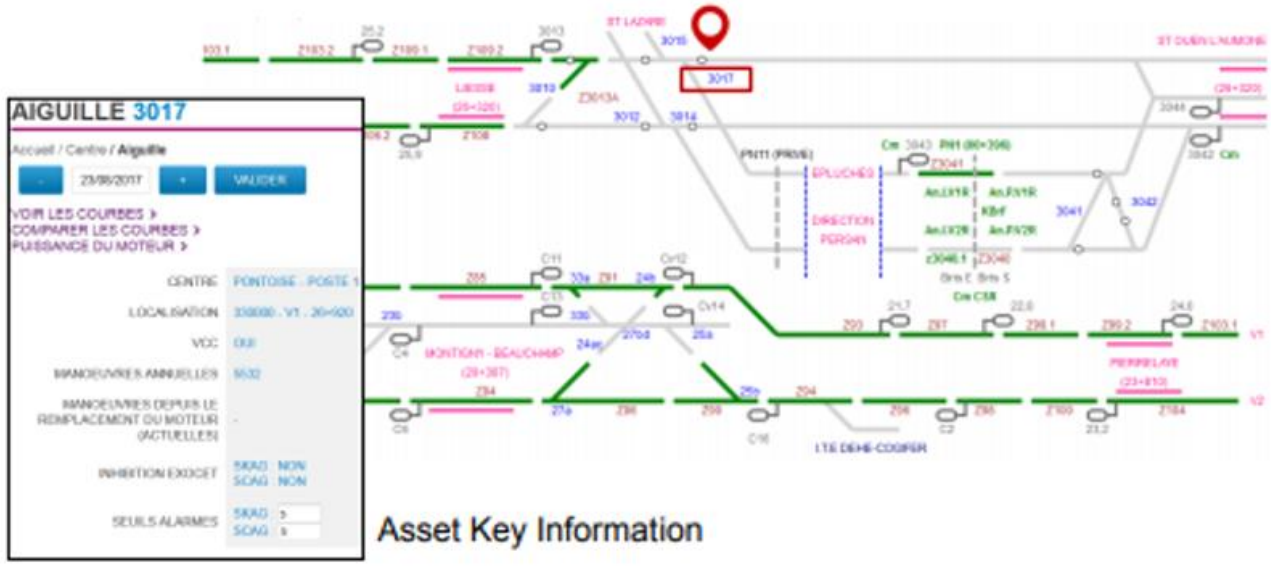


Figure 37 Sensor location and technical parameters

Self-Service Access to Switch Motor Curves



Figure 38 System diagnostic interface

Technical characteristics:

- Remote monitoring deployment through new technologies (Sensors, wireless and connected objects).
- Equipment surveillance (fix and on-board measurements).

Operational characteristics:

- Reinforce network supervision for regional remote monitoring centres.
- Asset management defining and adjusting degradation curves helping to capitalize on asset knowledge for new maintenance policies.

6.6.7 If it is not a rail application, how can this technology be implemented in rail freight yards and networks?:

Rail application

6.6.8 Outcomes/Expected results:

Increase the development of remote monitoring improving asset knowledge

Accelerate data projects supporting new innovative tools

6.6.9 Description of Impacts:

Operational:

- Improve fix and on board surveillance system in order to limit the impact on the network;
- Improve reliability anticipating incidents;
- Reducing risk, disruptions;
- Lower maintenance costs.

Commercial:

- Improve the quality of the service provided by SNCF Réseau;
- Rediscover assets leveraging over +10 years' data collection;

- New analysis and tools for maintenance teams.

6.6.10 Lessons Learnt/Conclusions

The use of real-time monitoring and machine learning techniques enable SNCF Réseau to identify anomalies on the system anticipating possible events before the events happen.

Multiple datasets can be used for the machine-learning suite (temperature, pressure, consumption levels, vibrations, electric signals, compositions, weather data) to improve the maintenance activities of the system.

