INTERMODEL EU

Simulation using Building Information Modelling Methodology of Multimodal, Multipurpose and Multiproduct Freight Railway Terminal Infrastructures

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D7.2 – Assessment of the rail interconnection pilot case

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Executive Summary

The INTERMODEL EU project aims at developing an integrated decision support platform to assess different pilot cases of multimodal, multiproduct and multipurpose freight rail terminals in terms of a wide range of Key Performance Indicators (KPIs). By integrating simulation modules of the terminal operation and its relationship to the hinterland into a BIM design, both the throughput time and the quality of the decision-making will be improved.

The main objective of WP7 is to build a simulation-based decision support environment that supports investigation into rail interconnection between two intermodal freight terminals and its effect on the operational performance as well as to assess network resilience. WP7 should be viewed as an extension of the WP5 terminal operational simulation models for rail operations. This document is the second deliverable of the WP7 and describes the initial results of the model. The build-up of the simulation model is described in D7.1 Rail interconnection simulator. D7.2 Assessment of the rail interconnection pilot case uses the design of D7.1, as well as the data mostly from WP5 to provide first results of the case, i.e. the evaluation of the current connection between Melzo and La Spezia. D7.2 is also a base for D7.3 Assessment of rail interconnection resilience.

The goal of this document is to describe the activities connected to the Deliverable 7.2 Assessment of the rail interconnection pilot case, which is also a written testimonial to the presented conclusions for milestone MS17 (Presentation of the conclusions derived from the assessment of rail interconnection pilot cases).

This document contains information on the data used for the assessment and how experimentation was performed, followed by results with KPIs and their discussion, concluding tasks T7.3 Assessment of interconnection La Spezia – Melzo corridor case. We start with a description of the model inputs, considering in more detail the layout, terminal characteristics, and the rolling stock. In particular, we test the interconnection with known trains visiting the terminals, based on the historical data. Also, we try to estimate the amount of other traffic, i.e. trains that do not visit either of the two investigated terminals, whether they are passenger or freight trains.

Finally, we present the results, displaying the KPIs. A comparison is made with the respective terminal results from WP5. Based on that, we perform the validation of the model. Finally, conclusions are drawn based on the results and the added value of the interconnection model is discussed.

On behalf of authors,

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Table of contents

List of Figures

List of Tables

1. Introduction

1.1. Scope

This document describes the activities necessary for the assessment of the rail interconnection simulator, previously defined in deliverable D7.1 Rail interconnection simulator. The model described there is used with real terminal data, coming mostly from WP5 models (both inputs and results). It concerns the following milestones:

- MS17 – Presentation of the conclusions derived from the assessment of rail interconnection pilot cases
- MS19 Validation of DSS in real location (pilot)

And the following deliverables:

- D7.2 – Assessment of the rail interconnection pilot case

The objective of WP7 is to create a simulation-based Decision Support Environment to:

- Assess the rail interconnectivity between two cargo terminals
- Align the design of terminals and network

In particular, the DSE should help to identify potentials for optimising network capacity and network resilience (minimise tardiness). The DSE should support in locating potential bottlenecks and test new logistic (bundling) concepts. Assessment of the rail interconnection resilience is included in the report for D7.3.

Due to the document's public nature, some sensitive data is not shared. This should in no case affect its understanding and usefulness.

1.2. Audience

This document is mainly written for the participants of the H2020 INTERMODEL EU project. Nonetheless, the authors deem the content useful for any party interested in integrated container terminal design and especially simulation of it. Hence a public nature of the document.

1.3. Glossary and Abbreviations

Table I. Definitions and abbreviations

Term	Abbrev.	Description
Actual time of arrival	**ATA**	The time a MoT actually arrives at a location.
Actual time of departure	**ATD**	The time a MoT actually departs from a location.

Animation	-	A visualisation of the events that occur in the system that is being simulated over time.
Automated Guided Vehicle	**AGV**	Unmanned horizontal transporter controlled by the TOS or Equipment Control System.
Automated Stacking Crane	**ASC**	A cumulative name for automated, unmanned cranes servicing container stacks, typically an ARMG.
Automatic Block Signalling	**ABS**	A railroad communications system that consists of a series of signals that divide a railway line into a series of sections, or "blocks".
Baseline scenario	-	Also called Base Case. A scenario in which the analysis is done based on the current way of working in a place, without changes. This scenario serves as a comparison and starting point to other scenarios
Capacity (handling)	-	The number of containers or goods that can be handled by equipment in a certain time window.
Capacity (storage)	-	The amount of goods that can be stored in a particular place (stack) or vehicle at a given moment. Can be expressed in volume, mass, units, etc.
Container Handling Equipment	**CHE**	Any equipment used for lifting, transporting and/or supporting the servicing of containers.
Control (layer)	-	All elements in the simulation tool that represent control over equipment, means of transport and infrastructure.
Data	-	A set of values of qualitative and/or quantitative variables. Pieces of data are individual pieces of information.
Dashboard	-	A set of KPIs joined together in a single overview screen. This way a user gets the whole overview of the performance aspect in one view.
Data model	-	An abstract model that organizes elements of data and standardizes how they relate to one another and to properties of the real-world entities.
Decision support environment	**DSE**	An information system that supports business or organizational decision-making activities.
Distribution	-	Mathematical description of a random phenomenon in terms of the probabilities of events. The PSP platform contains many of the distribution used in simulation (normal, uniform, etc.).
Dry bulk	-	Loose cargo transported in bulk carriers, e.g. coal, ores, fertilizers.
Dry port	-	Or inland port. Intermodal terminal directly connected by road or rail to a seaport and operating as a transhipment base for other hinterland destinations.
Dwell Time		The time goods (or containers) stay or are stored at the terminal.
Empty Container	**MT**	Container without any cargo in it.
Equipment Control System	**ECS**	Middleware that provides container handling equipment coordination and control as well as a single interface to TOS.
European Rail Traffic	**ERTMS**	The system of standards for management and interoperation of signalling for railways by the European Union

