Ref. Ares(2018)6398084 - 12/12/2018

This project has received funding from the Shift2Rail Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement no. 777594 (OptiYard)

# Optimised Real-time Yard and Network Management

## D 4.1 Yard and Network Simulation Model

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Reviewed: YES

| Dissemination Level | | |
|---|---|---|
| PU | Public | ✓ |
| PP | Restricted to other programme participants (including the Commission Services) | |
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Start date of project: 01/10/2017 Duration: 24 months

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# ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| DSS | Decision Support System |
| IT | Information Technology |
| IVG | Intelligent Video Gate |
| PCS | Path Coordination System (RNE tool) or Port Community System |
| RMG | Rail Mounted Gantry cranes |
| RNE | RailNetEurope |
| SWL | Single Wagonload |
| TAF | Telematics Applications for Freight |
| TIS | Train Information System (RNE tool) |
| TSI | Technical Specification for Interoperability |

# 1. SCOPE AND PURPOSE

This document addresses the Yard and Network models for the two OptiYard case studies: Česká Třebová (Czech Republic) and Trieste (Italy).

Its purpose is to record the modelling choices and their correspondence with the functional requirements specified in Deliverable D3.2 [1] for future reference.

# 2. GENERAL DESCRIPTION OF YARD AND NETWORK MODELS

## 2.1. Purpose of the yard and network models

The models described in this deliverable fit in with the development of a highly innovative yard management Decision Support System (DSS), capable of generating optimal disposition decisions and recommendations for yard-resource utilisation in real time. In parallel with the on-going innovation in real-time network management, this will allow in turn to improve decision-making in ad-hoc timetable planning to optimise operational processes that connect freight traffic in yards and terminals with timetable slots to and from the network.

Two case studies - Česká Třebová in the Czech Republic and Trieste in Italy have been addressed and models have been developed for the respective yards and surrounding networks.

The interacting models are three for each case study: two microscopic models of yard and surrounding network - described in this deliverable - and one model implementing the optimisation algorithm which is the topic of OptiYard WP5. They are developed on the basis of data obtained from the yard managers and from public sources of network information. An overview of their expected interactions, including those with the IT systems for the relevant parts of the railway infrastructure, is shown in Figure 1.

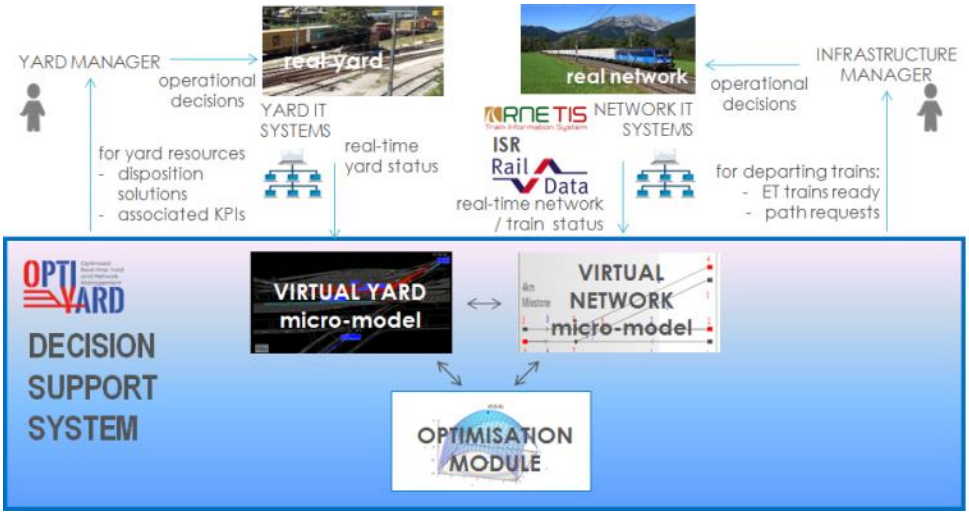



**Figure 1: overview of the architecture and interactions between models**

The outputs of the DSS are directed mainly to the yard manager. The system allows more informed decisions regarding the disposition of yard resources - locomotives, staff, wagons etc. However, in order to optimise yard operations, it is also important to provide information to the network infrastructure manager, in terms of expected times for trains to be ready and train path requests, and obtain information from infrastructure managers and operators. Through these interactions the DSS can thus also contribute to the optimisation of operations on the wider network.

The OptiYard DSS complements and receives input from the eventually existing (and nowadays increasingly developed) IT systems that the yard manager may use to monitor the state of the yard via e.g. the IVG (Intelligent Video Gate) of Shift2Rail IP5, a dedicated sensor network, portals, or manual data input. The OptiYard DSS is also conceived to draw input from the IT systems representing railway network status for timing data and train composition data. The target for this issue is full compatibility with RailNetEurope's Train Information System (TIS), along with the legacy IT systems of the infrastructure manager, as well as with the Telematics Applications for Freight Technical Specification for Interoperability (TAF TSI). Moreover data from wagon tracking & tracing systems, such as RailData's ISR may be used as input.

The outputs are produced by the optimisation model, with the virtual yard model validating results through micro-simulation and contributing to the representation of results and calculation of Key Performance Indicators (KPI). For the purposes of optimisation, the network micro-simulation model delivers Expected Times of Arrival (ETAs) of trains at the yard's home signals with higher accuracy than available from the network's IT systems. For departing trains it determines the foreseeably available train paths. The DSS is capable also of providing expected times at which a given train will be ready for departure and suggesting when path requests are necessary.

This deliverable provides a general description of the yards and surrounding networks and reports on the functional specifications of the yard and network models in accordance with the structure defined in OptiYard deliverable D3.2 [1].

## 2.2. Status of the yard and network models

At the time of writing, the yard model for Česká Třebová and both the yard and network models for Trieste have been completely set up and are in the validation phase. The validation aims at verifying the physical correctness of the models and their results by comparison with data provided by the yard managers. It was decided to develop the Česká Třebová network model in a second step in order to benefit from the validation results and the insight regarding the data analytics methods from the Trieste case.

## 2.3. Česká Třebová: yard and network layout

The yard in Česká Třebová is a conventional marshalling yard situated in the central eastern part of the Czech Republic (Figure 2). Its position is quite strategic and permits the yard to be fed with heavy traffic. Its layout permits trains to be received and sent from and to all the surrounding railway directions.




Figure 2: Česká Třebová yard area

The receiving or arrivals yard (Figure 3) is made of 13 tracks split into two blocks differing according to the possibility to receive trains from different incoming directions.

The first block is made of 10 tracks marked by a usable length between 747 and 933 metres: it permits the access of trains from all the incoming directions (Dlouhá Třebová, Opatov and Třebovice v Čechách).

The second block is made of 3 tracks marked by a usable length between 772 and 832 metres: it permits the access of trains just from 2 incoming directions, Opatov and Třebovice v Čechách.

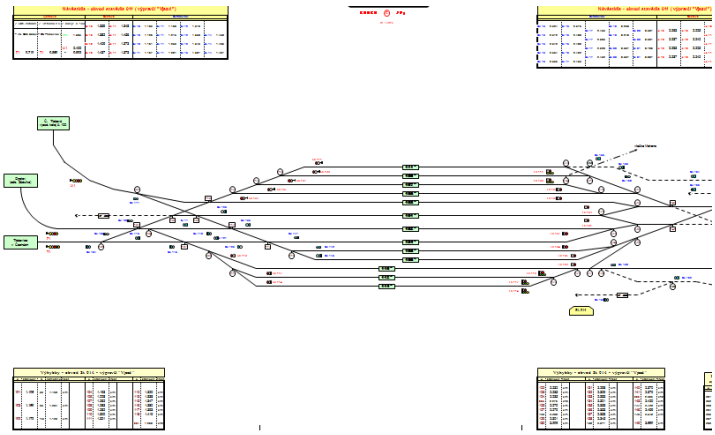


Figure 3: Česká Třebová arrivals yard

The classification bowl comprises 38 tracks. Its layout is represented in Figure 4.

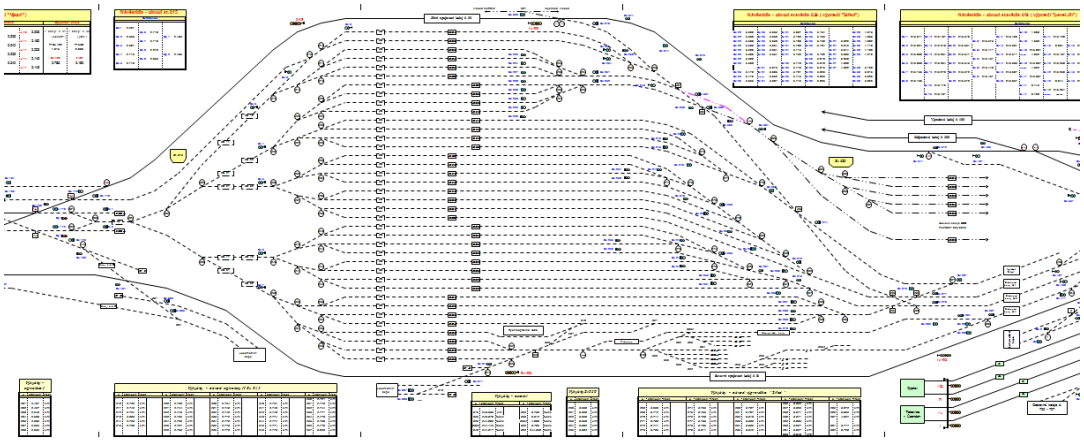


Figure 4: Česká Třebová classification bowl

The departure yard (Figure 5) comprises 19 tracks marked by a usable length between 357 and 829 metres: five of them permit trains to be sent only in the direction Parník, four of them only in the direction of Les, two of them are used as receiving and departure tracks and two more permit entry and departure from and to all directions.

There are then three of them used for emergency and long-term shutdown of wagons while three more are used just for trains arriving and departing to Parník.

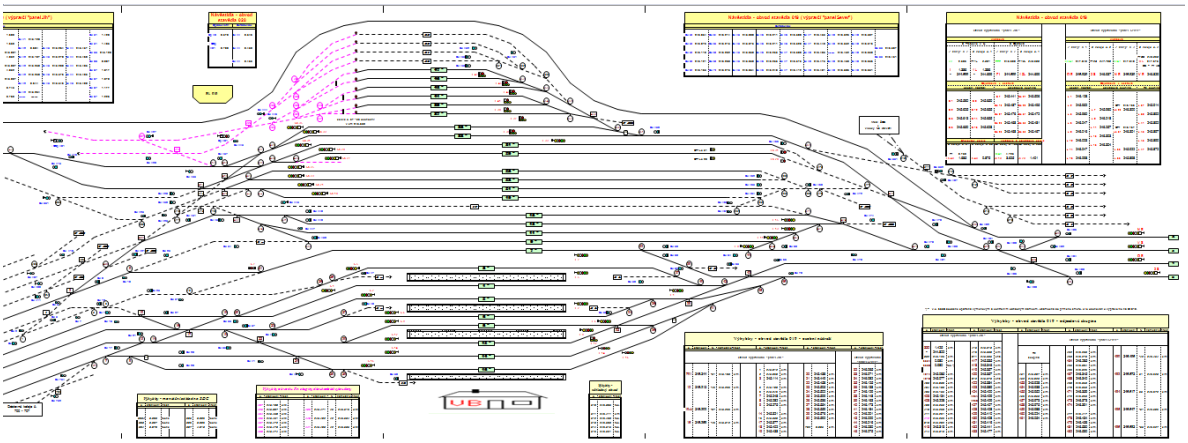


Figure 5: Česká Třebová departure yard

As mentioned above, one of Česká Třebová's strengths is the possibility to be served by several railway directions, as shown in the following figure.

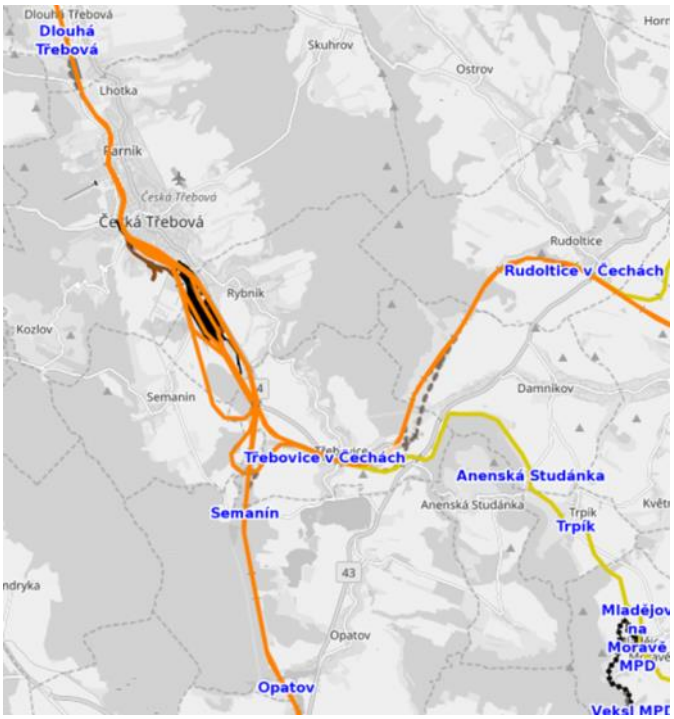



**Figure 6: rail network surrounding CT (lines with 3-aspect bi-directional automatic block system)**

Groups of wagons marshalled in the Česká Třebová yard can reach different partial or final destinations travelling through one of the three rail freight corridors that feed the yard.

In particular, these rail freight corridors are:

- Corridor 5: from Poland *(Międzylesie)* to Austria (*Hohenau*) passing through Brno and vice versa. This corridor is made of another link combining Austria (*Hohenau)* to Poland (*Chałupki* and *Zebrzydowice)* and Slovakia (*Čadca)* passing through Ostrava and vice versa. The station where the two links meet is Břeclav.
- Corridor 6: from Prague to Brno and vice versa. In the station of Kolín the corridor is split in two links to the North-West and two links to the South-East.
  To the North-West both of them lead to Germany (*Bad Schandau),* one passing through Prague and one passing through Nymburk while through the South-East one link goes to Česká Třebová and then to Brno while the second one goes to Brno passing through Havlíčkův Brod bypassing Česká Třebová. From Brno the corridor continues with just one link till Břeclav station where it is divided in two again: one to Germany (*Hohenau*) and one to Slovakia (*Kúty*).
- Corridor 9: from Prague to Slovakia and vice versa. The corridor is made of one link from Prague to Hranice na Moravě. where it is split in two different links: the first one goes to Čadca passing through Ostrava or Kunčice while the second one goes to Lúky pod Makytou passing through Valašské Meziříčí.

## 2.4. Trieste: yard and network layout

The Trieste "Campo Marzio" rail-yard serves a port with three quays, where the wagons are loaded and unloaded. The shunting locomotives haul the rakes of wagons, either complete

length or half-length according to the available tracks, to and from the yard. The trains are handled on the departure/arrival tracks of the national infrastructure manager RFI. The present layout of the port is shown in Figure 7.

