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Optimised Real-time Yard and Network Management

D 6.2 – Business Case Feasibility and Simulation Test of the virtual yard/terminal software

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Report Contributors

Name	Company	Details of Contribution
Eric FEYEN	UIRR	Structure and main content
Pekiye BICICI	UIRR	Quality review
Milos ZATKO	SIMCON	Contributor to both business cases
Armand TOUBOL	NEWOPERA	Contributor to Trieste Business Case
Petr JINDRA	CD CARGO	Contributor to Česká Třebová Business Case
Paola PELLIGRINI	IFSTTAR	Contributor to conclusions and lessons learned

1. EXECUTIVE SUMMARY

Task 6.2 aims at compiling all activities and tasks performed by the two selected business cases/demonstrators: (1) Česká Třebová (Czech Republic) and (2) Trieste.

This deliverable contains the contributions of both demonstrators involved in all aspects of the project, either as 'input provider' (data gathering, process description, functional requirements…) and as 'output validator' (validation of the yard simulation software in a non-optimised environment and evaluation of the optimisation algorithms).

The results reported in this deliverable show that the production of an integrated simulation and optimization framework is possible. Both demonstrators, Česká Třebová (Czech Republic) and Trieste (Italy), tested and validated the yard simulation software based on operational data and provided a proof-of-concept showing that the results of the optimization can be at least as good as those obtained in a real-world context.

Three lessons can be extracted from the OptiYard project and should serve as basis for future development activities: (1) complexity of the data retrieval for both demonstrators, (2) the difficulty in designing a simulator capable of replicating all the available possibilities in a yard management process and (3) the difficulty of the problem definition in case of implementing optimisation capabilities.

OptiYard is the first step along the ambitious path of optimizing and automating yard management. The consortium managed to show that such an optimization and automation is indeed possible but, as pointed out, the lessons learned from OptiYard are crucial for future research projects on the same issue.

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4. SCOPE AND PURPOSE

The aim of the two selected business cases has been to contribute to the project either as 'input provider' for all technical work packages or either as 'output validator' of the yard simulation software developed by the project partner SIMCON.

- 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 simulation software for marshalling yard and network 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).

This deliverable integrates the results of the validation activities performed by both use cases with the support of the WP4 and WP5 project partners in two different environments: (1) validation in a non-optimised environment (based on the preliminary results of WP4) and (2) validation in an optimised environment (based on the two demo cases as described in deliverable 6.1 - Business Case specifications and plans).

5. DEMONSTRATORS

The two selected demonstrators (see Figure 5-1 - The two case studies in OptiYard) are located in Italy (Trieste) and Czech Republic (Česká Třebová) and 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 have played a central role in the project by participating and contributing to all project work packages (from conceptual/design to final output validation and demonstration).

Figure 5-1 - The two case studies in OptiYard

5.1 Demonstrator 1 - Česká Třebová (Czech Republic)

The station Česká Třebová, located in the Czech Republic, ranks among the 7 key marshalling yards utilized by the partner CD Cargo, a.s. With its marshalling capacity of up to 1 200 wagons in 24 hours and location in the centre of the Czech rail network, it belongs to yards with a very high future potential. 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, on the main line between Prague and Slovakia with a branch to Brno and Vienna, Austria. It is a hub of 3 directions (all electrified double lines).

Česká Třebová has the most convenient railway marshalling topology, i.e. the entry yard, hump, classification yard and departure yard. All terminating trains arrive from the same direction. That’s why the marshalling process is disturbed as little as possible.

The basis of the Česká Třebová marshalling yard is created by 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 (see Figure 5-2 for overall design). The arrival yard is made by 13 tracks with the length of up to 900 meters and the departure yard consists of 15 tracks with the length of 850 meters.

There are 3 shunting locomotives employed in the station. The hump locomotive is dedicated only for the marshalling work. Another engine is assigned primarily to assemble the first-mile service trains and to pull the finished trains away from the classification yard into the departure yard. The last engine is intended to compact the wagons on the sorting tracks to be coupled.

Figure 5-2 - Česká Třebová (design)

The marshalling operation begins with the arrival of a terminating train. The train set is then prepared for sorting and the marshalling locomotive pushes the wagons towards the hump. The shunting list is being transferred from the ČD Cargo operation IT system into the shunting IT system of the Infrastructure Manager. The operation of switches and braking of individual cuts is then controlled fully automatically. Both the hump shunting master and the signalman can interfere in the automatic process any time (e.g. if the sorting track is full or a previous cut is too slow or stopped prematurely).

Air brake tests are performed exclusively by compression stations in the classification yard, which saves the need of physical locomotives and reduces the dwell time in the departure yard.

The station currently builds about 30 domestic and international destinations, including Engelsdorf (Germany), Vienna (Austria), Bratislava and Žilina (Slovakia) and Wroclaw (Poland). The minimum transition time between all sorts of trains (measured from arrival of the first to departure of the second) is 200 minutes.

5.1.1 Main reasons for demonstration

The marshalling yard Česká Třebová was chosen for the project above all on the reason that despite European's marshalling yards of today have currently rather surplus of capacity and the biggest problem of the freight railway transport is lack of slots for freight trains during the day, it can be expected that within a couple of years, as construction of high-speed lines for passenger traffic will continue, freight railway will take over the released capacity of the conventional lines and regain its place as the most capacious and environment friendly means of transport again. It can be expected that the social needs for carbon neutral transport will turn towards the railway in a very near future and freight railway needs to be prepared well in advance for this "revolution".

Due to the fact, that the range of infrastructure is more or less stable and cannot be extended in a short time and without large investments, the operational side of railway transportation can be administered rather flexibly, however, at the price of significant costs too. This is the reason why simulation plays that important role today and of course, optimization of the simulated situations can save considerable costs of everyday operation. It would be possible to employ a couple of locomotives and marshalling personnel in the marshalling yard processes to increase the operational capacity immediately, but the costs would hardly ever be justified. That's why the most cost-benefit solution is to involve advanced systems of information science into the railway operation to reconcile the always conflicting goals of costs and benefits.

5.1.2 Virtual yard software: from validation to optimisation

The simulation and optimization of the Česká Třebová business case took place in several comprehensive steps:

1. The basic issue of the process was to get valid and precise data on the infrastructure to be assessed.
2. Next part of the process was to gain access to the operational data of the selected week for the selected infrastructure, in this case for the marshalling yard Česká Třebová.
3. Collection and validation of the data on the local technological work procedures in the overall railway junction.
4. Access to the data on trains in connection with the traffic in the essential vicinity of the marshalling yard.
5. Data acquisition on the technological procedures in individual elemental servicing parts in the station.
6. Partial validation of the model – technological work procedures validated by the local technological chiefs.
7. Model validation – comparing of real and simulated operation:
    - check of real-world field data provided by operators;
    - processing of field data needed for comparison with simulation outputs;
    - processing of input data needed for validation simulations;
    - definition of outputs needed for validation (e.g. KPIs, ETA/ETD, etc.);
    - design of simulation scenarios;
    - development of test simulations, with possible iterations;
    - comparison of simulation outputs with field data;

- assessment and quality check of results;
- possible feedback on model and software structures.

8. Comparison of arrivals, content of terminating trains.
9. Comparison of train sorting.
10. Comparison of departures and content of departing newly built trains.
11. Preparation of additional (artificial) scenarios simulating delay of trains, extra trains, breakdown of a hump locomotive for a period of time.
12. Evaluation of simulation scenarios without optimization.
13. The simulations run of operation with proposition of allocation of resources (choice of the track, shunting locomotive, personnel) with the aid of optimization module.
14. Comparison of simulation without optimization and with optimization.

In step 7 (validation), the aim of the validation was not the final decision support system including the optimisation model, which is addressed in the next chapters but rather the "non-optimised" simulators of the Česká Třebová yard-systems and interacting network in several scenarios comprising typical operational situations based on past experiences and field data.

5.1.3 Field Data: description and processing

The Marshalling Yard data of Česká Třebová were delivered and collected directly on-site in several steps. It was necessary to enter the data for each subsystem of the simulation model (resources, customers and control subsystems).

- The **infrastructure data** for the marshalling yard Česká Třebová was delivered in shapefile format (geospatial vector data format for GIS software). In the first step, a conversion into a CAD format was necessary, including the differentiation of the meaning of each geometric object (track, switch). Additional data (not included in the shapefile) were added in the second step, e.g. signals or limits. The infrastructure model used for simulation does not include any slope profile due to the lack of data. Simplifications in the simulation model were made by regarding wagons with humping restrictions. These wagons are sorted normally as any other wagons without restriction. The main reason was to simplify this process, as it is too complicated and not useful for the purposes of this model to prepare an algorithm for solving every possible case.
- The **vehicle movement** (train and shunting unit) is modelled by utilising continuous simulation with employment of differential equations. The computation takes into account the engine power characteristics as well as the parameters of the infrastructure the vehicle is moving on (e.g. curve diameters, radii, slopes, maximum speed allowed, etc.).
- **Real data of each wagon type** (Eas, Falls, Habis…), i.e. weight, length over buffer, number of axles and so on, are used for the modelling. Therefore, the train composition is modelled at a high level of detail.
- The **train handling** was prepared and parametrized according to data collected on site. The train handling includes the sorting over the hump. The process of sorting the train over a hump is modelled in a simplified way. The movements, like pushing trains over the hump, running cuts down the hill and rolling of cuts into the sorting tracks, are using only average speed for computation of movement duration.

5.1.4 Simulation scenarios and outputs

Figure 5-3 summarises the four simulation scenarios that were conducted during the validation process:

Scenario	Basis	Description
1	Default configuration	Modelling of real operation based on data from 10.4.2018 to 14.4.2018
2	With delays (based on default configuration)	On the Thursday, there are two inbound trains delayed, trains 45732 and 59754. Both inbound trains are assigned a simulated delay of 2 hours, compared with the arrival time in the real week (default configuration).
3	Hump locomotive ZC1 broken down (based on default configuration)	On the Thursday, the hump locomotive ZC1 is simulated as broken down for 1 hour, between 4:30 and 5:30.
4	Additional Trains (based on Default configuration)	On the Thursday, there are three additional inbound trains arriving: **62133 – Fictive** Entry time into simulation model is at 4:15:00 from direction Prague. The wagon list is the same as with the original train 62133 operating on the Thursday. **Fictive_01** Entry time into simulation model is at 2:30:00 from direction Brno. The wagon list is fictive. **Fictive_02** Entry time into simulation model is at 3:10:00 from direction Olomouc. The wagon list is fictive.

Figure 5-3 - Česká Třebová: simulation scenarios

The Simulation scenario 1 is comparable to real operation. All other scenarios were artificially created to model some examples of degraded operation in marshalling yard Česká Třebová. The evaluation of each scenario was focused on track, personnel and shunting locomotive occupation. For the model validation and comparison with real operation, different evaluations were used during simulation run and post-simulation (see Figure 5-4 for detailed components).

Evaluation: SIMULATION RUN	**Evaluation: POST-SIMULATION**
Observing process animation (position of train, current speed, sorting wagons in proper sorting track) Current occupation of resources (tracks, shunting locomotives) Processing of handling technologies (train service) Log file with conflicts, train delays Initialization of outbound trains	Occupation and utilization of resources (tracks, shunting locomotives) Waiting time for resources Sorting statistics (number of sorted wagons per hour, sorted trains) Dwell time of train and wagons in the yard Movement dynamics

Figure 5-4 - Česká Třebová: evaluation criteria of simulations

5.1.5 Comparison of simulation results with field data

The comparison of the simulated yard model with real operations was conducted on three pre-identified locations in the marshalling yard, which corresponds to real data delivered by CD-Cargo and Oltis Group: (1) at arrival, (2) at hump and (3) at departure.

The arrival of inbound trains in the simulation model exactly reflects the data from real operation. The inbound trains appear in the simulation model on the respective main line track approximately 3 kilometres before the reception track in marshalling yard Česká Třebová. Depending on the direction, from which the train is entering, the entry time into the model is shifted between 6 to 12 minutes earlier than the real arrival time of inbound train in order for the arrival time at the reception track to match the real arrival time as closely as possible.

The validation of the simulation model of the marshalling yard Česká Třebová exposed that it is possible to reach a high degree of model accuracy. In fact, for all departing trains except for 2 and in spite of the modelling simplifications, it was possible to ensure the correct departure times with good accuracy (to within minutes) given the correct arrival times. This shows that the timings and process flows are realistic. However, it was not possible to match the outbound wagon numbers exactly train by train, since on some occasions the dispatchers made sorting decisions that are apparently irrational and probably due to verbally defined priorities and other constraints for which information was not available. This has led to wagons being left behind by some trains and having to be added to later trains.

We can conclude that the difference between accuracy of the current model and 100% accuracy lies in the modelling of human behaviour during dispatching day-to-day railway operation in marshalling yard and complex rules covering some special handlings of wagons (priority goods, humping restrictions, damaged wagons etc.) as well as in human long-term experience based on case-by-case situation. Simplifications of the simulation model within this project were focused mainly on special rules defining non-standard wagon handling. Trying to achieve a higher level of accuracy by modelling used the adopted operational rules, would lead to tight tailoring of the simulation model to fit the single case of marshalling yard Česká Třebová and thus reducing the flexibility of the model. Such an approach has been identified as a potential disadvantage at the current state of the research, since it would lengthen validation times enormously without any particular benefit regarding the simulations being realistic enough for a successful demonstration phase.

In this respect, during the final phase of implementation of the decision support system with the optimization of resource utilization, it is recommended to extend the logic and algorithms in the optimization module to cover the most used operational rules but not the train-by-train priorities that might arise day to day.

Degraded operation in the marshalling yard has been simulated as well, and a concisely reported here although not necessary for validation purposes. For the proposed simulation scenarios, no real data were available. Therefore, it is hard to make any comparison with real degraded operation. The comparison of the executed simulation scenarios is integrated in Figure 5-5 and Figure 5-6.

Day	Outbound train	Scenario 1 -Default Configuration	Scenario 2 - With Delays	Scenario 1 – Broken loco ZC1	Scenario 4 - Additional Trains
10.4. (Tuesday)	62015	0:07:18	0:07:18	0:07:18	0:07:18
11.4. (Wednesday)	60204	0:00:24	0:00:24	0:00:24	0:00:24
12.4. (Thursday)	62101	0:03:51	No delay	0:01:48	No delay
	62015	0:18:49	0:25:37	0:18:49	0:34:33
	62200	No delay	0:05:08	No delay	0:04:50
13.4. (Friday)	44727	0:09:01	0:19:04	0:09:00	0:14:22
	62013	0:09:57	No delay	0:09:56	0:20:14
	45711	No delay	No delay	No delay	0:00:37
	62200	0:02:41	0:02:41	0:02:41	0:17:33

Figure 5-5 - Česká Třebová: comparison 'Departure delays of outbound trains'

Day	Outbound train	Scenario 1 -Default Configuration	Scenario 2 - With Delays	Scenario 1 – Broken loco ZC1	Scenario 4 - Additional Trains
10.4. (Tuesday)	62017	3	3	3	3
	62015	9	9	9	9
	62200	4	4	4	4
	62222	3	3	3	3
	45310	34	34	34	34
	62224	5	5	5	5
11.4. (Wednesday)	45713	6	6	6	6
	44725	8	8	8	8
	60204	12	12	12	12
	62011	18	18	18	18
	45027	10	10	10	10
	62132	30	30	30	30
	83111	3	3	3	3
	62101	31	31	31	31
	45711	21	21	21	21
	44727	2	2	2	2
	60104	19	19	19	19
	62220	8	8	8	8
	62013	30	30	30	30
	62017	23	23	23	23
	62015	20	20	20	20
	62200	13	13	13	13
	62222	11	11	11	11
	45310	27	27	27	27
12.4. (Thursday)	44725	17	17	17	17
	60204	8	8	8	8
	45713	24	24	24	24
	83121	16	16	16	16
	62011	14	14	14	14
	59737	16	16	16	16
	45027	16	16	16	16
	62132	35	37	35	36
	44251	10	10	Not in operation	12
	62101	38	26	38	37

	44727	9	9	9	2
	62013	37	37	37	36
	62220	Not in operation			1
	45711	22	22	22	32
	62017	16	28	16	21
	62015	22	22	22	26
	62200	24	24	24	25
	47336	30	31	30	30
	45310	35	35	35	35
	62222	7	7	7	8
13.4. (Friday)	44725	15	15	15	22
	60204	21	22	21	25
	62134				43
	83037	8	8	8	8
	45713	34	34	34	34
	62011	33	33	33	33
	45027	1	1	1	1
	62132	36	35	37	24
	44251	22	22	27	22
	62101	24	24	24	24
	44727	14	14	14	14
	62013	37	37	37	43
	45711	29	29	29	29
	62017	14	14	14	14
	62015	11	11	11	11
	62200	19	19	19	25
	45310	27	27	27	27
	62222	19	19	19	19
14.4. (Saturday)	60204	26	26	26	26
	45713	31	31	31	31

Figure 5-6 - Česká Třebová: comparison wagon count in outbound trains

The detail of the simulation model was kept as close to reality as possible, however, certain degree of abstract had to be performed in terms of locomotive depot and wagon repair shop and district for adjustment of load, whose inputs are impossible to take into consideration either due to the fact that they are run by foreign entity or depend purely on individual performance and case-by-case basis.

5.1.6 Optimisation activities

Figure 5-7 illustrates an example of the possible differences between reality and optimization recommendation. It depicts occupation of the hump and clearly shows that the train 62222 was sorted between 20:19 and 20:29 but the optimization proposed changing the sequence of trains to be sorted (train 45313 to be rolled-in first to better utilize the hump). For all optimisation comparisons, please consult annex A.

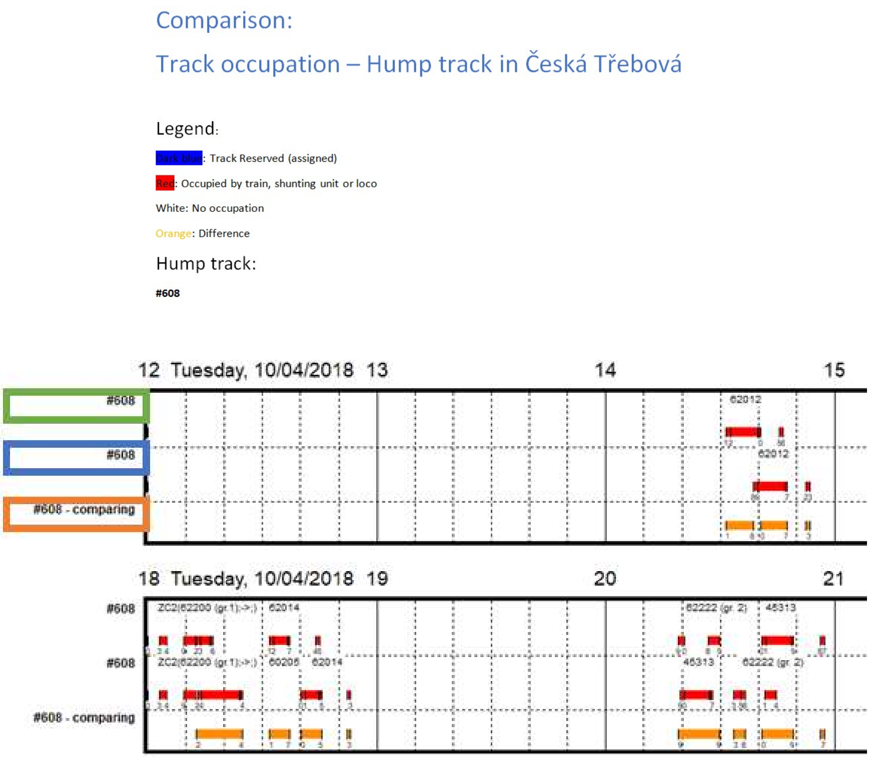


Figure 5-7 - Česká Třebová: hump track utilisation (non-optimised vs optimised)

Due to the relatively short period of optimization run of the simulation scenarios, the results of the Česká Třebová optimization case is very difficult to assess the "ex-ante" (non-optimized) and "ex-post" (optimized) environments. It needs to be mentioned that the difference between the two statuses is minimal. On the other hand, the mechanism, communication with the station and simulation model verification was achieved.

It is not possible to prove that the simulation/optimization itself brought any improvement in this rather short period but the foundations have been laid – to prove it more, the optimization would have to run in parallel with reality for a couple of weeks to obtain better results.

5.2 DEMONSTRATOR 2 - TRIESTE (ITALY)

The preparation of this demonstrator started from the beginning till the end of the project. This was justified by the needs to understand the context, the constraints and the fundamental objectives of the stakeholders (port authorities, operators, clients and city authorities).

The port of Trieste is situated at the extreme north east point of Italy on the Adriatic coast (see Figure 5-8). It is very close from the Slovenian border and from the Port of Koper. The accessibility of the port from central Europe is easier than Koper's accessibility because of the connection with Austria at Tarvisio border and its excellent connections with Northern Italian industrial region. The water depth is more important in Trieste than in Koper. However, the feeling of fierce competition is highly present and precise data on the operations were difficult to capture. A second connection with Slovenia is less convenient due to the steep slopes on the railway line linking Trieste to Villa Opicina.