Management System		
European Train Control System	**ETCS**	The signalling and control component of the ERTMS. It is a replacement for legacy train protection systems and designed to replace the many incompatible safety systems currently used by European railways.
Estimated time of arrival	**ETA**	A measure of indication when a MoT is planned or scheduled to arrive at a particular place.
Estimated time of departure	**ETD**	Indication when a MoT is to depart from a location. Comparing estimated with actual times is a measure of scheduling performance.
Event	**-**	An instance when a state change in the system might occur.
Experiment	**-**	A number of simulation runs in which a single scenario is studied.
Forty-foot equivalent unit	**FEU**	Measure of container length equal to 2TEU, used less frequently.
Infrastructure (layer)	**-**	All elements in the simulation tool that represent infrastructure (tracks, sidings, crossings, switches, areas, etc.). This will be an input from the BIM.
Inter-terminal transport	**ITT**	Inter-Terminal Transport to facilitate transport of containers between terminals in one port.
Intermodal	**-**	Movement of cargo containers interchangeably between transport modes where the equipment is compatible within the multiple systems.
Intermodal transport unit	**ITU**	Container, swap body or semi-trailer/goods road motor vehicle suitable for intermodal transport.
Key performance indicator	**KPI**	Indicator that tells what to do to increase performance dramatically. They represent a set of measures focusing on those aspects of organizational performance that are the most critical for the current and future success of the organization. The KPI will be calculated on the results of the simulation model.
Lift-on lift off	**Lo/lo**	Cargo handling method by which vessels are loaded or unloaded by either ship or shore cranes.
Means of transport	**MoT**	Any vehicle that can travel or carry goods. Cumulative name for vessels, trains, vehicle and/or yard equipment
Mixed cargo	**-**	Or hybrid cargo. Two or more products carried on board one transporter.
Moves per hour	**Mph**	KPI for Container Handling Equipment that indicated the operational performance in moves per hours. A move can consist out of one or more container or boxes and is often viewed as a measure of terminal and CHE productivity.
Prescriptive Simulation Platform	**PSP**	Macomi's simulation platform software tool.
Rail yard		The area for the rail side handling of terminals. Consists of a set of railroad tracks for storing, sorting or loading railroad vehicles, buffer positions and possible small stack.

Rail mounted gantry crane	**RMG**	A crane built atop a gantry, the movements of which are limited by rails.
Reach stacker	**RS**	CHE used at many terminals for handling containers.
Scenario	**-**	A situation that the user wants to study in the simulation tool. An experiment is the cross section of volume, control, equipment and infrastructure.
Shunting yard		Or classification yard. A railroad yard with multiple tracks used for assembling freight trains.
Spreader	**-**	Piece of equipment to grab and lift containers by their corner castings. Attached to STS, RC or other CHE.
Stripping	**-**	Or unstuffing. Unloading of a container.
Tare weight	**-**	The weight of wrapping or packing (e.g. an empty container); added to the net weight of cargo to determine its gross weight.
Terminal operating system	**TOS**	Control system of a terminal responsible for issuing instructions to workers and equipment.
TEU factor	**-**	A measure of average size of container within certain population.
Turnaround time	**TAT**	The time it takes between the arrival of a vessel and its departure from port; frequently used as a measure of port efficiency.
Twenty-foot equivalent unit	**TEU**	Standard (but inaccurate) measure of a 20-foot container length. The capacity (handling and storage) of terminals, stacks, CHE and vessels is often measured in TEU.

1.4. Structure

The document is divided into six chapters, organized as below. There is also an appendix containing the input data table structure.

Chapter 1: Introduction

Contains an overview of this document, providing its structure:

- **Section 1.1:** Scope
- **Section 1.2:** Audience
- **Section 1.3:** Glossary and abbreviations
- **Section 1.4:** Structure

Chapter 2: Implementation characteristics

Describes how the generic model was used and configured for the pilot case:

- **Section 2.1:** Input data

Chapter 3: Model validation

Describes the activities to validate the model implementation

Chapter 4: Simulation execution

Describes how the simulation is executed in the tool

Chapter 5: Results

Depicts high-level results from the experimentation

- **Section 5.1:** Terminal traffic
- **Section 5.2:** Other traffic

Chapter 6: Conclusions and future work

Outlines the outputs of the simulation model

2. Implementation characteristics

A specific configuration is built upon a generic model, described in D7.1, to assess the performance of the Melzo – La Spezia interconnection. The model could be applied to other cases with limited effort due to its generic design. Especially the network model including pathfinding and routing, train dynamics, train control, could be used with other layouts. Terminal implementations and train behaviour within are specific cases of their respective terminals and typically cannot be reused anywhere else. Where trains stop, how they drive within terminals and where they are processed are specific to each terminal and not easy to generalize. Volumes also need to be generated first in accordance to specific layout and then to what is being investigated.

This customisation mostly relates to:

- Rail network layout
    - Tracks and connectivity
    - Network end points (sources and sinks)
    - Maximum speeds
    - Stations and sidings
    - Signalling
- Terminal characteristics
    - Specific processes
    - Shunting logic
    - Processing locations
    - Available equipment and its productivity
- Rolling stock
    - Types of trains
    - Train characteristics
        - Locomotives (influencing e.g. acceleration or max speed)
        - Braking behaviour
        - Length
        - Capacity
- Control logic and protection systems

    - E.g. Automatic Block Signalling vs. ERTMS

The tool allows to investigate a range of scenarios and their impact on the rail operations on two container terminals: Melzo and La Spezia, as well as on the route. The scenarios include changes in cargo volume, closure or restrictions of infrastructure, train re-routing, shift in other train traffic on the route. The rail interconnection simulator is capable of not only examining the influence both terminals have on each other due to rail link, but also exploring the interconnection resilience. Resilience is the capability of absorbing the effects of disturbances to ensure operational continuity. The simulation tool includes:

- The layout between La Spezia and Melzo terminals, including two currently used routes via Genova and via Pontremoli.
- The terminals of La Spezia and Melzo.
- Trains visiting La Spezia/Melzo and other train traffic.

