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Optimised Real-time Yard and Network Management

D 6.1 – Business Case specifications and plans

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Report Contributors

Name	Company	Details of Contribution

1. EXECUTIVE SUMMARY

Task 6.1 aims at organising the selected Case Studies of Ceske Trebova (Czech Republic) and Trieste (Italy) (1) to guide the research activities throughout the project from a practical industry-driven perspective and (2) to ensure a coherent and harmonised demonstration approach. The coherency has been ensured by the involvement of all technical work package leaders (WP2 to WP5) and of all demonstrators at all levels of the simulation, validation and feasibility tests.

The main output of this task is the production of a standardised demonstration plan useable by both case studies. In order to avoid duplication of activities, **it was finally agreed that the demonstration activities related to WP6 should be focus on the potential benefits of the optimisation capabilities** designed by the WP5 partners for different scenarios. The validation of the yard models with field descriptions, processes, simulation scenarios, outputs and comparisons is part of deliverable 'D4.3 – Optimised Real-Time Yard and Network Management'.

With the two selected use cases – Ceske Trebova (CZ) and Trieste (IT), **a large variety of operational components of a marshalling yard was covered**: (1) types of transport (single wagon load transport and Combined Transport trains with intermodal loading units), (2) type of network connections (industrial sidings and terminal service facilities), (3) type of shunting (horizontal and hump shunting) and (4) type of traffic (maritime and continental related marshalling yards). Both case studies have been contributed to the project either as 'input provider' for all technical work packages or either as 'output validator/demonstrator' for the selected yard simulation tool, Villon (developed by the project partner SIMCON).

Two optimisation scenarios for the marshalling yard have been identified as general approach with the objective to (1) minimize total delay of outbound trains and (2) minimize wagons duration in yard. A demonstration test with the network (outside the marshalling yard) is not foreseen. It is assumed that more punctual trains at departure and/or improved communication between the yard and the network will automatically improve the overall quality performance of the trains on the network.

- The **DEMO 1** focuses on the optimization of the yard operations in a nominal mode where no changes are introduced to the reference scenario.
- The **DEMO 2** concentrates on the optimization of the yard operations in degraded operations. Degraded operations occur when part of the marshalling yard continues to operate in a restricted manner. The adopted degraded modes are for both cases: (i) broken locomotives (ii) additional trains. For Ceske Trebova, delayed trains should be added. For Trieste, also the failure of a track should be considered.

The detailed processes/results of the optimisation exercise and its related assessment will be explained in the respective business case studies report of Trieste and Ceske Trebova (Deliverable 6.2).

The result of the demonstrator on the new optimisation capabilities should be, beyond a possible efficiency gain at different operational levels of the yard, a possible tool for suggesting alternative operative solutions for the dispatchers.

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4. SCOPE AND PURPOSE

The task 6.1 is aimed at organising the selected Case Studies of Ceske Trebova (Czech Republic) and Trieste (Italy) to guide the research activities throughout the project from a practical industry-driven perspective and to ensure a coherent and harmonised demonstration approach. The coherency has been ensured by the involvement of all technical work package leaders (WP2 to WP5) and of all demonstrators at all levels of the simulation, validation and feasibility tests.

The main output of this task is the production of a standardised demonstration plan useable by both case studies as defined in task 6.2. A Demonstration Plan states what the demonstration will attempt to prove, the methodology which will be followed, the criteria for success, and the measurements that will be made to determine success. Normally, it ensures that pertinent and reliable data are collected during the demonstration to support future decisions on implementing the technology.

Intense discussions appeared in the last months about what exactly is meant by demonstration: what kind of test should be carried? How does it differ from the validation as requested in WP4? What are the boundaries between WP4, WP5 and WP 6 in order duplication of tasks and activities?

The following definitions were agreed upon during a WP6 workshop in July to clearly distinguish WP4 validation, WP5 optimisation (yard and network) and WP6 demonstration.

