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ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA
(ICAI)

Master Universitario en Sistemas Ferroviarios

APPLICATION OF RAILML MODELLING TO ERTMS-ETML

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Madrid, Julio de 2016

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Academic course: 2015-2016.

Title: APPLICATION OF RAILML MODELLING TO ERTMS-ETML

Summary:

In the project, it has searched to develop the rail traffic management of the ERTMS. This area of ERTMS is that historically has made less depth, reaching the conclusion that has been null after studying of the state of art. The ERTMS arose from a need that involved the unification of the numerous signaling systems that existed in Europe. Before ERTMS, a train to circulate on different countries, it needs to have equipped each signaling system of each country.

It has made great strides towards interoperability in two of the three areas of ERTMS. These two areas are ETCS and GSM-R, setting standards for them, which are mandatory to ensure interoperability. This is where arises the idea of trying a first approach to the standardization of the third area of ERTMS, the ETML, which covers part of rail traffic management.

This project has been used as a basis railML language, based on their standard models. As a reference for identifying the different parameters involved in the area of rail traffic management is taken as a reference Málaga metro project, lines 1 and 2 developed by Alstom. The analysis and study of the different databases that were part of the Málaga metro signaling was proceeded, identifying the variables that were part of the rail traffic management area. Once identified the parameters used in the Málaga metro project, it has proceeded to its configuration using the RailML models, one by one defining its purpose and the necessary elements for perfect definition. Once configured with RailML, this model could be applied to the management area of ERTMS rail traffic, i.e. it can be applied to ETML.

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Chapter 1. DESCRIPTION

1.1 INTRODUCTION

The railway world nowadays, is in continuous progress and expansion. More and more people use it to make their daily commutes to their jobs or long trips. Cities of all size have seen a great development of the rail network around urban centers to reduce traffic; pollution is now and from long ago a big problem all around the world. At state level, an increasingly number of itineraries connects urban centers, while safer and faster trains have been developed. At the same time railway network has proved itself as a serious alternative to roads for transportation of goods, accounting for fuel savings and in turn increased the speed and ease of transport.

All of this has been achieved largely thanks to the advances of the different subsystems that comprise the railway and especially signaling systems and communication, which has led to a significant increase in performance in capacity trains per hour and security.

This project was born with the idea of focusing on the analysis of one of these signaling systems, the ERTMS, specifically in one of its elements, most likely the one that have been put aside, **ETML**.

The ERTMS (European Railway Traffic Management System) is a system of command and control which has been promoted, sponsored and adopted by the European Union to match all new lines to be built in the countries that compose it. The goal pursued is that signaling and communications between track and onboard equipment is compatible across Europe and the interoperability of railways circulations between the various States of the European Union to make possible; the idea was to contribute to cost efficiency and to coherence the railway safety.

This system harmonizes basically three types of elements, on the one hand the ETCS (European Train Control System), with regard to signaling (in infrastructure and trains), providing data on the maximum speed at each point; the GSM-R, which regulates aspects relating to communications between the train and the third element, the ETML.

The functions of these elements are:

- **ETCS**, (European Train Control System) the signaling element of the system which includes the control of movement authorities, automatic train protection and the interface with the interlocking.
- **GSM-R**, (Global System for Mobile Communications – Railway) a radio system for providing voice and data communication between the track and the train, based on standard GSM using frequencies specifically reserved for rail application with certain specific and advanced functions.
- **ETML,** European Traffic Management Layer.

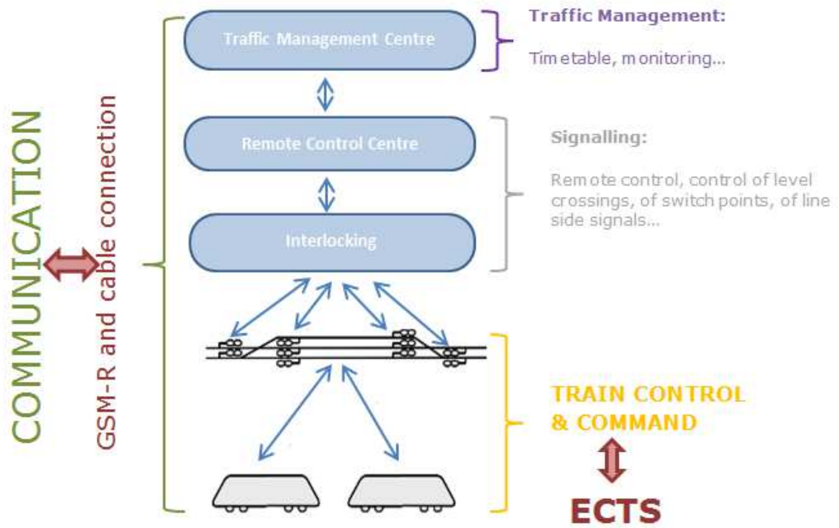

Figure nº: 1 ERTMS elements

The motivation of this project is ETML, which is key area for the optimization of rail services. The deployment of a unique harmonized train command/control and telecommunication systems and the creation of trans-European traffic management facilities constitute crucial elements toward the achievement of a real integrated rail network.