2.1. Input data

This section describes in detail all the inputs used for the base case model.

Rail network layout

The layout cosists of the two terminals from WP5 and the rail network connecting them with two alternative routes, via Genova (western) and via Pontremolli (eastern). Network layout is imported from OpenStreetMap[1], which for Italian network is not of a sufficient quality with some missing or inaccurate information. This is however, the most detailed layout that was possible to obtain, and with many advantages, mostly due to open data licensing and GIS-based data. With some manual corrections and additions, we managed to obtain a detailed and very usable network layout. Manual corrections mostly relate to the necessity to draw missing connections between tracks, in the few cases where the data from OSM is not fully reliable. Figure 1 shows the final layout on a road map, where the green lines are the rail tracks. All rail infrastructure in between the two terminals, including shunting yards or stations is included in the layout.

[1]See https://www.openstreetmap.org/

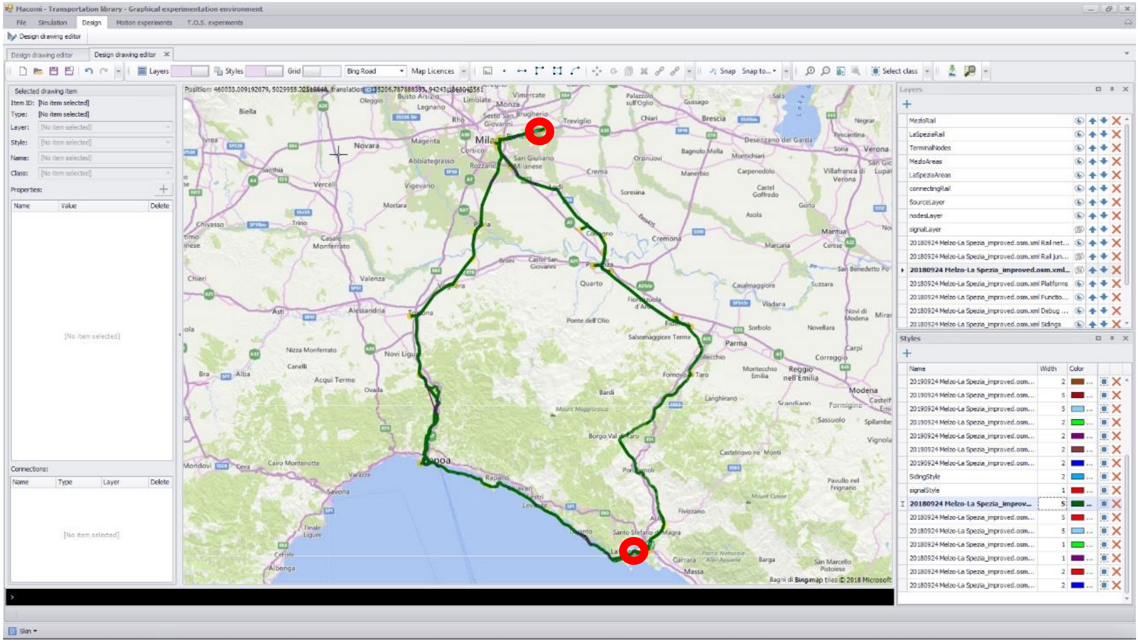

Figure 1. Network layout overlaid on a map

From the perspective of the entire investigated network the individual terminals are not visible, that is why red circles are drawn around them, where Melzo is on top near Milan and La Spezia is located at the bottom of the picture. Terminal layouts are taken from WP4 where BIM models were made, exactly how they were used for WP5. What used to be the end points is now connected to the rest of the network.

Melzo

For Melzo connection to the main network comes with an extra shunting yard where trains wait before entering the terminal and after departure. Shunting operations and locomotive swap are more difficult due to the layout restrictions.