- Verification – Meet the requirements/specifications. Independent check must be possible
- Validation – ‘Fit for purpose’ in a non-optimised marshalling environment (nominal situation with pre-defined simulation scenarios) (all activities related to WP4)
- Demonstration – Demonstrating impacts of (1) commonly agreed degraded modes for all use cases (based on the validation in WP4) and (2) the benefits of the optimisation algorithms developed in WP5 on the daily marshalling yard operations

In this context, the WP6 demonstration activities were focused on the potential benefits of the optimisation capabilities developed within WP5 in different degraded modes. The validation of the yard models with field descriptions, processes, simulation scenarios, outputs and comparisons is part of deliverable ‘D4.3 – Optimised Real-Time Yard and Network Management’.

The two selected use cases in Italy and Czech Republic are covering a large variety of operational components of a marshalling yard: (1) types of transport (single wagon load transport and Combined Transport trains with intermodal loading units), (2) type of network connections (industrial sidings and terminal service facilities), (3) type of shunting (horizontal and hump shunting) and (4) type of traffic (maritime and continental related marshalling yards). Both demonstrators (Ceska Trebova and Trieste) have played a central role in the project by participating and contributing to all phases (from conceptual/design to final output validation and demonstration.

Figure 5-1 - The two case studies in OptiYard

Conventional rail freight or wagonload includes trainloads and single wagonloads. Single wagonload (SWL) is a sophisticated product by which a wagon or a group of wagons are shunted into the facilities of a shipper, and once loaded, they are shunted back and marshalled to form trains that run over longer distances. This production method is now being relaunched. Single wagonload generally requires marshalling yards. A typical example is a hump yard.

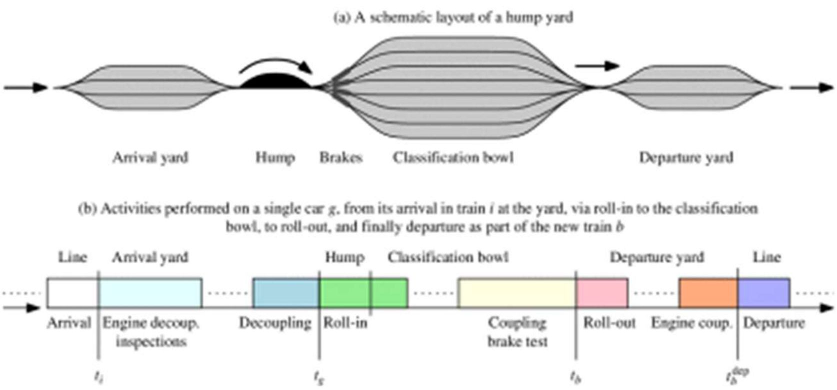

Figure 5-2 - Typical layout of a hump (marshalling) yard.

Intermodal transport involves the movement of goods in the shape of standardized loading units, i.e. containers, semi-trailers and swap-bodies, transferred between at least two modes without handling the goods as such. This type of transport offers the possibility of an easy and rapid transhipment of goods, using transferable loading units (container, swap bodies, semitrailers, even trucks themselves, in case of accompanied transport). This implies the shipment of goods from an origin to an intermediate destination, and from there to another destination. Transhipment takes places in terminals or hubs where the freight is consolidated or deconsolidated. Transhipment makes also possible the change of the modes of transport during the journey without handling the goods as such.

Typical intermodal terminals are (1) port terminals; (2) large, medium and small intermodal terminals, (3) industrial intermodal terminals and (4) end terminals and liner train terminals.

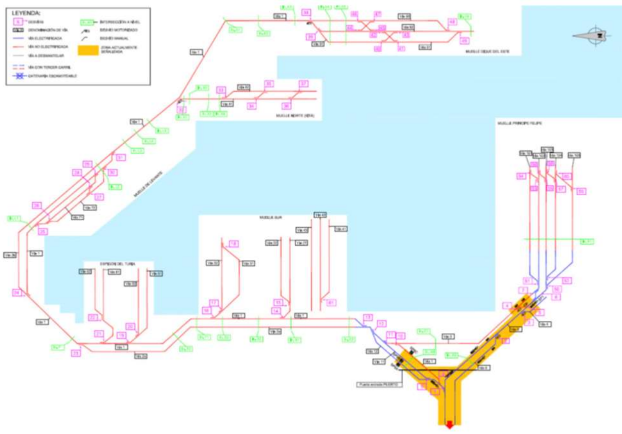

Figure 5-3 - Example of a layout of an intermodal maritime rail network (Valencia)

5.1 CESKA TREBOVA (CZECH REPUBLIC)

Situated in the centre of the Czech Republic rail network and with a marshalling capacity of up to 1,200 wagons in 24 hours and, the marshalling yard Ceska Trebova ranks among the 7 key railway facilities utilized by the partner CD Cargo. The current average marshalling throughput is around 700 wagons in 24 hours, some 18% of which are intermodal wagons.