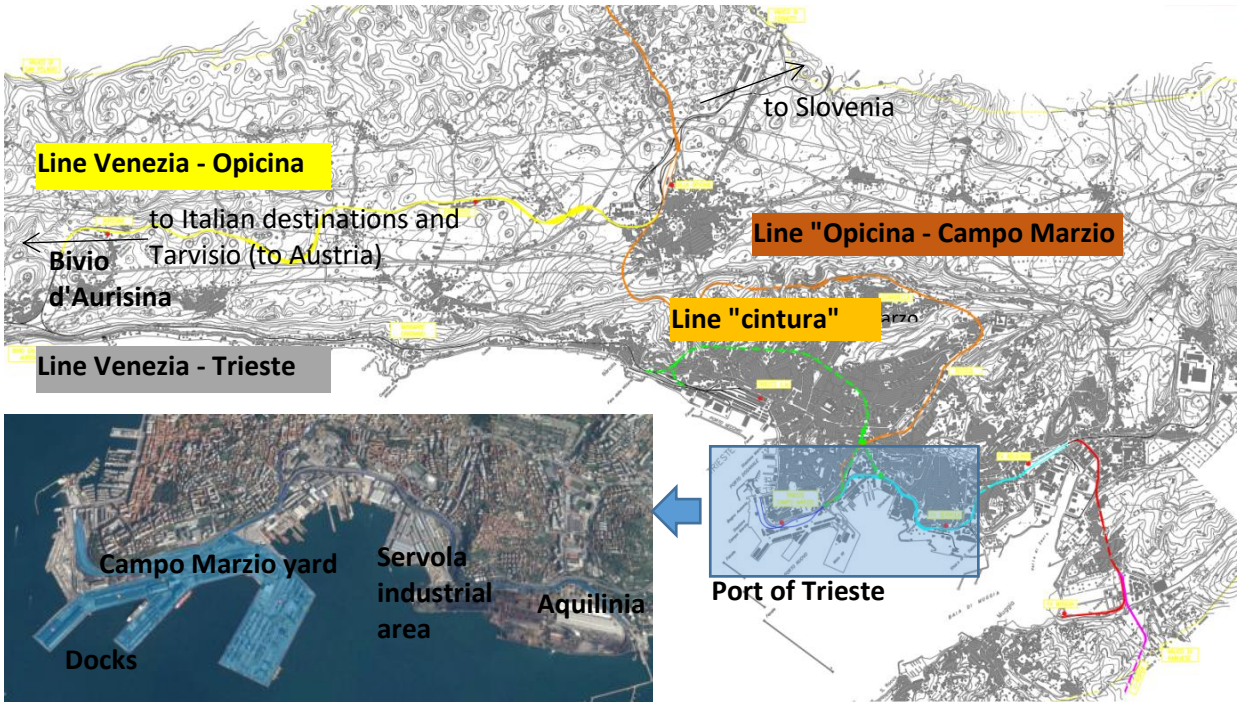



Figure 7: present layout of the port

This plan view shows the various connections in Trieste's port and its surroundings.

Today all trains arriving from Tarvisio and from Slovenia are received in Campo Marzio. Then, if they are bound for the industry part on the Eastern side of the port, they have to be transferred to the Servola sidings and Aquilinia sidings (closed today but to be reopened in the near future). This is done by using, after manoeuvring on RFI sidings, the departure tracks (limited to 5) of Campo Marzio.

When trains are bound to be handled in the Western part of the berths of the port, the trains have to be manoeuvred out of the RFI sidings through the first exit to the port area to arrive on the waiting sidings of Adriafer inside the port. When they are bound to the Eastern berths of the container port, they have to use the second exit gate from RFI sidings to enter the port network.

Work is under way to reopen a direct connection to avoid using Campo Marzio for the industry-bound trains thus increasing the potential rail capacity of Trieste. To enable this with a good reliability, two more tracks of Servola will be reopened and the tracks of the Aquilinia yard will also be reopened to enable to have a buffer to receive the trains at any time and retain them on departure to send them at the right time when the path is available. This will offer flexibility and reliability.

A second important modification will be introduced with the reopening of the direct connection from the Villa Opicina yard to Campo Marzio. It is a single-track line with a steep

gradient usable downhill which is much shorter (14 km length) than the existing route via the "cintura" line (34 km length). However, it will free some capacity on the "cintura" line to accommodate more trains arriving from Tarvisio while the yard in Campo Marzio will be relieved of the industry trains which can use the new connection directly to Servola and Aquilinia.

The surrounding network is represented in Figure 8.The lines from Aurisina to Trieste and to Opicina are double-track, including the "cintura" line that runs in a tunnel under the city and reaches Campo Marzio. The Opicina - Campo Marzio is single track. Automatic block signalling is present on all lines.

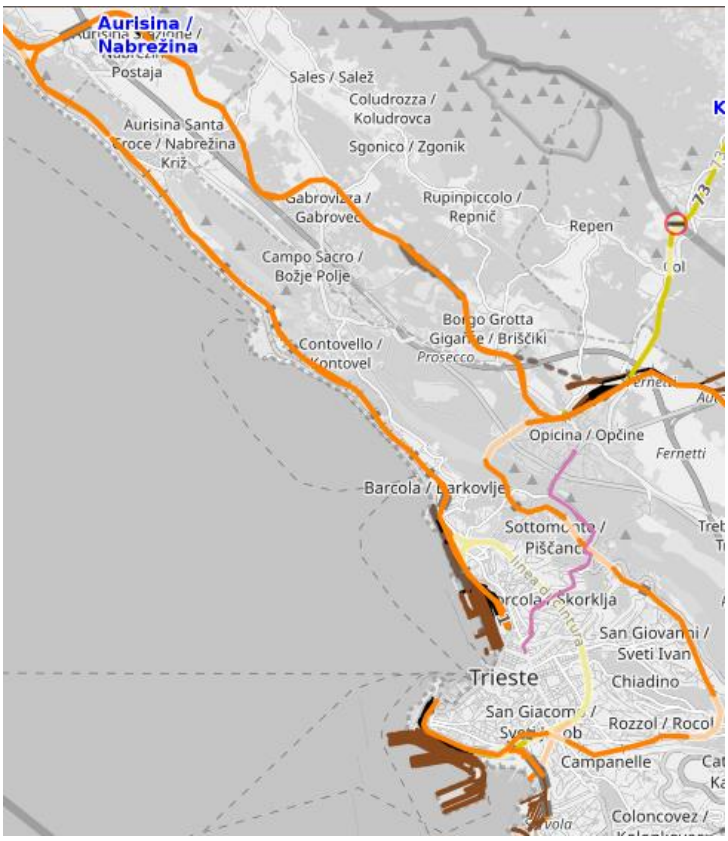



Figure 8: surrounding railway network

## 2.5. Yard and network model scopes and interactions, including with optimisation model

The diagrams in Figure 9 and Figure 10 represent the overlapping scopes of the yard and network models for the case of Trieste. The scope of the optimisation model of WP5 broadly coincides with that of the microsimulation model addressed in this report. The Česká Třebová case is similarly modelled.

For the purposes of OptiYard, in which the main objective is to demonstrate the real-time functionalities of the software being developed, the operations in the port and in the Servola -

Aquilinia sidings are not represented in detail. The same applies to the Opicina - Campo Marzio connection. On the other hand the connections between the Campo Marzio yard (infrastructure manager sidings and shunting company sidings) and the port terminals are modelled to a high degree of accuracy on the basis of CAD drawings and signalling system diagrams.

The network model considers essentially the interactions between freight traffic and passenger traffic to and from Trieste Centrale, the city's main railway station. The line characteristics modelled are those needed for an accurate calculation of expected times in given waypoints - speed limits, signal positions, gradients etc., considering the possible failures and disruptions that might occur.

The yard model starts considering the inbound trains as they pass the third block section before the home signal to the yard. Outbound trains are similarly followed for a certain distance outside the yard. The network model considers inbound trains up to the home signal, where it provides, and ETA based (conceptually) on real-time network information. Outbound trains are followed from the departure signal, where available train paths are calculated on the basis (conceptually) of real time information.

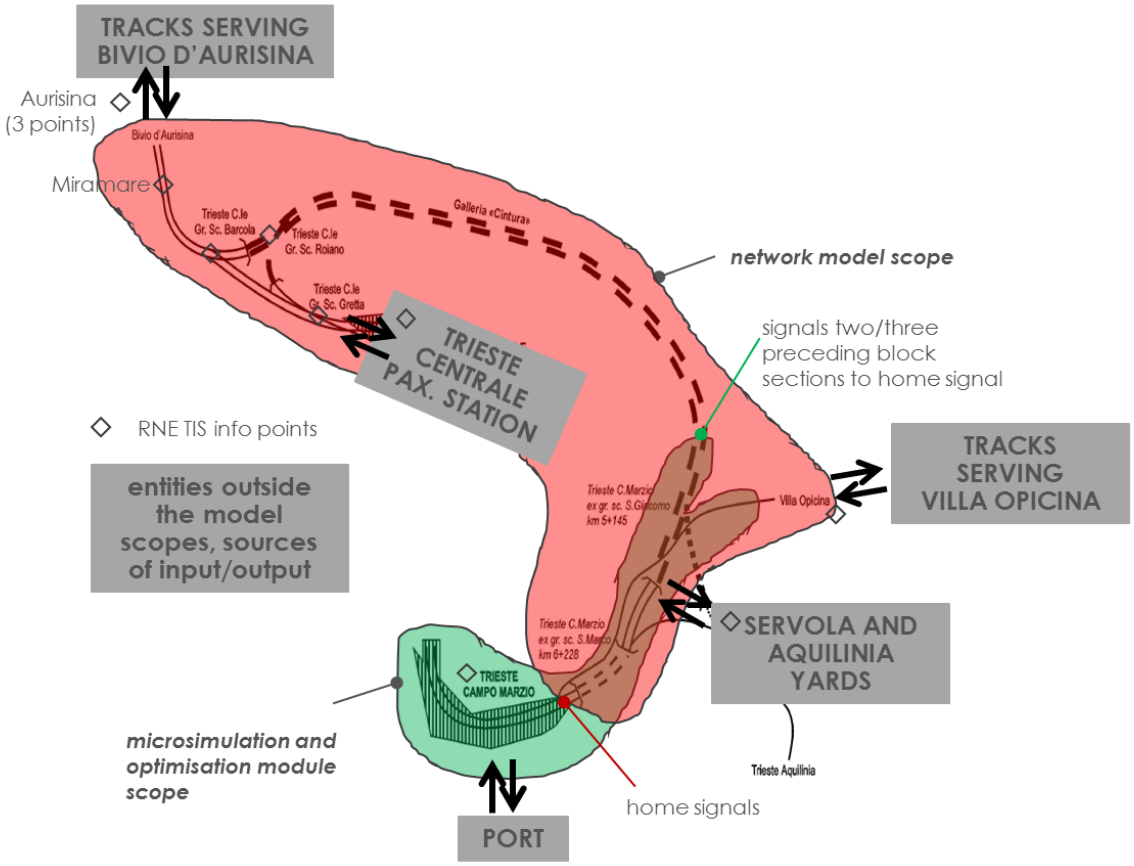



Figure 9: scopes of the yard and network models

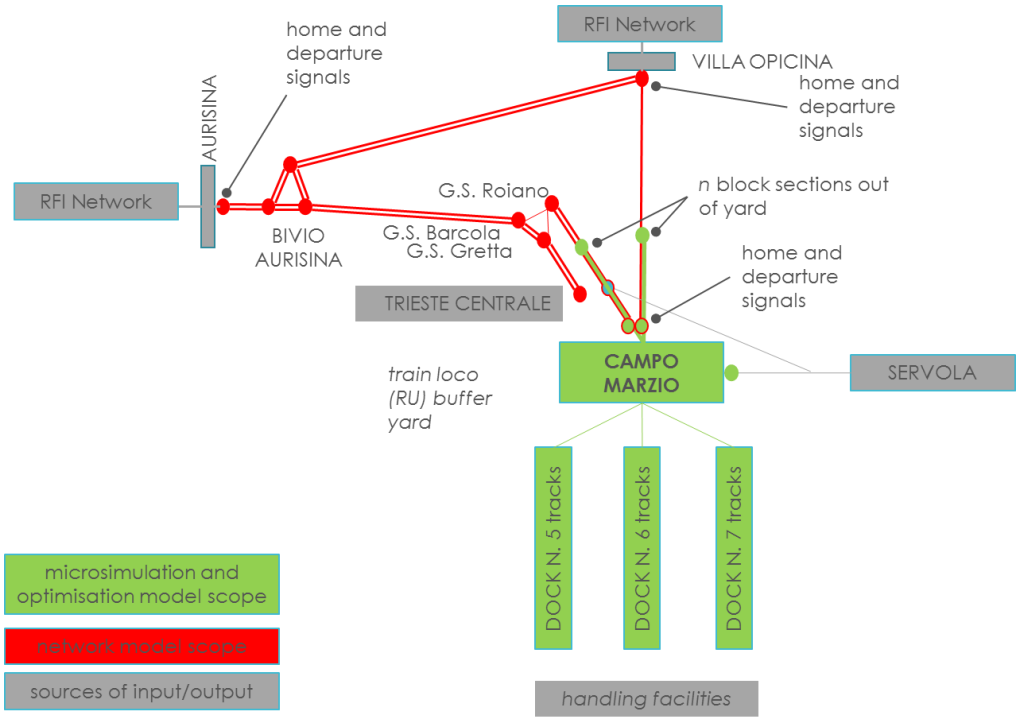



**Figure 10: block diagram representing model scopes**

If operations are going to plan in the yard and the surrounding network, both the network model and yard model will not sense any deviations with respect to the timetables. The expected times at which trains will be ready to depart will coincide with the planned available train path, and ETAs to the yard will coincide with the timetable. The optimisation model will propose a tactic that will be the usual one.

In case of a network disruption, the network model will sense the problem via the IM's IT systems. Certain train paths will foreseeably slip, and the model will alter the real-time input data on their availability to the optimisation model. The latter will propose a number of alternative possible tactics along with the yard model if required, as well as associated KPIs. Based on the yard manager's decision, the times at which trains are expected to be ready will be updated and fed to the network model as well as to the infrastructure manager's IT systems.

In case of a yard disruption, the optimisation model along with the yard model if required, will propose updated tactics which will alter the times at which trains are expected to be ready. This information will be fed to the network model which will update the times at which freight trains are expected to leave the network and make it available for the infrastructure manager's IT systems.

# 3. ČESKÁ TŘEBOVÁ YARD MODEL

A snapshot of the Česká Třebová infrastructure model is shown in Figure 11. It is implemented in the software Villon [2],[3]. The applicability of this software was verified in a previous task (Deliverable 3.1 [3]). The railway infrastructure is represented in detail, with the single wagons occupying the classification bowl tracks and trains in the arrivals tracks each identified. The time-domain simulation follows all trains and wagons simultaneously.