6.7 OLIN BÉCANCOUR

Olin Bécancour is part of the chloralkali division of Olin Corporation, producing Liquid chlorine, Hydrochloric acid, Sodium hypochlorite and others. PI System has been in use by Olin Bécancour since 2010 for monitoring industrial process (Stocks level temperature, pressure).

6.7.1 Location:

Montreal – Canada

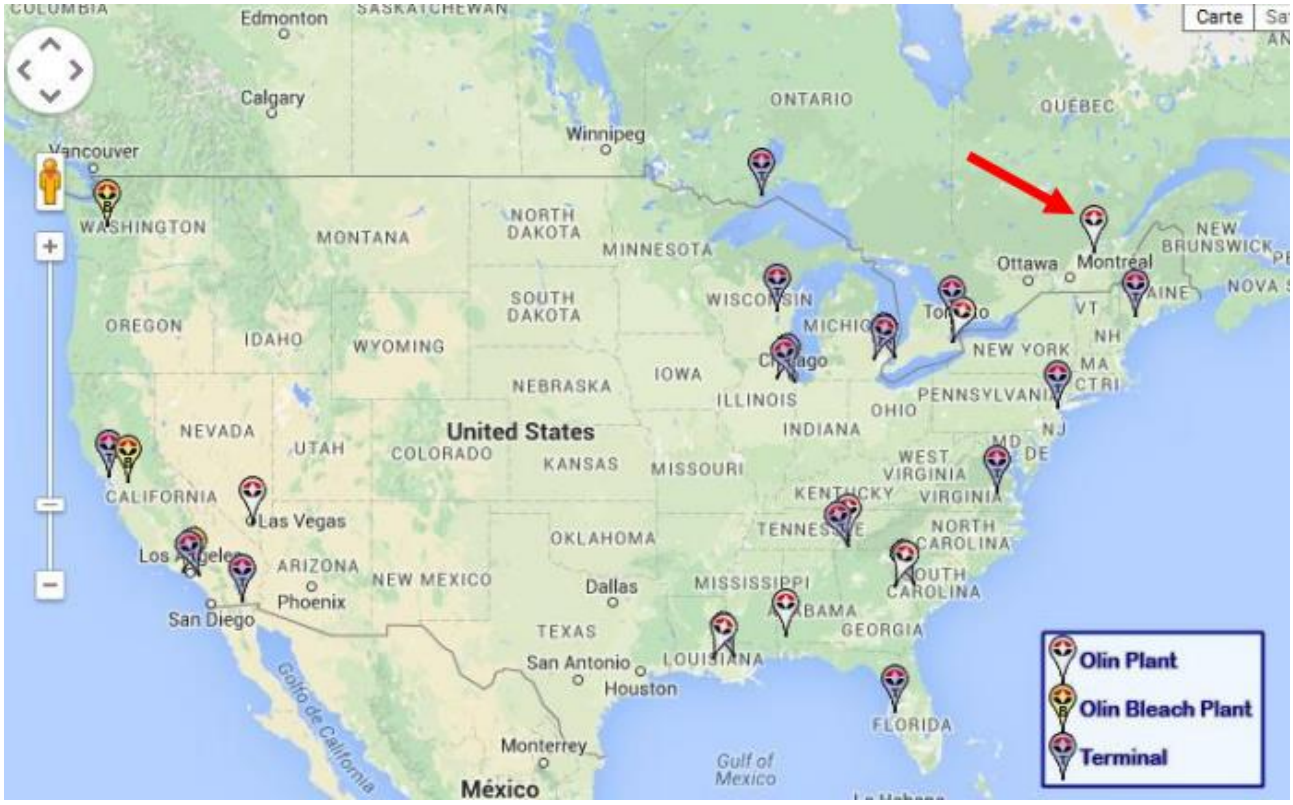


Figure 39 Olin Bécancour plants

6.7.2 Challenges and motivation before initiation of case study:

The main challenge was how to control and improve the management and utilisation of rail freight assets within the yard. The motivation for the rail yard monitoring study was the need for shareable real-time information system, to be spread efficiently across the plan.