The station is located on the busiest main Czech railway corridor East-West and on the main line between Prague and Slovakia with a section to Brno and Vienna. Ceska Trebova has the most convenient railway marshalling topology, i.e. the entry yard, hump, classification yard and departure yard. The station currently operates about 30 domestic and international destinations, including Engelsdorf (Germany), Vienna (Austria), Bratislava/Zilina (Slovakia) and Wroclaw (Poland).

Figure 5-4 - Ceska Trebova (location)

Ceska Trebova is designed with 38 sorting tracks (with the length of up to 1 000 meters), divided into 5 clusters, each equipped with 3 series of pneumatic brakes (up to final fine-breaking) so that no shunters are necessary in the classification yard except for the couplers. The arrival yard is made by 13 tracks with length of up to 900 meters and the departure yard consists of 15 tracks with length of 850 meters.

Figure 5-5 - Ceske Trebova – design

The yard and network models of Ceske Trebova have been described the deliverable 4.1 on yard and network and simulation model (chapter 2.3). It consists of detailed description of (1) the three areas of the marshalling yards (arrival, classification bowl, departure), (2) the surrounding rail network. Annex A of the same deliverable summaries the model description according to the functional specifications as written down in deliverable 3.2. Annex C provides examples of handling process charts (inbound trains, transit trains and outbound trains).

5.2 TRIESTE (ITALY)

Located in the heart of Europe, at the intersection between shipping routes and the Baltic-Adriatic and Mediterranean TEN-T core network corridors, the Port of Trieste is an international hub for overland and sea trade with the dynamic market of Central and Eastern Europe. The port of Trieste handles around 8,000 trains (see figure) of which around 25% are conventional in a horizontal marshalling system closely interconnected with the terminals and logistics areas of the vicinity. Rail services are available with different frequencies to Austria, Germany, Hungary, Czech Republic, Slovakia and Switzerland; the destinations for domestic connections are Milan Certosa and Padua/ Bologna.

Porto Franco Nuovo	
Gennaio	591
Febbraio	452
Marzo	655
Aprile	632
Maggio	679
Giugno	656
Luglio	653
Agosto	556
Settembre	627
Ottobre	661
Novembre	646
Dicembre	552
TOTALE	7360

Porto Industriale	
Gennaio	1
Febbraio	0
Marzo	12
Aprile	17
Maggio	24
Giugno	28
Luglio	14
Agosto	15
Settembre	18
Ottobre	22
Novembre	34
Dicembre	26
TOTALE	211

Interporto Trieste	
Gennaio	35
Febbraio	39
Marzo	50
Aprile	16
Maggio	23
Giugno	45
Luglio	42
Agosto	35
Settembre	36
Ottobre	44
Novembre	36
Dicembre	25
TOTALE	426

TOTALE	7997

Figure 5-6 - Port of Trieste: Number of trains handled in 2018

The Port of Trieste layout for rail activities is quite complex and the shunting operations have been restructured since 2016 on two main sites at Campo Marzio and Servola to serve conventional terminals and combined terminals. The marshalling yard is situated at the end of the Baltic Adriatic corridor and propose frequent connections to Austria with 80 trains per week. The operator ADRIAFER, subsidiary of Port of Trieste authority, is certified as railway undertaking for the last mile operations in the region of Trieste (Campo Marzio – Villa Opicina, Monfalcone, Aquilinia).