Figure 5-8 - Trieste Port

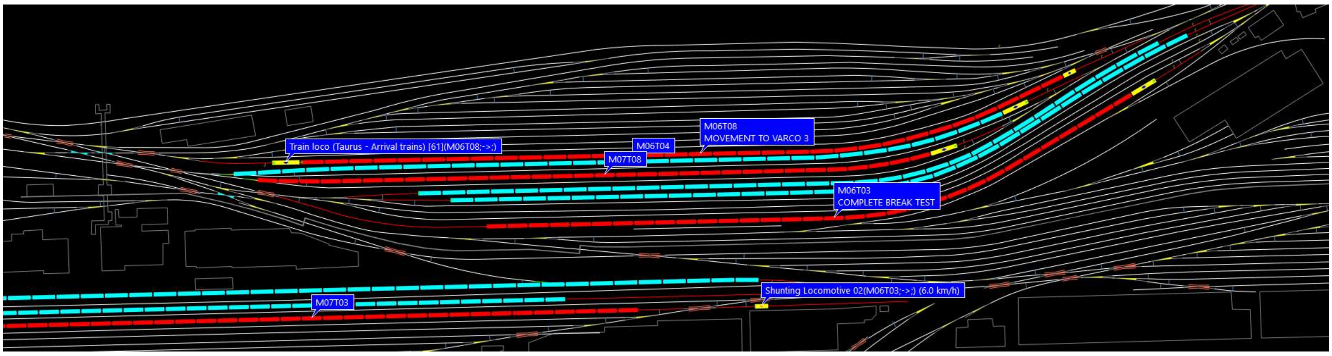
The port has also two different activities: (1) a commercial one on the moles 5-6-7 and (2) an industrial activity (steel and oil industry), south of the commercial port, is served by the same railway yard of Campo Marzio as the commercial port. The traffic dedicated to the industrial area represents roughly 25% of the overall traffic of the port (2000 trains per year).

The Trieste traffics are growing strongly because of the nautical and geographical characteristics of the port. Deep sea traffics are interested to call in Trieste as it shortens the distance to central Europe compared to Piraeus Port and reduces the transit time compared to North European range ports despite the long penetration in the Adriatic Sea. The second category of traffics are short sea transports coming from Turkey for northern Italy, central and northern Europe.

For all those reasons, simulating and optimizing the operations of the marshalling yard of Campo Marzio are essential for facing the continuous transport development within the port of Trieste.

5.2.1 The basis situation

The first step was to analyse the way the traffic was handled in the yard and to understand fully the organization of the operations in Trieste (see Figure 5-9 for general lay-out). Trains in Trieste arriving in Campo Marzio cannot enter the port without leaving campo Marzio to Parenzane, then returning towards Campo Marzio using the only exit for Molo 5 and 6 after a check point Gate 3 or using inside Campo Marzio Tracks to reach Gate 4 check point for Molo 7. If the train must wait inside the port, it will perform again a double movement to enter the parking tracks and another double movement to exit the parking tracks. If the train goes to the industrial area, it must however wait on Campo Marzio until a locomotive drags it to Servola. The layout is far from optimal to handle more than 800 train movements per month.



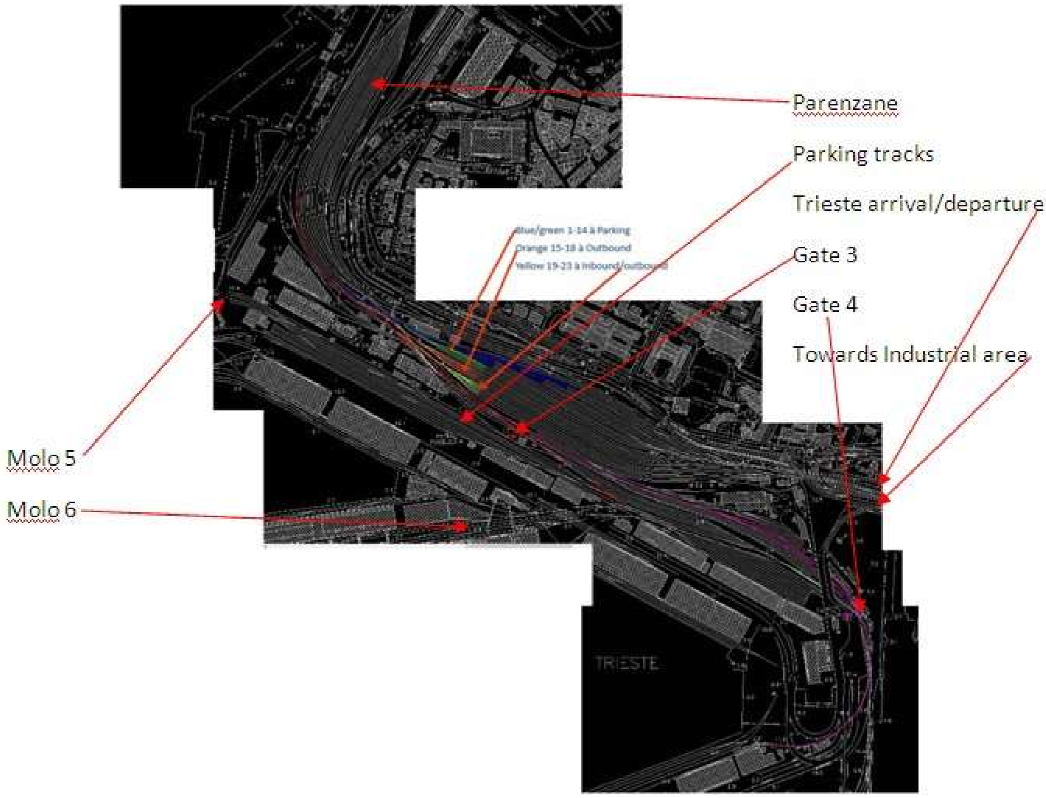


Figure 5-9 – Port of Trieste, Campo Marzio and Parenzane yards (lay-out)

Four main categories of stakeholders intervene on the Trieste port activity:

- The port authority in charge of (1) the strategic planning and of (2) the funding of the various investments to further develop the Trieste port activities and of (3) organizing the general promotion of the north Adriatic ports.
- The railway undertakings bringing the trains to Trieste on the European network like Mercitaliarail (former Trenitalia).
- The infrastructure manager: for the Italian railway network RFI in collaboration with its European colleagues of RailnetEurope (RNE) and the corridors 6 and 5 management.
- The local train operator ADRIAFER (having also a license to operate on the RFI network with some of its locomotives) in charge of serving all commercial port terminals and the industrial zone with, for this last activity, a threat of competition organized by the industry.

The operations on Campo Marzio and the port terminals are subject to many constraints:

- RFI is the authority on the Campo Marzio yard and on the Parenzane set of tracks totally interdependent to perform the operations. RFI is also responsible of all access tracks to Campo Marzio connected to the Italian National railway network.
- Campo Marzio yard layout is divided in three categories of tracks: (1) tracks dedicated to arrival trains, (2) tracks dedicated to departing trains and (3) some tracks able to accommodate both departure and arrivals trains. The tracks have different lengths creating more constraints on the operations by forcing some trains to be split.
- All exits from Campo Marzio yard towards the port are using one dedicated track coming from Parenzane blocking any movements from Campo Marzio to Parenzane during the operation, giving access to two gates (Gates 3 and 4), and subject to specific control by authorities at the exit points.
- A set of tracks inside the port allows a temporary storage of a limited number of trains but offers a buffer enabling the operational use of the shunting locomotive and of the departure tracks.
- Arrival from Tarvisio representing 80% of the movements are known 2 hours and 30 minutes before arrival and arrivals from Villa Opicina are known 30 minutes before arrival.
- From 23h00 to 04h00 no departures are allowed from Campo Marzio to inland. From 23h59 to 06h00, no arrivals in Campo Marzio are allowed from inland.

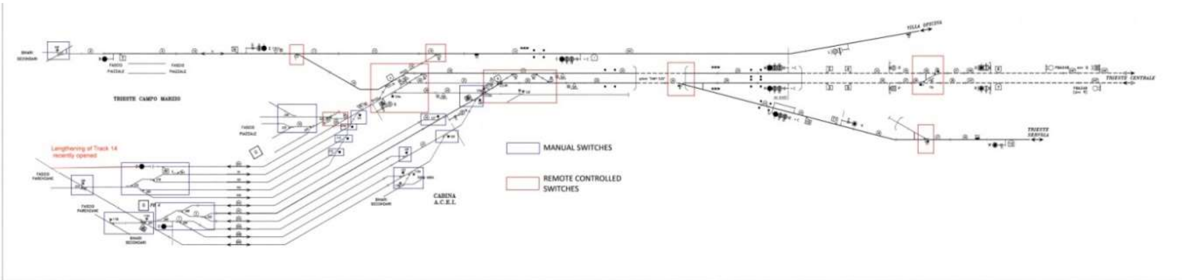


Figure 5-10 – Trieste Campo Marzio (detailed switches configuration)

- As regards the Rolling stock of Adriafer, some locomotives are certified to operate on the RFI tracks (Campo Marzio, Parenzane and main lines) and port tracks while some other are restricted to inside port operation only. This implies a change of traction some time when necessary because of workload. Shunting on the Campo Marzio yard is done with two shunting locomotives certified on the national network while other locomotives are used inside the port.
- Most operations of switches on Campo Marzio yard are manual and all switches are manual on Parenzane (see Figure 5 10 for detailed configuration).

5.2.2 Preparation of the demonstrator

The objective of the project being to optimize the functioning of the yard and to elaborate a demonstrator, the analysis of the operational processes and related constraints, while essential, were not enough to progress. The knowledge of the evolution of the infrastructure was also important. For that reason, a first onsite visit was organized with the administrator delegato of Adriafer to understand the envisaged planned infrastructure modifications in order to define the right basis on which the project should work. During this meeting, Adriafer reported on the important project of establishing a direct connection of the Tunnel tracks to the industrial area with an increase of the number of Servola tracks. This modification would have such a major impact on the activity of Campo Marzio by withdrawing 25% of the traffic that the question was on the table on whether this new element should be considered in the project. Without integration; the optimization would be useless at the end of the project. Adriafer had also the project to have an office near the yard concentrating the control of their operations with better IT links with RFI.

When analysing the operations, it was noted that several changes of locomotives were taking place to save time for the two certified locomotives authorized in the area under RFI control at the exit point giving access to the port and also where constraints on train length were important. In this context, the following proposals for a first optimization were suggested during the following exchanges:

- Improve the knowledge on the train arrivals by using TIS information to which Adriafer as a railway undertaking was entitled to access.
- Improve the use and the efficiency of the shunting locomotives handicapped by their multiple train couplings and train un-couplings specifically inside Campo Marzio.

Figure 5-11 - Trieste: rail infrastructure

Based on some extracts from TIS (train arriving from Germany for Campo Marzio – see annex B), it was demonstrated that anticipation is possible giving more time to prepare the effective operation plan. This anticipation should be progressively more realistic than the weekly provisional plan in term of effective ETA.

5.2.3 The reference scenario

The next step was to find a reference situation on which the optimization research could be developed. A standard week activity operation plan was provided by Adriafer to serve as a reference to test the possible optimisation but as it was impossible to test it on site due to the very high tension existing in the operations and the traffic growth pressure. It was necessary to simulate the nominal and the optimized operations. This task was under the responsibility of SIMCON using the Villon software adapted to the specific Trieste infrastructure and operation. The Villon software needs very precise inputs on the layout of the whole track configuration (including definition and precise position of switches), precise data on the characteristics of the shunting locomotives and the rules applicable on the yard and on the port.

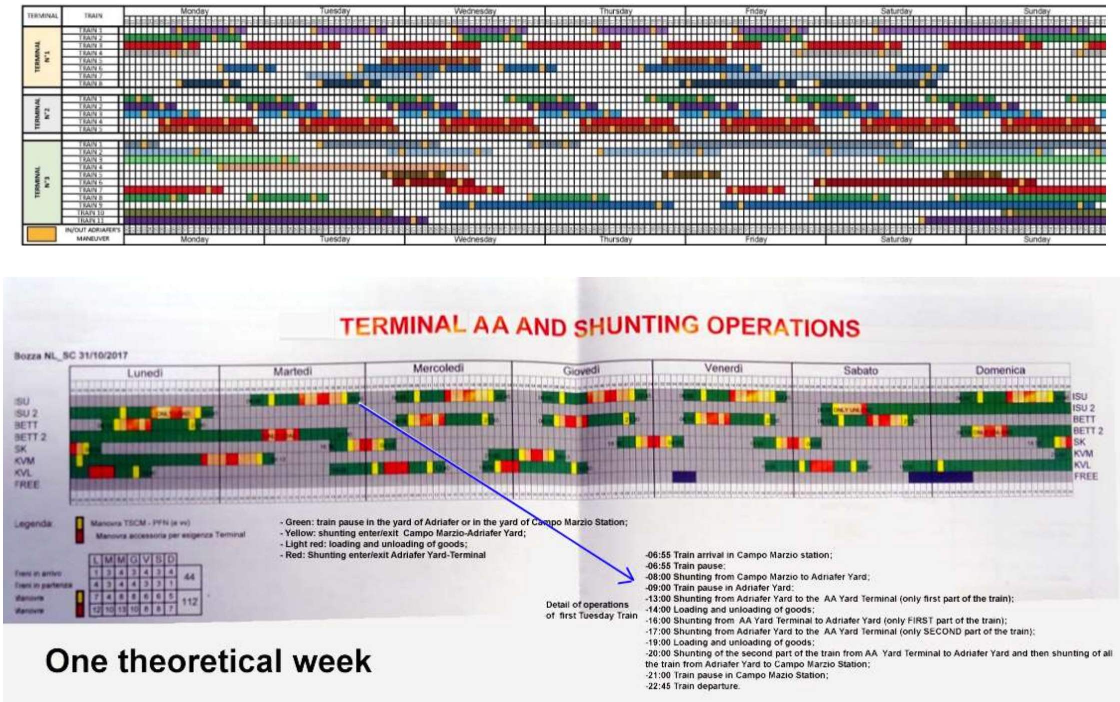


Figure 5-12 - Trieste - theoretical week of operations

These elements were not directly totally available in the Adriafer hands but mainly in the hands of RFI. The precise layout with the main characteristics were provided later enabling SIMCON to prepare the simulation tool which was validated using the standard week of traffic and movements of shunting locomotives explained by Adriafer. Because precise characteristics of the trains as regards the nature of the wagons for instance were not given at that stage, assumptions were made by Simcon to validate the tool. An actual operational week with precise details on the trains and on the operations is still necessary to comfort this validation. A detailed explanation of the theoretical week is shown in Figure 5-12).

At this stage, the works planned by RFI to by-pass Campo Marzio for the industrial traffic appeared to be significantly delayed, leading us to consider the present situation as fixed for the simulation. However, for Track N°14 extension, a new access to Parenzane tracks was effectively opened during the development of the project. At the same time, a significant decrease of the industrial transports representing less than 10% of the train movements but is compensated by an increase on the maritime containers and semi-trailers.

The traffic until July 2019, using Campo Marzio, is booming and should offset that loss in industrial traffic which is regaining a little. This confirm the interest of focusing on Campo Marzio efficiency.

5.2.4 Constraints for the elaboration of the simulation

During the elaboration of the simulation tool, exchanges with Adriafer enabled to analyse which criteria were the most important for Adriafer to deliver the adequate service required by its clients:

- Respect the time allocation to pick up the train from Campo Marzio yard and deliver it to the adequate terminal after doing the necessary manoeuvres to place the train on the right track in due time for its handling even if the train must be split because of its length longer than any single mole track.
- Respect the time allocation to convey the loaded train from the terminal to the designed RFI track of Campo Marzio in order to respect the departure time.
- Manage the buffer tracks existing inside the port to meet the requirements of RFI or of the terminal in case of any delay beyond the theoretical operation timing.

Taking that last constraint as a major objective in any optimization process, it seemed useful to simulate some degraded situations to test the efficiency of the simulation software capabilities. These situations involved one unavailable track on the moles, or one shunting locomotive being out of order or a delayed train at arrival or an extra train not expected in the weekly plan regularly elaborated by Adriafer and RFI. These simulations performed on the theoretical week were satisfactory showing the necessary resilience of the operations.

The next step to enhance the validation of the simulation tool appeared when Adriafer provided much later (Feb 2019) a real week of traffic with precise timings of the movements showing some very few unexpected movements due to the necessity to consolidate some parts conveyed from different terminals to constitute a departing train for instance.

5.2.5 Definition of KPIs

The next step to progress in the preparation of the demonstrator was to define the main KPIs attached to an operation for an assessment of the efficiency (link to activity 6.3). Many KPIs could be selected keeping in mind the constraint of the alignment on the allocated time allowed for the shunting operation to and from Campo Marzio:

- Minimizing the track utilization specifically in Campo Marzio to avoid any barrier of departures or arrivals
- Reducing the time of utilization of the shunting locomotive and/or the travelled distance
- Reducing the dwell time of a train on the waiting tracks of the yard inside the port and on Campo Marzio tracks
- Developing the overall capacity of Campo Marzio yard.

Arriving at that stage, the reference situation of the demonstrator was given by the simulation of the standard week, the possible KPIs retained were those quoted here above but for the capacity as it is clear that even with a certain delay the direct connection with the industrial area will give immediately an extra capacity to Campo Marzio even if the industrial traffic is lower than before.

5.2.6 First progress of efficiency

In the meantime, during the second visit, the consortium noticed an efficiency increase by the railway operator Adriafer:

- To shorten the time dedicated to the brake test necessary when coupling a locomotive to a new train, they have upgraded the power of the compressors of their shunting locomotive reducing significantly the time to refill the brake pipe and the reservoirs and thus to finalize the procedure of coupling the locomotive to a new train.
- They have also deployed in their new operation control office a large screen showing the path of all the trains in real time and the programmed path on a period of around 3 hours enabling to improve the anticipation and also to see what suggestion they can make to RFI if a delay is expected in their operations (see Figure 5-13).
- RNE TIS might be of some support providing interesting information to improve their operations.

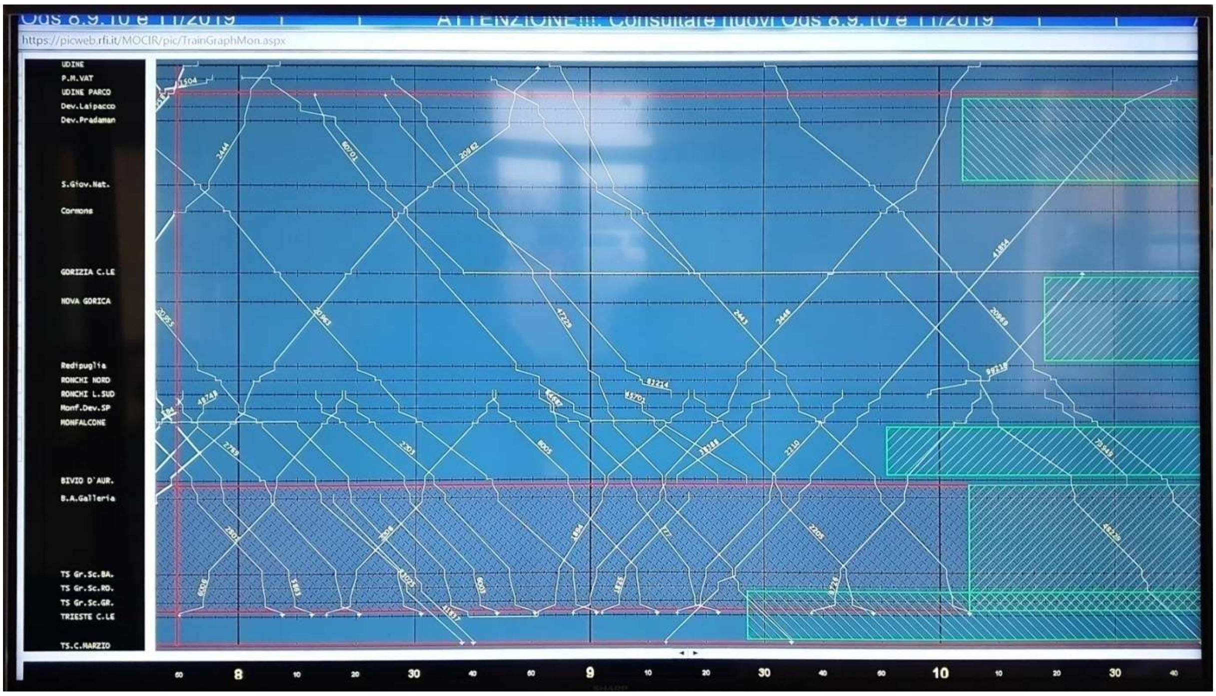


Figure 5-13 – Trieste: the control tower (screenshot)

The simulation tool was also fully validated on a real week given during that second visit but too late to serve for the optimization.

5.2.7 Principles in the assessment of optimization

To assess the efficiency of the optimization, the demonstrator needs to have the basic costs of the operation, utilization of the shunting locomotive per hour, cost per hour of the team used for the shunting. These elements were provided by Newopera but no indication on the cost of the occupation of a track per hour was available as they are included in the track access charge paid by the train to RFI.

The development of the optimization was under IFFSTAR responsibility with a support of Simcon for the use of the VILLON simulation tool. The simulation tool being ready, the algorithm of optimization should be elaborated and integrated with the simulation tool which role was to simulate each movement requested by the algorithm.

As the integration of the two software was quite difficult, it appeared impossible to test a whole week on Trieste and only 22 hours of the first day have been simulated for the optimized operation. The Demonstrator operations are recorded by the simulation tool and put by SIMCON on the same diagram to see the comparison of the non-optimized and optimized operations. The analysis of the shunting locomotive occupation has been put in this report as it shows how the demonstrator works. All important parameters compared between optimized and non- optimized simulation including the tracks occupation are in the annex C. Figure 5-14 summarises the situation of the movements of the shunting locomotives whereas Figure 5-15 provides the detailed comparison results for the shunting locomotive occupation (non-optimised versus optimised).

	Travelled distance in meter	
State of sh. loco (1 and 2)	Non-Optimized	Optimized
Moving to train	23439	33106
Work	51929	62854
Moving from train	12665	18288

The reason for higher travelled distance in optimized simulation run is because the trains return immediately after un-/loading in port to yard Trieste Campo Marzio. Therefore, in the same time period more tasks are assigned to shunting locomotives in scenario with optimized operation comparing to non-optimized simulation run. In following table, the number of served trains by two shunting locomotives are compared.