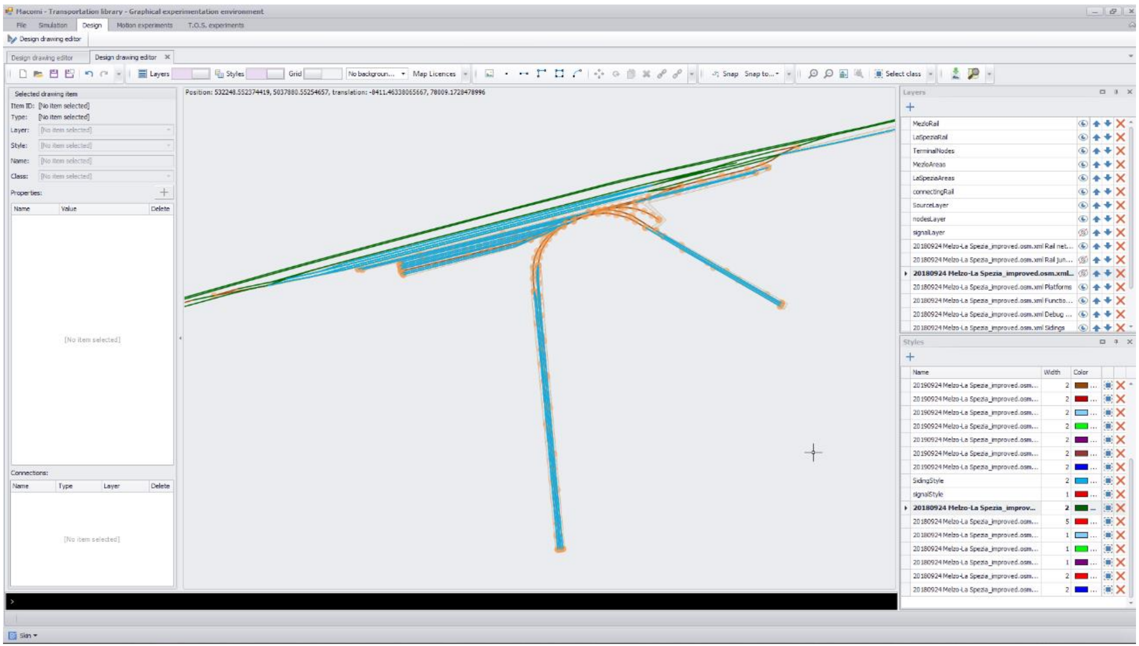

Figure 2. Melzo terminal close-up layout

Green lines from Figure 2 are part of the main network and blue ones are sidings where the trains can stop.

La Spezia

La Spezia layout and its connection to the main network is shown in Figure 3. Green lines are part of the main network while brown come from the BIM-based layout from WP4.

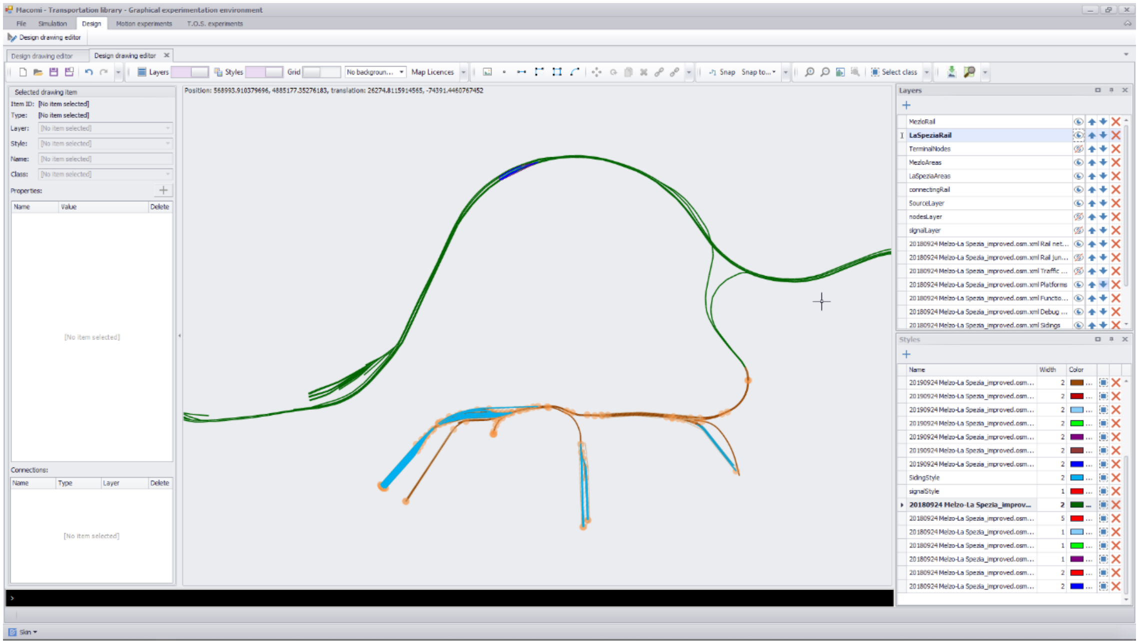

Figure 3. La Spezia terminal close-up layout

La Spezia has two tracks connecting it to the main network, which allows trains to arrive from or depart in two directions.

Network end points

Investigated rail network had to be distinguished from the remainder of the Italian rail network. The main goal of that process was to sufficiently represent the interconnection routes between the two terminals, as well as to try to limit the number of cut-off points, where the tracks continue but are no longer part of the model. In these places we create special network nodes called sources and sinks, used to create or destroy trains. In the specific layout we can distinguish 39 of those points: 16 sources, 16 sinks and 7 hybrid nodes.

Signalling

The information provided in OpenStreetMap for northern Italy is not complete. It contains full GIS-based geometry and speed limits but lacks data on the location of signals.

As it is not possible to section the tracks without them it was decided to add them manually, based on the information provided by CSI and common signalling practice. In Figure 4 the layout is displayed with supplement of signals, which are shown as red dots.