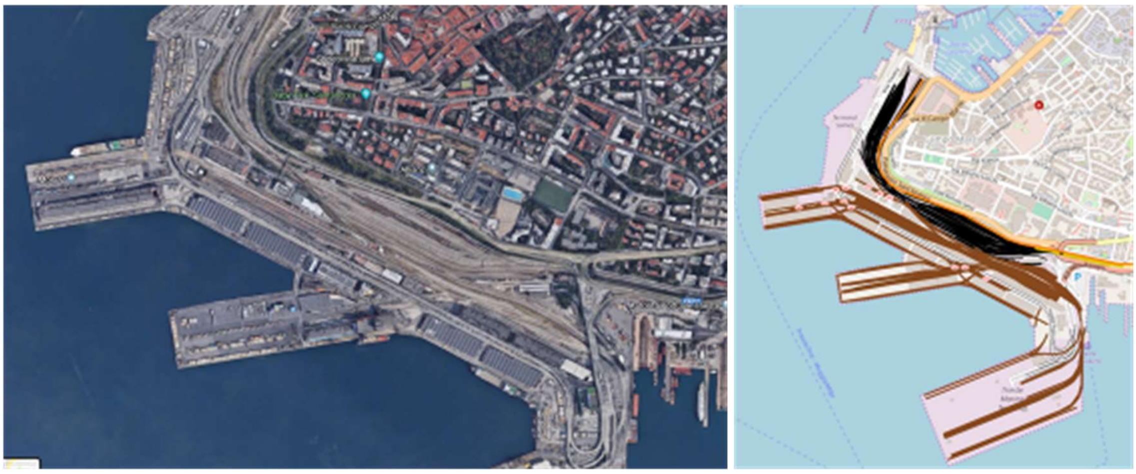

Figure 5-7 - Port of Trieste (main shunting sites)

Due to train length limitations (only 550 m train), the railway infrastructure is currently upgraded to 6 tracks of 750m. 12 locomotives are available for the shunting operations and 2 Zephyr railroad engines has been recently purchased to increase the efficiency of the operations and enables to a better use of existing tracks. The communication system with RFI is also being upgraded to monitor the trains two hours before their arrival in the yards. A program to automate their marshalling operations is under analysis. This complex case in term of layout, of variety of traffics, of tight space conditions and with a rapidly growing activity due to their strategic position offers interesting possibilities of optimizing a medium-sized marshalling yard.

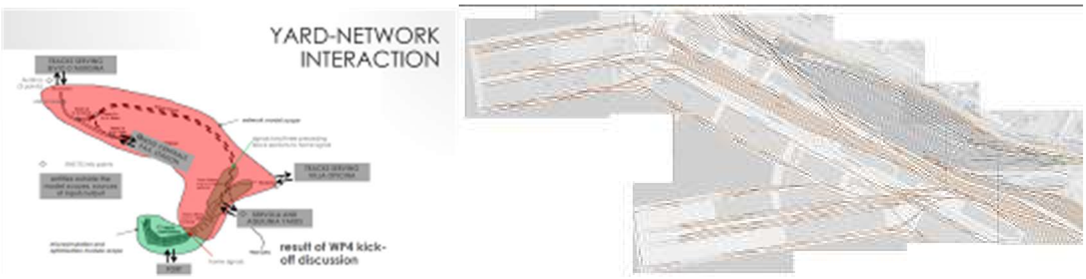

Figure 5-8 - Trieste: detailed yard and network connection

The yard and network models of Trieste have been described the deliverable 4.1 on yard and network and simulation model (chapter 2.3). It consists of detailed description of (1) the areas of the marshalling yards, (2) the surrounding rail network. Annex B of the same deliverable summaries the model description according to the functional specifications as written down in deliverable 3.2. Annex C provides examples of handling process charts (inbound trains, transit trains and outbound trains).

6. ROLES OF THE CASE STUDIES

Both case studies have been contributed to the project either as 'input provider' for all technical work packages or either as 'output validator/demonstrator'.

- As '**input provider**', they have delivered (1) a state-of-the art description on how the operating/shunting processes are currently performed and on how the data are currently managed in real-time (link to WP2), (2) a catalogue of functionalities and requirements of the simulation environment (link to WP3), (3) the necessary static and dynamic data of all the operational processes for the development of the models and a first validation of the tool (input for WP4) and (5) an analysis; an evaluation and prioritization of the optimization possibilities and capabilities in order to develop the right and industry-driven optimization algorithms (input for WP5).