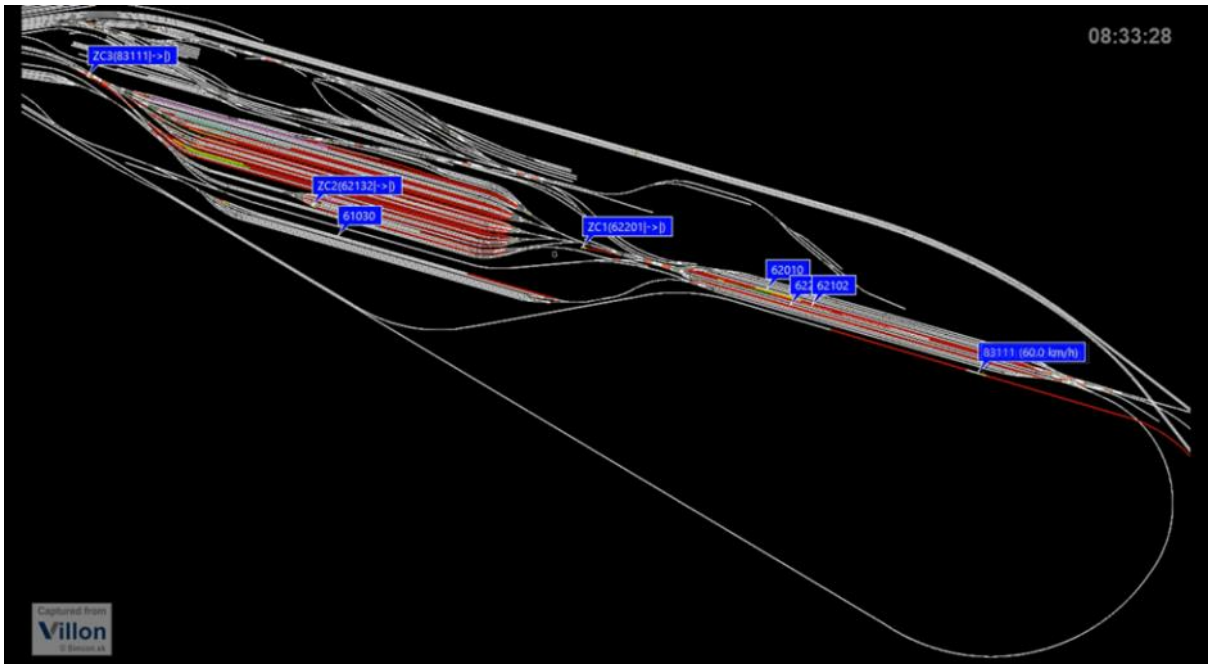



**Figure 11: Česká Třebová arrivals yard and classification bowl as represented in the Villon software**

The other main modelling characteristics are usefully summarised in tabular form according to the functional specifications identified in OptiYard Deliverable D3.2 [1]. In order to keep the main text of this deliverable short, the related tables - describing the yard facilities, wagon and wagons groups, train characteristics and more - are given in Annex A.

Arriving and departing trains are handled by means of detailed processes derived from the field observations performed on the yard. The trains are followed in terms of locomotive, wagons, staff, actions performed, and documentation. An extract of the handling chart for arriving trains is given Figure 12, with more complete examples provided also in annex (Annex C).

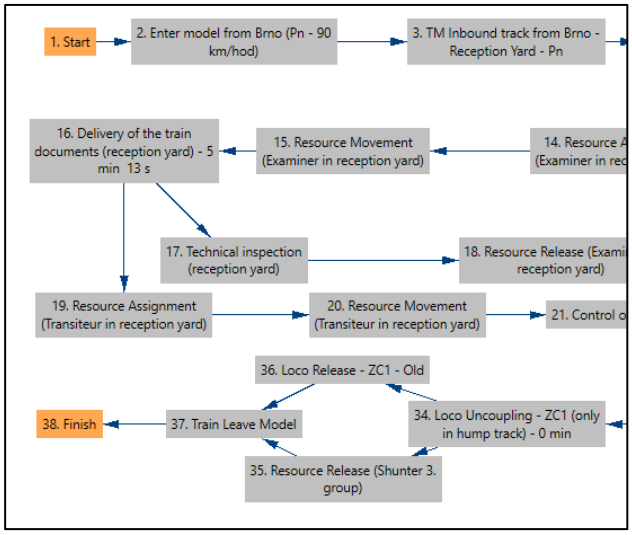



**Figure 12: extract from handling process chart for Česká Třebová inbound trains**

Similarly to the Česká Třebová model, for Trieste Campo Marzio the railway infrastructure is modelled in extreme detail (Figure 13) in the Villon software.

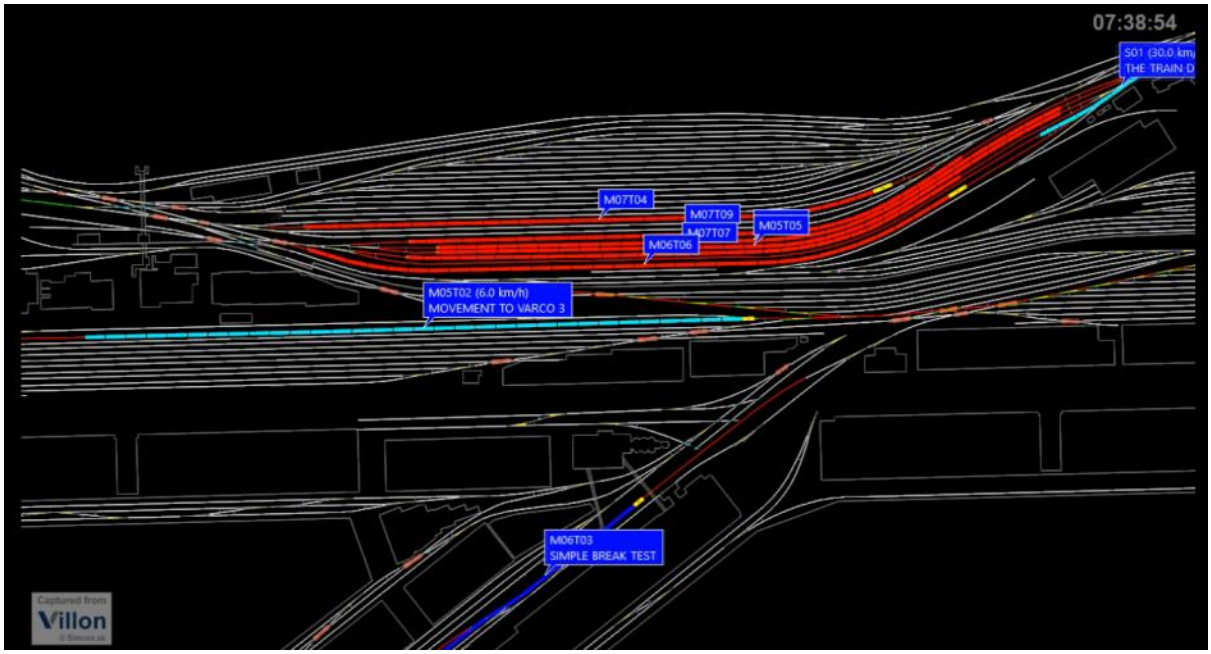



**Figure 13: infrastructure of the Trieste Campo Marzio yard as represented in the Villon software**

Although software implementation is not a problem, it was decided to limit the degree of detail of port terminal operations modelling, given the purpose of the OptiYard software, in which the rail operations are of interest. Figure 14 shows and extract of the handling chart for trains going to a dock.

Annex B and Annex C contain more detailed descriptions according to the functional specifications of D3.2.

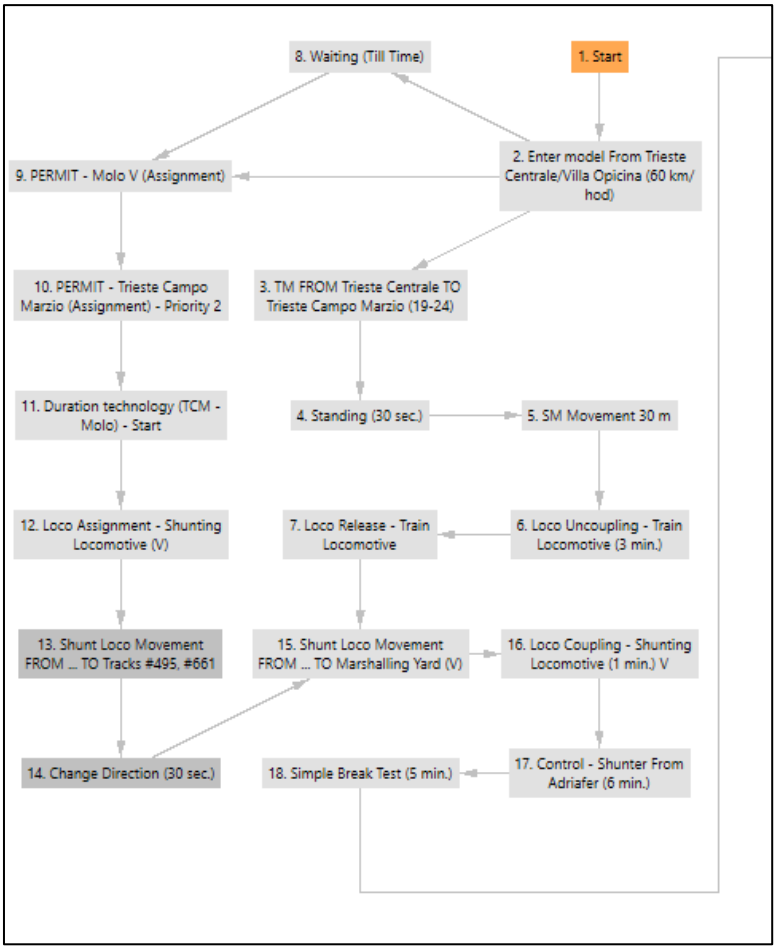
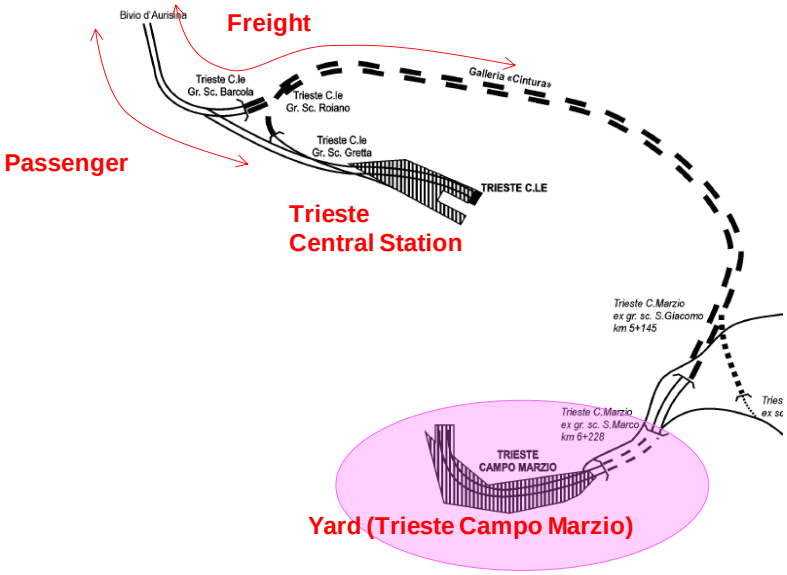


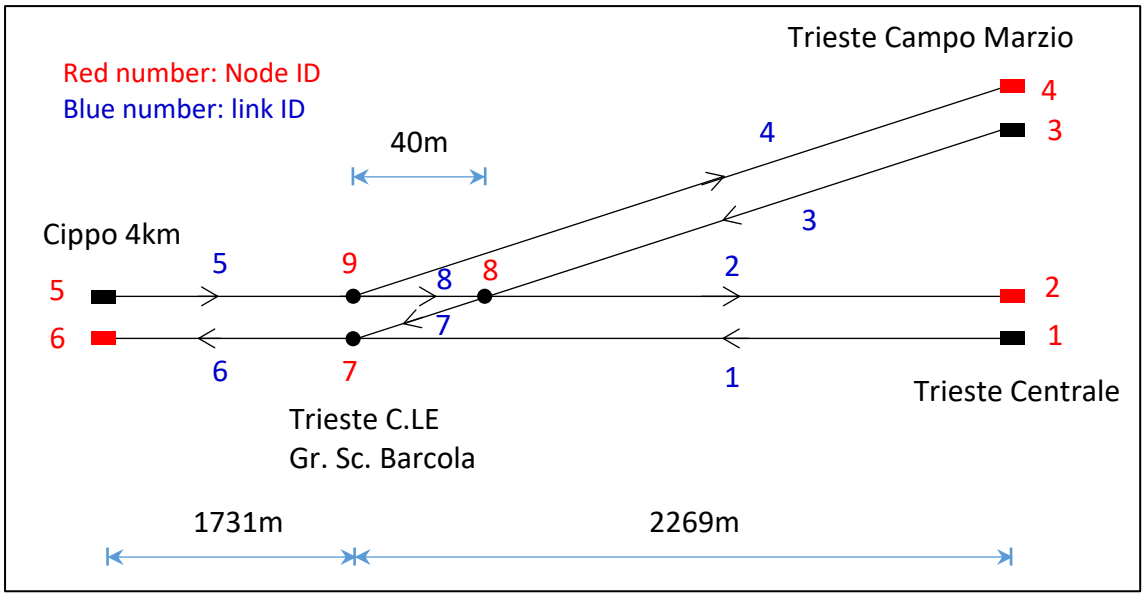

**Figure 14: extract from handling process chart for trains to the docks in the port of Trieste**

# 5. TRIESTE NETWORK MODEL

The network is described as a graph, with nodes representing the stations and merging/diversion/crossing points, and links tracks connecting nodes. The approach is described in more detail in Liu et al. [5],[6], Ye et al. [7],[8]. This is a macroscopic representation of the infrastructure, typical of that for timetabling analysis. The individual switches, points, signalling block sections are not explicitly represented. The track gradients are represented to model their impact on train running speeds. The graph representation of the surrounding network to the Trieste yard is shown in Figure 15 below.




(a)




(b)

**Figure 15 infrastructure layout of Trieste network model: (a) the surrounding network considered; and (b) its graph representation in the network model**

The network description includes the link locations on the network, link start and end locations (and link length), and gradient of the link, as well as four different speed limits on the link for four different train types (Table 1). Train types A represents freight trains, B regional trains, C Inter City trains, while P is used for tilting trains that are used for the high speed "Frecciarossa" connections.

The input timetables for a typical weekday passenger trains to/from Trieste Central (the passenger terminal station), and timetables for freight trains to/from Campo Marzio (the Yard), are shown in Table 1 and Table 2 respectively.

