

Digital Twin for Rail Maritime Applications

Prof. Roberto Revetria, Ph.D.



UNIVERSITÀ DEGLI STUDI
DI GENOVA



Introduction

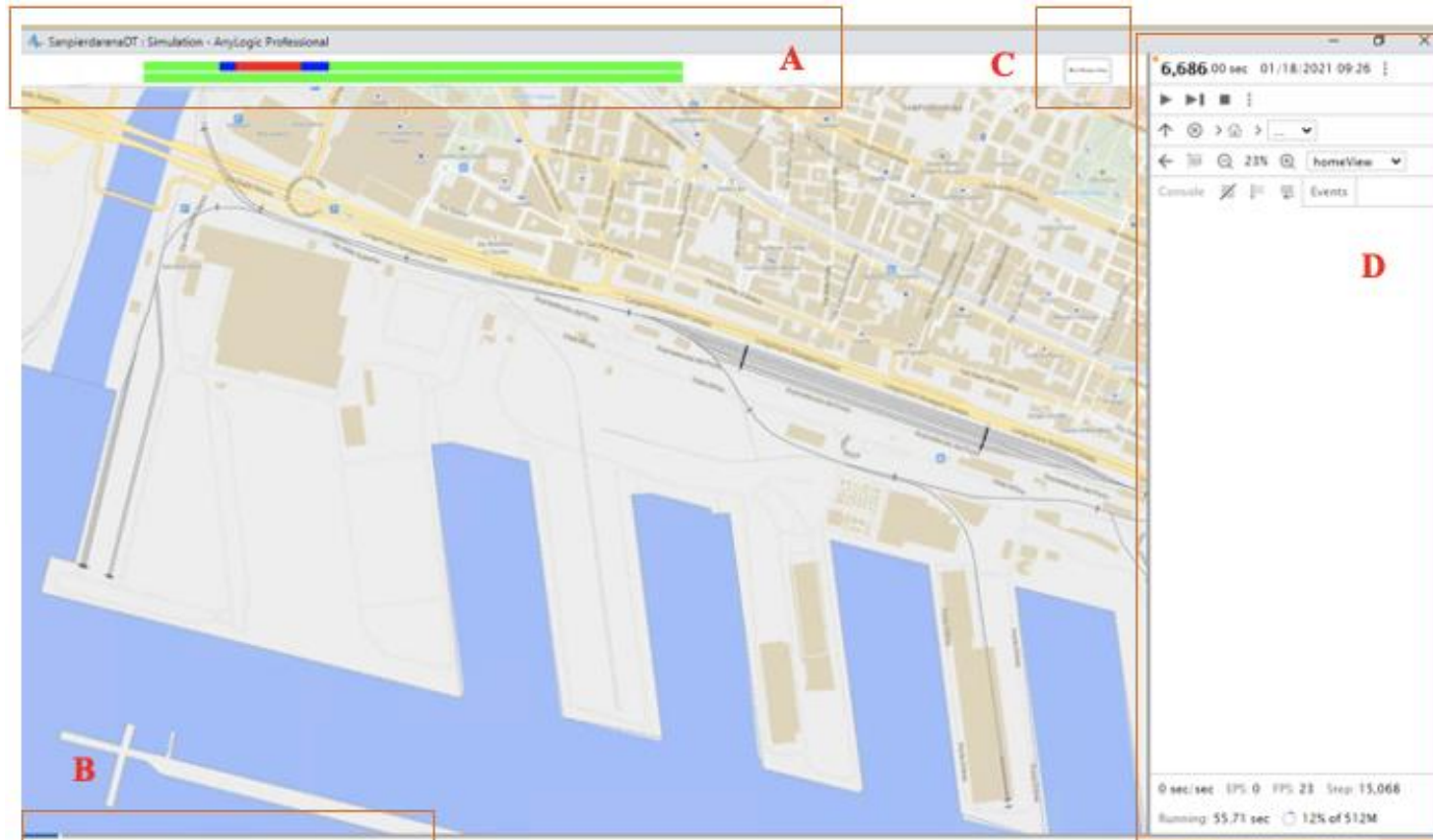
Digital Twin for the simulation and optimization of railroad maneuvers using simulation through AnyLogic software.