- As '**output validator**', they have tested and validated the developed virtual software for marshalling yard and network (WP4) in a production-like environment (with actual data and processes of the marshalling yard) with the aim to assess if the model – in a non-optimised ecosystem - is 'fit for purpose'. In a second step, the demonstrators have tested and validated the WP5 optimisation modules based on the demonstration scenarios (see chapter 5).

All details of the specific actions and tasks performed by both use cases are integrated in the deliverable 6.2 on Business Case Feasibility and Simulation Test of the virtual yard/terminal software.

7. VILLON AS THE SELECTED YARD SIMULATION TOOL

Villon is the software simulation tool chosen for yard simulation in OptiYard. It is a software simulation tool, developed by Simcon, for creation and application of universal and detailed simulation models of transportation logistic terminals and their technological processes. Villon supports microscopic modelling of various types of transportation logistic terminals containing railway and road infrastructures (e.g. marshalling yards, railway passenger stations, factories, container terminals, depots, airports, etc.).

Villon supports microscopic modelling of various types of transportation logistic terminals containing railway and road infrastructures (e.g. marshalling yards, railway passenger stations, factories, container terminals, depots, airports, etc.).

The Villon's prime features are (and have been partially applied and used for the purpose of the project):

- *Precise infrastructure modelling*: the infrastructure model (see figure 6.1 for screenshots) is accurate and respects all important physical properties (such as shape, length, diameter or slope) of infrastructure elements (e.g. tracks or roads). The infrastructure model contains also information about signalling equipment and additional structures, e.g. buildings, platforms, retarders, etc.

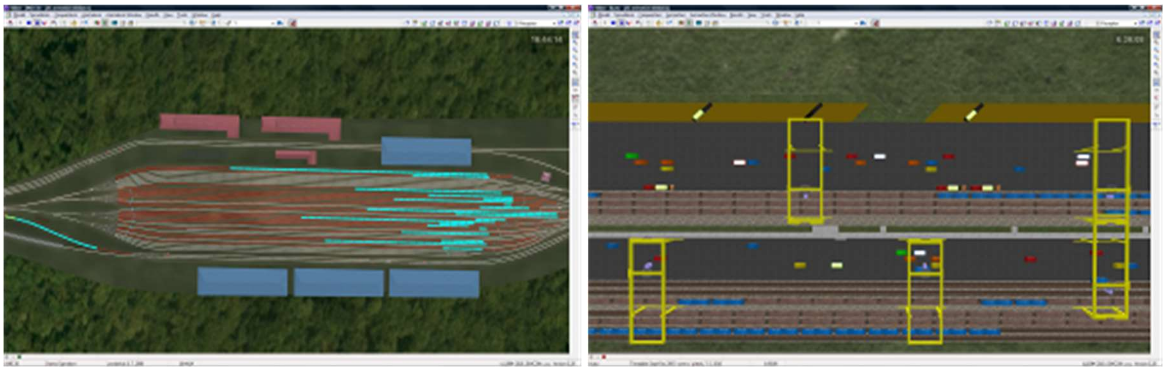

Figure 7-9 - VILLON – 3D infrastructure modeling

- *Individual Modelling of Resources*: it enables individual (single entity level) modelling of stabile (infrastructure, storage places) as well as mobile resources (e.g. personnel, engines, trucks). Resources are modelled individually, respecting their working hours, professions and other properties.

- *Detailed and Flexible Modelling of Operation*: Definition of operating procedures in Villon is realised utilising network charts (flowcharts, also called technologies) that are assigned to each customer of the system (e.g. train, truck). Flowcharts are composed of activities, which represents single tasks executed during serving of customers (e.g. moving, loading, resource assignment, brake testing, storing etc.). Villon contains a set of predefined template activities (more than 30) which cover the whole spectrum of functions found in operations of transportation terminals and marshalling yards.