Table 1 network description of the modelled Trieste network

| Link | Location | Start (km) | End (km) | Length | Gradient (‰) | Speed limit (km/h) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A | B | C | P |
| 1 | TRIESTE C.LE. - BARCOLA | 0.000 | 1.000 | 1.000 | 14 | 30 | 30 | 30 | 30 |
| | | 1.000 | 2.269 | 1.269 | 14 | 60 | 75 | 80 | 80 |
| 6 | BARCOLA - Cippo 4km | 2.269 | 4.000 | 1.731 | 14 | 60 | 75 | 80 | 80 |
| 5 | Cippo 4km - BARCOLA | 0.000 | 1.731 | 1.731 | -14 | 60 | 75 | 80 | 80 |
| 8 | BARCOLA - Node 8 | 1.731 | 1.771 | 0.040 | -14 | 60 | 75 | 80 | 80 |
| 2 | Node 8 - TRIESTE C.LE. | 1.771 | 3.000 | 1.229 | -14 | 60 | 75 | 80 | 80 |
| | | 3.000 | 4.000 | 1.000 | -14 | 30 | 30 | 30 | 30 |
| 4 | BARCOLA - CAMPO MARZIO | 0.000 | 0.739 | 0.739 | 0 | 60 | 75 | | |
| | | 0.739 | 4.000 | 3.261 | 0 | 85 | 95 | | |
| | | 4.000 | 4.810 | 0.810 | 0 | 60 | 60 | | |
| | | 4.810 | 6.000 | 1.190 | 1 | 60 | 60 | | |
| | | 6.000 | 6.211 | 0.211 | 1 | 30 | 30 | | |
| | | 6.211 | 7.668 | 1.457 | 0 | 30 | 30 | | |
| 3 | CAMPO MARZIO - Node 8 | 0.000 | 1.457 | 1.457 | 0 | 30 | 30 | | |
| | | 1.457 | 1.668 | 0.211 | -1 | 30 | 30 | | |
| | | 1.668 | 2.668 | 1.000 | -1 | 60 | 60 | | |
| | | 2.668 | 2.858 | 0.190 | -1 | 85 | 95 | | |
| | | 2.858 | 6.929 | 4.071 | 0 | 85 | 95 | | |
| | | 6.929 | 7.628 | 0.699 | 0 | 60 | 75 | | |
| 7 | Node 8 - BARCOLA | 7.628 | 7.668 | 0.040 | 0 | 60 | 75 | | |
| | | | | | | | | | |

Table 2 the passenger train timetable used in the Trieste network model

| Departure time | Type of train | Type Abbr. | No. of train | Station of destination (arrival time) | Starting track | Transport company | Next stops | Next Stop Abbr. | arrival time |
|---|---|---|---|---|---|---|---|---|---|
| 05:15 | Fast Regional Train | B | 2204 | VENICE S.LUCIA (07.20) | 6 | YOU | Monfalcone | MF | 05:38 |
| 05:27 | Regional Train | B | 20952 | VENICE S.LUCIA (08.55) | 5 | YOU | Biv.D'aurisina | BA | 05:43 |
| 05:55 | Regional Train | B | 20956 | VENEZIA S.LUCIA (09.46) | 8 | TI | Biv.D'aurisina | BA | 06:11 |
| 06:08 | High Speed Frecciarossa Train | P | 9710 | TORINO PORTA NUOVA (11.00) | 1 | TI | Monfalcone | MF | 06:30 |
| 06:15 | Fast Regional Train | B | 2206 | VENEZIA S.LUCIA (08.20) | 6 | TI | Monfalcone | MF | 06:37 |
| 06:20 | Regional Train | B | 6004 | CARNIA (08.13) | 8 | TI | Monfalcone | MF | 06:43 |
| 06:27 | Regional Train | B | 20958 | SACILE (08.42) | 5 | TI | Biv.D'aurisina | BA | 06:43 |
| 06:44 | Frecciargento Train | P | 8412 | ROMA TERMINI (12.10) | 4 | TI | Trieste Airport | TA | 07:07 |
| 06:57 | Fast Regional Train | B | 2444 | VENEZIA S.LUCIA (09.55) | 1 | TI | Monfalcone | MF | 07:20 |
| 07:05 | High Speed Frecciarossa Train | P | 9716 | MILANO CENTRALE (11.15) | 2 | TI | Monfalcone | MF | 07:28 |
| 07:15 | Fast Regional Train | B | 2680 | VENEZIA S.LUCIA (09.24) | 5 | TI | Monfalcone | MF | 07:38 |
| 07:21 | InterCity Train | C | 584 | ROMA TERMINI (15.30) | 7 | TI | Monfalcone | MF | 07:44 |
| 07:27 | Regional Train | B | 20962 | UDINE (08.51) | 4 | TI | Biv.D'aurisina | BA | 07:43 |
| 07:50 | Fast Regional Train | B | 6006 | UDINE (08.52) | 5 | TI | Monfalcone | MF | 08:13 |
| 08:15 | Fast Regional Train | B | 2208 | VENEZIA S.LUCIA (10.20) | 6 | TI | Monfalcone | MF | 08:38 |
| 08:57 | Fast Regional Train | B | 2448 | VENEZIA S.LUCIA (11.55) | 1 | TI | Monfalcone | MF | 09:20 |
| 09:15 | Fast Regional Train | B | 2210 | VENEZIA S.LUCIA (11.20) | 2 | TI | Monfalcone | MF | 09:38 |
| 09:38 | High Speed Frecciarossa Train | P | 9726 | TORINO PORTA NUOVA (14.55) | 3 | TI | Monfalcone | MF | 10:01 |
| 10:57 | Fast Regional Train | B | 2452 | VENEZIA S.LUCIA (13.55) | 2 | TI | Monfalcone | MF | 11:20 |
| 11:27 | Fast Regional Train | B | 20968 | VENEZIA S.LUCIA (14.55) | 1 | TI | Biv.D'aurisina | BA | 11:43 |
| 12:15 | Fast Regional Train | B | 2212 | VENEZIA S.LUCIA (14.24) | 5 | TI | Monfalcone | MF | 12:38 |
| 12:20 | Regional Train | B | 6018 | TARVISIO BOSCOVERDE (14.50) | 6 | TI | Monfalcone | MF | 12:43 |
| 12:27 | Regional Train | B | 20970 | UDINE (13.51) | 7 | TI | Biv.D'aurisina | BA | 12:43 |
| 12:57 | Fast Regional Train | B | 2456 | VENEZIA S.LUCIA (15.55) | 4 | TI | Monfalcone | MF | 13:20 |
| 13:02 | InterCity Train | C | 594 | ROMA TERMINI (20.42) | 2 | TI | Monfalcone | MF | 13:25 |
| 13:15 | Fast Regional Train | B | 2682 | VENEZIA S.LUCIA (15.24) | 6 | TI | Monfalcone | MF | 13:38 |
| 13:20 | Regional Train | B | 6024 | CARNIA (15.13) | 7 | TI | Monfalcone | MF | 13:43 |
| 13:27 | Fast Regional Train | B | 20976 | VENEZIA S.LUCIA (16.55) | 3 | TI | Biv.D'aurisina | BA | 13:43 |
| 13:48 | Regional Train | B | 6028 | UDINE (14.52) | 6 | TI | Biv.D'aurisina | BA | 14:02 |
| 14:15 | Fast Regional Train | B | 2214 | VENEZIA S.LUCIA (16.20) | 5 | TI | Monfalcone | MF | 14:38 |
| 14:27 | Regional Train | B | 20978 | UDINE (15.51) | 6 | TI | Biv.D'aurisina | BA | 14:43 |
| 14:57 | Fast Regional Train | B | 2460 | VENEZIA S.LUCIA (17.55) | 4 | TI | Monfalcone | MF | 15:20 |
| 15:15 | Fast Regional Train | B | 2684 | VENEZIA S.LUCIA (17.20) | 2 | TI | Monfalcone | MF | 15:38 |
| 15:50 | Fast Regional Train | B | 6034 | UDINE (16.52) | 5 | TI | Monfalcone | MF | 16:13 |
| 16:00 | Regional Train | B | 21010 | CARNIA (18.13) | 3 | TI | Biv.D'aurisina | BA | 16:16 |
| 16:15 | Fast Regional Train | B | 2216 | VENEZIA S.LUCIA (18.20) | 6 | TI | Monfalcone | MF | 16:38 |
| 16:30 | Regional Train | B | 20984 | UDINE (17.54) | 5 | TI | Biv.D'aurisina | BA | 16:46 |
| 16:49 | Regional Train | B | 6036 | TARVISIO BOSCOVERDE (19.15) | 3 | TI | Monfalcone | MF | 17:12 |
| 16:57 | Fast Regional Train | B | 2464 | VENEZIA S.LUCIA (19.55) | 4 | TI | Monfalcone | MF | 17:20 |
| 16:59 | High Speed Frecciarossa Train | P | 9758 | MILANO CENTRALE (21.15) | 1 | TI | Monfalcone | MF | 17:22 |
| 17:15 | Fast Regional Train | B | 2686 | VENEZIA S.LUCIA (19.20) | 6 | TI | Monfalcone | MF | 17:38 |
| 17:20 | Regional Train | B | 6038 | CARNIA (19.13) | 7 | TI | Monfalcone | MF | 17:43 |
| 17:27 | Regional Train | B | 20986 | UDINE (18.51) | 2 | TI | Biv.D'aurisina | BA | 17:43 |
| 17:50 | Regional Train | B | 6040 | TARVISIO BOSCOVERDE (20.15) | 2 | TI | Monfalcone | MF | 18:13 |
| 17:57 | Fast Regional Train | B | 2826 | VENEZIA S.LUCIA (20.58) | 5 | TI | Monfalcone | MF | 18:20 |
| 18:15 | Fast Regional Train | B | 2218 | VENEZIA S.LUCIA (20.20) | 4 | TI | Monfalcone | MF | 18:38 |
| 18:27 | Regional Train | B | 20990 | UDINE (19.51) | 1 | TI | Miramare | MI | 18:36 |
| 18:50 | Regional Train | B | 6044 | CARNIA (20.38) | 2 | TI | Monfalcone | MF | 19:13 |
| 18:57 | Fast Regional Train | B | 2468 | VENEZIA S.LUCIA (21.55) | 5 | TI | Monfalcone | MF | 19:20 |
| 19:15 | Fast Regional Train | B | 2220 | VENEZIA S.LUCIA (21.20) | 4 | TI | Monfalcone | MF | 19:38 |
| 19:27 | Regional Train | B | 20992 | UDINE (20.51) | 6 | TI | Biv.D'aurisina | BA | 19:43 |
| 20:15 | Regional Train | B | 2688 | PORTOGRUARO-CAORLE (21.24) | 3 | TI | Monfalcone | MF | 20:38 |
| 20:31 | Regional Train | B | 2472 | VENEZIA S.LUCIA (23.56) | 4 | TI | Sistiana-Visogliano | SV | 20:47 |
| 20:40 | InterCity Train Night | C | 770 | ROMA TERMINI (06.35) | 1 | TI | Monfalcone | MF | 21:04 |
| 21:15 | Regional Train | B | 2692 | PORTOGRUARO-CAORLE (22.24) | 8 | TI | Monfalcone | MF | 21:38 |
| 22:06 | Fast Regional Train | B | 2678 | VENICE MESTRE (00.05) | 6 | YOU | Monfalcone | MF | 22:28 |
| 22:17 | Regional Train | B | 20996 | UDINE (23.40) | 1 | YOU | Biv.D'aurisina | BA | 22:32 |

**Table 3 the freight train timetable used in the Trieste network model (track closure for maintenance 10.00-12.00)**

Extracted from 'Campo Marzio_typical schedule.pdf'

The Wednesday schedule is used for the network simulation

| Terminal | Train | Schedule |
|---|---|---|
| 1 | 1 | 8-21, daily |
| | 2 | Wed/ Fri 9-20, Sun 9- Mon20 |
| | 3 | 20-13, daily |
| | 4 | Fri 18 – Sat 13, Sun 18 - Mon 13 |
| | 5 | Tue 20 – Wed 13, Thu 20 – Fri 07, |
| | 6 | Mon 16 – Tue 02, Tue 16-Wed 13, Wed 16-Thu 02, Thu 16 – Fri 13, Sat 11-Sat 21, |
| | 7 | Tue 07 – Wed 05, Fri 06-Sat 20 |
| | 8 | Mon/Tue 09-20, Thu 23-Fri 19, Fri 22-Sat19 |
| 2 | 1 | 17 –05, daily |
| | 2 | 21-09, daily |
| | 3 | 23-13, daily |
| | 4 | 06-22, daily |
| | 5 | 06-23, daily |
| 3 | 1 | 09 Tue – 06 Wed, 21 Wed – 06 Thu, 21 Thu – 15 Sat, 21 Sat – 06 Mon |
| | 2 | 21 Tue – 15 Wed, 09 Thu-06 Fri, 21 Fri-15 Sun, 21 Sun-15 Mon |
| | 3 | 09 Sat-06 Tue |
| | 4 | 16 Mon-11 Wed, |
| | 5 | 20 Tue – 07 Wed, 20 Thu – 06 Fri, 20 Sat-06 Sun |
| | 6 | 22 Tue-12 Wed, 22 Fri-12 Sun |
| | 7 | Wed/Fri 07 -17, Sun 07 – 17 Mon |
| | 8 | 21 Mon-11 Tue, wed 21 -11 Thu, 21 Fri- Sat 11, Sat 21 – 11 Mon |
| | 9 | 06 Wed- 22 Thu,06 Fri-22 Sun |
| | 10 | 06 Sun-Tue 22 |

The results of the network simulation for the above example include the detailed train trajectories through the modelled network.

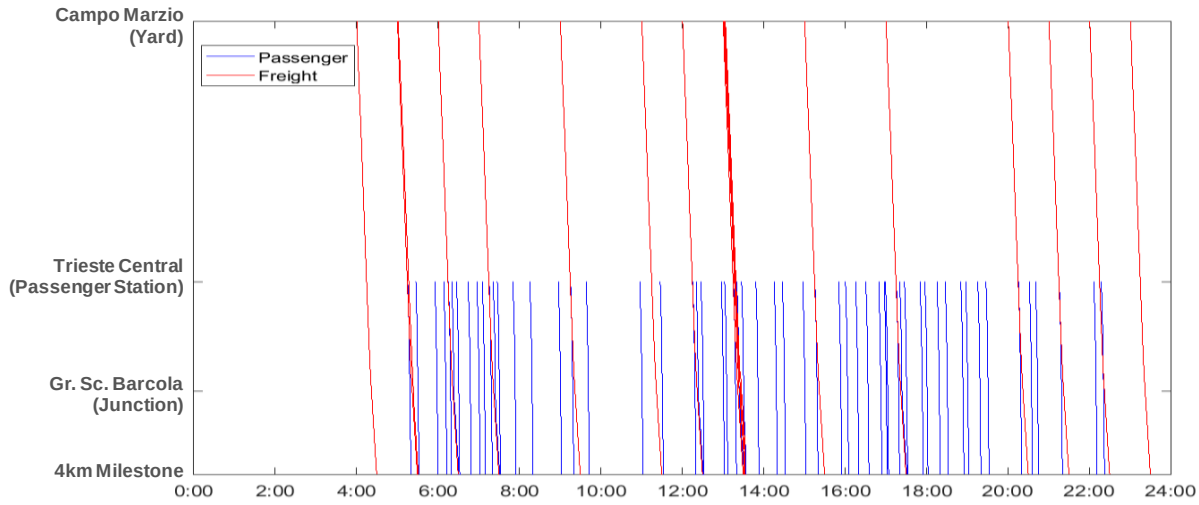
Figure 16 (a) shows the simulated trajectories of the outbound trains. The red lines are for freight trains, while blue ones the passenger trains.

It can be seen in Figure 16 (a) that there are periods during the day when it was very congested on the network (with densely packed train trajectories), often involving both passenger trains and freight trains. Whilst during other times of the day, there are large time gaps in the train trajectories, such as between 10:00 – 12:00.

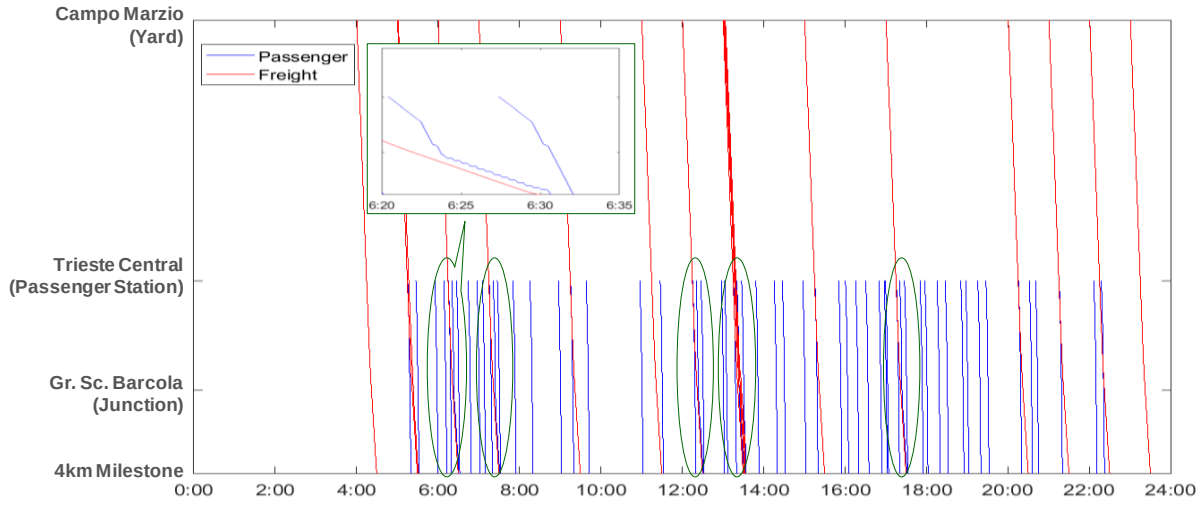
Figure 16 (b) highlighted some of the congested periods of the day. It shows that, in one of such busy periods between 06:20 and 06:35, there appears to be some delays to the passenger trains due to a slow freight train ahead.