	Number of served trains	
	Non-Optimized	Optimized
2 shunting locos	16	18

Figure 5-14 – Trieste: summary of optimisation

Comparison of non-optimized and optimized simulation for simulation model Trieste Campo Marzio (TCM)
Scenario: Theoretical week operation - Basic 00
Time period: Saturday 8:00 till Sunday 6:00

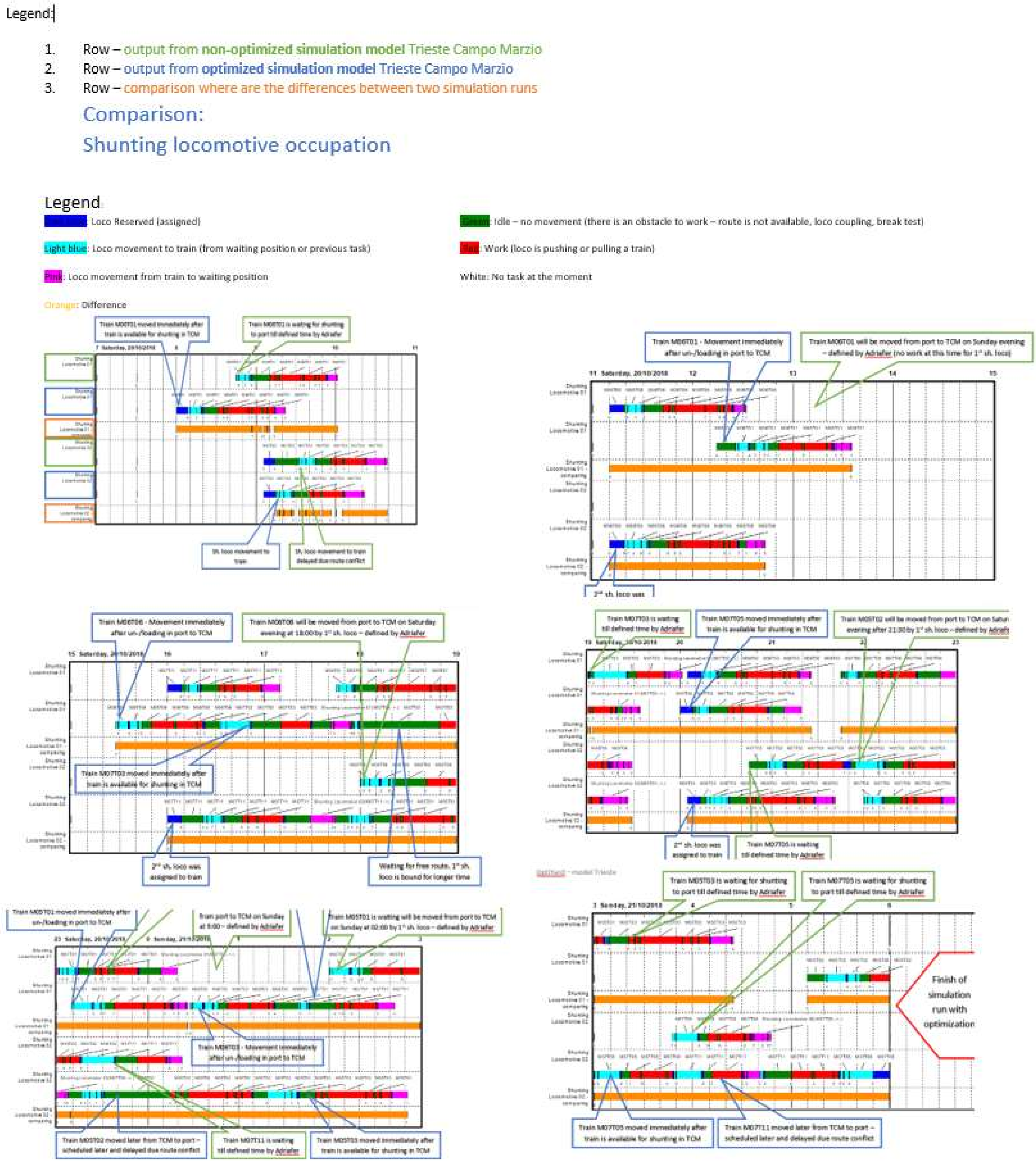


Figure 5-15 - Trieste: comparison of shunting locomotive occupation (non-optimised vs optimised)

5.2.8 Optimisation assessment

This short period of demonstration is not conclusive, but it shows the capacity to integrate progressively the two software which is to be done step by step.

Some more conclusions may be derived as regards the mean wagon transit time where no difference emerge, and no delays appear in respect of the main constraint.

The main difference that could be noticed in these first results is that the algorithm has not taken into account the management of the waiting times which could be imposed to trains in order to minimize the risk of creating a deadlock on critical tracks essential to access to the port or to the main rail network in both directions specifically at certain moments in the middle of the week when the inbound and outbound traffic are more intense and at the period where night traffic restrictions approaches.

So, extending the optimization on a whole week should be continued in the future to confirm the interest of the optimization. We expect an interesting scope of progress as a manual improvement test on the first 24H of the standard week showed the possibility to gain some 5% of the travelled distance of the shunting locomotive with a different strategy but with the risk of creating a deadlock during the week.

Finally, the use of the simulation tool and its visualisation developed for Trieste seems to be a good basis for an active support for the training and the decision making of the dispatchers. This could be also improved by a better knowledge of the information on the progress of the incoming trains even beyond the border thanks to the use of TIS and the traffic screen information.

6. CONCLUSIONS

The results reported in this deliverable show that the production of an integrated simulation and optimization framework is indeed possible. Both demonstrators, Česká Třebová (Czech Republic) and Trieste (Italy), tested and validated the yard simulation software based on operational data and provided a proof-of-concept showing that the results of the optimization can be at least as good as those obtained in a real-world context.

Several lessons can be extracted from the OptiYard project and should serve as basis for future research and development activities.

- The first lesson learned is related to the **complexity of data retrieval**. Indeed, one may think that working with a simulated environment rather than with a real implementation may simplify the process of data gathering. However, if the simulation model is accurate enough as the one successfully achieved in this project, a large amount of accurate data must be gathered, and detailed processes must be compiled: it is very difficult and time-consuming exercise. Even when the data are numerically available in some forms and formats, their complete collection and organization is far from trivial. An obstacle that intervenes in this sense is the unequal level of understanding of the needs that must be satisfied to carry out the foreseen activities within OptiYard. Typically, technicians may often not offer practitioners enough insights into the details of these needs, and practitioners may retain some information possibly considered useless, either consciously or unconsciously. Another obstacle to the data sharing is the wish to keep information anonymous, at the risk of missing important practical aspects. We think that the proof-of-concept provided by OptiYard may help to overcome these obstacles in future projects thanks to the detailed reporting we provided, step by step, on the whole process that was carried out.

- A second lesson learned concerns **the difficulty in designing a simulator capable of replicating all the available possibilities in a yard management process**. Indeed, it happens in some cases that the optimization capabilities propose management choices that are not considered in the simulation model design. For example, the order chosen for train humping in Česká Třebová sometimes brought to unexpected combinations of ready-to-depart trains. Being unexpected, these combinations could not be simulated and hence assessed. Within the OptiYard project, specific procedures were implemented in the optimization algorithm to find a way to avoid the productions of such non-considered choices. Indeed, OptiYard being the first research project aiming at integrating microscopic simulation and optimization, due to the limited time available, it was decided to focus more on the integration between simulation and optimisation rather than on the complete exploration of optimization possibilities. As shown in this deliverable, this decision allowed us to produce a valid proof-of-concept that has been considered by the demonstrators as the right one. However, further research will need to be devoted to the refinement of the optimization algorithm and to the completion of the simulation model to manage a complete analysis of the impact of an optimized yard management.

- Finally, a third lesson learned is related to **the difficulty of the problem definition**. The results show that the demonstrators make their management decisions considering information that are not supposed to be available when stating the problem a priori. For example, in Trieste, it was discussed how trains in a non-optimized scenario are kept waiting in strategic locations to avoid the occupation of tracks that will become necessary in the future. In other words, some knowledge on what trains will arrive in the next hours and days is exploited to make present decisions. Another example is the flexibility of resource utilization. In some cases, in the validated non-optimized simulation, resources are exploited to carry out tasks for which they are not in general considered available. This is done to solve some particularly critical situation. Within the project, it was obvious that it is extremely difficult for practitioners to formalize all aspects of the yard management. For the OptiYard proof-of-concept, it was decided to stick to the following problem definition: to make the best of the available time. In OptiYard, train arrivals are forecasted no more than two hours in advance, and absolutely no knowledge of future traffic is considered when optimizing yard management. Hence, the optimization has no need whatsoever to retain trains instead of preparing them for departure as soon as possible, to guarantee their punctuality. Moreover, no flexibility is considered for resource utilization: if a resource is supposed to be used only for a specific type of operation, it will not be used for anything else, no matter how critical the situation is. Although this decision allowed to successfully achieve our proof-of-concept, it definitely penalizes optimization performance. In future studies, it will be necessary to devote quite some additional effort to the precise problem formulation in order to make it possible for the optimization to really exploit the yard capabilities even in non-straight forwarded situations.

In conclusion, OptiYard is the first step along the ambitious path of optimizing and automating yard management. The consortium managed to show that such an optimization and automation is indeed possible but, as pointed out, the lessons learned from OptiYard are crucial for future research projects on the same issue.

Evaluation

Comparison of non-optimized and optimized simulation for simulation model Česká Třebová (CT)

Scenario: Operation 04 - With additional inbound trains

Time period: Tuesday 12:00 till Tuesday 23:59

Legend:

1. Row – output from **non-optimized simulation model** Česká Třebová
2. Row – output from **optimized simulation model** Trieste Česká Třebová
3. Row – comparison where are the differences between two simulation runs

Comparison:

Shunting locomotive occupation

Legend:

Dark blue: Loco Reserved (assigned)

Light blue: Loco movement to train (from waiting position or previous task)

Green: Idle – no movement (there is an obstacle to work – route is not available, loco coupling, break test)

Red: Work (loco is pushing or pulling a train)

Pink: Loco movement from train to waiting position

Grey: Off duty

White: No task now

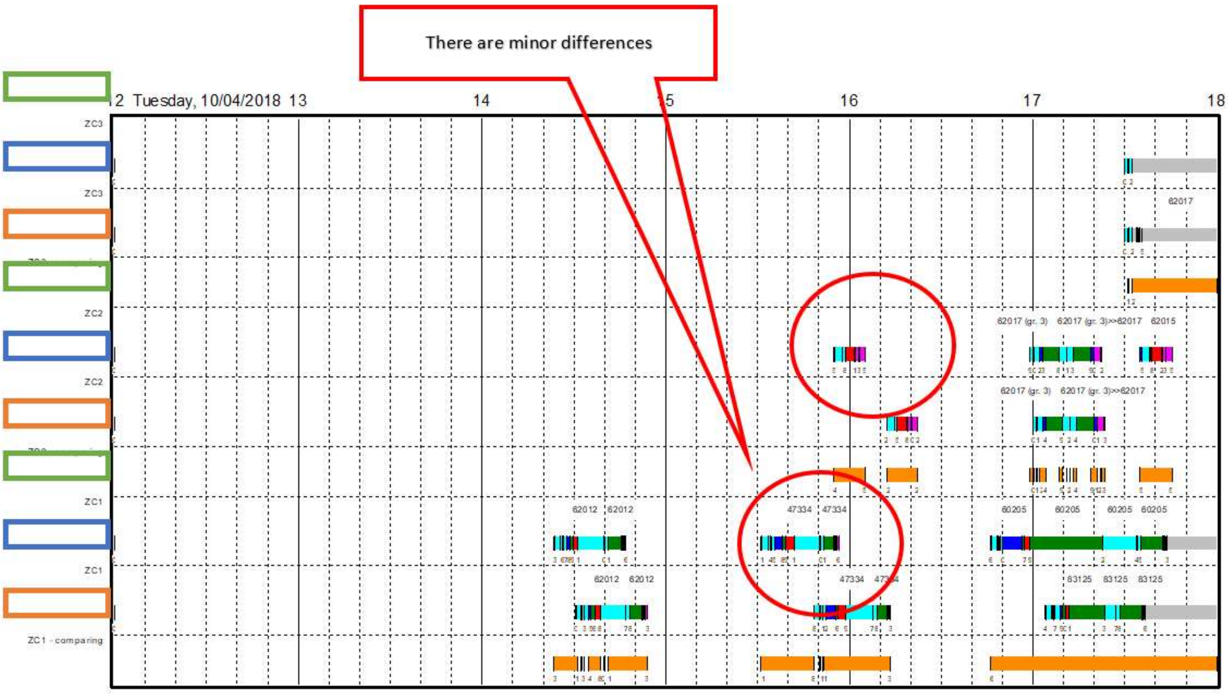
Orange: Difference

Shunting locomotives:

ZC3: shunting locomotive operating between sorting and departure yard

ZC2: shunting locomotive operating in sorting yard (wagon compression and coupling outbound group trains)

ZC1: shunting locomotive operating in reception yard (sorting the trains over the hump)


There are minor differences
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There are minor differences
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Comparison:

Personnel occupation

Legend:

Dark blue: Personnel Reserved (assigned)

Light blue: Personnel movement to train (from waiting position or previous position)

Green: Idle – no work (there is an obstacle to work – waiting for other resource)

Red: Work (inspecting, coupling…)

Pink: Personnel movement from train to waiting position

Grey: Off duty

White: No task now

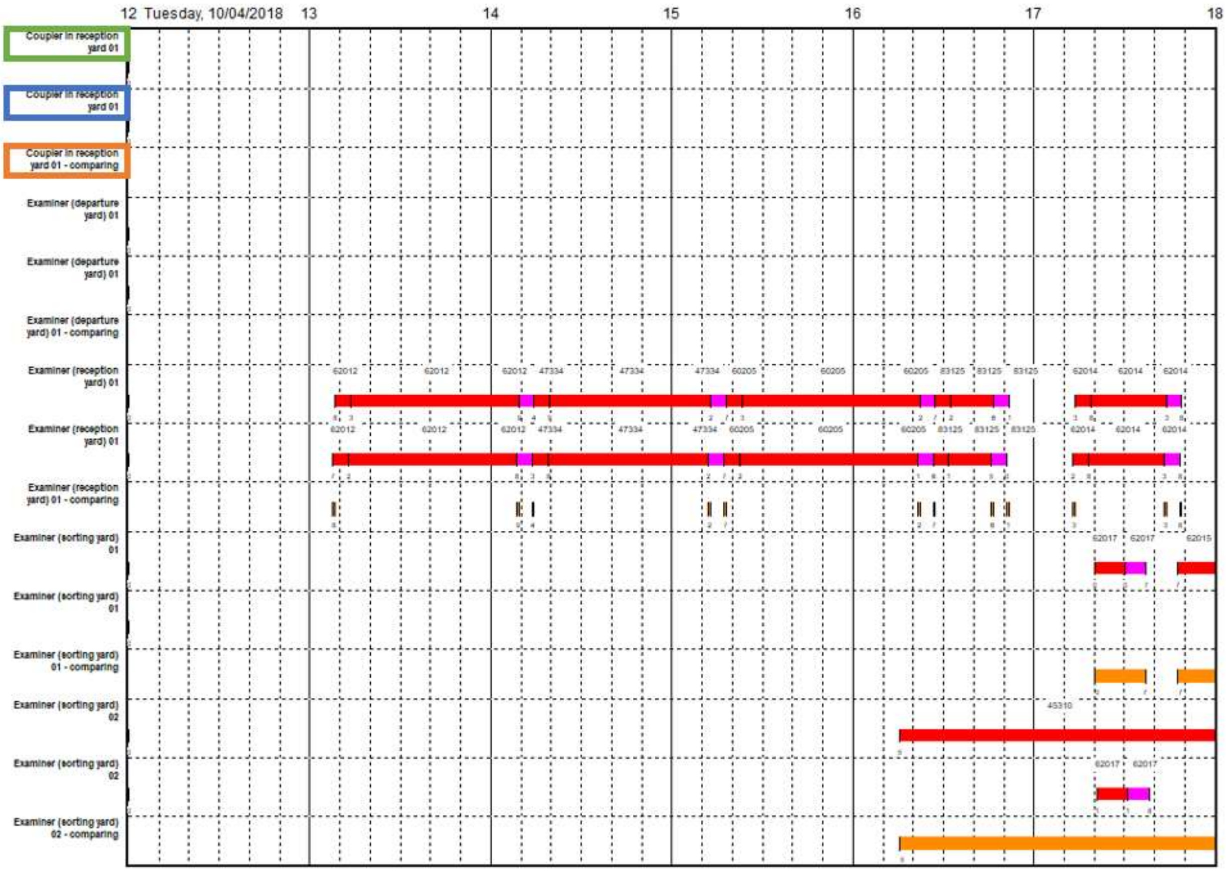
Orange: Difference

Personnel:

Examiners: wagon inspection and brake test

Couplers/shunters: locomotive or wagon un-/coupling

Transiteurs: data collection and preparation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Coupler in reception yard 01
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Coupler in reception yard 01 - comparing
Examiner (departure yard) 01
Examiner (departure yard) 01
Examiner (departure yard) 01 - comparing
Examiner (reception yard) 01
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Examiner (sorting yard) 01
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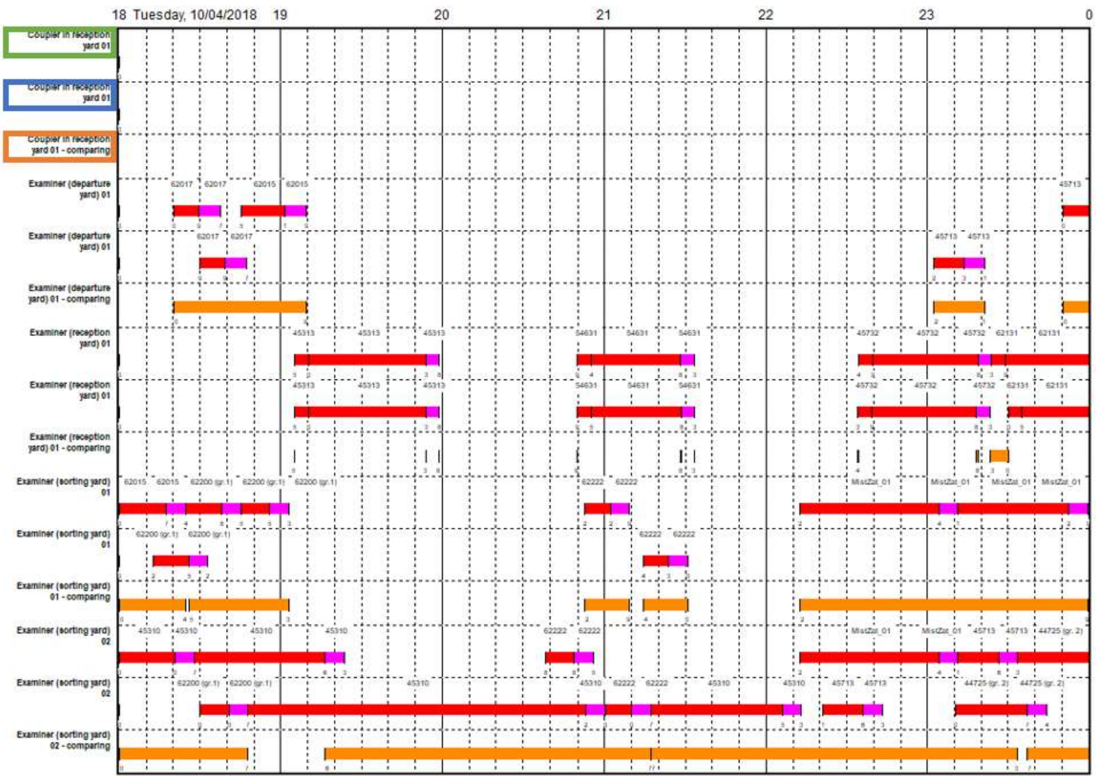
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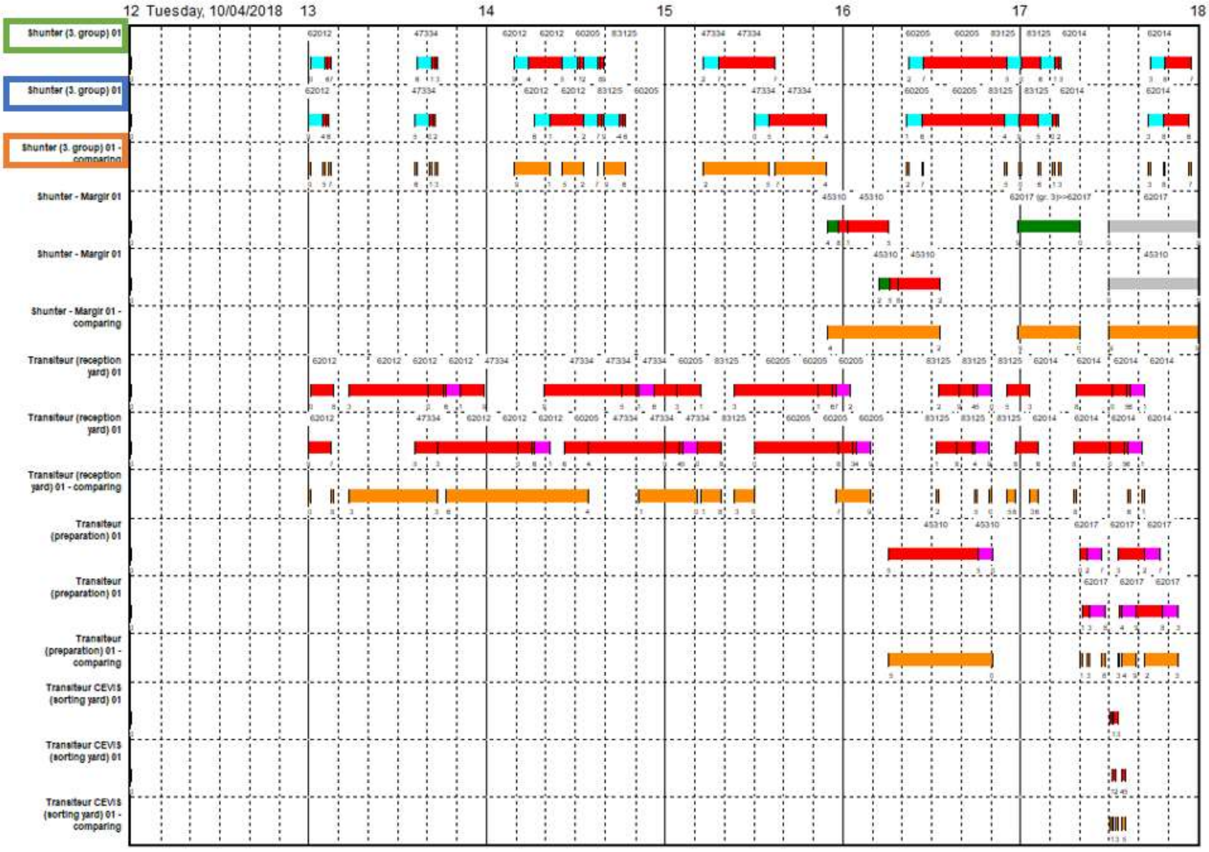