Simulation in Port/Train— Previous works

The use of simulation in port and Railway environment is not new and it has already been proved effective. The following two scientific contributions from the D.I.M.E. of the University of Genoa show large benefits in the use of simulation in port/train environment.

1. *Sizing of a 3Mt bulk cargo port through discrete and stochastic simulation integrated with response surface methodology techniques:* A discrete/stochastic simulator has been created to size a bulk cargo port for the unloading of coal to cover the annual requirements of a thermal power plant located next to the berth. The simulator was able to identify problems and critical situations, which, if neglected or not duly considered, would have caused system malfunctions and higher operating costs. Moreover, it was also possible to test the robustness of the solution chosen in the presence of possible changes in the power plant's demand due to possible expansions.
2. *A Different use for Systems Dynamics formalism in harbor modeling: a Case Study:* this paper considers two modeling techniques in order to analyze and design the container terminal systems in a port in the Arabian Gulf region. It aims to evaluate the performance of the maritime operations, the suitability of the loading-unloading devices, the coefficient utilization of berths and the performances of trains and trucks thanks to the integration of Discrete-Event Simulation (DES) with System Dynamics (SD). In particular, SD demonstrated more flexibility in providing rapid prototyping and turned out to be useful for evaluating the number of stored materials, while DES was proved to be more effective in hi-fidelity, hi-detailed models.

Interface



- The Digital Twin is based on operational schemes that were identified during the design phase and validated through several missions simulated according to the project plan.
- The interface is composed by:
 - Main screen with an indicator of the motors state
 - Georeferenced map
 - Series of 3D visualization of selected point of the net
- The interface is divided into 4 areas:
 1. Area A: temporal scheme on the locomotive usage
 2. Area B: representation speed and Digital Twin control
 3. Area C: activation of windows for 3D representation (cameras for operative area and terminal visualization)
 4. Area D: allows different functionality such as selecting a particular time instant in the representation, tuning the zoom factor, exploring the objects in the DT etc.