The results illustrate that there is potential for timetable rescheduling, to ensure the best use of network capacity and to reduce conflicts between freight and passenger trains.

It should be noted that the results presented above are for illustrative purposes; the main objective here is to demonstrate what a network model can do with integrated yard and network management.




(a)




(b)

**Figure 16 the simulated train trajectories**

# 6. CONCLUSIONS

This WP4 deliverable describes the models to be used in the subsequent OptiYard activities of WP5 "process optimisation" and WP6 "business cases, feasibility and simulation tests".

The models address the two OptiYard case-studies, Česká Třebová (Czech Republic) and Trieste (Italy). The former is a classic marshalling yard for Single Wagon Load transport, whereas the latter is a railway yard serving the city's port and industrial area.

Models were developed for both yard and surrounding network and are ready for validation.

# 7. REFERENCES

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[5] Liu, R., Ye, H. and Whiteing, T. (2015) Dynamic Simulation for Real Time Operations of ERTMS Level 3. DITTO Project Deliverable 3.1, RSSB. (http://www.its.leeds.ac.uk/fileadmin/documents/research/F2-DITTODeliverable31Milestone6.pdf)

[6] Liu, R., Ye, H. and Whiteing, T. (2016) Simulation and Control of ERTMS Level 2. DITTO Project Deliverable 3.2, RSSB. (http://www.its.leeds.ac.uk/fileadmin/documents/research/F3-DITTOMilestone7Deliverable_32Final.pdf)

[7] Ye, H., and Liu, R. (2016) A multiphase optimal control method for multi-train control and scheduling on railway lines. **Transportation Research B: Methodological,** 93(A), 377-393. http://dx.doi.org/10.1016/j.trb.2016.08.002.

[8] Ye, H. and Liu, R (2017) Nonlinear programming methods based on closed-form expressions for optimal train control. **Transportation Research Part C: Emerging Technologies,** 82, 102-123. https://doi.org/10.1016/j.trc.2017.06.011

## 7.1. Yard facilities

Table 4: yard facilities in Česká Třebová

| Functional requirement | Characteristic / modelling choice |
|---|---|
| Type of yard | hump marshalling yard |
| Infrastructure layout of yard<br>• Receiving yard, classification bowl and departure yard: tracks and switches<br>• Hump<br>• Maintenance track, repair track, etc.<br>• Sorting bowl and the associated hump for the secondary shorting/marshalling (if provided) | Receiving yard<br>• 13 tracks (No. 101-112, 114)<br>Sorting yard<br>• 38 tracks (No. 201 – 238)<br>Departure yard<br>• 14 tracks (No. 9, 11, 13, 15, 17, 18, 19, 21, 23, 25, 29, 31, 33, 35)<br>Switches<br>• Electrically and manually operated<br>primary hump<br>• 1 hump track<br>• 2 feed tracks<br>Maintenance track, repair track, etc…<br>• Out of scope<br>Secondary hump<br>• Out of order |

| | |
|---|---|
| Characteristics of tracks<br>• Running direction<br>• Speed limit<br>• Gradient<br>• Curvature<br>• Signal<br>• Electrification | Running directions<br>• Dlouhá Třebová<br>• Třebovice v Čechách<br>• Opatov<br>Speed limit in marshalling yard<br>• 40 km/h<br>Gradient<br>• Data not available<br>Curvature<br>• According to the provided data<br>Signal<br>• 2-aspect, 3-aspect, shunting signals<br>Electrification<br>• 3kV DC<br>• Arrival, departure, hump |
| Classification bowl: deceleration technology | Hydraulic and single-sided pneumatic beam retarders<br>• Main retarder<br>• Intermediate retarders before each series of sorting sidings<br>• Target retarders at the beginning of each sorting track.<br>Occupancy of sorting sidings is detected by means of isolated sections.<br>Wagon cuts compression on sorting tracks (to close gaps between wagon groups) is done by shunting locomotive identified as ZC2. |

| | |
|---|---|
| Asset: shunting and line locomotives<br>• ID<br>• Weight<br>• Length<br>• Number of axles<br>• Electric or diesel traction<br>• Traction and braking characteristics<br>• Signalling system compatibility (required for train locomotives) | Shunting locomotives<br>• Types - 111, 742<br>• Names: ZC1, ZC2, ZC3<br>Type 111<br>• Weight: 70 400 kg<br>• Length: 14,4 m<br>• 4 axles<br>• Electric traction<br>• Traction, braking – technical sheet<br>• Signalling system – not known<br>Type 742<br>• Weight: 64 000 kg<br>• Length: 13,85 m<br>• 4 axles<br>• Diesel traction<br>• Traction, braking – technical sheet<br>• Signalling system – not known<br>Train locomotives<br>Type - 363<br>• Weight: 87 000 kg<br>• Length: 16,8 m<br>• 4 axles<br>• Electric traction<br>• Traction, braking – technical sheet<br>• Signalling system – not known |

| | |
|---|---|
| Personnel<br>• ID<br>• Qualification, i.e. type of work that each staff can do, including: yard operations, dispatching/disposition processes, inspection of incoming/outgoing trains, brake test and related preparation work, shunting engine driving, incoming/outgoing freight train driving, etc. | Examiner<br>• 1 employee in reception yard<br>  ○ Technical inspection<br>• 1 employee in departure yard<br>  ○ Brake test<br>• 2 employees in sorting yard<br>  ○ Brake test<br>  ○ Simple brake test<br>  ○ Technical inspection<br>Shunter<br>• 1 employee in sorting yard<br>  ○ Loco coupling<br>  ○ Loco uncoupling<br>  ○ Couple cuts<br>  ○ Compression<br>  ○ Securing train set<br>• 1 employee in reception yard<br>  ○ Loco coupling<br>  ○ Loco uncoupling<br>  ○ Primary humping<br>  ○ Prepare for humping<br>  ○ Securing train set<br>Transiteur<br>• 1 employee in reception yard<br>  ○ Data control of train set<br>  ○ Creating labels<br>• 2 employees in sorting yard<br>  ○ Preparation of the train documents<br>  ○ Delivery of documents<br>  ○ Summary of train<br>Other personnel in marshalling yard is out of scope of the simulation model. |

## 7.2. Intermodal terminal facilities

The container terminal in Česká Třebová is out of scope. OptiYard addresses the rail-rail part only.

## 7.3. Wagons and wagon groups

The wagon groups managed in Česká Třebová are listed in the following table.

Table 5: wagon groups in Česká Třebová

| Name | Length [m] | Modelled max. speed [km/h] | Weight [kg] | UIC Int. CodeMinimum | UIC Int. Code Maximum | Axle Count |
|---|---|---|---|---|---|---|
| Zgs | 9,7 | 100 | 14150 | 7317 | 7317 | 2 |
| Zas | 15,76 | 100 | 23850 | 7849 | 7966 | 4 |
| Zans | 14,96 | 100 | 21520 | 7836 | 7843 | 4 |
| Zags | 18 | 100 | 32650 | 7811 | 7819 | 4 |
| Zagns | 13,46 | 100 | 24970 | 7809 | 7809 | 4 |
| Zagks | 12,79 | 100 | 37450 | 7815 | 7815 | 4 |
| Zagkks | 17,9 | 100 | 34100 | 7912 | 7923 | 4 |
| Zafgkks | 14,14 | 100 | 20600 | 7892 | 7892 | 4 |
| Zaes | 15,24 | 100 | 22900 | 7879 | 7991 | 4 |
| Zacs | 12,64 | 100 | 23250 | 7845 | 7868 | 4 |
| Zacns | 15,11 | 100 | 22600 | 7829 | 7929 | 4 |
| Zaces | 15,24 | 100 | 23400 | 7873 | 7977 | 4 |
| Zacens | 16,24 | 100 | 25600 | 7932 | 7933 | 4 |
| Z | 16,8 | 100 | 84500 | 7163 | 7163 | 4 |
| Uy | 10,64 | 100 | 10000 | 9407 | 9407 | 2 |
| Us | 14,1 | 100 | 1396 | 9100 | 9100 | 2 |
| Ucs | 14 | 100 | 120000 | 9119 | 9119 | 8 |
| Uapps | 17,34 | 100 | 22780 | 9341 | 9341 | 4 |
| Uagps | 14,84 | 100 | 20300 | 9332 | 9339 | 4 |
| Uagpps | 15,39 | 100 | 20580 | 9338 | 9345 | 4 |
| Uacs | 14,45 | 100 | 24350 | 9305 | 9323 | 4 |
| Tds | 9,64 | 100 | 12900 | 730 | 735 | 2 |
| Tdns | 9,64 | 100 | 14400 | 130 | 130 | 2 |
| Tams | 14,04 | 100 | 22900 | 807 | 807 | 4 |
| Talls | 13,52 | 100 | 27300 | 675 | 675 | 4 |
| Tagnpps | 20 | 100 | 21680 | 764 | 764 | 4 |
| Tads | 14,86 | 100 | 22320 | 834 | 834 | 4 |
| Tadgnss | 21,64 | 100 | 27200 | 925 | 925 | 4 |
| Sps | 26,24 | 100 | 27380 | 4719 | 4719 | 4 |
| Special | 24,5 | 100 | 36690 | 9078 | 9078 | 4 |
| Snps | 21,84 | 100 | 24500 | 4723 | 4725 | 4 |
| Smmps | 15,24 | 100 | 23500 | 4728 | 4728 | 4 |
| Slps | 20,04 | 100 | 28700 | 4726 | 4726 | 4 |
| Shmmns | 12,04 | 100 | 22600 | 4766 | 4766 | 4 |
| Shimms | 12,4 | 100 | 23100 | 4768 | 4775 | 4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Shimmns | 12,04 | 100 | 20480 | 4668 | 4777 | 4 |
| Sgss | 20,6 | 100 | 2306 | 4548 | 4548 | 4 |
| Sgs | 20,04 | 100 | 23900 | 4540 | 4541 | 4 |
| Sgnss | 19,64 | 100 | 19000 | 4552 | 4575 | 4 |
| Sgns | 19,64 | 100 | 20000 | 4556 | 4557 | 4 |
| Sgjs | 21,84 | 100 | 23600 | 4536 | 4536 | 4 |
| Sggrss | 26,7 | 100 | 28200 | 4960 | 4980 | 6 |
| Sggrs | 26,78 | 100 | 28600 | 4950 | 4950 | 6 |
| Sggrrs | 26,71 | 100 | 36300 | 4854 | 4854 | 8 |
| Sggnss | 25,94 | 100 | 21500 | 4576 | 4663 | 4 |
| Sggns | 25,94 | 100 | 22000 | 4561 | 4561 | 4 |
| Sggmrss | 29,59 | 100 | 29300 | 4961 | 4961 | 6 |
| Sggmrs | 29,59 | 100 | 28100 | 4952 | 4952 | 6 |
| Sfps | 21,7 | 100 | 22700 | 4737 | 4742 | 4 |
| Sdgnss | 19,74 | 100 | 22150 | 4506 | 4506 | 4 |
| Sdgmns | 18,34 | 100 | 21000 | 4512 | 4512 | 4 |
| Sdggmrss | 34,2 | 100 | 35000 | 4992 | 4992 | 6 |
| Sdggmrs | 34,03 | 100 | 35500 | 4955 | 4993 | 6 |
| Samms | 16,4 | 100 | 29600 | 4852 | 4865 | 6 |
| Sahmms | 16,4 | 100 | 31300 | 4868 | 4871 | 6 |
| Sahlmmps | 13,2 | 100 | 34000 | 4838 | 4838 | 6 |
| Sahimms | 15 | 100 | 32300 | 4876 | 4876 | 6 |
| Rs | 19,9 | 100 | 22600 | 3903 | 3904 | 4 |
| Roos | 19,9 | 100 | 27500 | 3525 | 3527 | 4 |
| Rmms | 14 | 100 | 58330 | 3965 | 3965 | 4 |
| Rils | 19,9 | 100 | 23900 | 3537 | 3542 | 4 |
| Rilns | 19,9 | 100 | 25050 | 3552 | 3552 | 4 |
| Rijmmns | 19,9 | 100 | 25460 | 3536 | 3536 | 4 |
| Res | 19,9 | 100 | 25000 | 3936 | 3999 | 4 |
| Remms | 14,04 | 100 | 22000 | 3948 | 3948 | 4 |
| Lgs | 14,02 | 100 | 12500 | 4425 | 4427 | 2 |
| Lgns | 13,86 | 100 | 12200 | 4432 | 4435 | 2 |
| Laes | 26,5 | 100 | 29900 | 4292 | 4292 | 3 |
| Laaps | 28,04 | 100 | 29400 | 4309 | 4309 | 4 |
| Laails | 28,04 | 100 | 28900 | 4307 | 4307 | 4 |
| Laaiis | 27 | 100 | 26700 | 4218 | 4220 | 4 |
| Laaers | 31 | 100 | 37000 | 4356 | 4371 | 4 |
| Laaeks | 23,5 | 100 | 25100 | 4366 | 4366 | 4 |
| Laaefrs | 33 | 100 | 33020 | 4372 | 4372 | 4 |
| Laadgrs | 33 | 100 | 30700 | 4301 | 4301 | 4 |
| Kns | 13,86 | 100 | 14200 | 3379 | 3379 | 2 |
| Knps | 13,86 | 100 | 12900 | 3299 | 3299 | 2 |
| Kils | 14,02 | 100 | 14700 | 3380 | 3380 | 2 |
| Himrrs | 31 | 100 | 30000 | 2923 | 2923 | 4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Hillmrrss | 33,45 | 100 | 32500 | 2936 | 2936 | 4 |
| Hillmrrs | 31 | 100 | 31000 | 2931 | 2932 | 4 |
| Hbis | 14,02 | 100 | 15450 | 2245 | 2245 | 2 |
| Hbbillnss | 16,7 | 100 | 17400 | 2461 | 2461 | 2 |
| Hbbillns | 15,5 | 100 | 15500 | 2457 | 2459 | 2 |
| Habins | 23,24 | 100 | 26200 | 2783 | 2783 | 4 |
| Habils | 21,7 | 100 | 30000 | 2750 | 2750 | 4 |
| Habiins | 23,24 | 100 | 27150 | 2744 | 2745 | 4 |
| Habbins | 23,2 | 100 | 26500 | 2770 | 2770 | 4 |
| Habbillnss | 23,26 | 100 | 29700 | 2890 | 2890 | 4 |
| Habbillns | 23,26 | 100 | 28500 | 2780 | 2780 | 4 |
| Habbiinss | 23,27 | 100 | 26500 | 2741 | 2741 | 4 |
| Habbiins | 23,2 | 100 | 26500 | 2740 | 2743 | 4 |
| Gbqs | 14,02 | 100 | 14600 | 1542 | 1542 | 2 |
| Gbkkqs | 14,02 | 100 | 15470 | 1538 | 1538 | 2 |
| Gbgkks | 14,02 | 100 | 14900 | 1548 | 1548 | 2 |
| Gabs | 21,8 | 100 | 25700 | 1811 | 1811 | 4 |
| Fas | 14,04 | 100 | 26400 | 6735 | 6735 | 4 |
| Falns | 13,7 | 100 | 24970 | 6633 | 6633 | 4 |
| Falls | 13,52 | 100 | 26230 | 6675 | 6688 | 4 |
| Faccs | 12,74 | 100 | 21700 | 6995 | 6999 | 4 |
| Es | 10 | 100 | 12500 | 5537 | 5557 | 2 |
| Eas | 14,04 | 100 | 22150 | 5420 | 5979 | 4 |
| Eaos | 14,04 | 100 | 22000 | 5301 | 5499 | 4 |
| Eanos | 14,04 | 100 | 22370 | 5375 | 5377 | 4 |
| Ealos | 14,04 | 100 | 23300 | 5931 | 5946 | 4 |