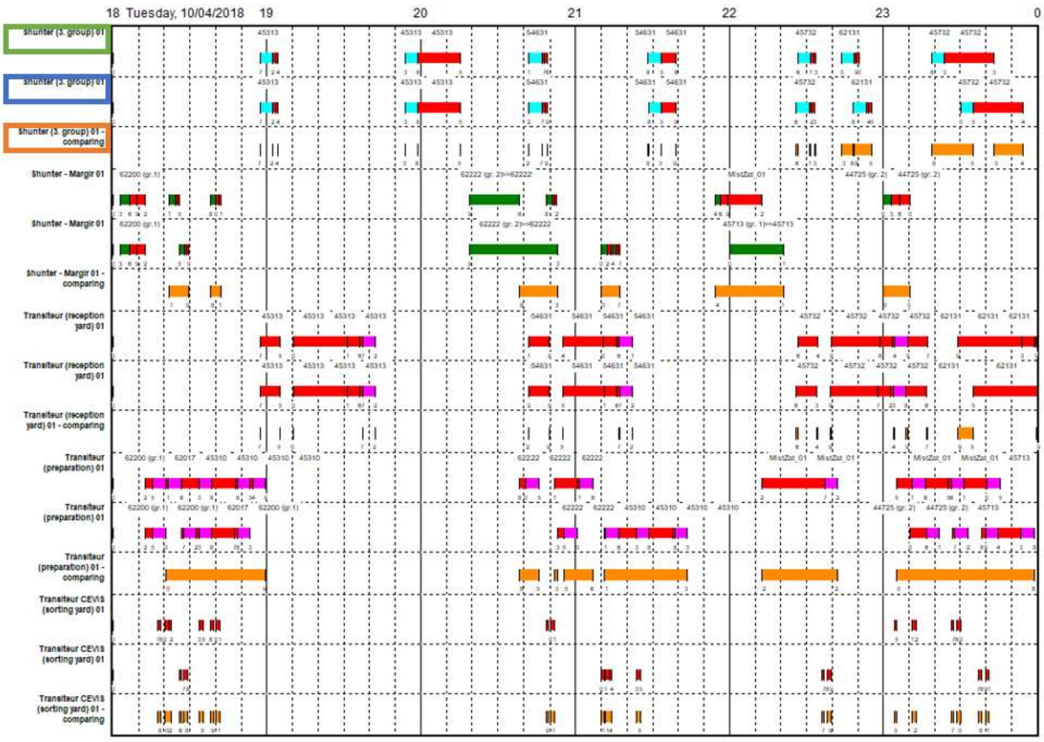

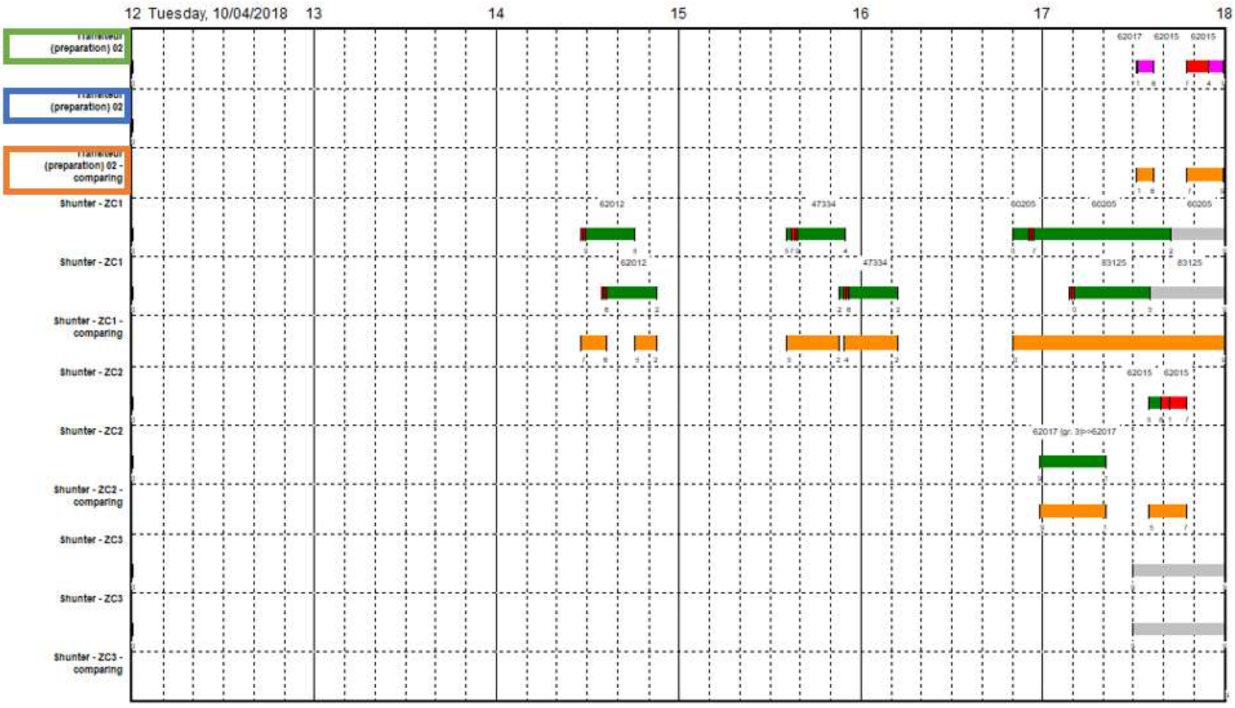
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Transiteur (preparation) 02
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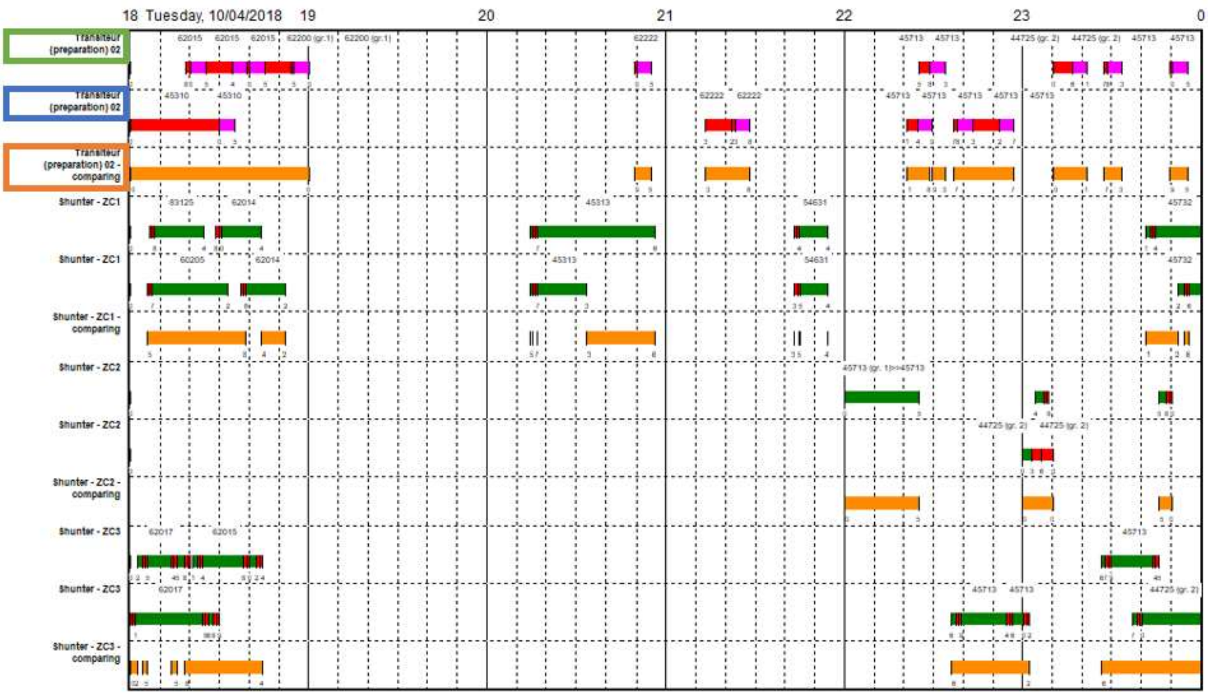
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Shunter - ZC3
Shunter - ZC3 - comparing

Comparison:

Track occupation – Reception tracks in Česká Třebová

Legend:

Dark blue: Track Reserved (assigned)

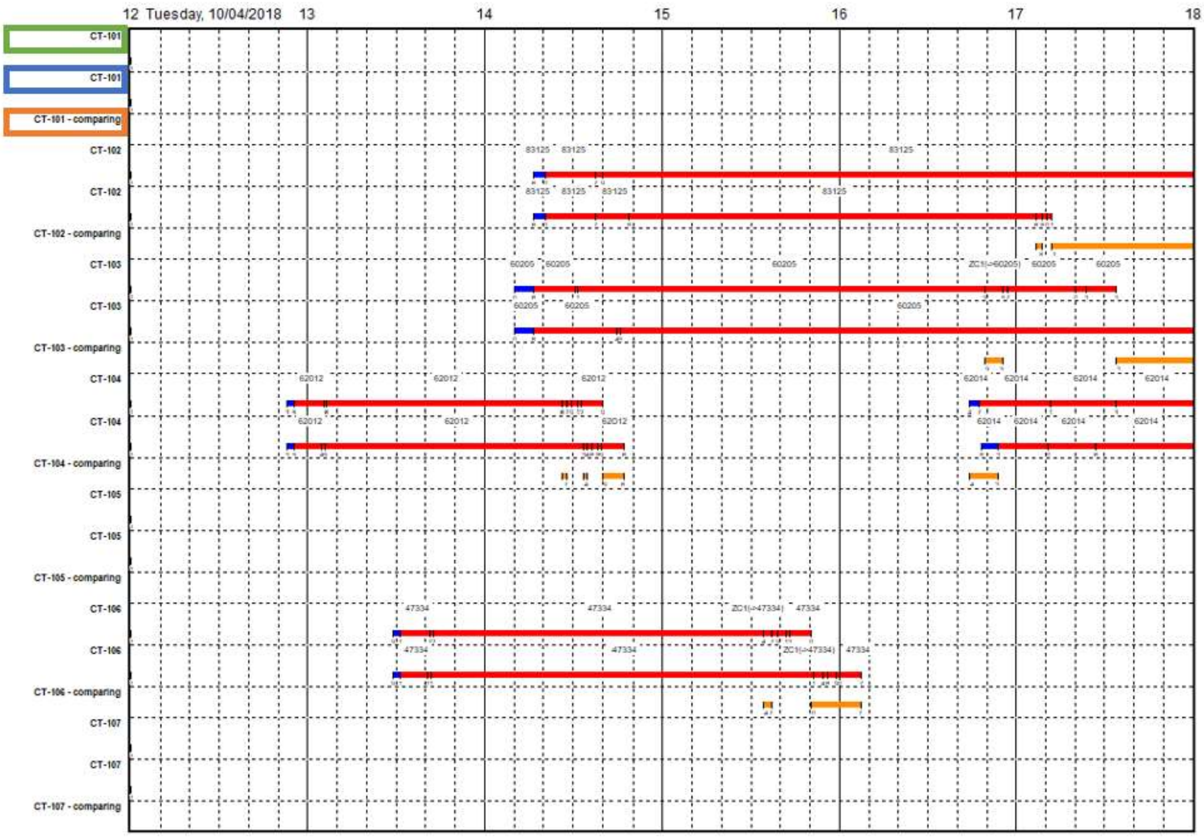
Red: Occupied by train, shunting unit or loco

White: No occupation

Orange: Difference

Reception tracks:

CT-101, CT-102, CT-103, CT-104, CT-105, CT-106, CT-107, CT-108, CT-109, CT-110, CT-111, CT-112, CT-114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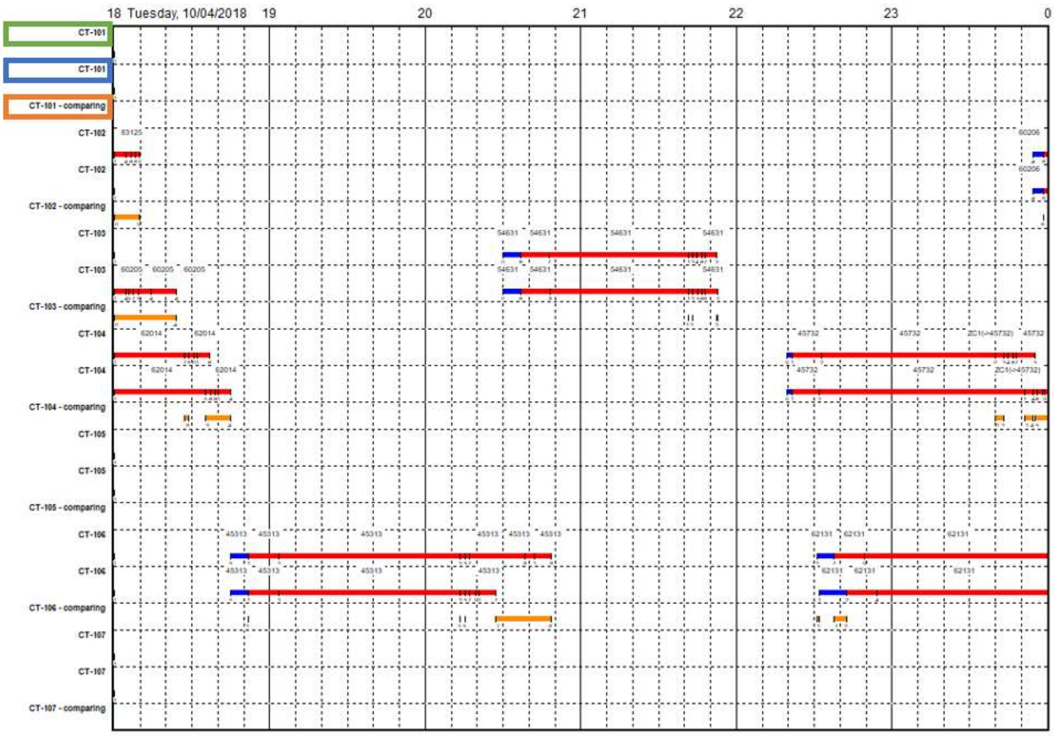
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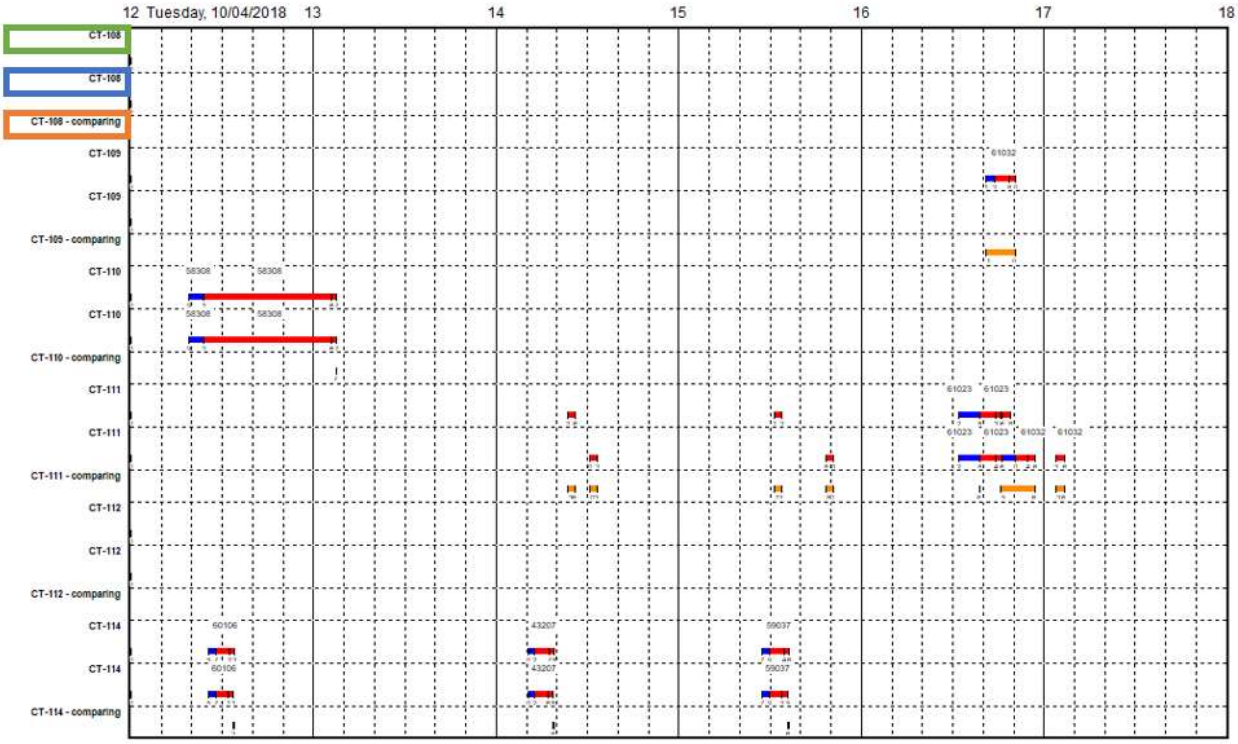
CT-107 - comparing



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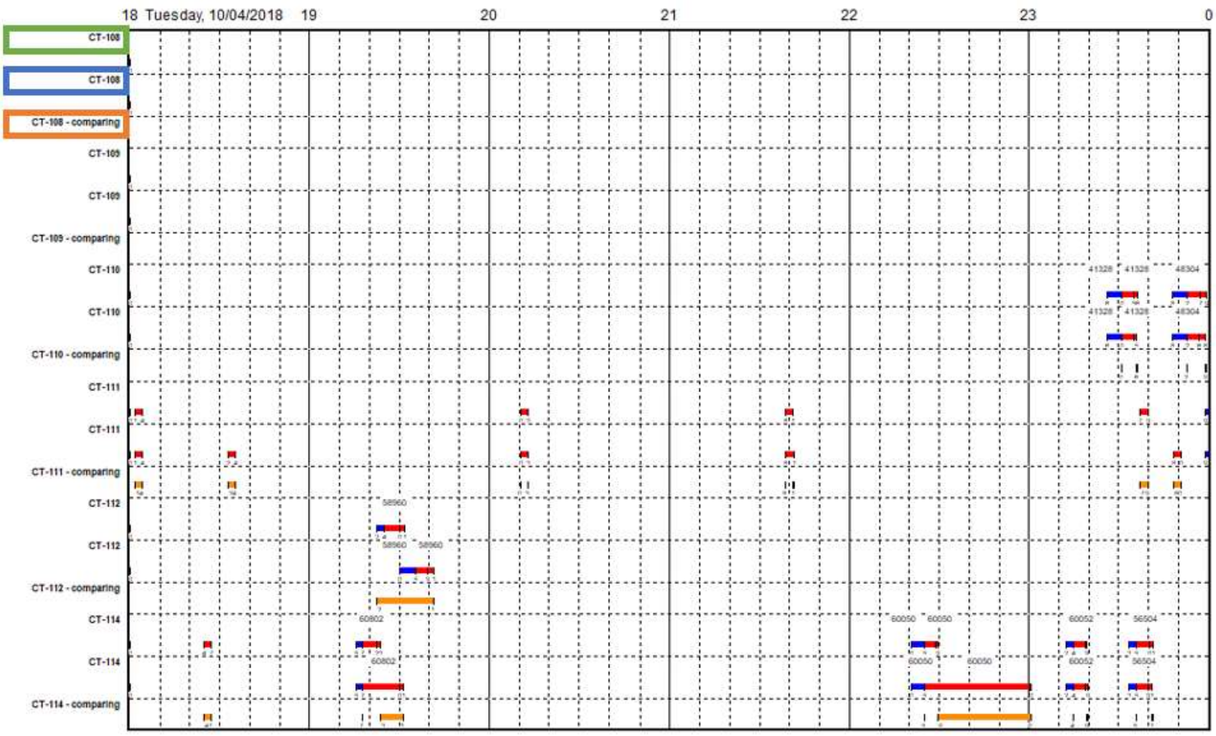

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CT-114
CT-114 - comparing

Comparison:

Track occupation – Departure tracks in Česká Třebová

Legend:

Dark blue: Track Reserved (assigned)