6.7.3 Problem formulation:

The main problem faced by Olin Bécancour was to better manage the rail yard. Managing the yard and all sets is a time consuming activity. In order to improve the quality of the service real-time data are required to understand the entire plant (e.g. How many chlorine rail wagons are available? Which ones are reserved for specific customers?).

6.7.4 Objectives:

Implementing a PI system in the rail yard to manage the fleet by collecting and transforming data from multiple sensors in shareable real-time data to spread the information efficiently across the plant improving the rail yard management. See Fig 40.

6.7.5 Methodology:

Implementation of OsiSoft system with On-Site Event Management (OSEM- SAP) for monitoring the rolling stock in real-time in a pilot experience was developed tracking 285 rail wagons per day.

6.7.6 Description of Technology:

The implementations of a data collecting system based on both Poste PI System and Poste SAP enable data capture from OSEM to the PI System substituting the existing analogic control system (magnetic board) from a digital operation to management helping to track all wagons avoiding shipping errors and supporting the decision making process. The connectivity between the PI System and SAP using the PI Interface for RDBMS, and data management with AF and visualization of the rail yard with PI ProcessBook. Architecture of the PI system is shown in Fig 41.

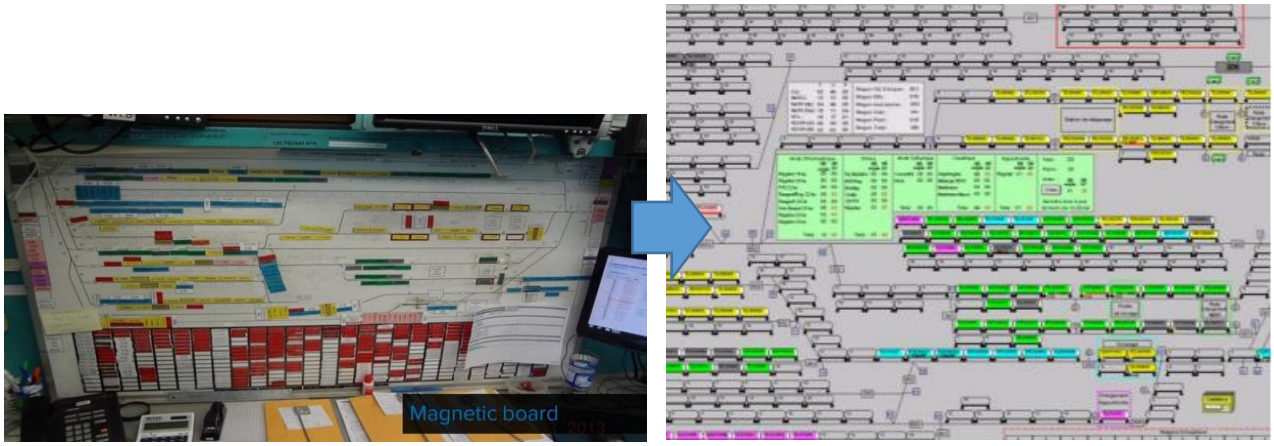


Figure 40 Olin Bécancour before and after the implementation of the PI System

Technical characteristics:

- PI System with SAP OSEM monitoring individual position on the yard, wagon ID, product transported, weight and others.

Operational characteristics:

- Color-coding based on product is used, and customer and reserved wagons management system are in place. With the PI DataLink system reports can be generated supporting the management of the fleet (e.g. rail wagons loaded in the last 24h).