## 7.4. Freight trains

**Table 6: freight train schedule for Česká Třebová**

| Train number | Planned arrival | Departure | Schedule | Direction of arrival | Direction of departure | Avg. braking |
|---|---|---|---|---|---|---|
| 41700 | 1:31 | | Mon, Thu | Třebovice v Čechách | | 0,3m/s$^2$ |
| 44250 | 17:48 | | Mon-Sat | Dlouhá Třebová | | 0,3m/s$^2$ |
| 45313 | 20:28 | | Mon-Sun | Dlouhá Třebová | | 0,3m/s$^2$ |
| 45315 | 2:32 | | Tue-Sat | Dlouhá Třebová | | 0,3m/s$^2$ |
| 45730 | 9:39 | | Mon-Sun | Třebovice v Čechách | | 0,3m/s$^2$ |
| 45732 | 23:39 | | Mon-Sun | Třebovice v Čechách | | 0,3m/s$^2$ |
| 47334 | 19:30 | 20:22 | Mon-Fri, Sun | Třebovice v Čechách | Dlouhá Třebová | 0,3m/s$^2$ |
| 49416 | 1:05 | | Mon-Sun | Dlouhá Třebová | | 0,3m/s$^2$ |
| 60205 | 14:22 | | Mon-Sun | Dlouhá Třebová | | 0,3m/s$^2$ |
| 60206 | 23:07 | 1:04 | Mon-Sat | Opatov | Dlouhá Třebová | 0,3m/s$^2$ |

| | | | | | | |
|---|---|---|---|---|---|---|
| 61010 | 0:39 | | Mon-Sat | Třebovice v Čechách | | 0,3m/s² |
| 61021 | 3:31 | | Mon-Sun | Dlouhá Třebová | | 0,3m/s² |
| 61023 | 15:47 | | Mon-Sun | Dlouhá Třebová | | 0,3m/s² |
| 61030 | 0:46 | | Mon-Sun | Třebovice v Čechách | | 0,3m/s² |
| 62010 | 5:20 | | Mon-Sun | Třebovice v Čechách | | 0,3m/s² |
| 62012 | 11:10 | | Tue-Sun | Třebovice v Čechách | | 0,3m/s² |
| 62014 | 17:48 | | Mon-Sun | Třebovice v Čechách | | 0,3m/s² |
| 62016 | 0:26 | | Mon-Sun | Třebovice v Čechách | | 0,3m/s² |
| 62100 | 11:53 | | Mon-Sat | Opatov | | 0,3m/s² |
| 62102 | 8:32 | | Mon-Sun | Opatov | | 0,3m/s² |
| 62130 | 18:03 | 21:21 | Mon-Sun | Opatov | Dlouhá Třebová | 0,3m/s² |
| 62131 | 16:51 | | Mon-Sun | Dlouhá Třebová | | 0,3m/s² |
| 62133 | 4:43 | | Mon-Sun | Dlouhá Třebová | | 0,3m/s² |
| 62201 | 5:16 | | Mon-Sun | Dlouhá Třebová | | 0,3m/s² |
| 62221 | 9:47 | | Tue-Sat | Dlouhá Třebová | | 0,3m/s² |
| 62227 | 5:45 | | Mon-Sun | Dlouhá Třebová | | 0,3m/s² |
| 83125 | 14:25 | | Tue, Thu, Sat | Opatov | | 0,3m/s² |
| 83200 | 19:58 | | Mon, Wed, Fri | Třebovice v Čechách | | 0,3m/s² |
| 41701 | | 18:32 | Wed, Sun | | | 0,3m/s² |
| 44251 | | 9:23 | Mon-Sat | | Dlouhá Třebová | 0,3m/s² |
| 44725 | | 0:10 | Mon-Sun | | Opatov | 0,3m/s² |
| 44727 | | 12:47 | Mon-Sun | | Opatov | 0,3m/s² |
| 45027 | | 6:58 | Mon-Sat | | Opatov | 0,3m/s² |
| 45310 | | 0:34 | Mon-Sun | | Dlouhá Třebová | 0,3m/s² |
| 45711 | | 12:31 | Mon-Sun | | Třebovice v Čechách | 0,3m/s² |
| 45713 | | 1:37 | Mon-Sun | | Třebovice v Čechách | 0,3m/s² |
| 60104 | | 12:22 | Tue-Sat | | Dlouhá Třebová | 0,3m/s² |
| 60204 | | 1:35 | Mon-Sun | | Dlouhá Třebová | 0,3m/s² |
| 61020 | | 5:28 | Mon-Sun | | Dlouhá Třebová | 0,3m/s² |
| 61022 | | 19:41 | Mon-Sun | | Dlouhá Třebová | 0,3m/s² |
| 61031 | | 15:40 | Mon-Sun | | Třebovice v Čechách | 0,3m/s² |
| 62013 | | 13:13 | Tue-Sun | | Třebovice v Čechách | 0,3m/s² |
| 62015 | | 19:21 | Mon-Sun | | Třebovice v Čechách | 0,3m/s² |
| 62017 | | 19:12 | Mon-Sun | | Třebovice v Čechách | 0,3m/s² |
| 62019 | | 8:10 | Sat, Sun | | Třebovice v Čechách | 0,3m/s² |
| 62023 | | 3:51 | Mon-Sun | | Třebovice v Čechách | 0,3m/s² |
| 62101 | | 11:12 | Mon-Sun | | Opatov | 0,3m/s² |
| 62132 | | 8:38 | Mon-Sun | | Dlouhá Třebová | 0,3m/s² |
| 62134 | | 2:21 | Mon-Sun, excep. | | Dlouhá Třebová | 0,3m/s² |

| | | | | | | |
|---|---|---|---|---|---|---|
| 62200 | | 19:29 | Mon-Sun | | Dlouhá Třebová | 0,3m/s$^2$ |
| 62220 | | 13:51 | Mon-Sat | | Dlouhá Třebová | 0,3m/s$^2$ |
| 62222 | | 22:58 | Mon-Sun | | Dlouhá Třebová | 0,3m/s$^2$ |
| 62224 | | 0:08 | Mon-Sun | | Dlouhá Třebová | 0,3m/s$^2$ |
| 83037 | | 2:45 | Mon, Wed, Fri | | Dlouhá Třebová | 0,3m/s$^2$ |
| 83111 | | 8:30 | Mon, Wed, Fri | | Třebovice v Čechách | 0,3m/s$^2$ |
| 83121 | | 5:20 | Tue, Thu | | Opatov | 0,3m/s$^2$ |
| 83123 | | 6:46 | Sat | | Opatov | 0,3m/s$^2$ |
| 83127 | | 18:24 | Mon | | Opatov | 0,3m/s$^2$ |
| 83201 | | 11:04 | Mon, Wed, Fri | | Třebovice v Čechách | 0,3m/s$^2$ |

## 7.5. Yard activities and real-time management

**Table 7: yard activities, Česká Třebová**

| Functional requirement | Characteristic / modelling choice |
|---|---|
| Working hours of the yard | |
| Required quantity and time (mean and standard deviation) of personnel and asset for each operation | • Loco coupling – 60s<br>• Loco uncoupling – 60s<br>• Couple cut – 30s per cut<br>• Primary humping – 1m/s (has to be validated)<br>• Prepare to humping – 180s per cut<br>• Brake test – 30s per wagon<br>• Simply brake test – 20s per wagon<br>• Compression – 60s per wagon<br>• Control of train set – 30s per wagon<br>• Creating labels – 470s<br>• Delivery of the train documents – 313s<br>• Execution of the train documents – 540s<br>• Finalization of train control – 60s<br>• Security train set off – 48s<br>• Security train set on – 60s<br>• Service documents – 386s<br>• Summary of train – 30s per wagon<br>• Technical inspection – 1s per meter |
| Way of secondary sorting/marshalling: e.g. pulling back over hump and roll over again, or flat shunting (i.e. using shunting engine) | Flat shunting |
| Method used for formation of multigroup trains:<br>Consecutive forming of multigroup trains: single-stage sorting method, Futhner's method, general method, special method, unified group method, Japanese method<br>Simultaneous formation of multigroup trains: elementary method, triangular method, geometrical | Single-stage sorting method |

| | |
|---|---|
| method | |
| Simulate the train and wagon processing in the yard | |
| – For block/transit trains, the process includes<br>- Arrival: reception of the arrival train to the arrival track<br>- Decoupling and changing locomotive (if needed)<br>- Commercial and technical inspection<br>- Brake test and other preparation<br>- Train departure | See example in appendix |
| – For SWL trains, the process includes<br>- Arrival: receiving the arrival train to the arrival track(s), decoupling and moving the locomotive to the loco tracks, commercial and technical inspection, decoupling the wagons<br>- Sorting/marshalling: moving shunting loco to the arrival yard, push wagons over the hump<br>- Secondary sorting/marshalling (if required): pulling the wagons over the secondary shunting hump or via the shunting locomotive<br>- Shunting: move wagons to the classification bowl track or the departure track, coupling, inspection, brake test and other preparation<br>- Departure: add mainline locomotive, brake tests, departure<br>- Other activities such as documents exchange and train identification | See examples in appendix<br>The process description for inbound trains differs only in direction of arrival. |
| Simulate the randomness in the processing time of the above-mentioned activities | Not known yet |
| Be able to estimate the ETD of a train from the yard | Not available data |
| Arrival: determining the time and track(s) in the arrival yard to accept the arrival train | According to the direction and availability |

| | |
|---|---|
| Sorting/marshalling: scheduling the sorting/marshalling procedure, including<br>– Track(s) allocation for assembly of wagons for each outgoing train<br>– Enquiring the network model about the restrictions of network infrastructure which may affect the composition of the outgoing trains<br>– Assigning wagons to outgoing trains<br>– Ordering wagons in the outgoing trains<br>– Ordering and time of propelling each wagon over the hump<br>– Schedules and routes of the yard locomotives on the yard tracks | Track allocation<br>• Fixed<br>Restriction of network<br>• Max allowed train length on network in specific direction<br>• Max allowed train weight on Assigning wagon<br>Ordering – not known<br>Shunting locomotive – ZC1<br>• Work in reception yard<br>• Schedule<br>○ Tue-Sat (6:00-17:30 and 18:00-5:30)<br>○ Sun (6:00-15:00) |
| Secondary sorting/marshalling: scheduling secondary sorting/marshalling procedures | Multigroup trains<br>• 44725<br>• 45711<br>• 45713<br>• 45027<br>• 47334<br>• 60204<br>• 62013<br>• 62017<br>• 62019<br>• 62023<br>• 62101<br>• 62130<br>• 62132<br>• 62134<br>• 62200<br>• 62222<br>• 62224<br>• 83037<br>• 83111 |

| | |
|---|---|
| Shunting: schedule the shunting procedure, including<br>– Assign track in classification bowl or departure yard to the outgoing train<br>– Determine the sequence and time to pull locomotive, each wagon and each wagon groups to form the train<br>– Schedule and route the yard locomotives on the yard tracks | Assign track<br>• According to relation and sorting schedule<br>To form the train<br>• According to actual situation and availability<br>Shunting locomotive – ZC2<br>• Work in sorting yard<br>• Schedule<br>o Mon-Sun (0:00-24:00)<br>Shunting locomotive – ZC3<br>• Pull wagons from sorting yard to departure yard<br>• Schedule<br>o Mon-Sat (6:00-17:30)<br>o Mon-Fri, Sun (18:00-1:00 and 3:30-5:30) |
| Departure<br>– Coordinating with network/terminal management model to determine the departure time from the yard<br>– Assign line locomotive to the train<br>– Preparation and checking activities prior to departure | • Based on current situation and incoming flow<br>• Based on line locomotive rostering plan and locomotive availability<br>• See flowcharts with description of handling services in appendix |

| | |
|---|---|
| Schedule personnel and asset in all above-mentioned processes and activities | Examiners<br>• Departure yard<br>  ○ Mon-Sun (0:00-24:00)<br>• Sorting yard<br>  ○ Mon-Sun (0:00-24:00)<br>  ○ Sun – only one employee<br>• Reception yard<br>  ○ Mon-Sun (0:00-24:00)<br>Shunters<br>• Departure yard<br>  ○ Mon-Sun (0:00-24:00)<br>• Reception yard<br>  ○ Mon-Sat (6:00-17:30)<br>  ○ Mon-Fri, Sun (18:00-1:00 and 3:30-5:30)<br>Transiteurs<br>• Sorting yard<br>  ○ Mon-Sun (0:00-24:00)<br>• Reception yard<br>  ○ Mon (0:00-6:00 and 18:00-24:00)<br>  ○ Tue-Sun (0:00-24:00) |

## 7.6. Terminal activities and real-time management

This sub-section is not applicable for this case study.