Red: Occupied by train, shunting unit or loco

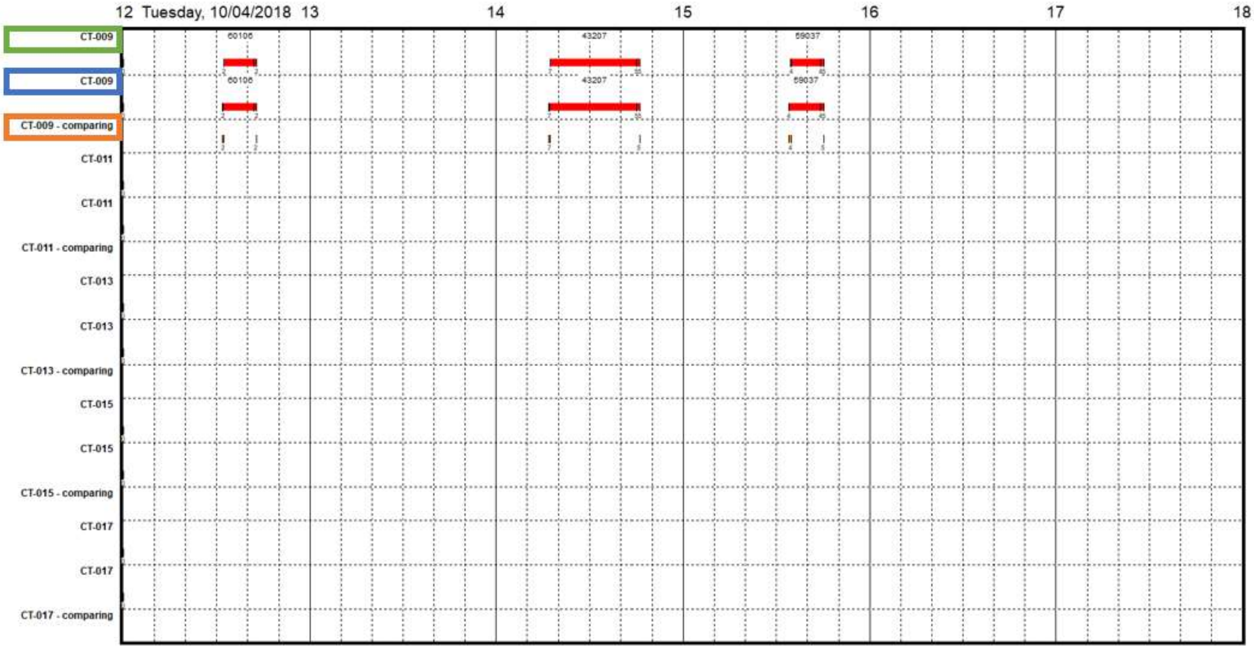
White: No occupation

Blocked: Track indirect blocked by other train (through interlocking system)

Orange: Difference

Departure tracks:

CT-009, CT-011, CT-013, CT-015, CT-017, CT-019, CT-021, CT-023, CT-025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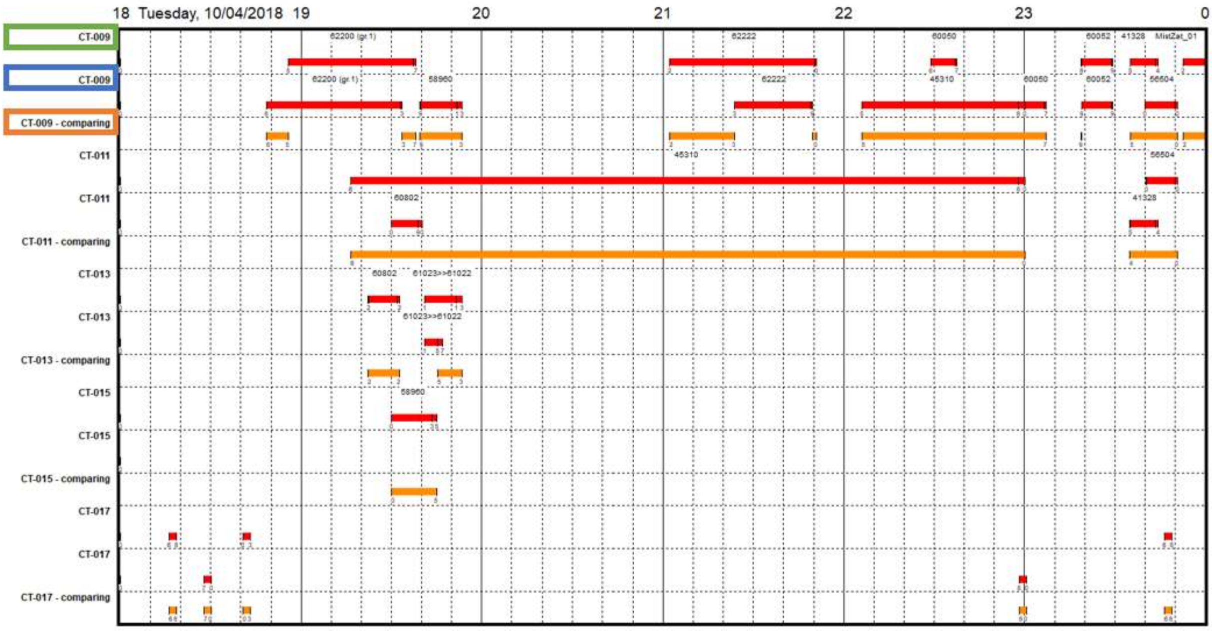
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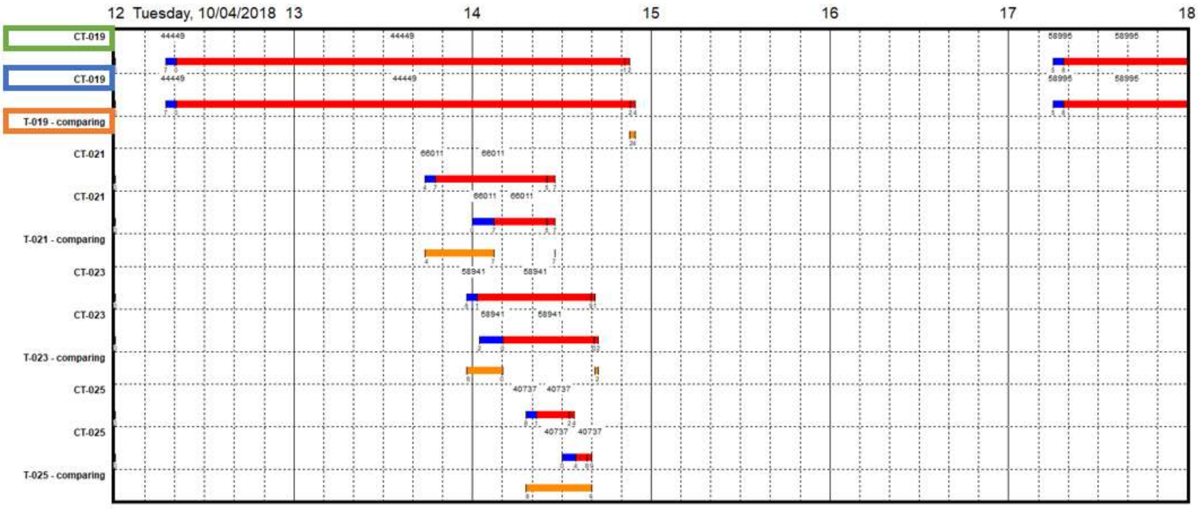
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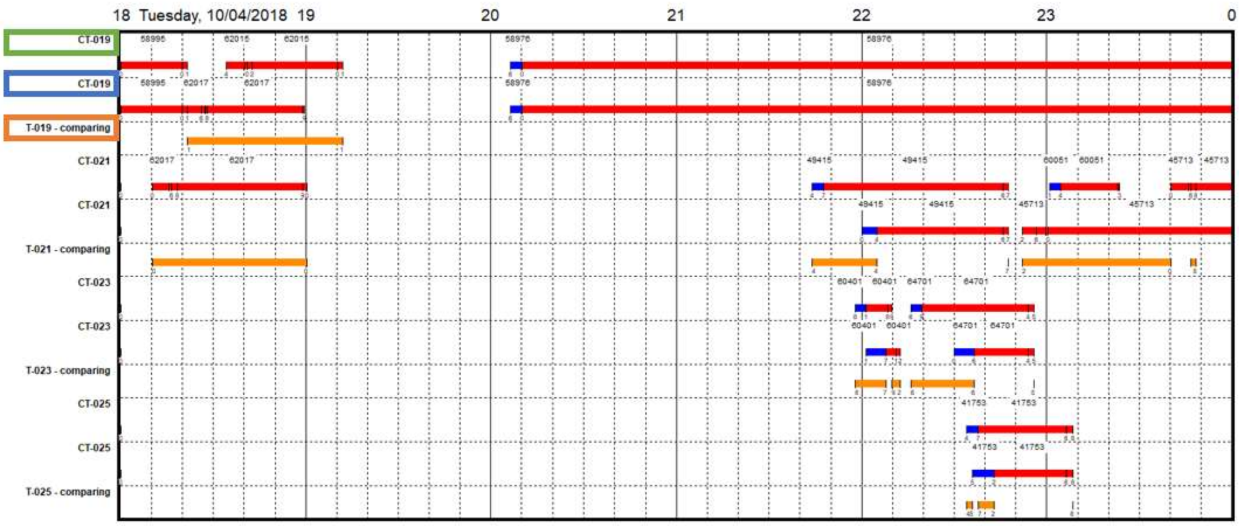
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CT-023
CT-023
T-023 - comparing
CT-025
CT-025
T-025 - comparing

Comparison:

Track occupation – Hump track in Česká Třebová

Legend:

Dark blue: Track Reserved (assigned)

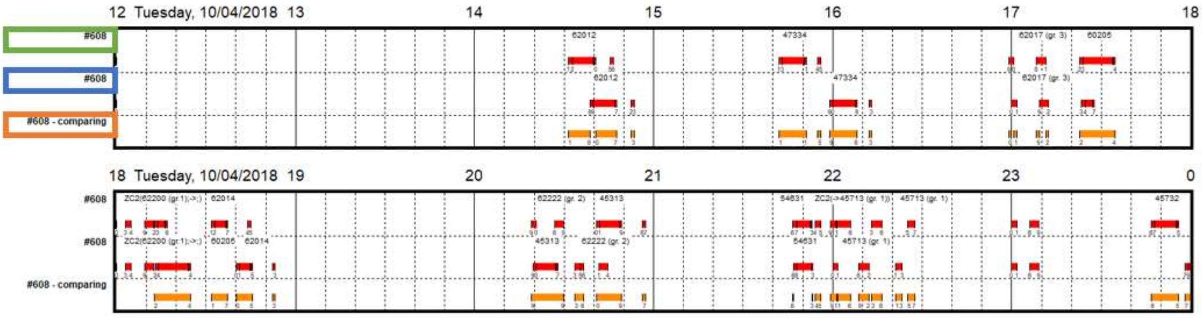
Red: Occupied by train, shunting unit or loco

White: No occupation

Orange: Difference

Hump track:

#608



Comparison prepared by Simcon.

2019/10/24

ANNEX B- TRIESTE – RNE TIS EXTRACTS

National Train Numbers	41871
TrainInfo	International Train
Last Update	11/12/2017 00:56:33 +01:00

International Train Number	Last Position	Status	Delta		
41871	Villach Westbf (in Vb) 11/12/2017 00:57:31 +01:00	Arrival	-37	From Point	München-Laim Rbf 10/12/2017 19:58:00 +01:00
				To Point	TRIESTE CAMPO MARZIO 11/12/2017 06:13:00 +01:00

Point Name	Contracted TT	CTT Point Status	RTFC	Delta	RA Point Status	Service Numb	IM	RU Code	Sub Station
München-Laim Rbf	10/12/2017 19:58:00 +01:00	Departure origin	10/12/2017 19:26:33 +01:00	-31	Departure origin	41871	80	M3605	
München Süd	10/12/2017 20:03:54 +01:00	Run-through	10/12/2017 19:39:18 +01:00	-25	Run-through	41871	80	M3605	
München Ost Pbf	10/12/2017 20:07:48 +01:00	Run-through	10/12/2017 19:43:42 +01:00	-24	Run-through	41871	80	M3605	
München-Trudering	10/12/2017 20:14:06 +01:00	Run-through	10/12/2017 19:46:57 +01:00	-27	Run-through	41871	80	M3605	
Zorneding	10/12/2017 20:23:24 +01:00	Run-through	10/12/2017 19:54:48 +01:00	-29	Run-through	41871	80	M3605	
Grafing Bahnhof	10/12/2017 20:45:30 +01:00	Run-through	10/12/2017 20:28:57 +01:00	-2	Arrival	41871	80	M3605	
Grafing Bahnhof	10/12/2017 20:45:30 +01:00	Run-through	10/12/2017 20:28:57 +01:00	-17	Run-through	41871	80	M3605	
Großkarolinenfeld (Üst)	10/12/2017 21:03:00 +01:00	Run-through	10/12/2017 20:45:27 +01:00	-18	Run-through	41871	80	M3605	
Rosenheim	10/12/2017 21:14:00 +01:00	Run-through	10/12/2017 20:49:31 +01:00	-24	Run-through	41871	80	M3605	
Rosenheim Ost	10/12/2017 21:15:48 +01:00	Run-through	10/12/2017 20:49:31 +01:00	-26	Run-through	41871	80	M3605	
Prien a Chiemsee	10/12/2017 21:33:00 +01:00	Run-through	10/12/2017 21:05:07 +01:00	-28	Run-through	41871	80	M3605	
Traunstein	10/12/2017 21:52:30 +01:00	Run-through	10/12/2017 21:26:30 +01:00	-26	Run-through	41871	80	M3605	
Teisendorf	10/12/2017 22:04:12 +01:00	Run-through	10/12/2017 21:36:51 +01:00	-27	Run-through	41871	80	M3605	
Freilassing	10/12/2017 22:14:12 +01:00	Run-through	10/12/2017 21:49:39 +01:00	-25	Run-through	41871	80	M3605	
Salzburg Liefering (in Sb)	10/12/2017 22:17:00 +01:00	Run-through	10/12/2017 21:52:19 +01:00	-25	Run-through	41871	81	TX	
Salzburg Taxham Europark (in Sb)	10/12/2017 22:18:00 +01:00	Run-through	10/12/2017 21:53:20 +01:00	-25	Run-through	41871	81	TX	
Salzburg Hbf (in Sb)	10/12/2017 22:22:30 +01:00	Arrival	10/12/2017 22:00:19 +01:00	-22	Arrival	41871	81	TX	
Salzburg Hbf (in Sb)	10/12/2017 22:23:00 +01:00	Departure	10/12/2017 22:00:57 +01:00	-22	Departure	41871	81	TX	
Salzburg-Mitte (in Sb)	10/12/2017 22:26:00 +01:00	Run-through	10/12/2017 22:03:02 +01:00	-23	Run-through	41871	81	TX	
Salzburg Gnigl-Vbf (in Sb)	10/12/2017 22:55:00 +01:00	Departure	10/12/2017 22:04:40 +01:00	-50	Departure	41871	81	TX	
Salzburg Gnigl-Einfgr (in Sb)	10/12/2017 22:59:00 +01:00	Run-through	10/12/2017 22:05:40 +01:00	-53	Run-through	41871	81	TX	
Salzburg Aigen	10/12/2017 23:01:00 +01:00	Run-through	10/12/2017 22:07:14 +01:00	-54	Run-through	41871	81	TX	
Hallein	10/12/2017 23:09:30 +01:00	Run-through	10/12/2017 22:15:21 +01:00	-54	Run-through	41871	81	TX	
Golling-Abtenau	10/12/2017 23:17:30 +01:00	Run-through	10/12/2017 22:21:49 +01:00	-56	Run-through	41871	81	TX	
Bischofshofen Fbf (in Bo)	10/12/2017 23:43:00 +01:00	Departure	10/12/2017 22:43:30 +01:00	-60	Departure	41871	81	TX	
St.Johann im Pongau	10/12/2017 23:52:00 +01:00	Run-through	10/12/2017 22:49:30 +01:00	-63	Run-through	41871	81	TX	
Schwarzach-St.Veit	10/12/2017 23:56:00 +01:00	Run-through	10/12/2017 22:54:22 +01:00	-62	Run-through	41871	81	TX	
Bad Gastein	11/12/2017 00:29:00 +01:00	Run-through	10/12/2017 23:16:56 +01:00	-72	Run-through	41871	81	TX	
Böckstein	11/12/2017 00:33:30 +01:00	Run-through	10/12/2017 23:21:14 +01:00	-72	Run-through	41871	81	TX	
Mallnitz-Obervellach (in Ma)	11/12/2017 00:43:00 +01:00	Run-through	10/12/2017 23:35:05 +01:00	-68	Run-through	41871	81	TX	
Spittal-Millstättersee	11/12/2017 01:06:30 +01:00	Arrival	11/12/2017 00:01:05 +01:00	-65	Arrival	41871	81	TX	
Spittal-Millstättersee	11/12/2017 01:06:30 +01:00	Departure	11/12/2017 00:09:45 +01:00	-57	Departure	41871	81	TX	
Gummern	11/12/2017 01:24:30 +01:00	Run-through	11/12/2017 00:47:34 +01:00	-37	Run-through	41871	81	TX	
Abzw Gu 2	11/12/2017 01:30:00 +01:00	Run-through	11/12/2017 00:52:53 +01:00	-37	Run-through	41871	81	TX	
Villach Westbf (in Vb)	11/12/2017 01:35:00 +01:00	Arrival	11/12/2017 00:57:31 +01:00	-37	Arrival	41871	81	TX	
Villach Westbf (in Vb)	11/12/2017 02:15:00 +01:00	Departure	11/12/2017 01:38:00 +01:00	-37		41871	81	TX	
Villach Süd Gvbf-Auen (in Vsv)	11/12/2017 02:20:00 +01:00	Run-through	11/12/2017 01:43:00 +01:00	-37		41871	81	TX	
Villach Süd Gvbf (in Vsv)	11/12/2017 02:21:00 +01:00	Run-through	11/12/2017 01:44:00 +01:00	-37		41871	81	TX	
Fürnitz (in Vsv)	11/12/2017 02:23:00 +01:00	Run-through	11/12/2017 01:46:00 +01:00	-37		41871	81	TX	
Villach Süd Gvbf-West (in Vsv)	11/12/2017 02:25:00 +01:00	Run-through	11/12/2017 01:48:00 +01:00	-37		41871	81	TX	
Arnoldstein	11/12/2017 02:29:00 +01:00	Run-through	11/12/2017 01:52:00 +01:00	-37		41871	81	TX	
Thörl-Maglern	11/12/2017 02:33:30 +01:00	Run-through	11/12/2017 01:56:30 +01:00	-37	Run-through	41871	81	TX	
TARVISIO BOSCOVERDE	11/12/2017 02:40:00 +01:00	Arrival	11/12/2017 02:03:00 +01:00	-37		41871	83	TI-DC	
TARVISIO BOSCOVERDE	11/12/2017 03:45:00 +01:00	Departure	11/12/2017 03:08:00 +01:00	-37		41871	83	TI-DC	
PONTEBBA	11/12/2017 04:06:00 +01:00	Run-through	11/12/2017 03:29:00 +01:00	-37		41871	83	TI-DC	
CARNIA	11/12/2017 04:23:00 +01:00	Run-through	11/12/2017 03:46:00 +01:00	-37		41871	83	TI-DC	
GEMONA DEL FRIULI	11/12/2017 04:34:00 +01:00	Run-through	11/12/2017 03:57:00 +01:00	-37		41871	83	TI-DC	
PM VAT	11/12/2017 04:53:00 +01:00	Arrival	11/12/2017 04:16:00 +01:00	-37		41871	83	TI-DC	
PM VAT	11/12/2017 04:55:00 +01:00	Departure	11/12/2017 04:18:00 +01:00	-37		41871	83	TI-DC	
S.GIOVANNI AL NATISONE	11/12/2017 05:09:00 +01:00	Run-through	11/12/2017 04:32:00 +01:00	-37		41871	83	TI-DC	
CORMONS	11/12/2017 05:13:00 +01:00	Run-through	11/12/2017 04:36:00 +01:00	-37		41871	83	TI-DC	
GORIZIA CENTRALE	11/12/2017 05:22:00 +01:00	Run-through	11/12/2017 04:45:00 +01:00	-37		41871	83	TI-DC	
MONFALCONE	11/12/2017 05:39:00 +01:00	Run-through	11/12/2017 05:02:00 +01:00	-37		41871	83	TI-DC	
BIVIO D'AURISINA	11/12/2017 05:49:00 +01:00	Run-through	11/12/2017 05:12:00 +01:00	-37		41871	83	TI-DC	
TRIESTE CAMPO MARZIO	11/12/2017 06:13:00 +01:00	Arrival terminal	11/12/2017 05:36:00 +01:00	-37		41871	83	TI-DC	

ANNEX C- Comparison of non-optimized and optimized simulation for simulation model Trieste Campo Marzio (TCM)

Evaluation

Comparison of non-optimized and optimized simulation for simulation model Trieste Campo Marzio (TCM)

Scenario: Theoretical week operation - Basic 00

Time period: Saturday 8:00 till Sunday 6:00

Legend:

1. Row – output from **non-optimized simulation model** Trieste Campo Marzio
2. Row – output from **optimized simulation model** Trieste Campo Marzio
3. Row – comparison where are the differences between two simulation runs

Comparison:

Shunting locomotive occupation

Legend:

Dark blue: Loco Reserved (assigned)

Light blue: Loco movement to train (from waiting position or previous task)