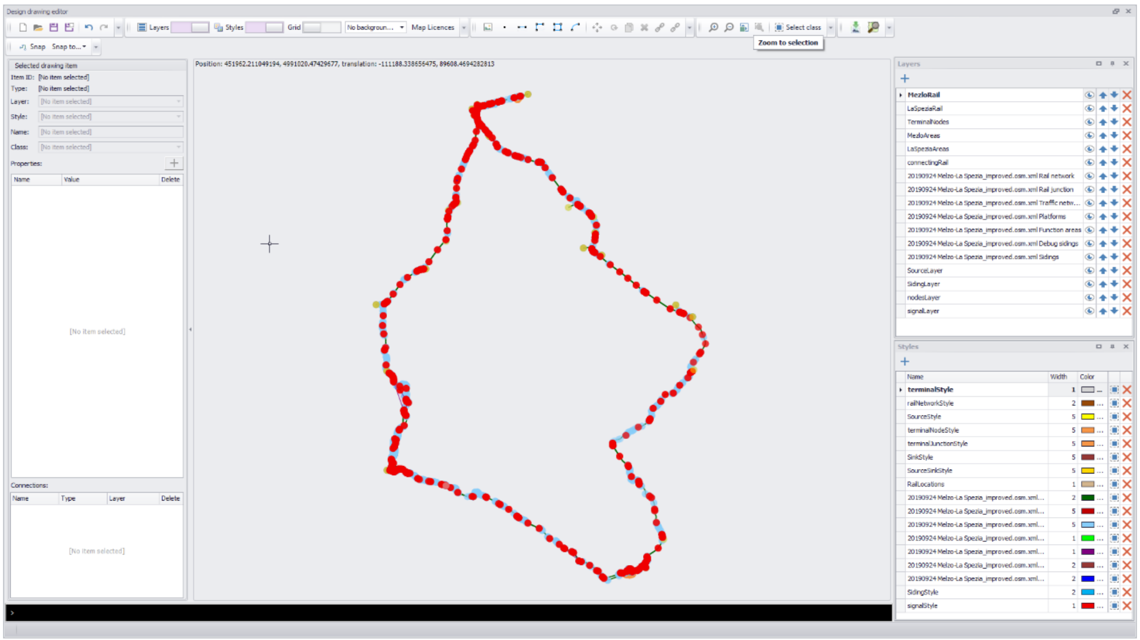

Figure 4. Network layout with signals (red dots)

For all tracks signalling is bidirectional, resulting in hundreds of signals. For simplicity, all signals are of the same type. According to the standard version of the ABS we distinguish three signal states, corresponding to three lights: green, yellow and red.

Sidings

Sidings, i.e. distinguished parts of tracks where trains can stop to be processed (loaded/unloaded or where passengers can disembark or enter) are also not part of the layout drawing. OpenStreetMap has some information on stations and platforms, but not the exact stopping positions of trains. That information was used to make an interpolation and automatically create sidings for passenger trains to stop. This was manually checked and improved.

Sidings being part of the terminals are used in the same manner as in WP5 model.

Train types

Due to its comprehensive nature the model contains several different train types, both in terms of physical structure and behaviour. As a big chunk of actual Italian rail network is investigated, other trains in the network must be taken into account as well. Moreover, trains in between Melzo and La Spezia are of particular interest, these are a separate class on their own. Thus, we distinguish four types of trains:

a) Interconnection trains – shuttles visiting both La Spezia and Melzo terminals
b) Terminal trains – visiting only one terminal
c) Other cargo trains – using only the network and not stopping anywhere
d) Other passenger trains – Using only the network and stopping at passenger stations

Routing

There are two major routes in the model in between La Spezia and Melzo, via Genova (west) and via Pontremoli (east). However, routing choices are more complex than that, as there are multiple tracks and resulting connections.

The trains are given waypoints from their starting point (source) till the end point (sink), which can be network nodes or locations that need to be visited. Sources are the only points a train can enter the model and sinks are the only points where it can leave. There can be multiple intermediate waypoints. Inside the terminals the routing is specific to the known processes and the available layout.

Volumes and schedules

A vital part of the model are the cargo volumes to be transported for each of the terminals and in between them. Table II presents the nominal rail volumes from both La Spezia and Melzo, including full and empty containers.

Table II. Transported volumes by rail

Name	Volume [TEU/year]

Melzo → La Spezia	65700
La Spezia → Melzo	79000
Melzo	160000
La Spezia	297000

Interconnection shuttle schedules are shown in Table III, provided by CSI. These are the trains that go both to Melzo and La Spezia. There are 17 trains from La Spezia to Melzo and 16 trains from Melzo to La Spezia.

Table III. Interconnection shuttle schedules

ARRIVAL/DEPARTURE	ORGIIN	Destination	VIA	Time	Mon	Tue	Wed	Thu	Fri	Sat	Sun
D	LA SPEZIA MIGLIARINA	MELZO SCALO	Ge	1:25				X			
D	LA SPEZIA MIGLIARINA	MELZO SCALO	Pont	2:30						X	X
A	MELZO SCALO	LA SPEZIA MIGLIARINA	Pont	7:40	X	X	X	X	X	X	X
D	LA SPEZIA MIGLIARINA	MELZO SCALO	Ge	11:30							X
D	LA SPEZIA MIGLIARINA	MELZO SCALO	Ge	13:00	X	X	X	X	X	X	
A	MELZO SCALO	LA SPEZIA MIGLIARINA	Pont	18:08	X	X	X	X	X	X	
A	MELZO SCALO	LA SPEZIA MIGLIARINA	Pont	18:08							X
A	MELZO SCALO	LA SPEZIA MIGLIARINA	Ge	18:55						X	X
D	LA SPEZIA MIGLIARINA	MELZO SCALO	Ge	20:55	X	X	X	X	X	X	X

A summary of the train numbers is given in Table IV. These are spread over weekdays and hours as according to historical data.

Table IV. Terminal train summary

	Melzo	La Spezia
Weekly trains	73	138
Shuttle trains	16	17

Comparing to WP5 model, the train numbers and cargo are the same, while their origins and scheduling had to be adjusted. Trains appear at one of the sources of the network according to its schedule, and proceeds to the terminal. After being processed at a terminal the train travels to its assigned sink and then leaves the network.

3. Model validation

Validation is one of the most difficult and the most useful steps to determine the suitability of the model. Especially, that as such a model is never fully valid, always representing a simplified version of the investigated system. Furthermore, not everything can be tested or compared, and arising discrepancies only make the model invalid if cannot be reasonably explained.

Most importantly, the interconnection model bases on the Macomi Platform and our rail transportation product RailGenie. These tools have been developed for the past few years and utilised successfully in a number of commercial projects. Every single specific implementation was validated and contributed to the overall tool design, which is being adopted for INTERMODEL EU project. A specific validation effort for WP7 model was executed in a number of steps:

- Adapt already valid components from previous Macomi railway projects from 2015-2018 instead of making new ones. Use the new components for the old projects and validate the results. These include various rail simulation studies in Europe.
- Expert walkthrough. The simulation component library to demonstrate to several experts from the field of rail freight operations experts working e.g. at intermodal terminals. Validation efforts included workshops with experts involving model walkthrough, and statistical analysis of the outputs, comparing them with historical data.
- Re-using validated elements from WP5

The parties to assist with the validation efforts:

- Intermodal terminal operator (Contship Italia)
- Port authorities of Rotterdam.
- Universities with research on intermodal terminals (Delft University of Technology).