1.2 SUMMARY

This project was created with the idea of developing the area of rail traffic management, focusing specifically in the ERTMS and analyzing the feasibility of implementation of the ETML from standard open models, in particular railML. ETML is selected in this project due to the great development and implementation that ERTMS is having in the world.

During the realization of this project, we will show that the ETML never has fully developed and never have been implemented in any real project. For this reason, Málaga Metro is taken as reference to identify the different elements which composed the traffic management. Even if it is an ERTMS project, it has been considerate that the regulation feature is basically identical. For the realization of this project, it tries to analyze and identify the parameters which have constituted the current signaling system of Metro Málaga (Urbalis 400 © Alstom) and its application in the traffic management and then implemented by railML model.

This chapter shows an overview of this project and a brief description of the three parts in which it is divided:

1. The railML initiative.
2. Metro Málaga project.
3. Traffic Management.

1.2.1 RAILML

The railML initiative was founded in early 2002 against the background of the chronic difficulty of connecting different railways applications. Its main objective is to enable heterogeneous railway applications to communicate with each other. The purpose of the railML initiative has been to find, discuss and present systematic, XML-based solutions for simplified data exchange between railway applications. railML is a joint, evolutionary project of railway companies, software and consulting firms and academic institutions located in a number of countries. The railML is composed for three main parts, which has a correspondence on a sub-schema. These sub-schemas are:

1. Infrastructure.
2. RollingStock.
3. Timetable.

These topics are themselves further divided into additional subschemas that address more specific areas.

1.2.2 AN APPLICATION PROJECT: MÁLAGA METRO

Málaga Metro signaling system was implemented by Alstom on lines 1 and 2. It is based on Alstom`s Urbalis 400 CBTC, a train control system using radio communication which allows real time information about the location of the trains and improves substantially line operability and safety.Radio Communication Based Train Control (CBTC) is the latest generation of signaling technology for metro and suburban rail networks facing increasing urban congestion. It provides operators with precise control in the movement of their trains, allowing more trains to run on the metro line at higher frequencies and speeds in total safety-with or without drivers. The system works with the "moving block" principle to ensure operating headways as short as 90 seconds, and is also generated for heavy metro application, resulting in high line capacity. The saving speed profile is calculated according to each operational context (e.g. peak off peak hour).

1.2.3 TRAFFIC MANAGEMENT (ETML)

The UIC defines ETML as: "The operation management level intended to optimize train movements by the "intelligent" interpretation of timetables and train running data. It involves the improvement of real-time train management and route planning - rail node fluidity - customer and operating staff information". This is the unique definition of the ETML issued by a transport reference entity. With this definition and the analyses of metro Málaga project, the different characterizes and functions of the traffic management should be:

Visualization of the states of the line

Visualization of the states of the line and its different element in real time.

Traffic Planning

Creation of the diagrams for the day`s operations, train list and traffic plan, and provide this information to the control center and operating companies.

Operation Management System

Creation and setting the routes based in the traffic plan. In case of degraded modes, the route control can be taking by the operator.

Power supply and infrastructure

With the control center it is possible to centralization in the control center the management of the central power supply, monitored and controlled each central power supply of the line

Information for passengers

It provides passenger information about the train's departures, arrivals, delays and other information important for the passengers. Also provides information in the emergency situations.

Information for maintenance

Definition the timetable for maintenance and provides this information to the maintenance staff. It provides the information about status of the maintenance in real time.

Driver-only and driverless operation

Control of the trains equipped with ATO (Automatic Train Operation) and control the platform gates.

Chapter 2. OBJECTIVES

The objectives of this project are the followings:

- To show the current state of the art of traffic management layer implementation.

- To demonstrate the advantages for both operators and industry, of sharing unambiguous set of data.

- To demonstrate the feasibility of traffic management layer based on railML models.

Chapter 3. METHODOLOGY

3.1 TASKS

The basic tasks defined to achieve the objectives and develop the assignment are the following:

- Task I: Study of state of the art.
- Task II: Analysis and study of railML models and the ETML used in metro Málaga project.
- Task III: Analysis and implementation of ETML based on ralML models.
- Task IV: Writing the project report.

3.2 PLANNING

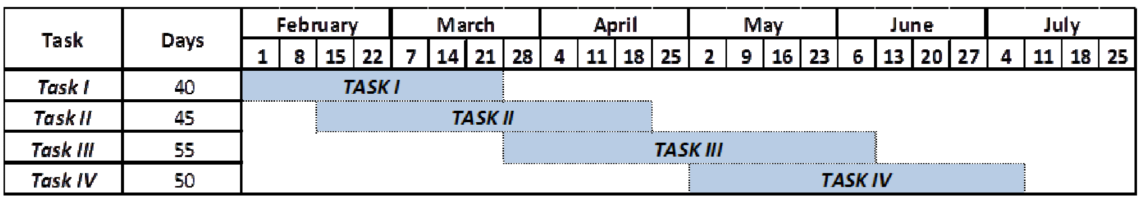

Figure nº: 2 Planning

3.3 STUDY OF THE STATE OF THE ART BASED ON ETML AND TRAFFIC MANAGEMENT LAYER

3.3.1 EXISTING PROJECTS

During the realization of the state of the art, the only project that found focus in the definition of the ETML is OPTIRAILS. The rest of projects are focus in the different areas that compose the rail traffic management.