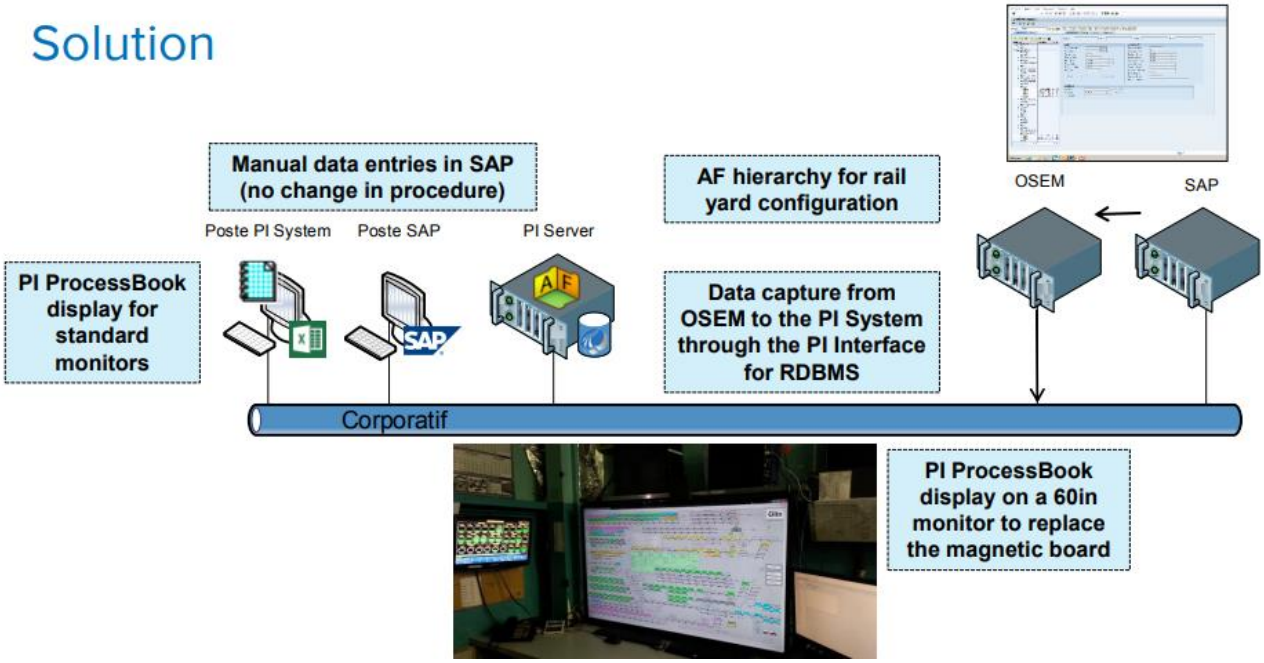


Figure 41 Olin Bécancour PI System structure

6.7.7 If it is not a rail application, how can this technology be implemented in rail freight yards and networks?:

The project is a rail application with a specific focus on rail freight yards, therefore it is directly related to the scope and objectives of the OptiYard project.

6.7.8 Outcomes/Expected results:

As consequence of the implementation of the OsiSoft PI system in the yard, improvements on the information sharing from operation to management have been experienced resulting in a better understanding of the rail yard operation, helping to avoid shipping errors.

6.7.9 Description of Impacts:

Real-time data for real-time decision making improves significantly the rail yard management thanks to its added features.

Operational:

- Real-time overview of the rail yard status supporting a faster and better decision-making.

Commercial:

- Processes have been improved; communications were made easier with standardised information for all stakeholders (24 different operators).

6.7.10 Lessons Learnt/Conclusions

The implementation of the PI system in Olin has improved the management of the rail yard operation on a daily basis.

The new system is able to provide better information sharable from operation to management and between other 24 operators who embraced the change.

6.8 CONCLUSIONS

Comparing the technologies of RFID and OCR, which are rather novel in the railway industry, for the purposes of simplifying and streamlining of the wagon identification processes, the OCR seems to have a bigger potential. The main advantage rests in the fact that fitting a reasonable number of wagons of cooperating wagon keepers to make the RFID technology fully utilisable will be a long-term and very costly objective. The RFID technology requires much more expenses incurred and its effectiveness is lower in terms of the risk of arrival of RFID non-equipped wagons into the yard.