Most difficult part to calibrate is other traffic in the network that does not use the terminals. Only partial data is available on the passenger train traffic, while we were unable to obtain any on the freight trains. This is thus estimated and can be changed once better data becomes available or when other assumptions are to be checked. Here, we perform a sensitivity analysis to estimate the impact of this functionality on the model results.

4. Simulation execution

The simulation run in the refreshed Macomi's PSP user interface takes the inputs of trains, volumes and properties and transforms them over time in a data-driven way. We utilise discrete-event simulation (DES) following the discrete event system specification (DEVS) paradigm, where the time is piecewise continuous. Depending on the number of trains and the investigated period, the simulation may take up to several hours to complete. Figure 5 displays a screen on scheduling a new experiment with necessary datasets and optional choices.

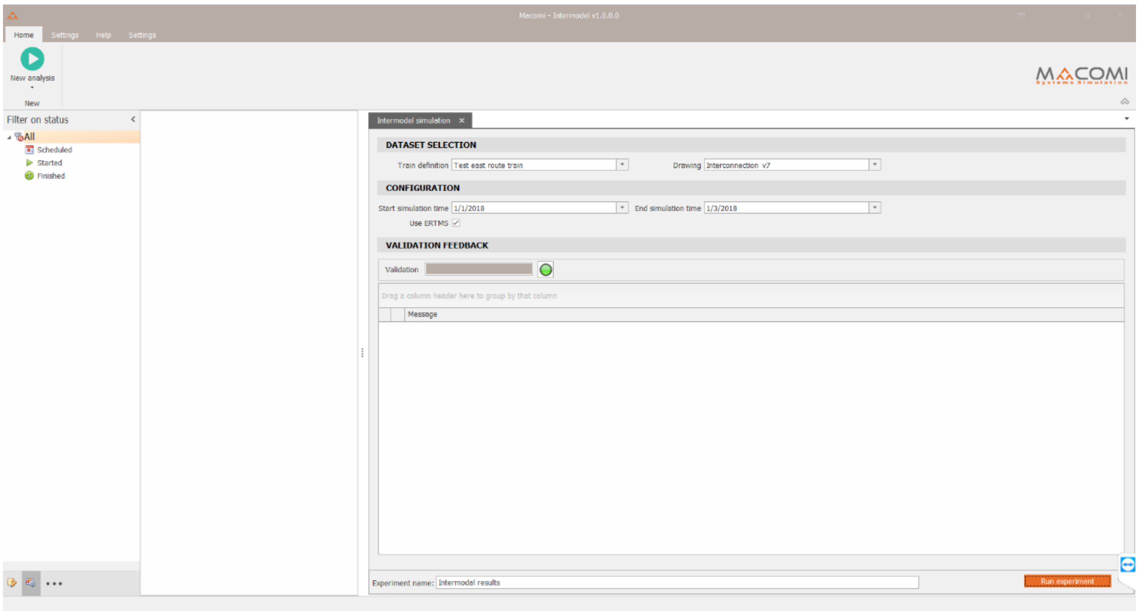

Figure 5. Scheduling a new run in the tool

Overall the model transforms the input data about the trains, volumes, processes and layout, and using the internal model logic over time creates a causal outlook of a future situation. This is recorded as animation and selected output datasets, comprising KPIs.

5. Results

This chapter presents some high-level results of the analysis. Due to the document's public nature data has been aggregated, not to reveal specific values. There are two main parts of the results, first simulating only trains visiting the terminals, i.e. terminal and interconnection trains. In the second part, other traffic is added, to account for congestion in the network and being dependent on other trains. This part can be viewed as a sensitivity analysis, as no certain numbers and routes could have been obtained.

5.1. Terminal traffic

We distinguish two main cases for terminal traffic, which differ in terms of the number of trains and thus transported volumes. The summary is given in Table V. We ran the simulation for both cases and compared the executed number with the input ones, as well as the resulting processing, waiting and turnaround times.

Table V. Terminal train number and volume summary

	Base terminal traffic	Increased terminal traffic
Yearly trains	11388	12740
Yearly boxes	700000	800000
Yearly TEU	1200000	1370000

Below Table VI contains average times for the base traffic, while Table VII has the same KPIs for the increased traffic. It needs to be noted that the turnaround time is counted for the terminal, while the waiting time contains the total waiting time for a train, also when it was not at the terminal and waiting due to inspection etc.

Table VI. Base traffic results

Type	Avg processing time [h]	Avg waiting time [h]	Avg turnaround time [h]
Melzo	4.34	7.96	9.25
La Spezia	2.71	6.54	7.74
Shuttles	10.22	19.73	26.31

As could be expected, with an increase in train numbers and volumes, the average times also rise, especially the waiting time.

Table VII. Increased traffic results

Type	Avg processing time [h]	Avg waiting time [h]	Avg turnaround time [h]
Melzo	5.26	11.07	14.11
La Spezia	2.62	6.58	10.56
Shuttles	11.11	30.58	44.33

The spread of terminal trains over the week for the base inputs is given in Figure 6, with division over the four rail yards at the terminals. Depending on the length of the train and according to historical records, some trains are processed by gantry cranes at international yards, and some are processed by reach stackers at domestic yards.