OPTIRAILS (Optimization of Traffic through the European Rail Traffic Management Systems). The main objective of this project is to specify rail traffic management system architecture (ERTMS/ETML) within the ERTMS framework and applicable to the international railway corridors, improving: real time train dispatching, route planning and operating staff information.

- **Developed by**: European Commission.
- **Country**: France.
- **Scope**: Specify rail traffic management system architecture.
- **Web:** http://www.transport-research.info/sites/default/files/project/documents/optirails.pdf

EUROPTIRAILS (European on line optimization of international traffic through rail management system). This system supports international train management by delivering real time train data concerning international passenger and freight trains. The system can follow the complete train run of an international train across European borders and this relevant train data information is processed directly from the Infrastructure Managers' systems.

- **Developed by**: European commission.
- **Country**: France.
- **Scope**: Optimization of rail traffic.
- **Web**: http://old.uic.org/spip.php?article691

INTEGRAIL (Intelligent Integration of Railway Systems) try to get the intelligent integration of the railway systems by developing a system architecture that establishes intelligent interfaces and processes capable of being used to integrate established railway infrastructure and operational systems. Traffic management is also considered in InteGRAIL.

- **Developed by**: Group of companies.
- **Country**: 10 European countries.
- **Scope**: The improved cooperation of the different existing systems.
- **Web**: http://www.integrail.info

ROMAN. It has been developed by Siemens, it is a propriety product. This application allows the operators to establish the movements of trains, ensuring complete coverage of their lines and minimizing the number of trains in operation. The system takes the timetable of trains and generates on-screen graphs that show the interplay among the vehicles. ROMAN is based in C++ language.

- **Developed by**: Siemens.
- **Country**: Austria.
- **Scope**: Traffic management and timetable planning.
- **Web**: https://www.siemens.com/global/en/home.html

VIRIATO is timetable planning tool that allows operators to optimize the railway planning process. The first version of Viriato was created in 1996 but during the next years, a number of additional functionalities have been added. The Viriato interface consists of the graphic timetable, travel time analysis, conflict detection, network diagrams, platform occupation and customer timetables in addition to data manipulation features. Large amounts of detailed data can be used to prepare precise plans to maximize network capacity and identify cost efficient strategies.

- **Developed by**: SMA and Partners Ltd.
- **Country**: Switzerland.
- **Scope**: Timetable planning.
- **Web**: http://www.sma-partner.com/en/

ON-TIME project is developing new methods and processes to help maximize the available capacity on the European railway network and to decrease overall delays in order to both increase customer satisfaction and ensure that the railway network can continue to provide a dependable, resilient and green alternative to other modes of transport. In the project, specific emphasis is being placed on approaches for alleviating congestion at bottlenecks. Case studies being considered include passenger and freight services along European corridors and on long distance main-line networks and urban commuter railways.

- **Developed by**: Consortium of 19 companies.
- **Country**: Italy.
- **Scope**: Maximize the available capacity.
- **Web**: http://www.ontime-project.eu/

OPENTRACK project stars as a research project at the Swiss Federal Institute of Technology. The railway simulation tool OpenTrack is planning software, which includes: Network data, Rolling stock data and timetable data based in railML.

- **Developed by**: The Swiss Federal Institute of Technology.
- **Country**: Switzerland.
- **Scope**: Railway simulation.
- **Web**: http://www.opentrack.ch/

MULTIRAIL is software for rail operational planning. This software allows the operators to create the operating plans based on infrastructure and demand. The different functionalities are: managing networks, importing and managing traffic data, designing blocks, flowing the traffic over the blocks, and building trains that support the traffic and blocks.

- **Developed by**: Oliver Wyman.
- **Country**: United States, France and Switzerland.
- **Scope**: Operational planning.
- **Web**: http://www.oliverwyman.com/index.html

RAILNET II software to represents train runs, obtaining data of train speed, running times, tractive effort, and energy consumption. With this information the operator can develop the timetable. The software presents data about graphic operations. The two principal functions of the software are the train run computation and timetable development. The software is based in track layout, rolling stock characteristics, and operating procedures.

- **Developed by:** The Swiss Federal Institute of Technology.
- **Country:** Switzerland.
- **Scope:** Trains representation and timetable planning.
- **Web:** http://railnet2.epfl.ch/

RAILSYS is software to optimize the capacity of the line. RailSys constantly follows the idea of an integrated planning system for the rail transport, but also provides a very flexible use for the integration and functionality.

- **Developed by:** RMCon.
- **Country:** Germany.
- **Scope:** Optimize the capacity.
- **Web:** http://www.rmcon.de/home-en/

DAVINCI is a Spanish system for the traffic control. This system allows the implementation from the planning until the implementation of this planning in real time. The different functionalities of this system are: Simulation travel time using advanced algorithms to calculate the speed of trains, administration of rolling stock, that it includes all vehicles and functions, management of timetables for planning (departures, arrivals, stops, speeds, delays, routes…etc), allow the automatic set of route and includes the evaluation of alternatives and conflict resolution, Space-Time diagrams in real time…etc.