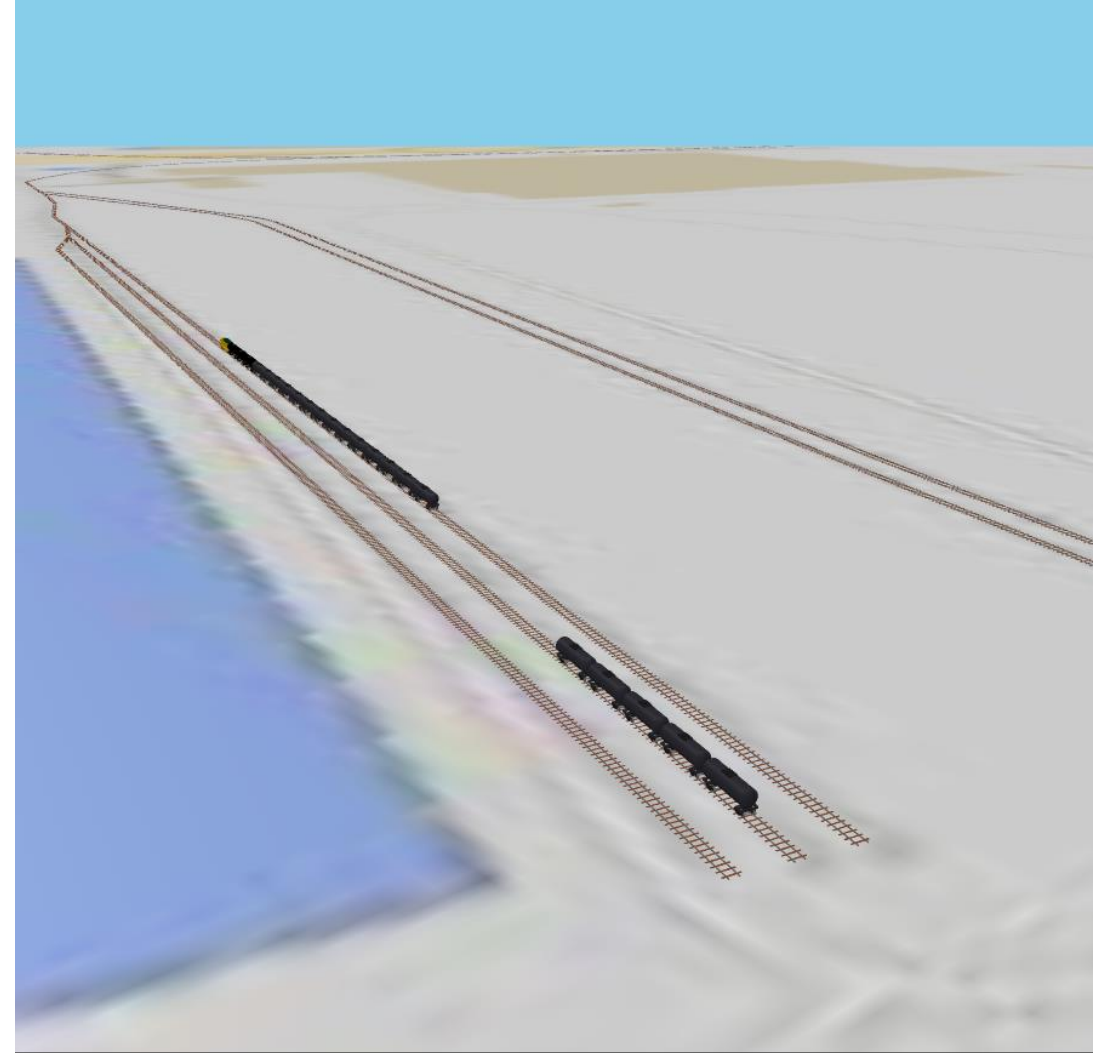
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Camera:9760,3600,100,0,-132
Camera:6820,2780,100,15,-120
Camera:5420,3260,100,0,-125

1
2

Camera 1
Camera 2

On board camera view of the maneuver locomotives

[Return to Home View](#)



3D View

- Since the Digital Twin performs missions and maneuvers defined outside, it is necessary that the data provided are consistent.
- In particular, it is important to guarantee:
 - Univocal train ID
 - Univocal sub ID
 - The maneuvers should always employ an available locomotive
 - The rails should be used in such a way to avoid overlap of maneuvers
 - All the trips from and through the railway net should start and end outside the net
 - The maneuvers should have always the possibility to reach the maneuver point considered

Insertion Rules for Missions

In the Digital Twin there are **two** available types of train movements:

1. Piloting missions that use external (electric) locomotive
2. Maneuver missions that use diesel locomotive

Piloting Missions

Each convoy comes from the outside and it has a unique ID assigned.)Note: there cannot be two convoys with same ID).

Moreover, another field called SUB defines all the wagons that constitute the convoy (i.e., all the convoy except the locomotive). This code is unique too.

There are 4 different topologies record in the “Arrives” table:

- 1) arriving convoy (export) with an electric locomotive that come back on the external line at the end of the piloting
- 2) arriving convoy (export) with electric locomotive that remaining in the terminal at the end of the piloting
- 3) Departing convoy (import) with electric locomotor from the external line
- 4) Departing convoy (import) with electric locomotor already available in the terminal

Maneuver Missions

Those missions are specified in the two tables “mission” and “mission sequence”. The maneuver locomotive must be available right away otherwise the mission cannot be completed.