On the other hand, due to the fact, that all wagons in operation are inherently identified with a wagon number written on their bodies, frames and undercarriages, and also taking into account the fact that the technology is already routinely widely applied in road and combined transport, the OCR technology is clearly worth analysing further, to test its economic viability.

Digital technology for real time data capturing and processing already exists. OsiSoft have demonstrated various successful applications of their PI system. Olin Bécancour PI System structure is an application for data management in real time, which has been successfully piloted in a marshaling yard in Montreal, Canada.

7. CONCLUSIONS

Many would say that while huge advances have been made in the road sector and with Inland Waterways with regards to information availability and track and trace, these have not been matched in the rail sector. Rail has proven to be cumbersome, and more often than not, too slow to change, adapt, and adopt new innovations. As an industry it mostly keeps up with the "*tried and tested*" practice.

Our studies suggests that the Rail Sector in Europe is active, already exchanging several million messages within the TAF/TAP TSI framework every month. It is suggested that TIS is a strong selling point towards RU's customers, because the RU now knows the position of every train. TAF TSI messages support the deployment of RNE's and RailData's tools.

TAF TSI messages already support a wide variety of data exchange needs for processes in the freight rail sector. Each message consists of obligatory and optional information, what enables a flexible usage within different national IT systems but on the other hand secures a reliable data exchange.

There is a gap between the pre-defined messages. Developments such as railML and RailTopoModel will assist in filling in this gap and further assist in meeting national and international requirements for data exchange, sharing and protection.

railML is a standard data exchange format with XML files, which is widely used in operational applications of the railway domain – namely timetabling software. Pure infrastructure as well as rolling stock data is also transferred with railML, but with significant smaller importance compared to market dominant tools. Considering the depth of data, railML may, on the one hand if applicable, be used to transfer required data between the different stakeholders, i.e. "line-IM", "MY-IM", "line-RU", "MY-RU", customer. On the other hand, it may be deployed to complete TAF TSI messages with nationally required data in a standardized format.

The development of new rail freight services now has to be designed with developments in IT systems. This is to guarantee that the new service will be digitally sound and equipped with the latest IT developments. There is also a need to take into account the opinions of a larger number of stakeholders over the whole geographic scope. These have to be designed in a way so that further smart rail freight developments are

user friendly and provide the relevant stakeholder with the relevant information at the right time. The basic information platform to do this exists through the products provided by RNE (TIS) and UIC (RailData), however a more robust system has to be developed to bring these together in a meaningful manner. "*If rail wants to be competitive in comparison with road, but doesn't engage with digitisation, it will fall increasingly behind in productivity. But we want to inspire customers with modern technology*."

A data shared input is of paramount importance to be achieved through:

- There should be just one stakeholder ("the terminal") entering the data in TIS. Therefore, there is no direct data exchange, but it is relatively easy to implement. TIS frontend should be further developed. A more user user-friendly possibility for the data input should increase acceptance (max. 30 seconds per data entry).

- There should be a direct information exchange via an IT interface of the individual production system (RU, Shunting RU, Terminal). This solution would be very efficient, but is costly, and thus a long-term solution.

The general analysis of processes and the required data exchange showed, that handling freight trains in MYs is highly complex, where various stakeholders participate in order to fulfil the customers' needs best way. The case studies Česká Třebová, München, Mannheim and Hallsberg showed, that already several IT systems support these processes and the concerned personnel. But these IT systems are specific to the country or even to the company. Each RU and/or IM has to develop its own IT assistance. Unfortunately, the same has also to be stated for the data exchange protocols.

The Rail Sector in Europe is already exchanging several million messages within the TAF/TAP TSI framework every month. Hence the TIS is a very important tool for freight trains and shall play a central role hereafter.

Digital technology creates an opportunity for smart asset management. Implementation of digital technology in rail freight will improve the rail freight operation and the performance of the whole system. Technology and platforms for data capturing and processing in real time already exist. An example of good practice is OsiSoft, PI System, which is very promising for:

–Data access and management in real time;
–Asset maintenance;
–Optimisation of asset performance.

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