- **Developed by:** Indra and Adif.
- **Country:** Spain.
- **Scope:** Implementation from the planning until the implementation of this planning in real time.
- **Web:** http://www.indracompany.com/es

Chapter 4. DEPLOYMENT

4.1 IMPLEMENTATION

4.1.1 MÁLAGA METRO PROJECT

Metro Málaga has been taken as reference. In this project, the traffic management was done from the point of view of time planning, without regulation in real time.

ATS (Automatic Train Supervision) is configured by Alstom through four files. A study of the four files was performed to obtain the parameters that were used to perform the timetable of the project. With this identification of the parameters, a study of each variable include in railML started.

4.1.2 RAILML

The version used to the realization of this project is version 2.3. The railML is composed for three main parts, which has a correspondence on a sub-schema.:

1. Infrastructure.
2. RollingStock.
3. Timetable.

1. Infrastructure:

The railML infrastructure sub-schema is focused on the description of the railway network infrastructure including all its various facets that are needed by the data exchange applications. In particular, the railML infrastructure schema contains the following information:

1. **Infra Attributes:** describes the properties of an infrastructure group, these elements are:
    - **Axle Weight** sets the maximum load per axle in tons for a track element.
    - **Electrification** defines the electrification system that is used at all tracks.
    - **Gauge** defines the distance of both rails.
    - **General Infra Attributes** works as a container element for defined infrastructure attributes, which are not covered by the other child elements of infra Attributes.
    - **Operation Mode** defines the operational system that is used at all tracks.
    - **Owner** defines the infrastructure manager (IM) of all tracks where the current Infra Atributes are used per reference.
    - **Power Transmission** defines the kind of railway in means of power transmission of all tracks.
    - **Speeds** works as a container element for defined static speed profiles.
    - **Train Protection** defines the train protection system that is used at all tracks.
2. **Operation Control Points:** works as a "container element" for operation or control point elements. These elements are:
    - **Area** specifies the region; an operation control point is responsible for.
    - **Geo Coord** provides the definition of a geographical position (e. g. longitude, latitude, altitude). It can be used in case that element positions should not only be specified by relative or absolute mileage along the track but via geographical reference as well.
    - **Prop Equipment** is a container which encapsulates two variants to define the (technical) equipment of an ocp.
    - **Prop Operational** contains attributes which further refine the operational properties of an ocp.
    - **Tsi** contains the standard numerical codings of locations set by the ERA in the Annex B9 of the Telematic applications for passenger service (TAP).

3. **Track Groups:** is a container that allows the definition of logically grouped tracks under various criteria.
    - **Locally Controlled Area** A locally controlled area is an area of tracks, points and signals which is usually operated by an (central) interlocking but which can be detached from this interlocking for local control.
4. **Tracks:** works as a container element for track elements.