## 7.7. Yard facilities

Table 8: yard facilities in Trieste

| Functional requirement | Characteristic / modelling choice |
|---|---|
| Type of the yard | Yard for terminating and starting freight trains with connection to intermodal terminal |
| Infrastructure layout of yard<br>• Receiving yard, classification bowl and departure yard: tracks and switches<br>• Hump<br>• Maintenance track, repair track, etc.<br>• Sorting bowl and the associated hump for the secondary shorting/marshalling (if provided) | • not separate reception and departure yard, classification bowl is not included<br>• tracks for train arrivals (14, 19-24)<br>• tracks for train departures (14-24)<br>• hump is not available<br>• maintenance tracks and repair tracks are out of scope<br>• depot tracks for mainline locomotives (02-06)<br>• track for direction change for train sets during the movement between yard and intermodal terminal (16P)<br>• secondary sorting is done |
| Characteristics of tracks<br>• Running direction<br>• Speed limit<br>• Gradient<br>• Curvature<br>• Signal<br>• Electrification | • Tracks for train arrivals (14, 19-24)<br>• Tracks for train departures (14-24)<br>• All tracks are available for shunting movements in both directions (1-26).<br>• 30 km/h for train movements<br>• 15 km/h for shunt movements<br>• Simulation model contains only critical gradient bigger than 5 ‰ (only on main track to direction Villa Opicina – mostly 24.90 ‰).<br>• Curvature in infrastructure model is based on supplied documents (dwg and pdf documents).<br>• Signal position and type is based on supplied documents (departure signals, home signals and block signals on main line tracks).<br>• Tracks 1-24 and relevant connecting sections have electrification. |
| Classification bowl: deceleration technology | Do not contain classification bowl |

| | |
|---|---|
| Asset: shunting and line locomotives<br>• ID<br>• Weight<br>• Length<br>• Number of axles<br>• Electric or diesel traction<br>• Traction and braking characteristics<br>• Signalling system compatibility (required for line locomotives) | • MaK 765 / Taurus (DE 182)<br>• 60 t / 86 t<br>• 10,35 m / 19,58 m<br>• 3 axles / 4 axles<br>• diesel traction / electric traction<br>• traction effort diagram based on technical sheet<br>• avg. deceleration 1,0 m/s2 / 1,0 m/s2<br>• - / compatible with national systems and ETCS |
| Personnel<br>• ID<br>• Qualification, i.e. type of work that each staff can do, including: yard operations, dispatching/disposition processes, inspection of incoming/outgoing trains, brake test and related preparation work, shunting engine driving, incoming/outgoing freight train driving, etc. | • ID is not known<br>• Traffic at the yard is managed by 1 dispatcher. Dispatcher prepares train routes and shunting routes and plans occupation of tracks.<br>• Train locomotive drivers provide uncoupling/coupling train locomotives, complete brake test before departure freight trains and shunt movements from/to waiting tracks.<br>• Adriafer's shunters provide uncoupling/coupling shunting locomotives, check of the train set after train arrival and simple break test before shunting movements.<br>• Shunting crew for one train set include 1 driver, 1 shunter, and 1 chief of operation. |

## 7.8. Intermodal terminal facilities

**Table 9: intermodal terminal facilities in Trieste**

| Functional requirement | Characteristic / modelling choice |
|---|---|
| Infrastructure layout of terminals<br>• transhipment tracks<br>• non-transhipment tracks<br>• switches | • Intermodal terminal contains 3 docks. Each dock has 4 transhipment tracks (dock 7 for whole train sets, docks 5 and 6 for divided train sets).<br>• All other tracks are non-transhipment tracks – for example waiting tracks, parking tracks, repair tracks, …<br>• Switches are electrically and manually operated. |

| | |
|---|---|
| Characteristics of tracks<br>• Running direction<br>• Speed limit<br>• Gradient<br>• Curvature<br>• Signal<br>• Maximum permissible weight per axle and per metre<br>• Electrification | • All tracks are available for shunting movements in both directions<br>• Speed limit is 6 km/h (through the gates Varco 3 and Varco 4 only 3 km/h due to police control)<br>• The simulation model contains only critical gradient bigger than 5 ‰. Layout of intermodal terminal has not critical gradient.<br>• Curvature in infrastructure model is based on supplied documents (dwg and pdf documents).<br>• Signal position and type is based on supplied documents (infrastructure layout in this area doesn't contain any signals).<br>• Data about permissible weight are at the moment not available.<br>• all tracks are not equipped with electrification |
| Equipment<br>• Type: ship-to-shore cranes, portal cranes, straddle carriers, reach stackers, etc.<br>• ID<br>• For cranes: location and tracks they serve<br>• Capabilities of each piece of equipment used | At the moment not available |
| Cost per unit of weight for loading/unloading of goods<br>• Monetary cost<br>• Energy cost<br>• Environmental cost | At the moment not available |

## 7.9. Wagons and wagon groups

**Table 10: wagon groups in Trieste**

| Functional requirement | Characteristic / modelling choice |
|---|---|
| Wagon ID | Sggmrss 90 / Sggmrss Twin |
| Owner | -/- |
| Length | 29,59 m / 34,03 m |
| Weight | 29 t / 35,5 t |
| Net weight of cargo | 77 t / 64 t |

| | |
|---|---|
| Number of axles | 6 axles / 6 axles |
| Maximum speed | 120 km/h / 120 km/h |
| Braking characteristic | -/- |
| Wagon content | At the moment not available |
| Trip plan<br>• Original terminal, intermediate yard(s), and destination terminal<br>• Scheduled arrival and departure times at terminals and yards<br>• Train ID and the ordering of wagon on the train when transhipped between yards | Wagons in the simulation model are coupled into complete train sets. For more information, see the chapter 3.2.4. |
| Preferred arrival time at the destination terminal and the penalty for late arrival | At the moment not available |

## 7.10. Freight trains

**Table 11: freight train description for Trieste**

| Functional requirement | • Characteristic / modelling choice |
|---|---|
| Train ID | Simulation contains two types of trains:<br>• from railway network to intermodal terminal and back (marked in simulation – MxxTxx, M07 – trains to/from dock 7, M06 – trains to/from dock 6, M05 – trains to/from dock 5, Txx - train identification number according the document ”Campo Marzio_typical schedule.pdf”)<br>• from railway network to Servola and back (marked in simulation – Sxx, odd numbers for trains to Servola, even numbers for trains from Servola) |
| Type and priority | All freight trains have the same priority. |
| Maximum speed | On modelled railway network part: 60 km/h<br>Arrival and departure is limited to 30 km/h |
| Traction and braking characteristics | Traction effort diagram is based on the technical sheet of train locomotive Taurus; average train deceleration is 0,3 m/s$^2$ |
| Running resistance characteristics | Train resistance - T4 |

| | |
|---|---|
| Train control system on board: fixed-block, ETCS (and level), etc. | At the moment not available. |
| Train route and schedule | Tracks for train arrivals in yard (14, 19-24)<br>Tracks for train departures in yard (14-24)<br>Train arrivals and departures are based on document ”Campo Marzio_typical schedule.pdf”. |
| Train driver ID | At the moment not available. |
| Composition: block train or single wagon load | Only block trains. Simulation contains two types of train sets:<br>• train sets for dock 7 consists 16 wagons of type Sggmrss 90 (473,44 m)<br>• train sets for docks 5 and 6 consist of 16 wagons of type Sggmrss Twin (544,48 m) |
| For SWL trains, Wagon ID and ordering | At the moment not available. |
| Wagon content | At the moment not available. |
| Status: incoming, waiting to be decoupled, waiting to be coupled, ready-to-depart | - |
| ETA time at the yard or ETD time from the yard | Train arrivals and departures are based on document ”Campo Marzio_typical schedule.pdf”. |

## 7.11. Yard activities and real-time management

**Table 12: yard activities, Trieste**

| Functional requirement | Characteristic / modelling choice |
|---|---|
| Working hours of the yard | 24 hours a day |
| Required quantity and time (mean and standard deviation) of personnel and asset for each operation | 1 dispatcher |
| Way of secondary sorting/marshalling: e.g. pulling back over hump and roll over again, or flat shunting (i.e. using shunting engine) | Not provided |

| | |
|---|---|
| Method used for formation of multigroup trains:<br>Consecutive forming of multigroup trains: single-stage sorting method, Futhner's method, general method, special method, unified group method, Japanese method,<br>Simultaneous formation of multigroup trains: elementary method, triangular method, geometrical method | Not provided |
| Simulate the train and wagon processing in the yard | The movements involve a necessary movement forward the end of north sidings of Campo Marzio, a change of locomotive position, then a move towards terminals through customs portal.<br>Nearly always locomotives delivering trains to terminals go back to the locomotive relay track near Adriafer offices |
| For block/transit trains, the process includes<br>• Arrival: reception of the arrival train to the arrival track<br>• Decoupling and changing locomotive (if needed)<br>• Commercial and technical inspection<br>• Brake test and other preparation<br>• Train departure | Trains to docks:<br>• Arrival<br>• Train loco uncoupling (3 min.)<br>• Train loco release<br>• Shunt loco assignment<br>• Shunt loco movement to train set<br>• Shunt loco coupling (1 min.)<br>• Control – shunter from Adriafer (6 min.)<br>• Simple brake test (5 min.)<br>Trains to/from Servola:<br>• Arrival to yard<br>• Train loco uncoupling (3 min.)<br>• Move train loco to other train side<br>• Train loco coupling (1 min.)<br>• Simple brake test (5 min.)<br>• Departure |

| | |
|---|---|
| For SWL trains, the process includes<br>• Arrival: receiving the arrival train to the arrival track(s), decoupling and moving the locomotive to the loco tracks, commercial and technical inspection, decoupling the wagons<br>• Sorting/marshalling: moving shunting loco to the arrival yard, push wagons over the hump<br>• Secondary sorting/marshalling (if required): pulling the wagons over the secondary shunting hump or via the shunting locomotive<br>• Shunting: move wagons to the classification bowl track or the departure track, coupling, inspection, brake test and other preparation<br>• Departure: add line locomotive, brake tests, departure<br>• Other activities such as documents exchange and train identification | • Simulation does not contain SWL trains. |
| Simulate the randomness in the processing time of the above-mentioned activities | - |
| Be able to estimate the ETD of a train from the yard | - |
| Arrival: determining the time and track(s) in the arrival yard to accept the arrival train | - |
| Sorting/marshalling: scheduling the sorting/marshalling procedure, including<br>• Track(s) allocation for assembly of wagons for each outgoing train<br>• Enquiring the network model about the restrictions of network infrastructure which may affect the composition of the outgoing trains<br>• Assigning wagons to outgoing trains<br>• Ordering wagons in the outgoing trains<br>• Ordering and time of propelling each wagon over the hump<br>• Schedules and routes of the yard locomotives on the yard tracks | It is not provided |
| Secondary sorting/marshalling: scheduling secondary sorting/marshalling procedures | - |

| | |
|---|---|
| Shunting: schedule the shunting procedure, including<br>• Assign track in classification bowl or departure yard to the outgoing train<br>• Determine the sequence and time to pull locomotive, each wagon and each wagon groups to form the train<br>• Schedule and route the yard locomotives on the yard tracks | It is not provided |
| Departure<br>• Coordinating with network/terminal management model to determine the departure time from the yard<br>• Assign line locomotive to the train<br>• Preparation and checking activities prior to departure | Trains from docks:<br>• Train locomotive assignment<br>• Train loco movement to train set<br>• Train loco coupling (1 min.)<br>• Complete brake test (10 min.)<br>• Waiting for departure<br>• Departure<br>Trains to/from Servola:<br>• Arrival to yard<br>• Train loco uncoupling (3 min.)<br>• Move train loco to other train side<br>• Train loco coupling (1 min.)<br>• Simple brake test (5 min.)<br>• Departure |
| Schedule personnel and asset in all above-mentioned processes and activities | - |

## 7.12. Terminal activities and real-time management

**Table 13: terminal activities and real-time management, Trieste**

| Functional requirement | Characteristic / modelling choice |
|---|---|
| Working hours of the terminal | 24 hours a day |
| Required quantity and time (mean and standard deviation) of each piece of equipment for wagon loading and unloading | • 2 groups of personnel<br>• to 1 shunting locomotive are assigned: 1 driver, 1 shunter, and 1 chief of operation. |
| Simulate the process of moving loads from trains to other modes | The simulation doesn't model it. |

| | |
|---|---|
| Simulate the movement of empty trains in the terminal network, which move to and from the terminal for loading wagons | - |
| Simulate the movement of loaded trains in the terminal network, which move from terminals to the yard/network | - |
| Simulate the random fluctuations in<br>• Availability and arrival of vehicles of other modes<br>• Processing time of wagon loading/unloading | • For the simulation are such data not available at the moment.<br>• the duration of the transloading is determined as fixed time:<br>  ○ 3 hours for terminal 1,<br>  ○ 4 hours for terminal 2,<br>  ○ 6 hours for terminal 3 |
| Estimate the ETD of the train from the terminal. | - |

# ANNEX C EXAMPLES OF HANDLING PROCESS CHARTS FOR THE ČESKÁ TŘEBOVÁ AND TRIESTE YARDS

Examples of trains handling in yards Česká Třebová and Trieste

- Marshalling yard Česká Třebová: Example of handling for inbound trains
- *Marshalling yard Česká Třebová: Example of handling for outbound trains (direction – Praha)*
- *Marshalling yard Česká Třebová: Example of handling for outbound trains (direction – Brno)*
- *Marshalling yard Česká Třebová: Example of handling for transit trains*
- *Yard Trieste Campo Marzio: Example of handling for freight trains to docks*
- *Yard Trieste Campo Marzio: Example of handling for freight trains from/to Servola*