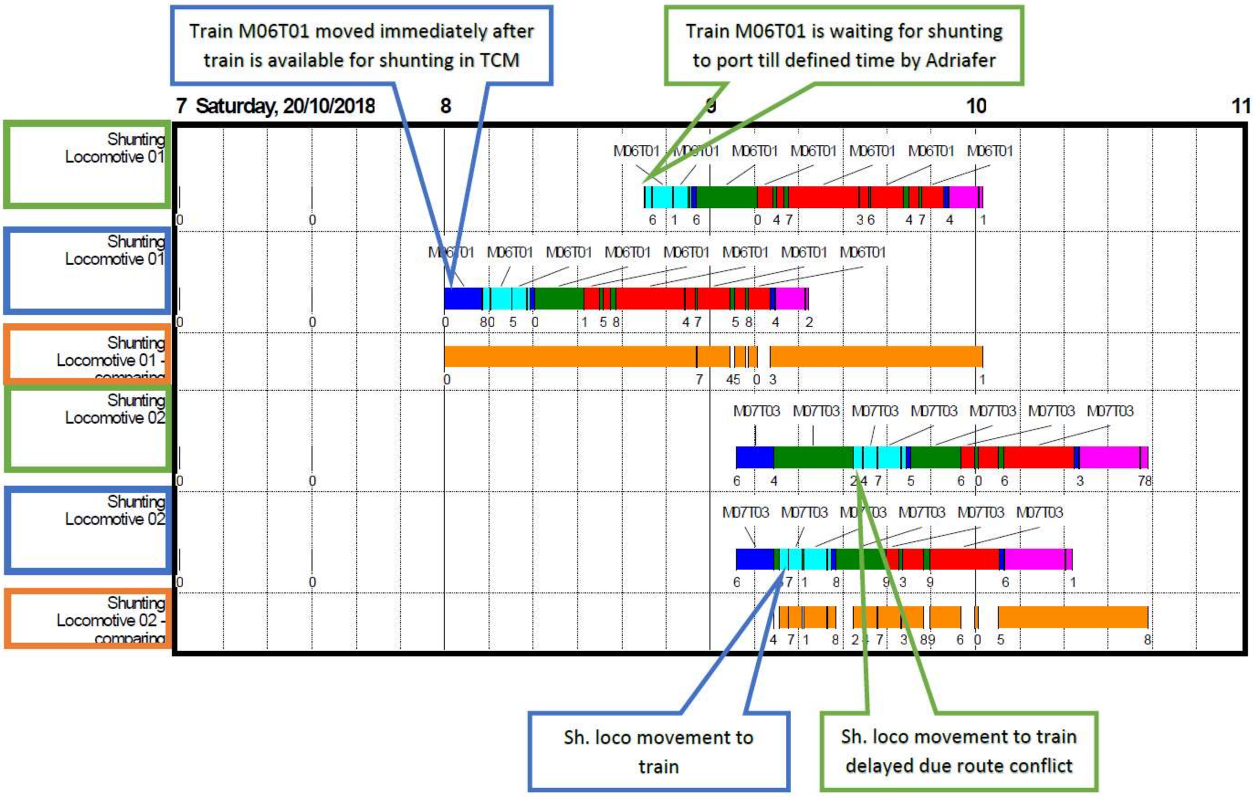
Green: Idle – no movement (there is an obstacle to work – route is not available, loco coupling, break test)

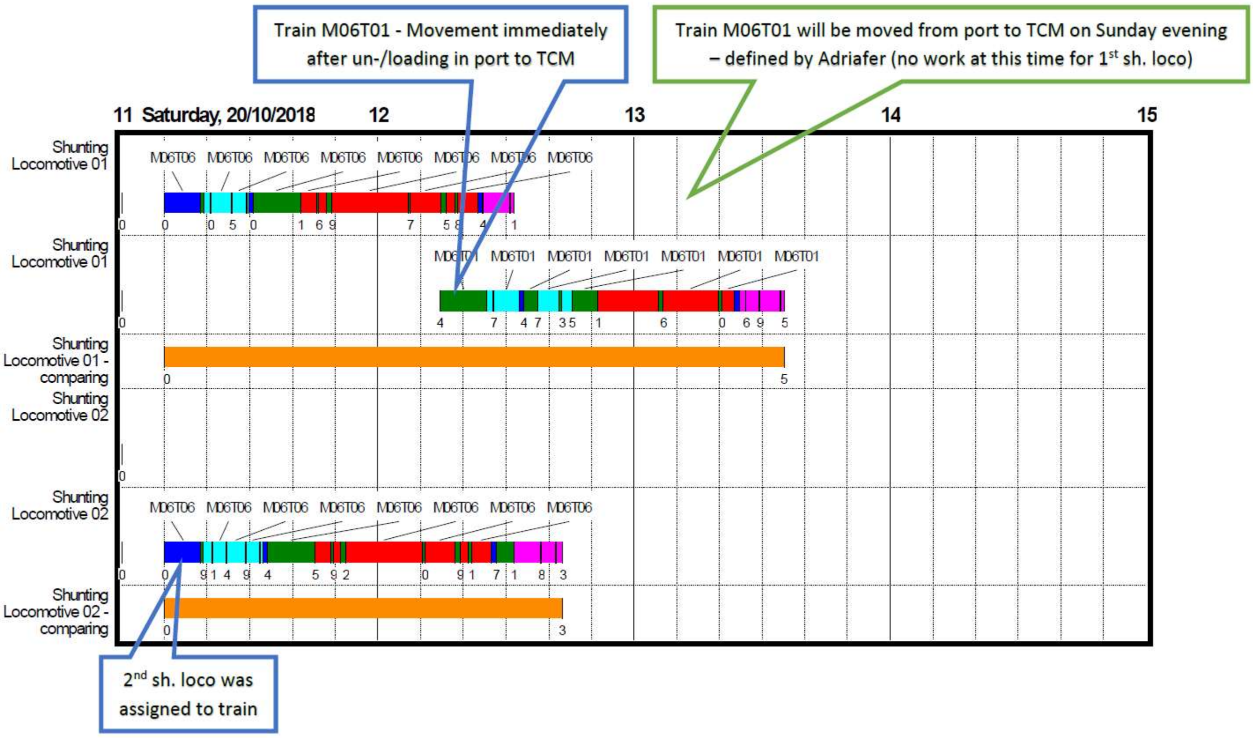
Red: Work (loco is pushing or pulling a train)

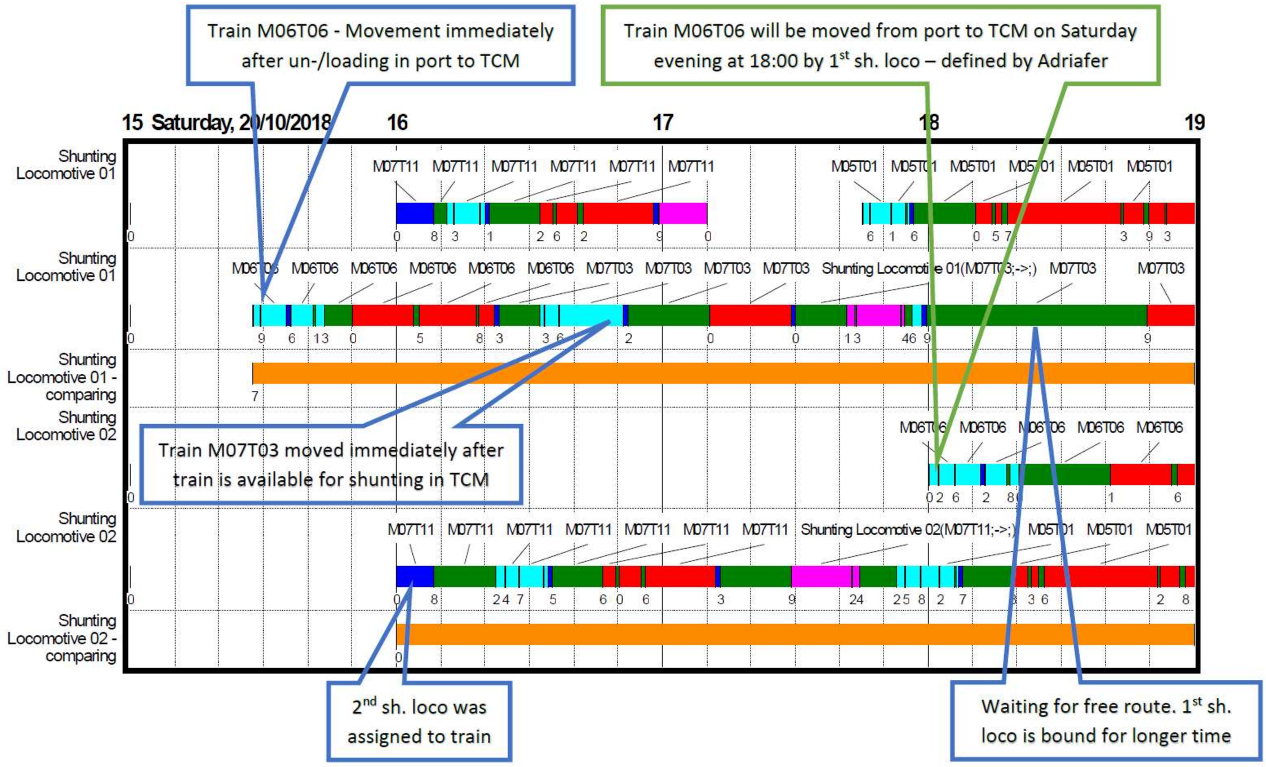
Pink: Loco movement from train to waiting position

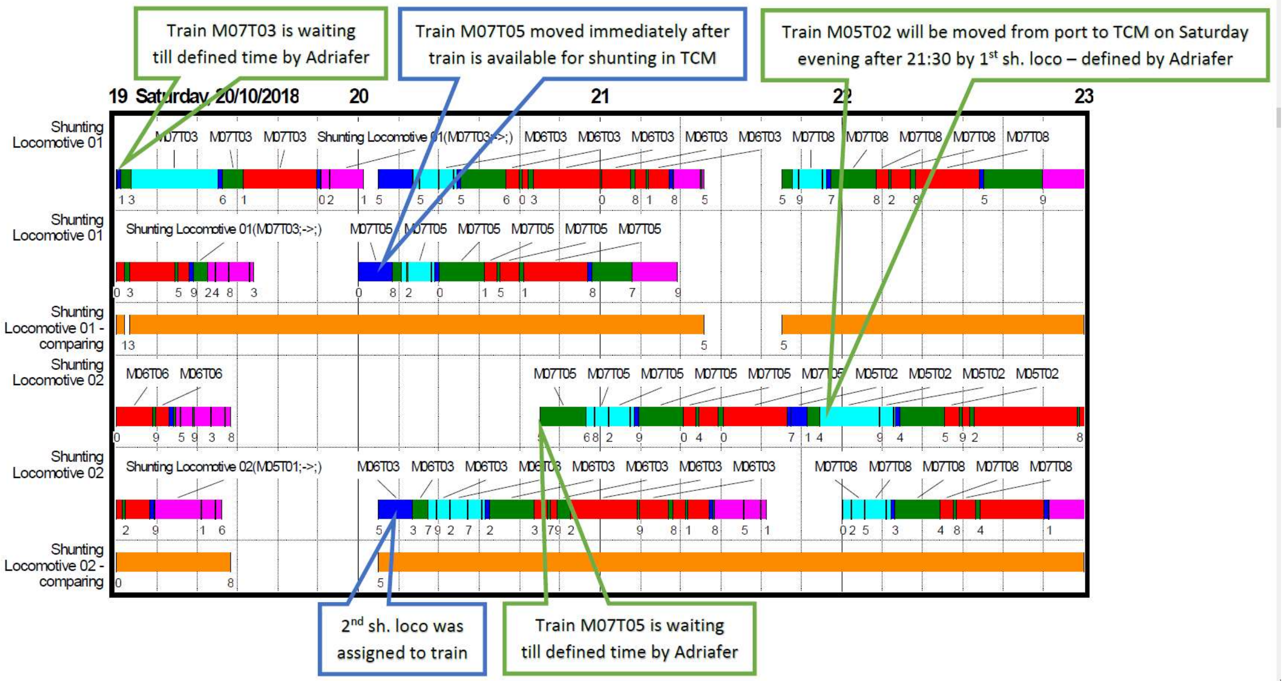
White: No task at the moment

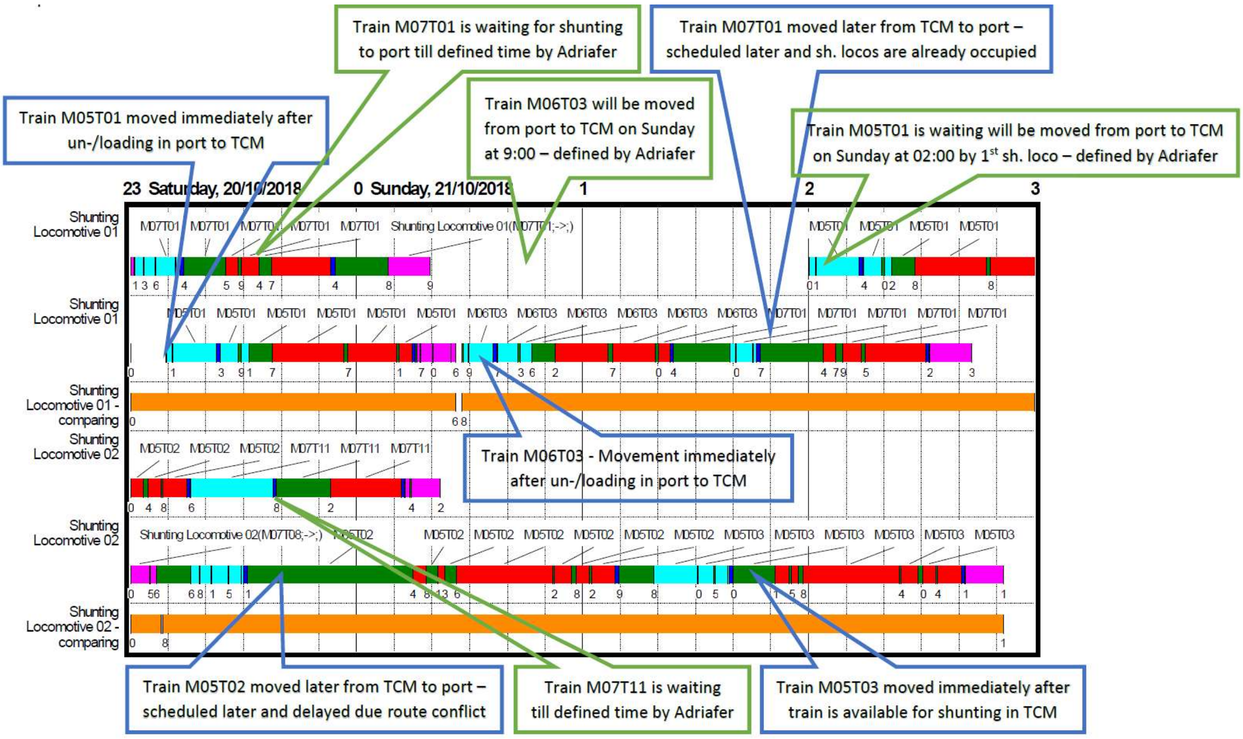
Orange: Difference


Train M06T01 moved immediately after train is available for shunting in TCM
Train M06T01 is waiting for shunting to port till defined time by Adriafer
7 Saturday, 20/10/2018
8
9
10
11
Shunting Locomotive 01
Shunting Locomotive 01
Shunting Locomotive 01 - comparing
Shunting Locomotive 02
Shunting Locomotive 02
Shunting Locomotive 02 - comparing
Sh. loco movement to train
Sh. loco movement to train delayed due route conflict

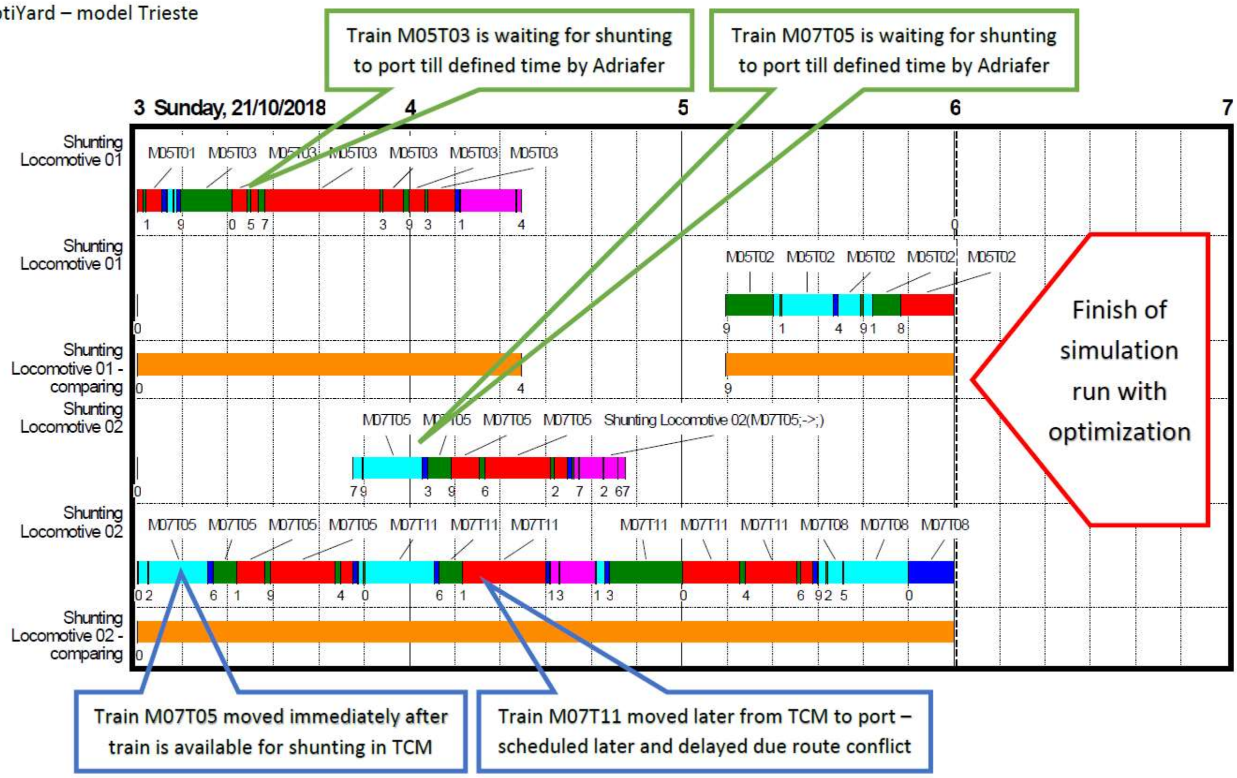

Train M06T01 - Movement immediately after un-/loading in port to TCM
Train M06T01 will be moved from port to TCM on Sunday evening – defined by Adriafer (no work at this time for 1st sh. loco)
11 Saturday, 20/10/2018
12
13
14
15
Shunting Locomotive 01
Shunting Locomotive 01
Shunting Locomotive 01 - comparing
Shunting Locomotive 02
Shunting Locomotive 02
Shunting Locomotive 02 - comparing
2nd sh. loco was assigned to train


Train M06T06 - Movement immediately after un-/loading in port to TCM
Train M06T06 will be moved from port to TCM on Saturday evening at 18:00 by 1st sh. loco – defined by Adriafer
15 Saturday, 20/10/2018
16
17
18
19
Shunting Locomotive 01
Shunting Locomotive 01
Shunting Locomotive 01 - comparing
Shunting Locomotive 02
Shunting Locomotive 02
Shunting Locomotive 02 - comparing
Train M07T03 moved immediately after train is available for shunting in TCM
2nd sh. loco was assigned to train
Waiting for free route. 1st sh. loco is bound for longer time


Train M07T03 is waiting till defined time by Adriafer
Train M07T05 moved immediately after train is available for shunting in TCM
Train M05T02 will be moved from port to TCM on Saturday evening after 21:30 by 1st sh. loco – defined by Adriafer
19 Saturday, 20/10/2018
20
21
22
23
Shunting Locomotive 01
Shunting Locomotive 01
Shunting Locomotive 01 - comparing
Shunting Locomotive 02
Shunting Locomotive 02
Shunting Locomotive 02 - comparing
2nd sh. loco was assigned to train
Train M07T05 is waiting till defined time by Adriafer



OptiYard – model Trieste



Comparison:

Track occupation – Reception/departure tracks in T. Campo Marzio

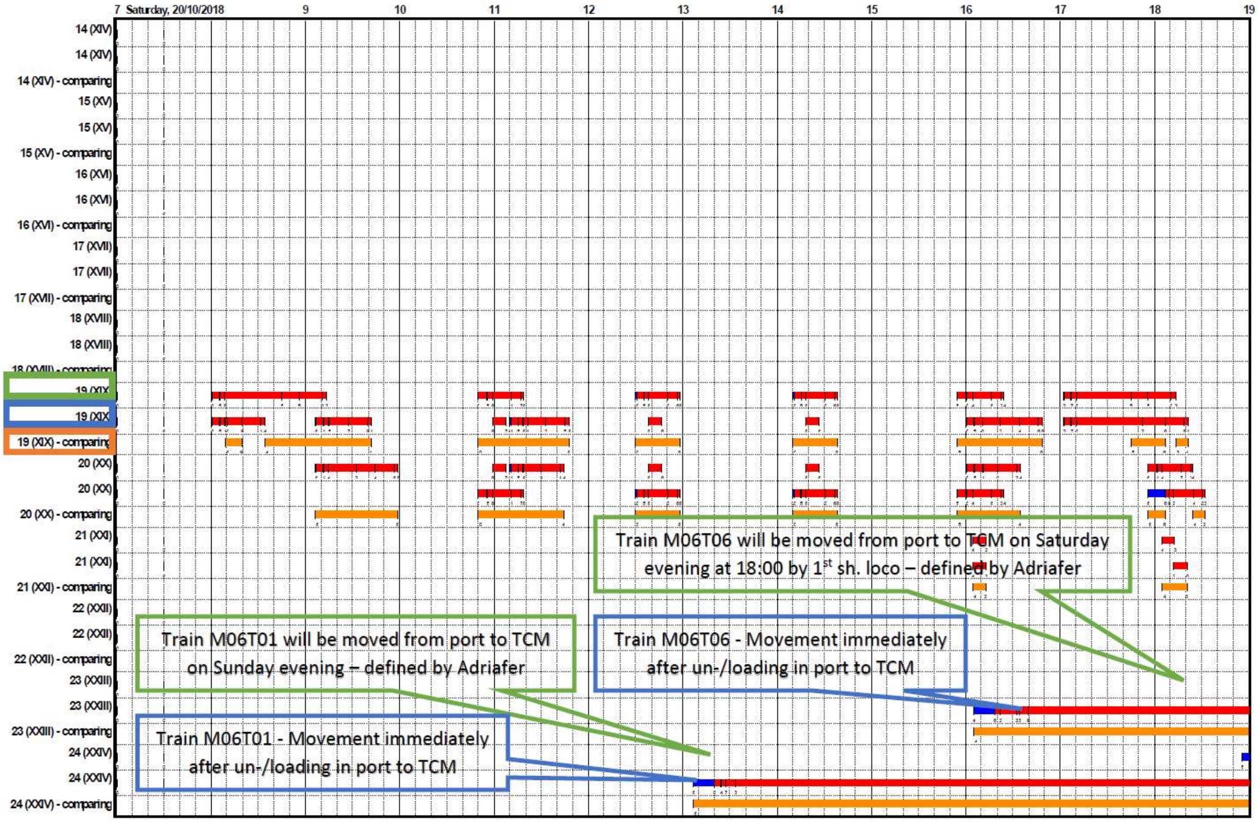
Legend:

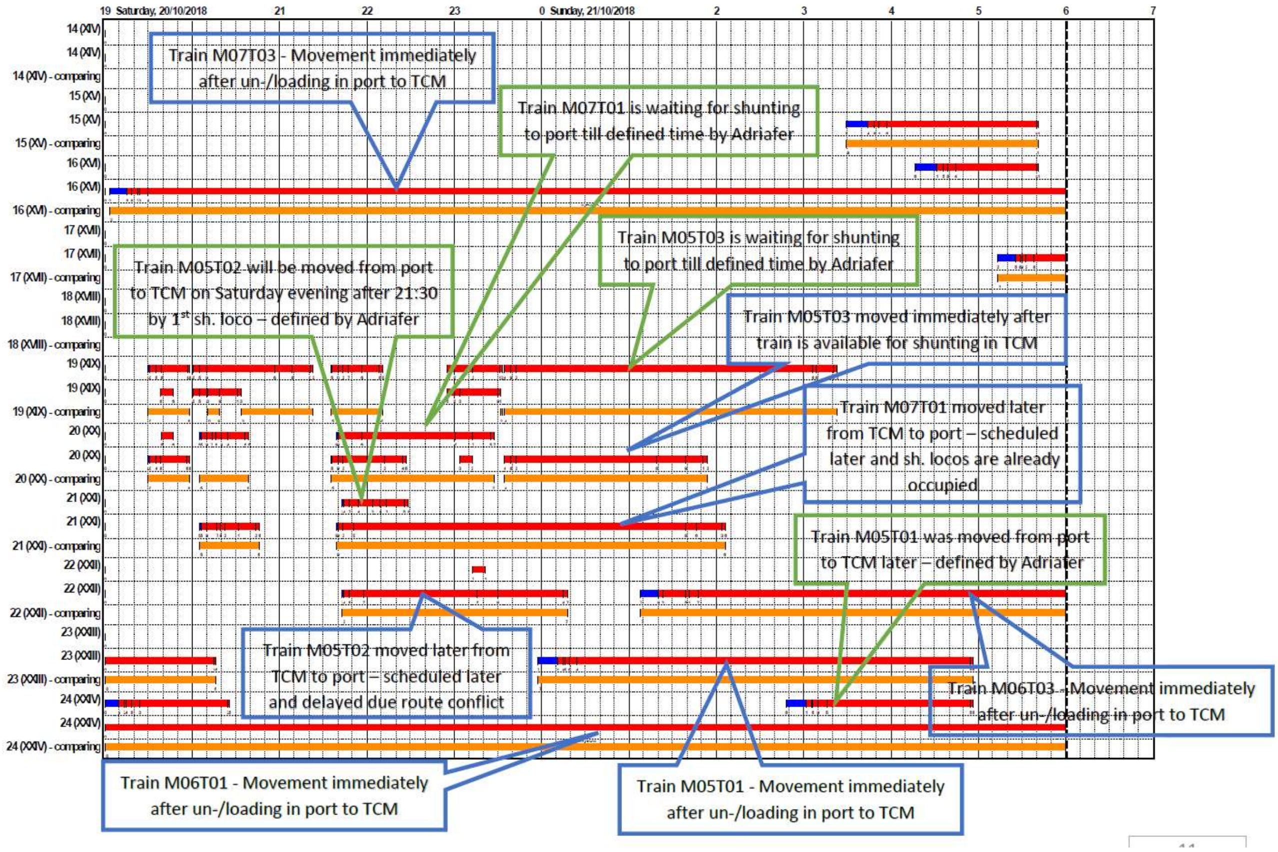
Dark blue: Track Reserved (assigned)

Red: Occupied by train, shunting unit or loco

White: No occupation

Orange: Difference




19 Saturday, 20/10/2018
21
22
23
0 Sunday, 21/10/2018
2
3
4
5
6
7
Train M07T03 - Movement immediately after un-/loading in port to TCM
Train M07T01 is waiting for shunting to port till defined time by Adriafer
Train M05T03 is waiting for shunting to port till defined time by Adriafer
Train M05T02 will be moved from port to TCM on Saturday evening after 21:30 by 1st sh. loco – defined by Adriafer
Train M05T03 moved immediately after train is available for shunting in TCM
Train M07T01 moved later from TCM to port – scheduled later and sh. locos are already occupied
Train M05T01 was moved from port to TCM later – defined by Adriafer
Train M05T02 moved later from TCM to port – scheduled later and delayed due route conflict
Train M06T03 - Movement immediately after un-/loading in port to TCM
Train M06T01 - Movement immediately after un-/loading in port to TCM
Train M05T01 - Movement immediately after un-/loading in port to TCM

Comparison:

Track occupation – Pull-out track 16P in Trieste Campo Marzio

Legend:

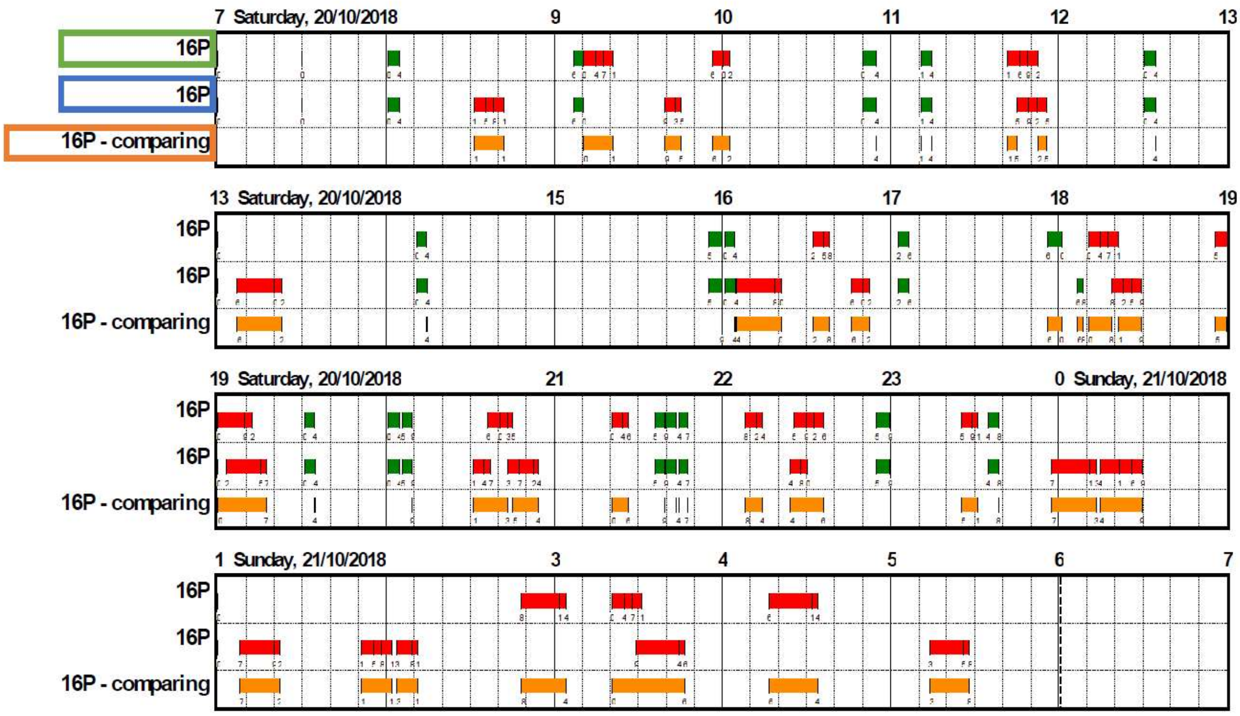
Dark blue: Track Reserved (assigned)

Red: Occupied by train, shunting unit or loco

White: No occupation

Blocked: Track indirect blocked by other train (through interlocking system)

Orange: Difference



Comparison:

Track occupation – Terminal 1 (Molo 5)

Legend:

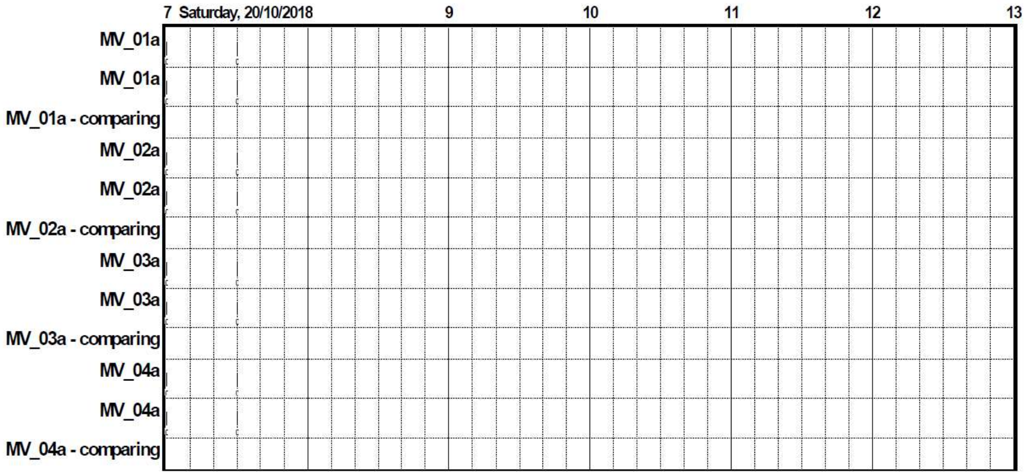
Dark blue: Track Reserved (assigned)

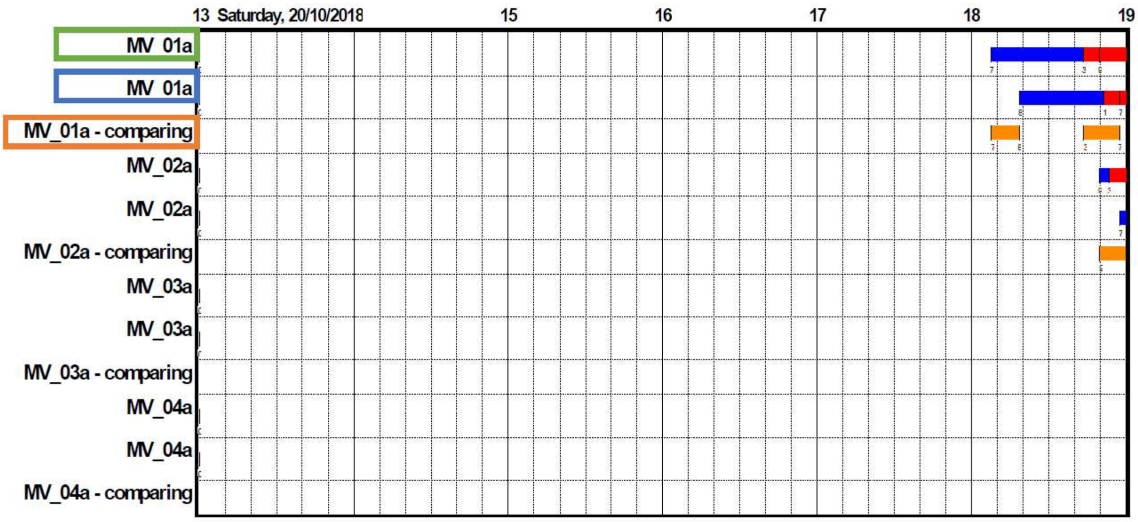
Red: Occupied by train, shunting unit or loco

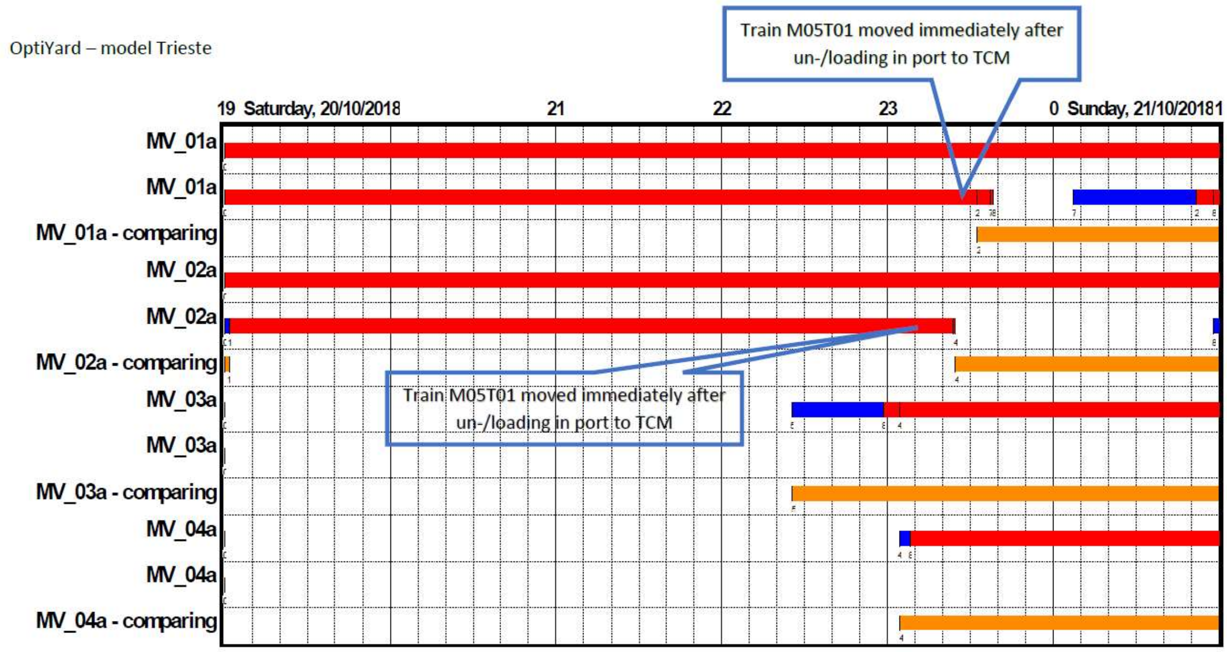
White: No occupation

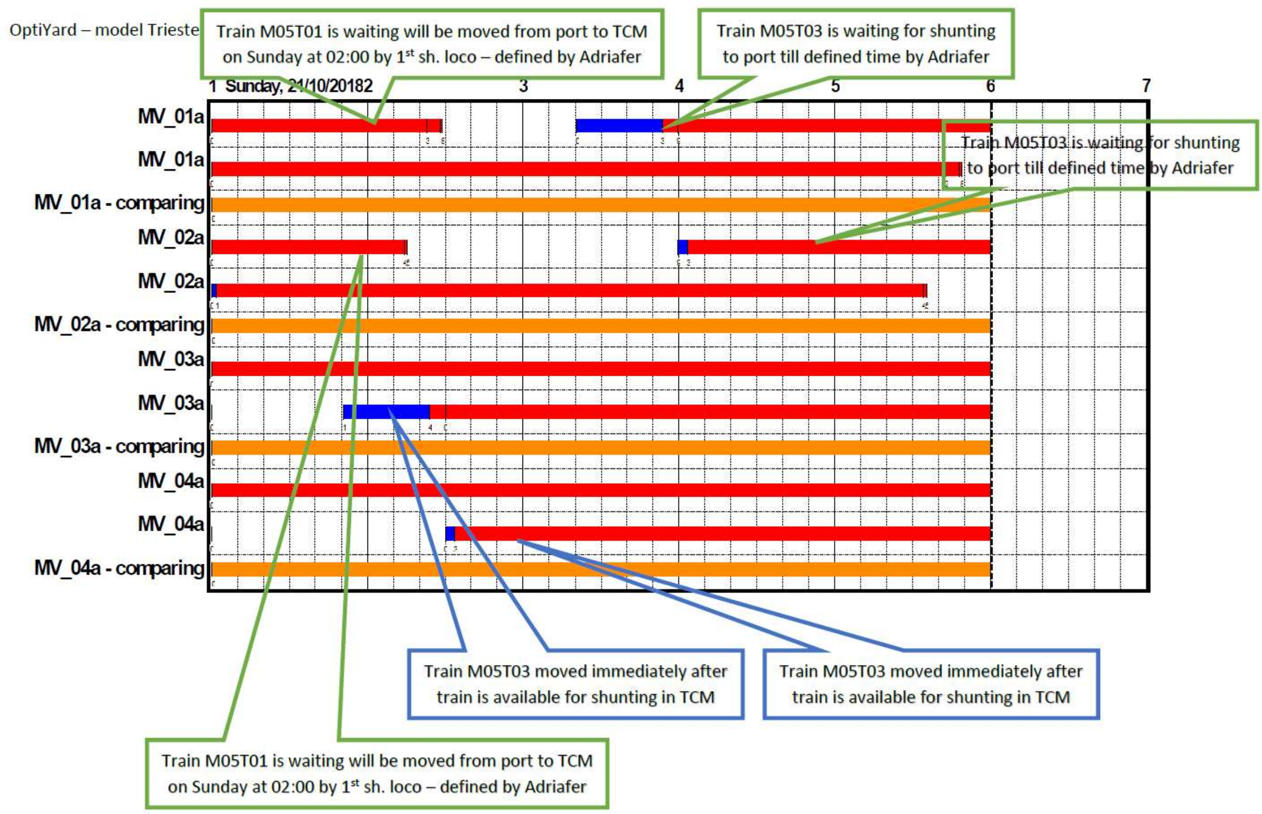
Orange: Difference

In terminal 1 the trains are split in two parts during the un-/loading due the short un-/loading tracks.