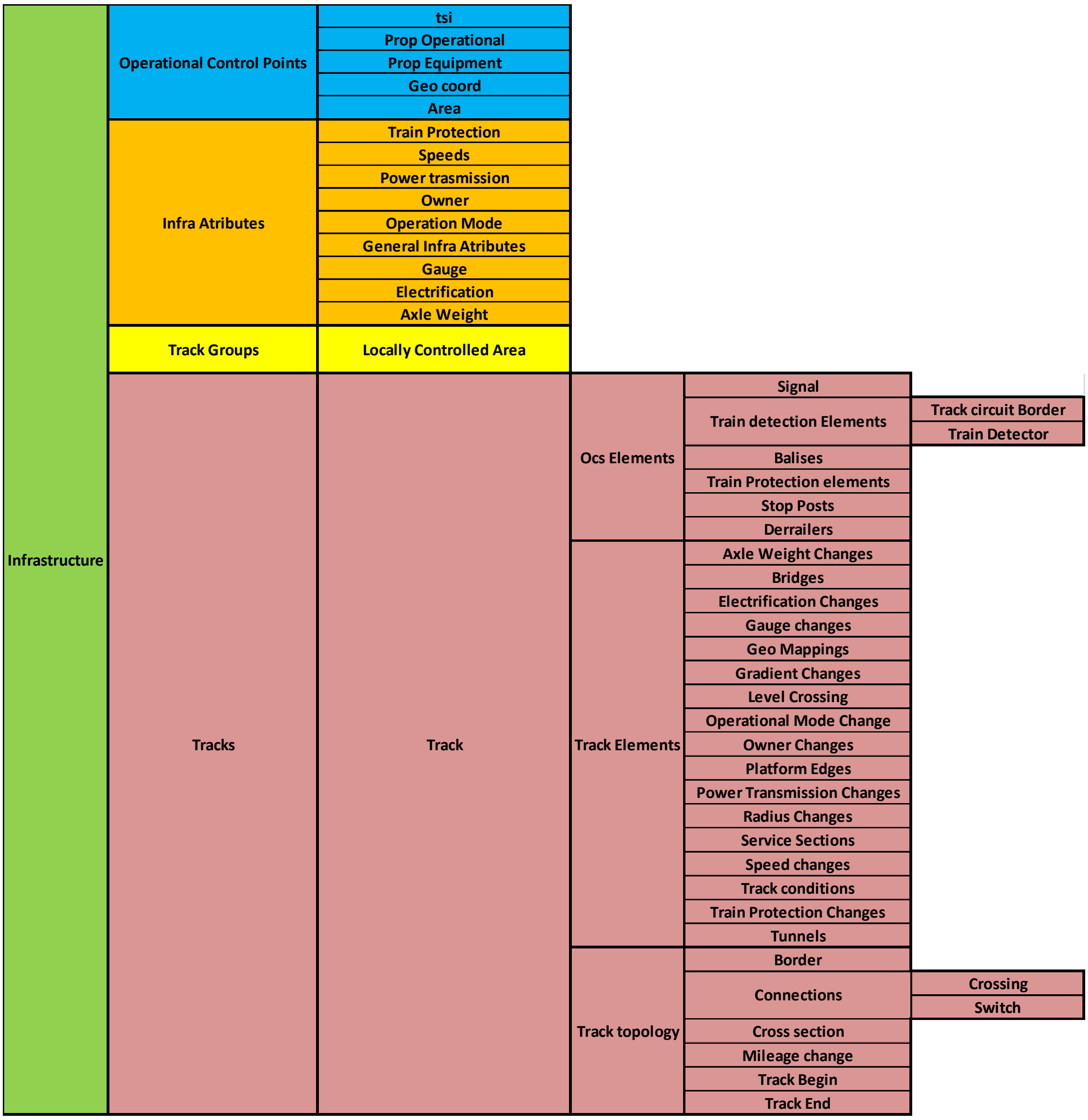

Figure nº: 3 Infrastructure sub-schemas

2. Rollingstock

The railML rollingstock subschema is focused on the description of the railways rolling stock including all its various facets that are deemed to be needed by the data exchange applications. In particular, the railML rollingstock schema contains the following information:

1. **Vehicles:** The characteristics of individual railway vehicles or vehicle families are described in this part of the schema. The description of vehicles considers some general data used for organizing assets like naming, classification or vehicle numbers as given by its operator. The majority within the schema is providing the structure to store the various technical aspects of railway vehicles with regard to their propulsion system, car body features, brakes or services installed within the vehicle.
    - **Vehicle**: The item is referenced via its attribute id. The data set of a single vehicle can refer to the common values and define more or deviating characteristics valid only for this particular vehicle.
2. **Formations:** The features of train sets or parts of it formed of several different or similar vehicles are described in this part. This combination of vehicles is used to describe train features as needed e.g. in timetables. However, the logical consistency between the formation and the vehicles it is made of is not enforced by the schema. It must be ensured by the application producing the data.
    - **Formation** contains all data related to a composition of single vehicles forming a complete train or a part of a train. It is not excluded to describe a train consisting of only one single vehicle.