- *Microscopic Modelling of Transport processes*: Vehicle movement is modelled utilising continuous simulation with the help of differential equations (see figure 6.2). The computation considers the engine power characteristics as well as the parameters of the infrastructure, the vehicle is moving on (e.g. curve diameters, slopes, maximum speed allowed, etc.).

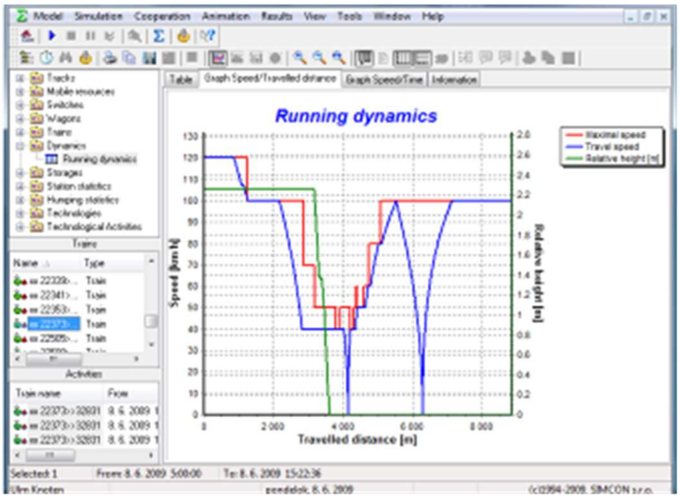

Figure 7-10 - VILLON - Modelling of Transport Processes

- *Modelling of Multi-modal Systems*: Villon's modelling abilities encompass rail, road as well as special (e.g. cranes) transport modes, respecting their distinct properties. In a single simulation model, all supported modes can be combined in order to evaluate their mutual interactions (e.g. blocking of road crossings by trains, occupation of shared unloading slot by trucks).

- *Extensive Evaluation Possibilities*: In addition to the detailed interactive 2D or 3D run-time animation of most simulated processes, Villon offers (during the simulation run) various tools for exploring the attributes of simulation entities (statuses of resources, positions of trains, cars, etc.).

- *3D Animation of Simulated Processes*: Animation of modelled transportation processes as well as other serving processes (e.g. brake testing) during simulation run is an integral part of Villon. The animation can be presented in a top view 2D (either GDI based or hardware accelerated, based on MS DirectX) or 3D environment (DirectX only). The environment is fully interactive (mouse object picking) and freely explorable (any camera position or viewing angle; even driving on vehicles is possible). Besides detailed infrastructure and vehicle models, the scene can be enhanced with models of station interiors, buildings, terrain, signs, signals as well as trees.

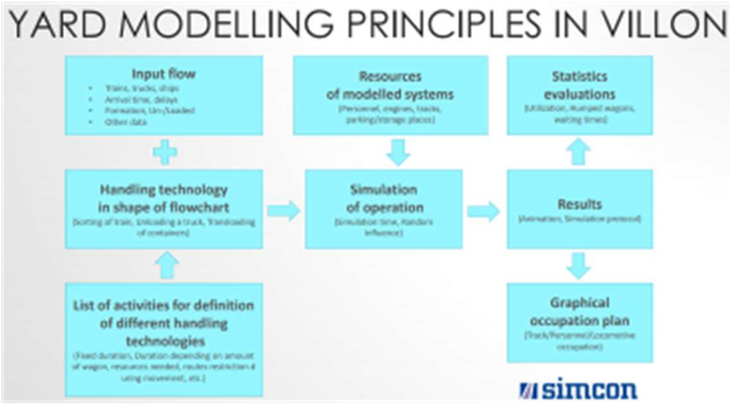

Figure 7-11 - Villon's yard modelling principles

The yard modelling principles are depicted in figure 6.3.:

1. **Input flow**: data consolidation on stable fixed resources (infrastructure) such as set of tracks, signalling system and interlocking system

2. **Handling technology in shape of flowchart**: flowcharts define the succession and mutual dependence of activities in the handling process. Flowcharts are created in a comfortable graphical editor with support for automatic validation of the entered flowcharts

3. **List of activities for definition** of different handling technologies: definition of the parameters for handling the trains in the marshalling yard (e.g. duration of shunting, time needed for inspection).