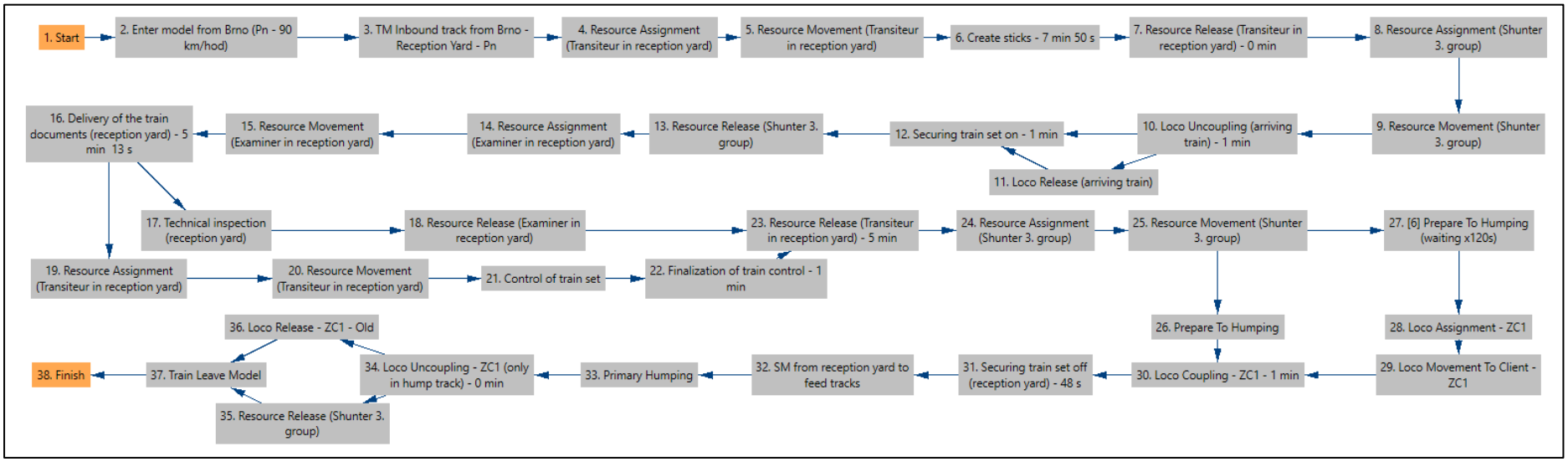



**Figure 17 marshalling yard Česká Třebová: example of handling for inbound trains**

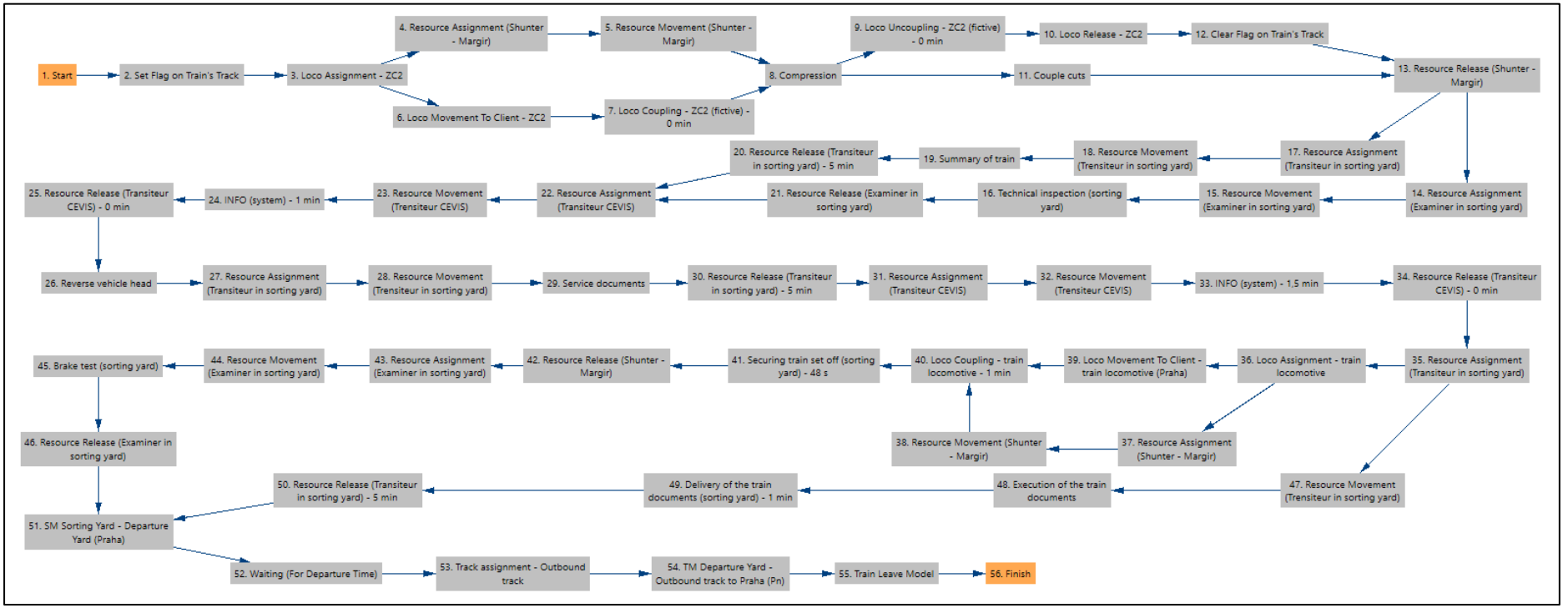



**Figure 18 marshalling yard Česká Třebová: example of handling for outbound trains (direction – Praha)**

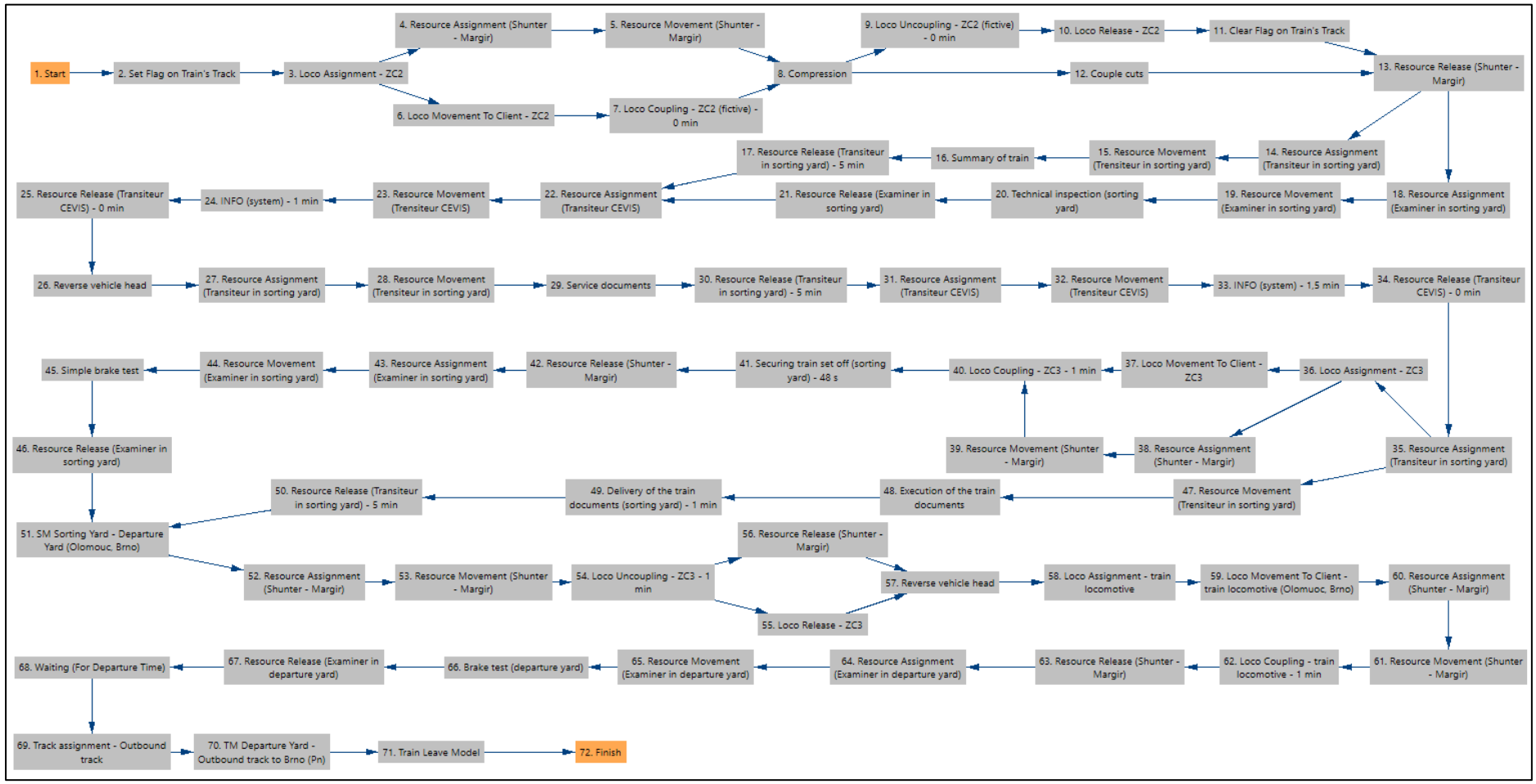



**Figure 19 marshalling yard Česká Třebová: example of handling for outbound trains (direction – Brno)**

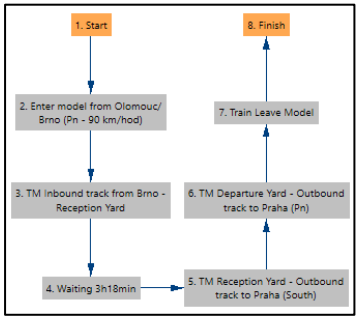



**Figure 20 marshalling yard Česká Třebová: example of handling for transit trains**

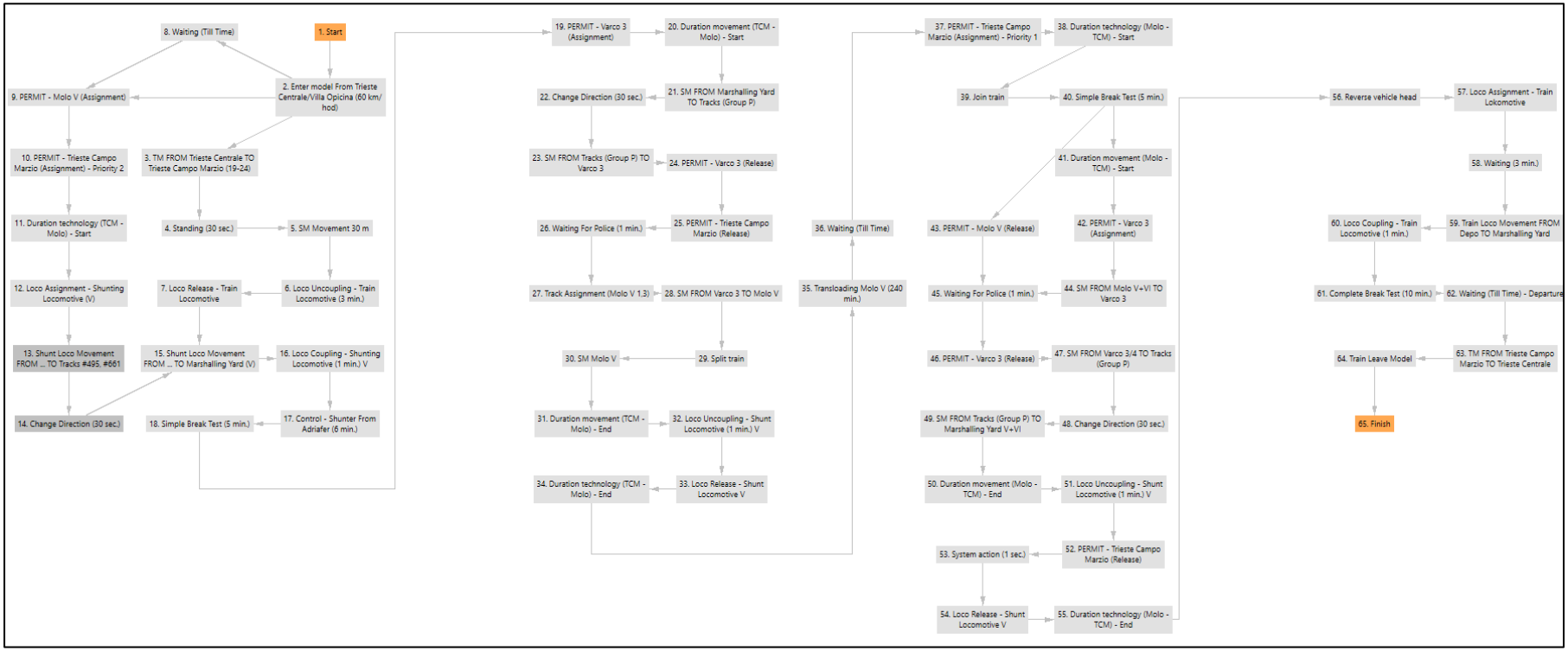



**Figure 21 yard Trieste Campo Marzio: example of handling for freight trains to docks**

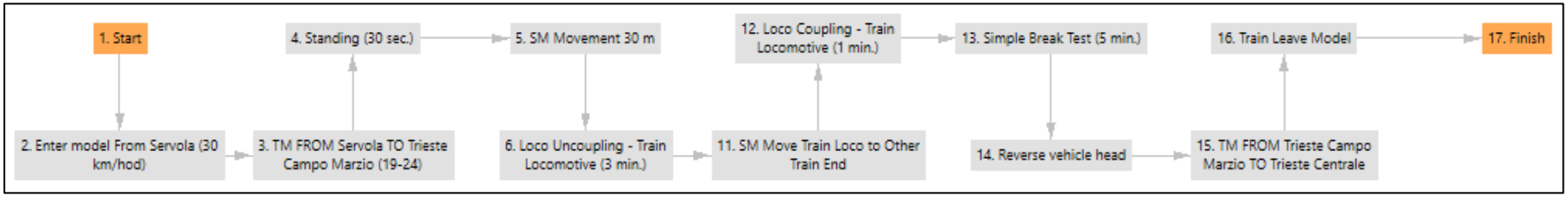



**Figure 22 yard Trieste Campo Marzio: example of handling for freight trains from/to Servola**

# ANNEX D TRIESTE NETWORK MODEL DESCRIPTION ACCORDING TO D3.2 FUNCTIONAL SPECIFICATION

## 7.13. Surrounding network infrastructures

**Table 14: Trieste network model, surrounding network infrastructures**

| Functional requirement | Characteristic / modelling choice |
|---|---|
| Infrastructure layout: tracks, junctions, switches, stations, tunnels, etc. | The network is described as a graph, with nodes representing the stations and merging/diversion/crossing points, and links tracks connecting nodes. This is a macroscopic representation of the infrastructure, typical of that for timetabling analysis. The individual switches, points, signalling block sections are not explicitly represented. The track gradients are represented to model their impact on train running speeds. |
| Railway signalling system and the regulation rules:<br>• Multi-aspect signalling (arrangement of blocks, number of aspects, and the associated temporary speed limits)<br>• ETCS (implementation level, arrangement of blocks if fixed-block, and location of balises) | ETCS Level 3, with moving authority (MA) revocable.<br>Maximum length of MA: 1km<br>Time interval for MA update: 30 seconds |
| Characteristics of tracks<br>• Running direction<br>• Speed limit<br>• Gradient<br>• Curvature<br>• Maximal weight per axle and per unit of train length<br>• Restrictions on the type of goods transmitted<br>• Profiles of static and temporary speed limits<br>• Electrification | Running direction: see Figure 15<br>Speed limit and gradient extracted from RFI “Fascicoli Circolazione Linee (PGOS Art.2)[1]” No. 63 & 67<br>Other characteristics not considered |

[1] https://normativaesercizio.rfi.it/Default.aspx

## 7.14. Freight and passenger trains

Table 15: Trieste network model, freight and passenger trains

| Functional requirement | Characteristic / modelling choice |
|---|---|
| Train ID | Passenger train ID from RFI online timetable[2]<br>Freight train ID from the document "Campo Marzio_typical schedule.pdf" |
| Type and priority | Type from RFI online timetable<br>Priority between passenger trains not considered in the simulation |
| Maximum speed | NA |
| Traction and braking characteristics | Functions decreasing with speed |
| Running resistance characteristics | Quadratic function of speed |
| Train control system on board: fixed-block, ETCS (and level), etc. | ETCS Level 3 |
| Train route and schedule | Train route is predetermined and fixed (according to Figure 15, each train has only one available route)<br>Passenger train schedule between stations are extracted from RFI online timetable; the running time between the Trieste Centrale and CIPPO (milepost) is then estimated according to the mileages of CIPPO and the stations.<br>Freight train departure (arrival) time from (at) the yard is obtained from "Campo Marzio_typical schedule.pdf". Running time from/to Cippo is assumed 30min. |
| Train driver ID | NA |

[2] Arrival at Trieste Central: https://prm.rfi.it/qo_prm/QO_Arrivi_SiPMR.aspx?Id=2718&dalle=00.00&alle=23.59
Departure from Trieste Central: https://prm.rfi.it/qo_prm/QO_Partenze_SiPMR.aspx?Id=2718&dalle=00.00&alle=23.59

## 7.15. Network activities and real-time management

**Table 16: Trieste network model, network activities and real-time management**

| Functional requirement | Characteristic / modelling choice |
|---|---|
| Simulate the movement of passenger and freight trains in the network, according to the schedule | Micro simulation model TrackULA (Liu et al., 2015, 2016) |
| Plan the speed profile for each train according to the schedule | The speed profile optimisation function embedded in TrackULA (Ye and Liu, 2016, 2017) |
| Estimate the ETA time at yards | Output of the microsimulation model |
| Provide the train location, speed and ETA to yards on request | Can be derived from the output train trajectories |
| Simulate the random delays occurring when trains are running on the line and/or dwelling at stations | Can be built into TrackULA once the distributions of random delays are given |
| Decide the train priority when two or more trains request to access the same resource at the same time | Two built-in rules in TrackULA: (i) first-come-first-serve; (ii) passenger-train prioritized.<br>For better decision making, TrackULA can provide an interface to other real time management models |
| Decide the train priority when two or more trains request to access the same resource at the same time | Two built-in rules in TrackULA: (i) first-come-first-serve; (ii) passenger-train prioritized.<br>For better decision making, TrackULA can provide an interface to other real time management models |
| Conduct ad-hoc rescheduling and rerouting triggered<br>• on request<br>• by delay<br>• at fixed time moments<br>• when a path request is sent by the yard<br>• when a train is ready to depart | This is a function of the network optimisation/management model; not considered in the microsimulation model.<br>TrackULA can provide an interface to the network optimisation/management model. |
| Determine the path for a waiting-to-depart freight train and the associated schedule in response to the path request considering the associated train and track characteristics | As above. |