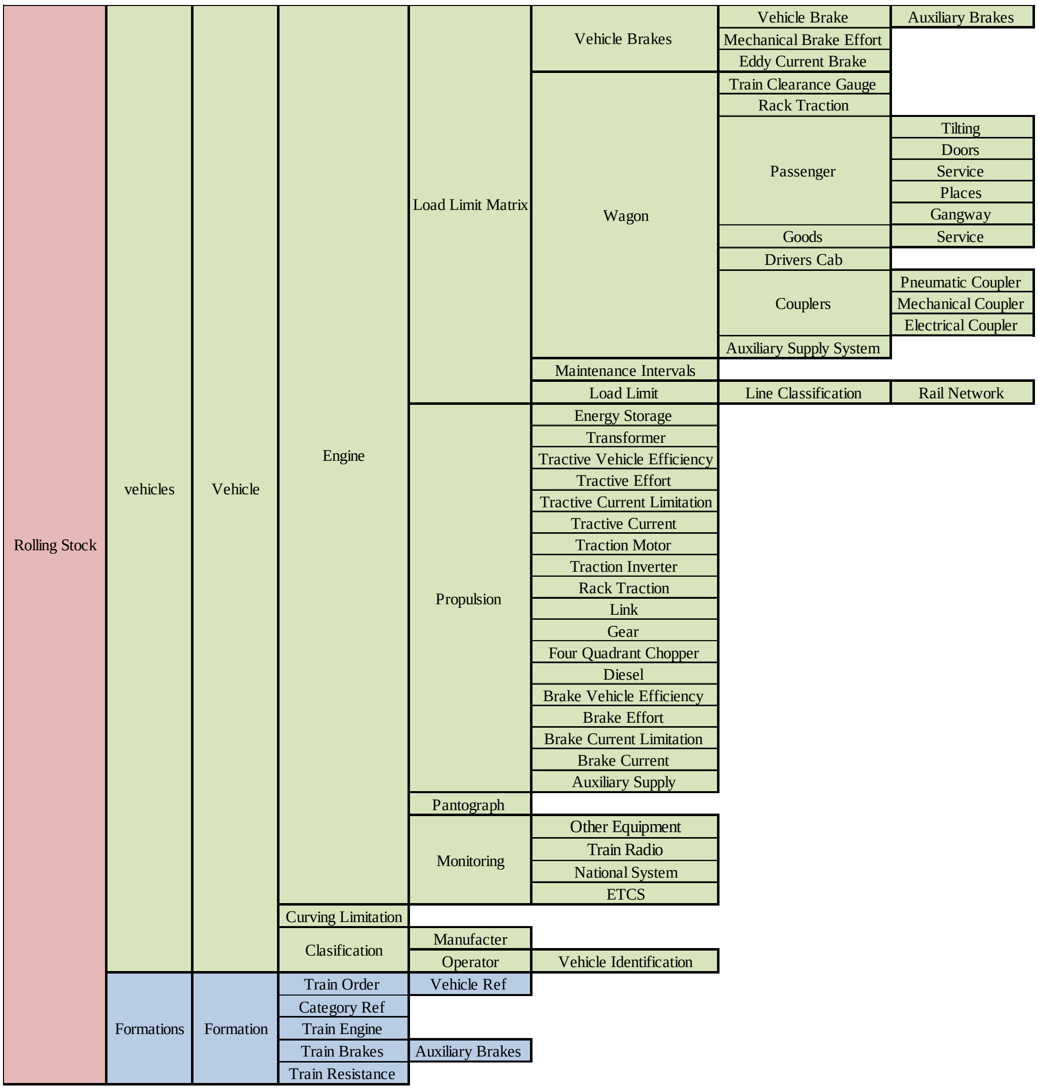

Figure nº: 4 Rolling stock sub-schemas

After the analyses of railML and Málaga metro, the basic parameters for ETML are identified.

3. ***Timetable***

The railML timetable sub-schema is focused on the description of the railway timetable. In particular, the railML timetable schema contains the following groups:

1. **Operating Periods:** The operating days for train services or roistering. It is composed of two groups:
   - **Operating Day**: gives a week based in the operating period for a normal day.

- **Special Service**: Describes a calendar based in the modification of the operation period by including or excluding certain days or periods.

2. **Timetable Periods:** Defines a timetable period, lasting typically about a year. It is composed for Holiday element.
    - **Holiday:** Defines one of the public holidays referred to by an operating period like all days, excluding public holidays.
3. **Category:** describes a "train type" or "train category".
4. **Annotation:** contains texts and messages dedicated for a passenger information system.
5. **Train Parts:** Includes the actual information regarding the path of the train as well as the corresponding schedule information. It is composed by:
    - **FormationTT:** describes how a formation is used for a Train Part.
    - **Operating Period Ref**: This group is used for referencing the **Operating Period** and **Train Part**.
    - **OcpsTT:** To define the different elements of the trip
    - **Organizational Unit Binding** describes what organizational units are responsible for this **Train Part**.
6. **Trains:** One or more train parts make up a train and represent either the operational or the commercial view of the train run. Describes a train for different perceptions. A train could either be an "operational train" in the view of a signal box, or it can be "commercial train" from the view of a passenger. It is composed by:
    - **Train Part Sequence:** all elements Train Part belonging to a train. The sequence is supposed to be used for successive parts along the train route.
    - **Taf Tap Tsi TrainID** describes the so called unique Transport ID, used for the explicit identification of a train, especially for international train runs.
7. **Train Group:** is linking different individual trains to a group. This could for instance be used for an interval group of trains belonging together in a train path allocation process.

8. **Rostering:** Train parts can be linked to form the circulations necessary for roistering (rolling stock schedules). It composed by:
   - The element **Block Part** contains all data, which are related to an atomic particle of a block.
   - The element **Block** contains all data, which are related to a "vehicle duty" containing a sequence of atomic tasks (Block Parts). The item is referenced via its id attribute.
   - The element **Circulation** is for chaining the blocks into a complete rostering.