4. **Resources of modelled systems**: collection of variable and mobile resources to reflect the real situation be means of exact definition of every train composition and parameters (arrival time, train groups, type), of the available personnel and shunting locomotives. An integrated editor of mobile elements permits the user to define all important properties of any resource as well as their composition corresponding to real terminal configuration.

5. **Simulation of operation**: The properties of the model are derived from the needs which are supposed to be satisfied by using it. The model may serve for investigating the variants of infrastructure configuration, service resources, technological procedures, decision making and even control strategies. This means that the model allows investigating marshalling yard properties under any circumstances (conditions, parameters) defined as a scenario.

6. **Results/statistics evaluation/graphical occupation plan**: during the simulation of operation, the results are displayed by means of animations (all train movements, sets and locomotives as well as the animation of other mobile resources). A detailed protocol of simulation is generated during the simulation run. These protocols can be separately processed, and information sought can be retrieved from them like statistics and detailed time-dependent reports (called graphical protocol).

OptiYard's requirements derived from data exchange and data analytics have been summarised in deliverable 3.1: exchange of information inside a rail yard, exchange of information between rail network and rail yard, exchange of information with other modes and rail yard, general data exchange formats and representation of the infrastructural elements of the rai network and rail yard.

An initial assessment of the applicability of the VILLON simulation environment to the OptiYard's specifications has been undertaken in WP3 with the production of the deliverable 3.1.

8. DEMONSTRATION SCENARIOS

In Work package 4, Simcon, as the developing company of the VILLON yard simulation tool, designed for both cases a virtual yard environment that should represent as closely as possible the reality of the yard operations. The following activities have been performed (more details in deliverable 4.3):

(1) Data of one real-time operational week has been integrated for both cases into the simulation tool.
(2) Various simulations scenarios have been designed and added to the simulation tool. It has been agreed that (i) for the use case 'Trieste', the theoretical approach will be used for all simulation scenarios and (ii) for the use case 'Ceske Trebova', the actual operational data.
(3) The different flow charts and decision processes have been designed and validated.

This 'non-optimised' yard model has been tested and validated by both use cases in WP4: both demonstrators have confirmed that the virtual yard lay-out and developed processes represent the reality of their operations. With this validation, a 'reference scenario' has been defined for both cases:

- Selection of a standard week based on standard operations (no significant occurrence affecting operations during this week – for example unavailability of several tracks/shunting locomotives);
- Identification of the traffic volumes in this standard week (number of inbound/outbound trains…)
- Detailed process description on the organisation of shunting operations, allocation of resources (tracks, shunting equipment and personnel) and information flows (contacts with terminals for example).

It has been commonly agreed that the optimisation capabilities developed in WP5 will be demonstrated in WP6 and will serve as a decision support tool for the marshalling yard dispatcher (what would happen if the dispatcher would decide differently). It was also decided that no graphical user interface will be specifically developed for the monitoring the optimisation outputs. The relationship between, the optimisation module and the simulation model is represented in figure 8-1: (1) XML files with all relevant data sets will be transmitted from the virtual yard model to optimisation module (2) the results of the optimisation algorithms will be send via pre-defined messages to the simulation model which will adjust the processes and contribute to the analysis of the impacts.

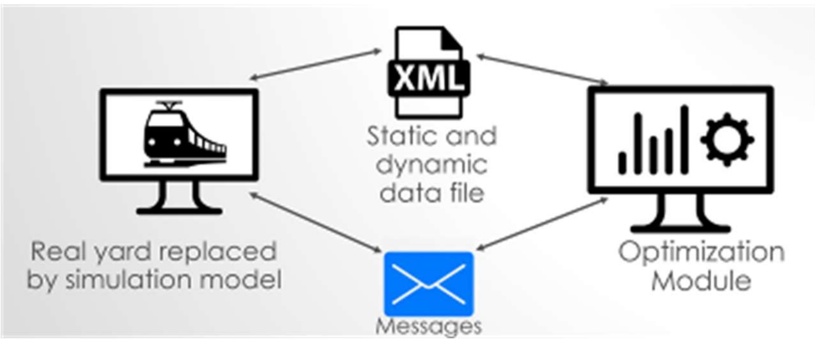

Figure 8-12 – Simulation and Optimisation

The impacts of the various possible decisions will be assessed during the demonstration tests (cf. task 6.2 and related specific business case reports) and will be economically evaluated (task 6.3 and related deliverable 6.3).