OptiYard – model Trieste
Train M05T01 moved immediately after un-/loading in port to TCM
19 Saturday, 20/10/2018
21
22
23
0 Sunday, 21/10/20181
MV_01a
MV_01a
MV_01a - comparing
MV_02a
MV_02a
MV_02a - comparing
MV_03a
MV_03a
MV_03a - comparing
MV_04a
MV_04a
MV_04a - comparing
Train M05T01 moved immediately after un-/loading in port to TCM


OptiYard – model Trieste
Train M05T01 is waiting will be moved from port to TCM on Sunday at 02:00 by 1st sh. loco – defined by Adriafer
Train M05T03 is waiting for shunting to port till defined time by Adriafer
1 Sunday, 21/10/20182
3
4
5
6
7
MV_01a
MV_01a
MV_01a - comparing
MV_02a
MV_02a
MV_02a - comparing
MV_03a
MV_03a
MV_03a - comparing
MV_04a
MV_04a
MV_04a - comparing
Train M05T03 is waiting for shunting to port till defined time by Adriafer
Train M05T03 moved immediately after train is available for shunting in TCM
Train M05T03 moved immediately after train is available for shunting in TCM
Train M05T01 is waiting will be moved from port to TCM on Sunday at 02:00 by 1st sh. loco – defined by Adriafer

Comparison:

Track occupation – Terminal 2 (Molo 6)

Legend:

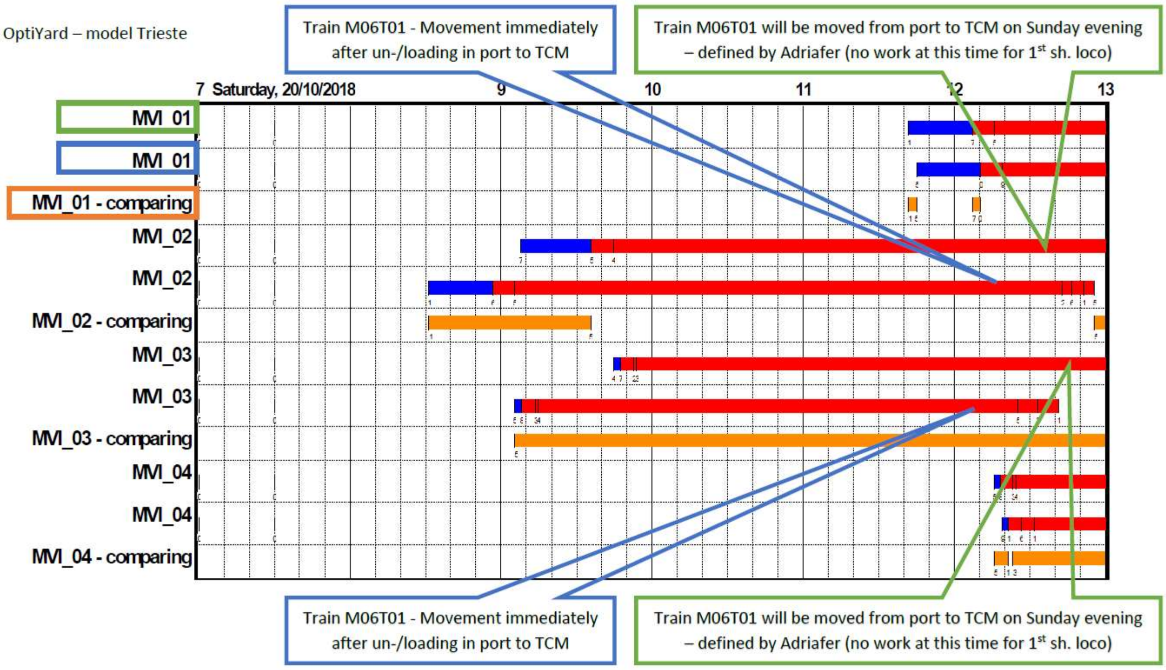
Dark blue: Track Reserved (assigned)

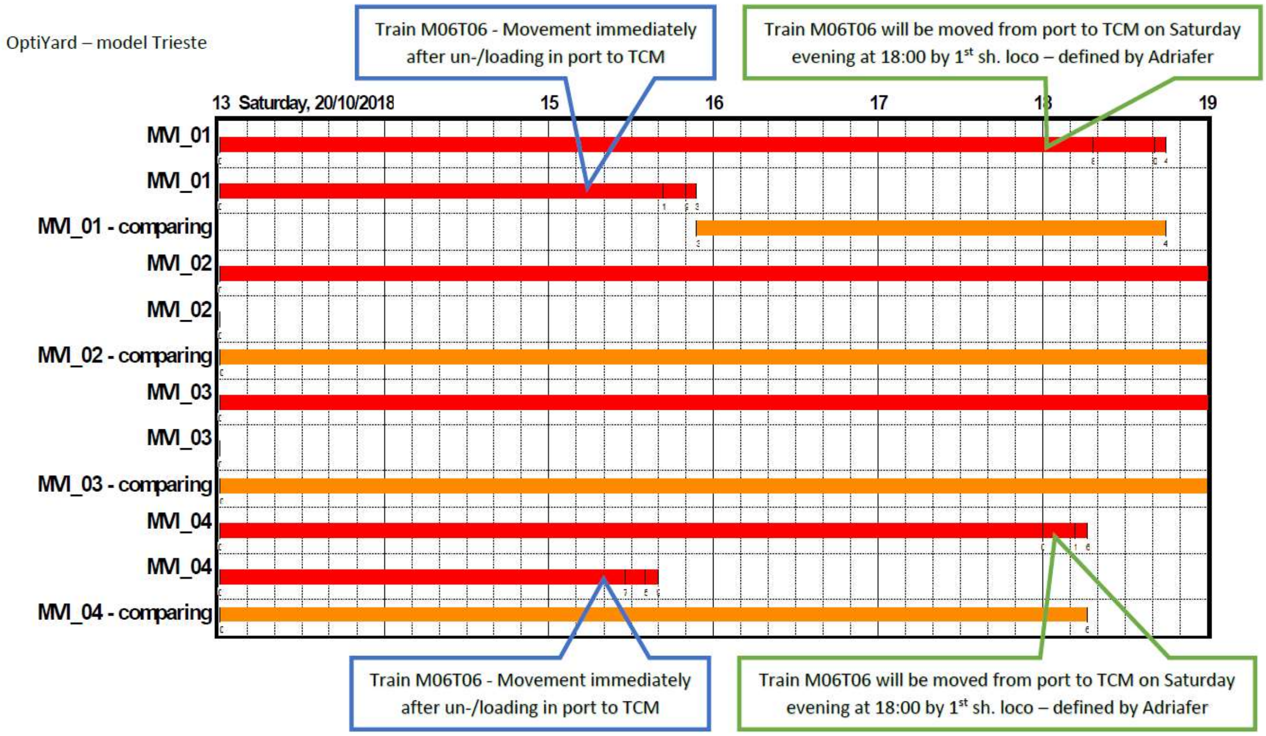
Red: Occupied by train, shunting unit or loco

White: No occupation

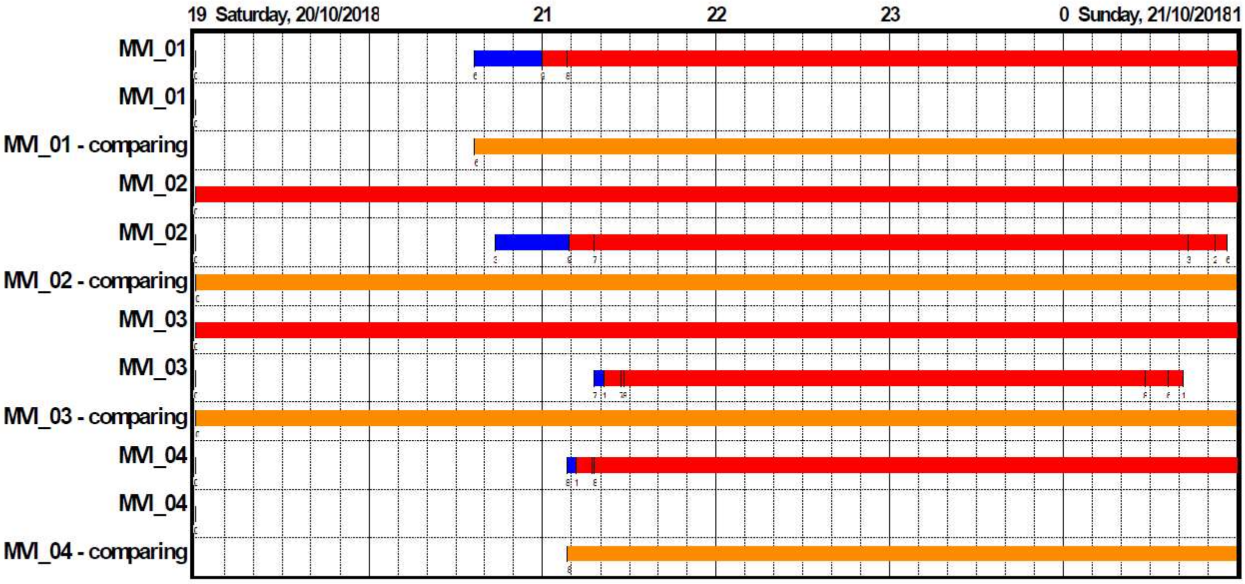
Orange: Difference

In terminal 2 the trains are split in two parts during the un-/loading due the short un-/loading tracks.

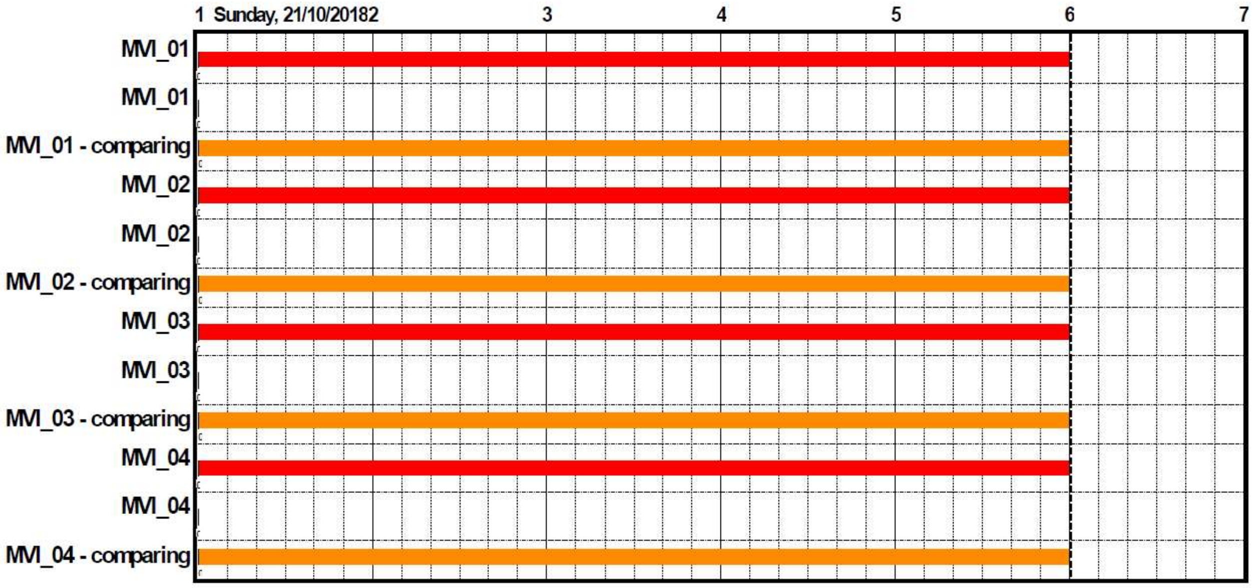




OptiYard – model Trieste
Train M06T06 - Movement immediately after un-/loading in port to TCM
Train M06T06 will be moved from port to TCM on Saturday evening at 18:00 by 1st sh. loco – defined by Adriafer
13 Saturday, 20/10/2018
15
16
17
18
19
MM_01
MM_01
MM_01 - comparing
MM_02
MM_02
MM_02 - comparing
MM_03
MM_03
MM_03 - comparing
MM_04
MM_04
MM_04 - comparing
Train M06T06 - Movement immediately after un-/loading in port to TCM
Train M06T06 will be moved from port to TCM on Saturday evening at 18:00 by 1st sh. loco – defined by Adriafer



19 Saturday, 20/10/2018
21
22
23
0 Sunday, 21/10/20181
MM_01
MM_01
MM_01 - comparing
MM_02
MM_02
MM_02 - comparing
MM_03
MM_03
MM_03 - comparing
MM_04
MM_04
MM_04 - comparing


1 Sunday, 21/10/20182
3
4
5
6
7
MVI_01
MVI_01
MVI_01 - comparing
MVI_02
MVI_02
MVI_02 - comparing
MVI_03
MVI_03
MVI_03 - comparing
MVI_04
MVI_04
MVI_04 - comparing

Comparison:

Track occupation – Terminal 3 (Molo 7)

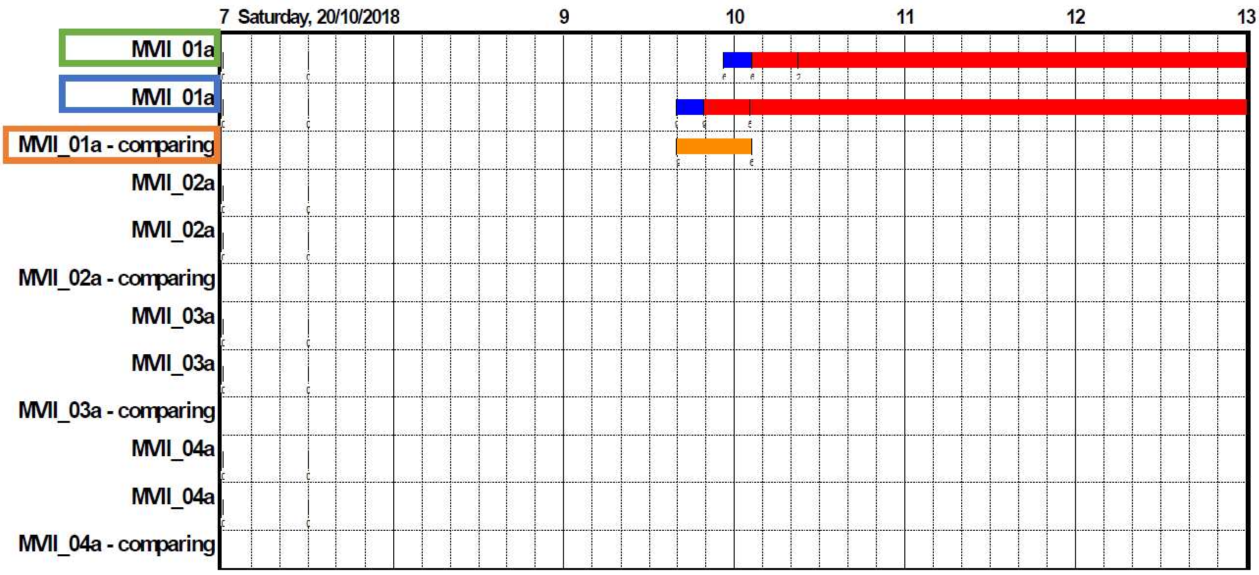
Legend:

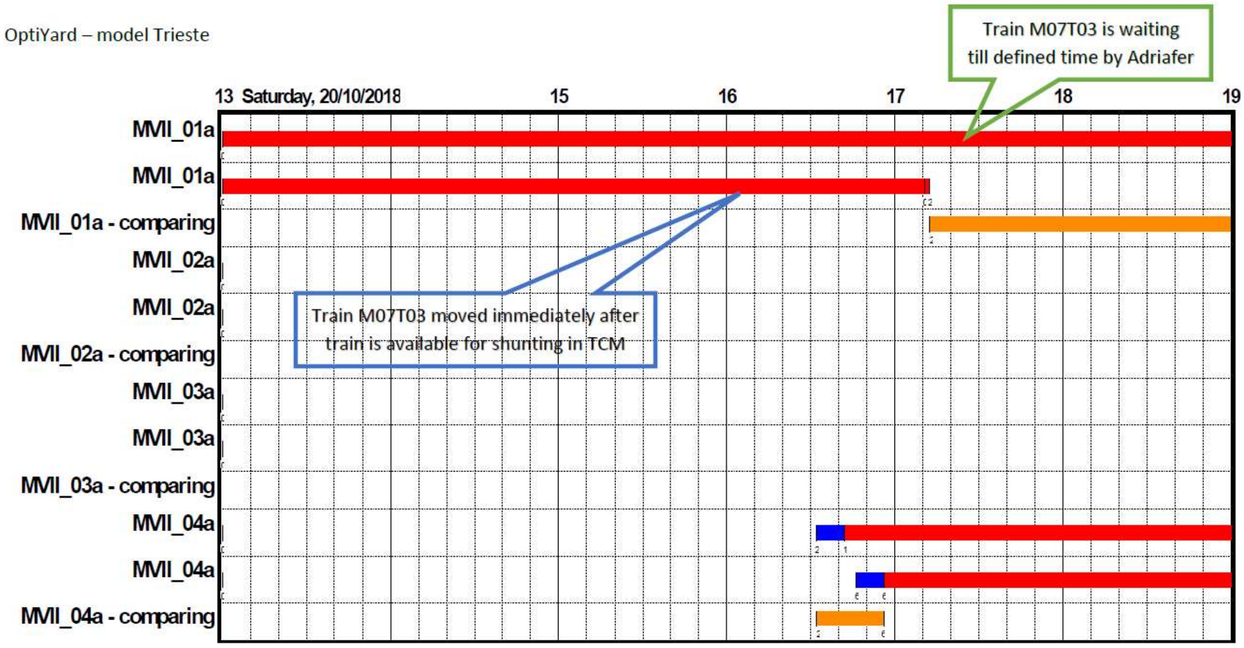
Dark blue: Track Reserved (assigned)

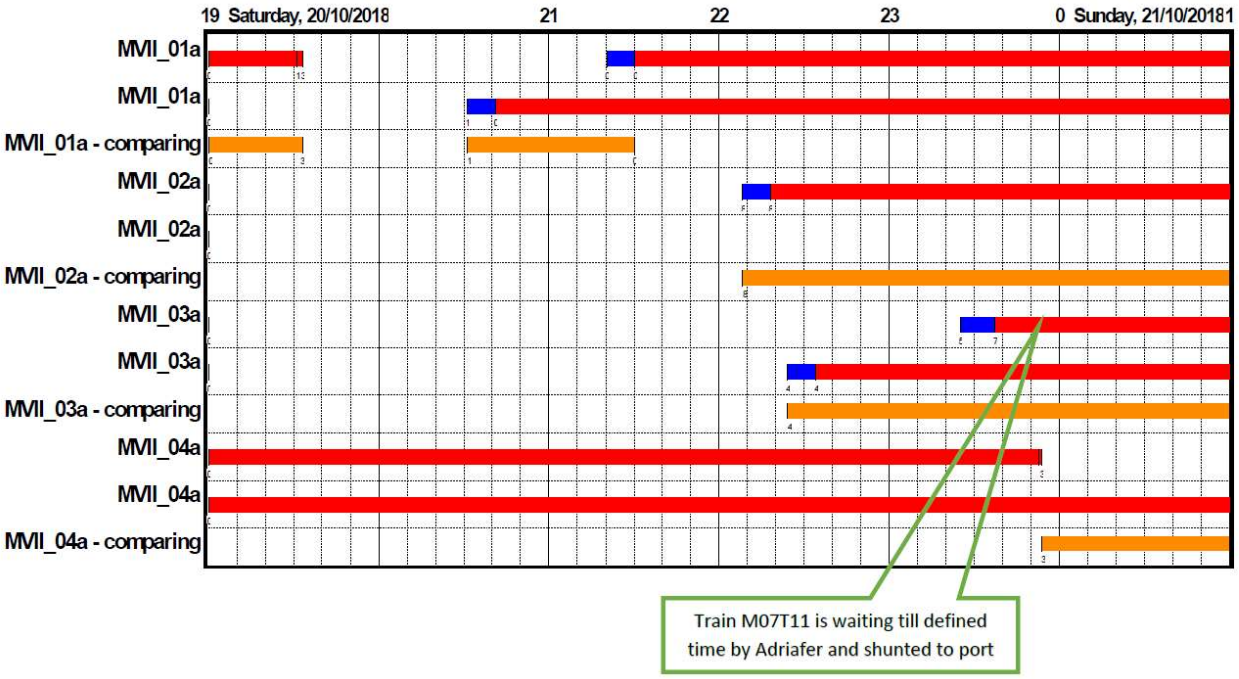
Red: Occupied by train, shunting unit or loco

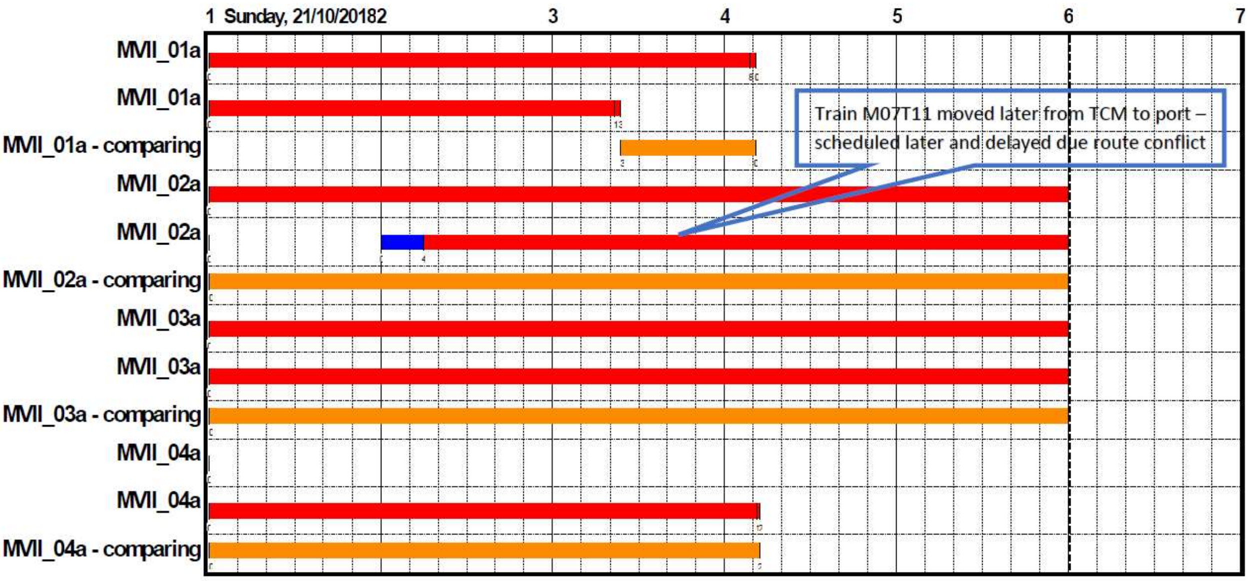
White: No occupation

Orange: Difference




OptiYard – model Trieste
Train M07T03 is waiting till defined time by Adriafer
13 Saturday, 20/10/2018
15
16
17
18
19
MVI_01a
MVI_01a
MVI_01a - comparing
MVI_02a
MVI_02a
MVI_02a - comparing
MVI_03a
MVI_03a
MVI_03a - comparing
MVI_04a
MVI_04a
MVI_04a - comparing
Train M07T03 moved immediately after train is available for shunting in TCM


19 Saturday, 20/10/2018
21
22
23
0 Sunday, 21/10/2018
MVI_01a
MVI_01a
MVI_01a - comparing
MVI_02a
MVI_02a
MVI_02a - comparing
MVI_03a
MVI_03a
MVI_03a - comparing
MVI_04a
MVI_04a
MVI_04a - comparing
Train M07T11 is waiting till defined time by Adriafer and shunted to port


1 Sunday, 21/10/2018
2
3
4
5
6
7
MVI_01a
MVI_01a
MVI_01a - comparing
MVI_02a
MVI_02a
MVI_02a - comparing
MVI_03a
MVI_03a
MVI_03a - comparing
MVI_04a
MVI_04a
MVI_04a - comparing
Train M07T11 moved later from TCM to port – scheduled later and delayed due route conflict

Comparison:

Travelled distance – Shunting locomotives

	Travelled distance in meter	
State of sh. loco (1 and 2)	Non-Optimized	Optimized
Moving to train	23439	33106
Work	51929	62854
Moving from train	12665	18288

The reason for higher travelled distance in optimized simulation run is because the trains return immediately after un-/loading in port to yard Trieste Campo Marzio. Therefore, in the same time period more tasks are assigned to shunting locomotives in scenario with optimized operation comparing to non-optimized simulation run. In following table, the number of served trains by two shunting locomotives are compared.

	Number of served trains	
	Non-Optimized	Optimized
2 shunting locos	16	18

Comparison prepared by Simcon.

2019/10/23