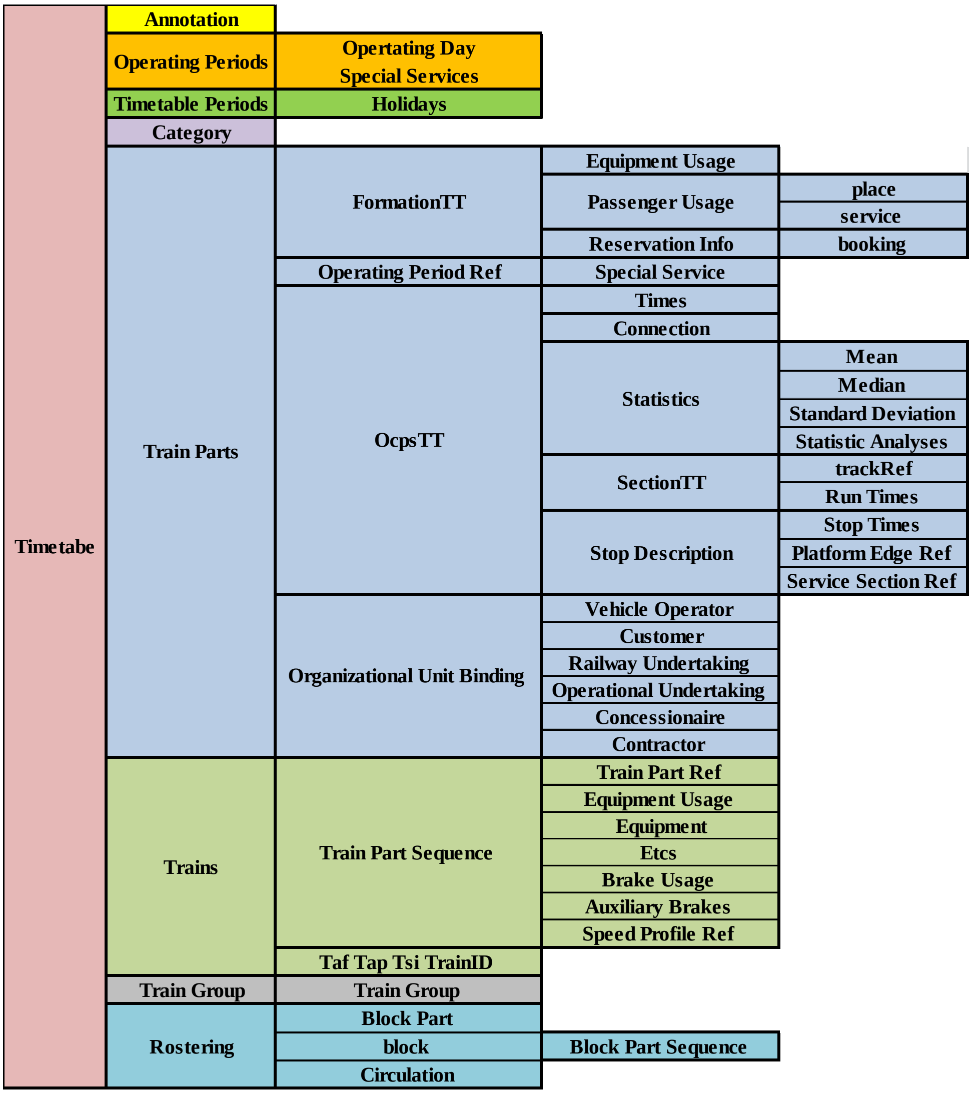

Figure nº: 5 Timetable sub-schemas

4.1.3 PARAMETERS IDENTIFICATION

Infrastructure and Operation:

First of all, it is necessary a track layout description of the line. For the traffic management, is important to know the track layout of the line and the position of the different signaling elements to follow the state of the line in real time. To earn this, the infrastructure part of railML is used. The line shall be divided in tracks. This division is free and the different **tracks** shall be containing three types of elements: **trackTopology**, **trackElements** and **ocsElements**.

```
<track id="" name="">
    <trackTopology>
    <trackElements>
    <ocsElements>
</track>
```

Figure nº: 6 track elements

trackTopology: contains the next information: trackBegin, trackEnd, and connections.

- **trackBegin**: Contains information about the beginning of the track. The track begin can be a buffer stop or connection. This element is defined as follow:

Parameter	Justification
trackBegin	Contain the track begin of the track
id	Id of the element
pos	Position of the element
absPos	Kilometric point of the element
bufferStop	Element at the beginning of the track
id	Id of the element
name	Name appears in the visualization
connection	Element at the beginning of the track
id	Id of the element
ref	Other track reference

Table 1: trackBegin elements description

```
<trackBegin id="" pos="" absPos="">
    <bufferStop id="" name=""/>
</trackBegin>
```

Figure nº: 7 Example of trackBegin

- **trackEnd:** Contains information about the ending of the track. The track end can be a buffer stop or connection. This element is defined as follow:

Parameter	Justification
trackEnd	Contain the track end of the track
id	Id of the element
pos	Position of the element
absPos	Kilometric point of the element
bufferStop	Element at the end of the track
id	Id of the element
name	Name appears in the visualization
connection	Element at the end of the track
id	Id of the element
ref	Other track reference

Table 2: trackEnd elements description

```
<trackEnd id="" pos="" absPos="">
    <connection id="" ref=""/>
</trackEnd>
```

Figure nº: 8 Example of trackEnd

- **connections:** contains information about the points located in this track. This element can be defined as follow:

Parameter	Justification
connections	Contain each switch exist in the track
switch	Switch exist in the track
id	id of the switch
name	Name appears in the visualization of the switch
dir	Switch direction
sen	Inverse direction of the switch
absPos	Kilometric point of the switch
connection	Connection associated to the switch
id	id of the connection

Parameter	Justification
ref	other trackBegin/trackEnd reference
orientation	Orientation of the switch
course	Direction of the switch
maxSpeed	Maximum speed of the point

Table 3: connections elements description

```
<connections>
    <switch id="" name="" pos="" absPos="" absPosOffset="" length="">
        <connection id="" ref="" orientation="" course="" maxSpeed="" />
    </switch>
</connections>
```