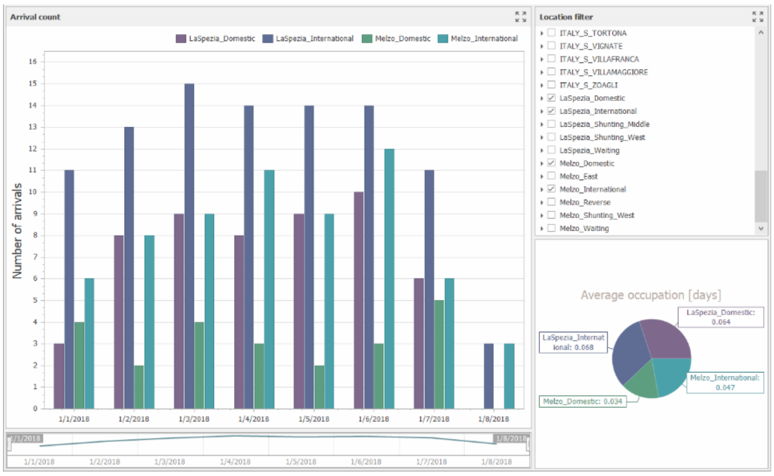

Figure 6. Base terminal trains arrivals and occupation

The processing resources and their productivity differs per yard. There are fewer trains scheduled for domestic yards, also due to the number of production sidings.

Figure 7. Increased terminal trains arrivals and occupation

5.2. Other traffic

Estimating other traffic is a challenging task as data sources are available for neither passenger trains nor other freight trains in the network. One can obtain some idea about passenger trains from the Italian railways, but the search engines operate on point-to-point basis and not on link basis, and there are multiple train categories (in the model simplified to a single passenger train category). Nevertheless, significant effort was made to obtain and estimate other traffic numbers and routes.

Figure 8. Base terminal trains arrivals and occupation (affected by other traffic)

Given that 39 sources and sinks were identified, the potential number of routes for other traffic is significant. We identified 107 major routes, i.e. series of paths the trains take in between a source and a sink, given them patterns and distributions, as well as properties for an average train.

In a typical setting we send 30 thousand trains a year through the network. In Figure 8 and Figure 9 we show the same corresponding train number and occupation dashboards as in the previous section for base and increased terminal trains, this time including the effects of other traffic.

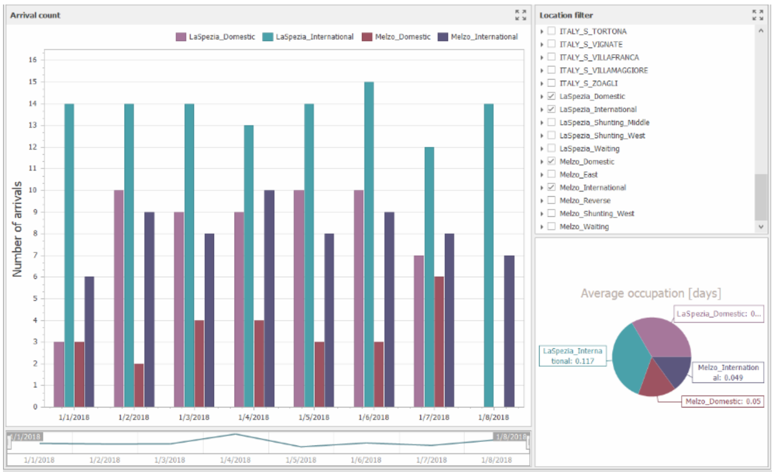

Figure 9. Increased terminal trains arrivals and occupation (affected by other traffic)

Other traffic clearly can influence the terminal trains, especially when it comes to the waiting time, as shown in Table VIII and Table IX. Especially for the shuttles, which take the longest route through the system.

Table VIII. Base traffic results (affected by other traffic)

Type	Avg processing time [h]	Avg waiting time [h]	Avg turnaround time [h]
Melzo	4.61	8.90	10.74
La Spezia	2.53	6.51	8.23

Shuttles	10.44	22.52	29.23

Processing times aren't affected and the differences in between them arrive from the causality of arrivals at the terminals. With greater delays, it is possible that there are fewer trains at the terminal at some points, and busier at others.

Table IX. Increased traffic results (affected by other traffic)

Type	Avg processing time [h]	Avg waiting time [h]	Avg turnaround time [h]
Melzo	5.26	11.07	14.11
La Spezia	2.63	6.73	12.91
Shuttles	10.76	25.12	46.22

For validation and testing there were other experiments made, varying the amount of other traffic (also included in deliverable D7.3). A high-level conclusion is that after reaching a certain threshold, varied on different routes, it is possible to clog the system to a point where the delays reach many days. This, of course is not a realistic scenario.

6. Conclusions and future work

6.1. Conclusions

The goal of WP7 is to build a rail interconnection simulation model to be a decision support environment in optimising operations of dependent container terminals. A prototype of such tool is developed and verified (as described in deliverable D7.1) and used for analysis of the pilot case for future deliverables, as described in this document. It is done based on the developments made for WP5 and extended to connect the two terminals via rail network.

One of the biggest challenges was the layout. Nor terminal operators have a detailed layout of the network and they could only supply with schematic drawings. Lack of dimensions and signalling data forced us to look for alternatives. Without another partner who could provide the data we had to resort to publicly available sources and OpenStreetMap had in our view the most complete data in the most suitable format. A very important factor was that it is GIS-based, so that we could draw exact network in scale. Overall, the import functionality has great potential to be used in the future as in the OSM database has a lot of coverage.

We analysed the pilot case for the current and increased traffic in between the investigated terminals and conclude that there are network-based interdependencies and that with increased traffic further delays should be expected. Furthermore, other traffic has significant influence on the delays in the network and this traffic should be further analysed for a more complete analysis.

6.2. Limitations

During the evaluation of the model several observations were made with regards to the current limitations of the system with some prospects of improvements.

Longer trains would be very beneficial to the cargo volume. Shorter trains are not very efficient for Melzo, as the terminal tracks capacity is underutilised. However, there are no long production tracks available in La Spezia and there is limited space to inspect long trains on either La Spezia or Melzo. Infrastructural investments should be made to improve that situation.