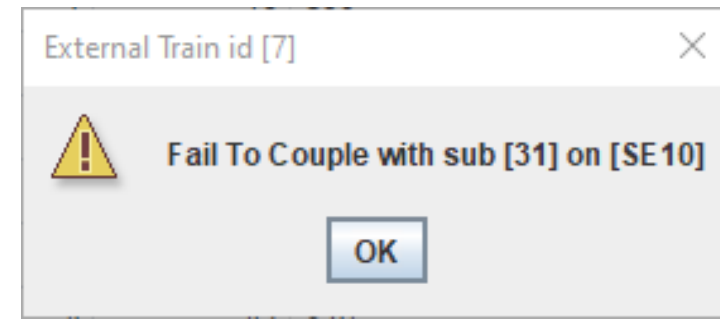
The missions has a sequence of segments (steps) that can be carried out in sequence according to what indicated in the column “seq”. The single segments can be of simple type (such as just one operation), of combined type (two operations) or special type (due combined segments).

Each segment expects a motion from a “dep_point” to an “arr_point”.

There are different segments:

- **Simple (transfer)**
- **Special (transfer with regress)**
- **Simple “couple”**
- **Simple “Decouple”**
- **Simple “Split”**
- **Combined “couple and split”**
- **Special “couple and split”**
- **Simple “end mission”**

Note that some error conditions can easily occur. In this case the visualization process stops, and an error message is shown:



Tables

Tables have been created in order to insert input data of the model:

1. **Car_types:** Type of train wagons/locomotive
2. **Directions:** possible directions of train/locomotive
3. **Locos:** locomotive ID, name, and rail deposit point
4. **Points:** points of interest on the layout
5. **Split_positions:** position where to start counting the train car for the splitting
6. **Trace_ids:** collection of all the trace_id of the the incoming train and of the destination terminal
7. **Arrives:** it has to be filled in by the user with the information about the incoming and departure trains
8. **Mission:** collection of operations performed by the locomotive in order to move the wagons between the different points of the route.
9. **Mission sequence:** information about each operations of each mission.