The WP6 demonstration activities should verify that the optimization functions will increase the overall value of pre-defined parameters (for example: increase of the % of punctual trains at departure time). The indicators will be selected from the inventory of the KPIs compiled for the marshalling yard and the network in task 6.2. The optimisation demonstration aims at (1) minimising the total delay of outbound trains and (2) minimising the time in the marshalling yard. A demonstration test with the network (outside the marshalling yard) is not foreseen. It is assumed that more punctual trains at departure and/or improved communication between the yard and the network will automatically improve the overall quality performance of the trains on the network.

The following chapters will describe the two basic optimisation scenarios for the use cases for designing and validating a yard model simulation application in an optimised environment. The detailed processes/results of the optimisation exercise and its related assessment will be explained in the respective business case studies report of Trieste and Ceske Trebova (Deliverable 6.2).

8.1 DEMO 1 -OPTIMISATION IN NOMINAL MODE

The DEMO 1 will focus on the optimization of the yard operations in **a nominal mode** where no changes are introduced to the reference scenario. Nominal Optimization, also known as Performance Optimization, is the process of modifying a set of parameter values to satisfy pre-determined performance goals (KPIs).

(1) Basics

In this scenario, no changes are introduced in the arrival notifications, in the constraints on staff employment conditions or on technicalities of shunting equipment. Data exchanges between entities are performed in the usual way. This is the reference situation as it has been tested and validated in WP4.

(2) Purpose of optimization & KPIs

(1) Increase number of punctual trains at departure (KPI= train departure time)
(2) Reduce the operational time in the marshalling yard (KPI = mean wagon transit time)

(3) Outputs & tasks

(1) Simulation results on possible impacts of the optimization
(2) Comparative situation between ‘before’ and ‘after’ simulation
(3) Assessment of the functioning with multi-stage process
(4) Several different test cases for debug
(5) Plausibility checks by the use cases (with the operational departments)

(4) Participants

The following partners are participating in this DEMO 1:
- IFSTTAR as the designer of the optimisation capabilities and modules
- SIMCON as the developed of the VILLON yard model and simulation tool
- Both Use cases: (1) NEW OPERA/ADRIAFER for Trieste and (2) CD CARGO for Ceske Trebova

8.2 Demo 2 – Optimisation in degraded modes

The DEMO 2 will focus on the optimization of the yard operations in degraded operations. Degraded operations occur when part of the marshalling yard continues to operate in a restricted manner, for example after the failure of a shunting locomotive or of a signal. Over time, marshalling yard operators develop 'work arounds' that help them to cope with these degraded modes. This has led to a culture of 'making do' where workers try their best to maintain service provision despite system failures. These adaptations and 'work arounds' undermine overall efficiency and in some cases safety.

The DEMO 2 should evaluate if optimization algorithms might support the yard dispatchers in the decision-making process and assess if alternative decisions might have a better impact on the pre-defined performance indicators.

(5) Basics

In this demonstration, some changes are introduced in the reference scenarios of both cases. The degraded modes are listed in the following table. The algorithms will be tested for one degraded item; a full integration of all degraded modes at once will not be tested.

Id	Degraded Features	Ceske Trebova	Trieste
1	Broken locomotives	YES	YES
2	Additional trains	YES	YES
3	Delayed trains	YES	-
4	Broken track	-	YES

(6) Purpose of optimization & KPIs

(1) Minimize the total delays of outbound trains (KPI = trains departure time)
(2) Minimize the operational time in the marshalling yard (KPI = mean wagon transit time)

(7) Outputs & tasks

(1) Simulation results on possible impacts of the optimization
(2) Comparative situation between 'before' and 'after' simulation
(3) Assessment of the functioning with multi-stage process
(4) Several different test cases for debug
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9. CONCLUSIONS