Then, the eastern route via Pontremoli has a significant part of it with only a single track, covering for both directions. In typical model, meet-pass decisions are investigated, and trains are scheduled to reduce waiting for the way to clear from the opposite side. Here, due to uncertainty of the other traffic, such exercise was not possible.

6.3. Future work

This document describes the efforts to build and validate the model, all activities to reach the MS16 and MS19. The remaining activities for the future are to complete deliverables:

- D7.3 Assessment of the rail interconnection resilience

To reach the following milestones:

- MS18 Presentation of the conclusion derived from the assessment of rail network resilience test

Furthermore, for a more complete and useful analysis of the interdependencies, better estimation of other traffic in the network is essential.

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Appendix A. Input tables

Table X. Terminal train definitions table (abbreviated example)

Name	Arrival date	Arrival time	Route name	TEU	Empty Wagon Weights in tons	Max speed (kph)
Melzo 1	01/01/2018	05:50:33	MelzoInternationalRoute_Main	80	22	80
Melzo 2	01/01/2018	07:44:59	MelzoInternationalRoute_Main	84	22	80
Melzo 3	01/01/2018	09:29:11	MelzoDomesticRoute_Main	40	22	80

Table XI. Terminal train routes definition table (abbreviated example)

Name	Full route
LaSpeziaInternationalRoute_Main	LaSpeziaSourceEast;T_LASPEZIA_INTERNATIONAL;LaSpeziaSinkEast
LaSpeziaDomesticRoute_Main	LaSpeziaSourceEast;T_LASPEZIA_DOMESTIC;LaSpeziaSinkEast
MelzoInternationalRoute_Main	MelzoSource;T_MELZO_INTERNATIONAL;MelzoSink
MelzoDomesticRoute_Main	MelzoSource;T_MELZO_DOMESTIC;MelzoSink

Table XII. Terminal train cargo definitions table (abbreviated example)

Train name	Location	Number 20ft	Number 40ft
Melzo 1	START	4	33
Melzo 1	Melzo_International	20	0
Melzo 2	START	26	24
Melzo 2	Melzo_International	0	37
Melzo 3	START	9	6
Melzo 3	LaSpezia_International	8	13
MLS 53010_TU	START	22	18
MLS 53010_TU	Melzo_International	21	18
MLS 53010_TU	LaSpezia_International	21	19

Table XIII. Non-terminal train type definitions table

Name	Type	Max speed (kph)	Wagon size (metres)	Number of wagons	Empty wagon weight (ton)	Percentage per week
Passenger A	Passenger	120	40	5	45	100.00%
Freight short	Freight	80	25	15	23	100.00%

Table XIV. Non-terminal train number definition table

Type	Weekly number
Freight	1000
Passenger	4500

Table XV. Non-terminal train weekday distributions per type

Train type	Freight	Passenger
Monday	15.00%	16.00%
Tuesday	12.00%	16.00%
Wednesday	10.00%	16.00%
Thursday	10.00%	16.00%
Friday	8.00%	16.00%
Saturday	25.00%	10.00%
Sunday	20.00%	10.00%

Table XVI. Non-terminal train hourly distributions per type

Train type	Freight	Passenger
0	7.00%	1.00%
1	7.00%	0.00%
2	7.00%	0.00%
3	7.00%	0.00%
4	7.00%	0.00%
5	6.00%	1.00%
6	5.00%	3.00%
7	2.00%	10.00%
8	2.00%	8.00%
9	3.00%	7.00%
10	3.00%	6.00%
11	6.00%	4.00%
12	6.00%	4.00%
13	6.00%	4.00%
14	3.00%	4.00%
15	3.00%	6.00%
16	1.00%	7.00%
17	2.00%	9.00%
18	2.00%	9.00%
19	2.00%	7.00%
20	2.00%	5.00%
21	3.00%	3.00%
22	3.00%	1.00%
23	5.00%	1.00%

Table XVII. Non-terminal train route definitions table (abbreviated example)

Name	Full route
FornoveSourceSink-LaSpeziaSinkEast	FornoveSourceSink;LaSpeziaSinkEast
FidenzaSourceNorth-LaSpeziaSinkEast	FidenzaSourceNorth;LaSpeziaSinkEast
PiacenzaSourceWest-LaSpeziaSinkEast	PiacenzaSourceWest;LaSpeziaSinkEast
SantoStefanoSource-LaSpeziaSinkEast	SantoStefanoSource;LaSpeziaSinkEast
OspedalettoLodigianoSourceSink-LaSpeziaSinkEast	OspedalettoLodigianoSourceSink;LaSpeziaSinkEast
MilanoPortaRomanaSource-LaSpeziaSinkEast	MilanoPortaRomanaSource;LaSpeziaSinkEast
MilanoPortaVittoriaSource-LaSpeziaSinkEast	MilanoPortaVittoriaSource;LaSpeziaSinkEast
MilanoSmistamentoSourceNorth-LaSpeziaSinkEast	MilanoSmistamentoSourceNorth;LaSpeziaSinkEast

Table XVIII. Non-terminal train route distributions table (abbreviated example)

Route name	Percentage	Train type
FornoveSourceSink-LaSpeziaSinkEast	2%	**Freight**
FidenzaSourceNorth-LaSpeziaSinkEast	1%	**Freight**
PiacenzaSourceWest-LaSpeziaSinkEast	1%	**Freight**
SantoStefanoSource-LaSpeziaSinkEast	1%	**Freight**
FornoveSourceSink-LaSpeziaSinkEast	2%	**Passenger**
FidenzaSourceNorth-LaSpeziaSinkEast	1%	**Passenger**
PiacenzaSourceWest-LaSpeziaSinkEast	1%	**Passenger**
SantoStefanoSource-LaSpeziaSinkEast	1%	**Passenger**
OspedalettoLodigianoSourceSink-LaSpeziaSinkEast	1%	**Passenger**