Mission and Mission Sequence

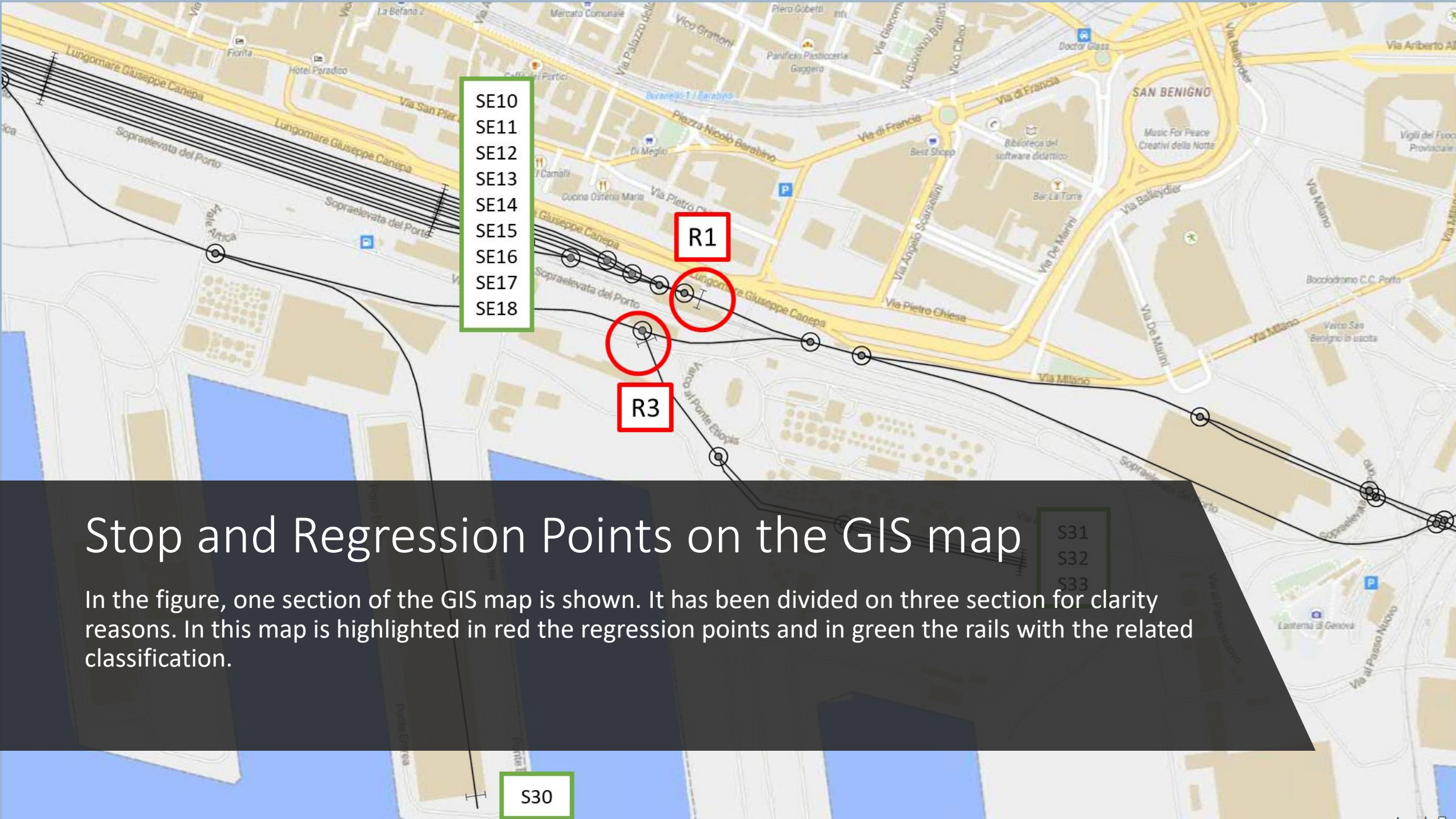
In order to better understand the meaning of mission and mission sequence, the following must be assumed: All the movement operations of the convoy are made by the locomotive. These operations include the train moving from Fuorimuro to the terminals and vice versa, the moving of the split trains to different working, splitting and recompositing rails.

A Mission is the set of operations occurring in a time frame that start from the exit from the depot of the locomotive to its return.

A Mission is composed by more operations described in the rows of the table `mission_sequence`. The operations included in the same mission have the same `id_mission` (for the mission identification) and a progressive sequence number.

Missions Parameters:

- **id_mission:** it identifies the ID of the mission (see table missions)
- **Seq:** it identifies the number of the operation for a determined mission
- **Train_id:** it identifies the train (see ID from table arrives)
- **Sub:** it identifies the train segment considered
- **Dep_point:** point on the starting rail (see table points)
- **Arr_point:** point on the arrival rail (see table points)
- **Direction:** It defined the train direction: 1 if forward or 2 if backward (see table directions)
- **Couple:** it is true If the locomotive docks with to another train/segment of another train
- **Decouple:** it is true if the locomotive undocks with another train/segment of another train
- **Split:** it is true if a train splitting occurs
- **Sub2:** it identifies the split portion of the train.
- **Split_position:** it identifies the position where starting to count the train cart for the splitting
- **N_cars:** it identifies the number of split wagons
- **Mission_end:** it is true when the locomotive has finished the operations and goes back to the depot



- SE10
- SE11
- SE12
- SE13
- SE14
- SE15
- SE16
- SE17
- SE18

R1

R2

R3

Stop and Regression Points on the GIS map

In the figure, one section of the GIS map is shown. It has been divided on three section for clarity reasons. In this map is highlighted in red the regression points and in green the rails with the related classification.

S30

S31
S32
S33



Thanks for your attention!