Figure nº: 9 Example of connections

```
<trackTopology>
    <trackBegin id="" pos="" absPos="">
        <bufferStop id="" name=""/>
    </trackBegin>
    <trackEnd id="" pos="" absPos="">
        <connection id="" ref=""/>
    </trackEnd>
    <connections>
        <switch id="" name="" pos="" absPos="" absPosOffset="" length="">
            <connection id="" ref="" orientation="" course="" maxSpeed="" />
        </switch>
    </connections>
</trackTopology>
```

Figure nº: 10 Example of trackTopology structure

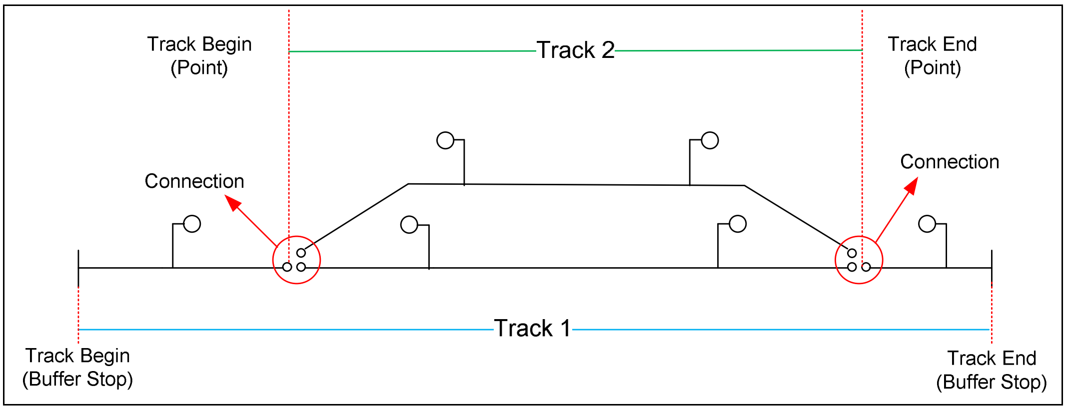

Figure nº: 11 Example of trackTopology elements

trackElements: Contains information about static speed profile, gradient profile and platforms of the track.

- **speedChanges:** Define the different SSPs located in the track. This Speed changes is defined as follow:

Parameter	Justification
speedChanges	**Contain each SSP exist in the track**
speedChange	**SSP exist in the track**
id	id of the SSP
name	Name appears in the visualization of the SSP
pos	Position of the SSP
dir	Direction of the SSP
absPos	Start kilometric point of the SSP
status	Status of the SSP
vMax	Speed of the SSP

Table 4: speedChanges elements description

```
<speedChanges>
    <speedChange id="" name="" pos="" dir="" absPos="" status="" vMax=""/>
    <speedChange id="" name="" pos="" dir="" absPos="" status="" vMax=""/>
</speedChanges>
```

Figure nº: 12 Example of speedChanges

- **gradientChange:** Define the different gradients located in the track. This gradient changes is defined as follow:

Parameter	Justification
gradientChanges	**Contain each gradient exist in the track**
gradientChange	**Gradient exist in the track**
id	id of the gradient
name	Name appears in the visualization of the gradient
pos	Position of the gradient
dir	Direction of the gradient
absPos	Start kilometric point of the gradient
slope	Slope of the gradient

Table 5: gradientChanges elements description

```
<gradientChanges>
    <gradientChange id="" name="" pos="" dir="" absPos="" slope=""/>
    <gradientChange id="" name="" pos="" dir="" absPos="" slope=""/>
</gradientChanges>
```

Figure nº: 13 Example of gradientChange

- **PlatformEdges:** Define the different platforms located in the track. This element is defined as follow:

Parameter	Justification
PlatformEdges	**Contain each platform exist in the track**
PlatformEdge	**Platform exist in the track**
id	id of the platform
name	Name appears in the visualization of the platform
absPos	Start kilometric point of the platform
Lenght	Length of the platform

Table 6: PlatformEdges elements description

```
<PlatformEdges>
    <PlatformEdge id="" name="" absPos="" Lenght=""/>
    <PlatformEdge id="" name="" absPos="" Lenght=""/>
</PlatformEdges>
```

Figure nº: 14 Example of PlatformEdges

```
<trackElements>
    <speedChanges>
        <speedChange id="" name="" pos="" dir="" absPos="" status="" vMax=""/>
        <speedChange id="" name="" pos="" dir="" absPos="" status="" vMax=""/>
    </speedChanges>
    <gradientChanges>
        <gradientChange id="" name="" pos="" dir="" absPos="" slope=""/>
        <gradientChange id="" name="" pos="" dir="" absPos="" slope=""/>
    </gradientChanges>
    <PlatformEdges>
        <PlatformEdge id="" name="" absPos="" Lenght=""/>
        <PlatformEdge id="" name="" absPos="" Lenght=""/>
    </PlatformEdges>
</trackElements>
```

Figure nº: 15 Example of trackElements structure

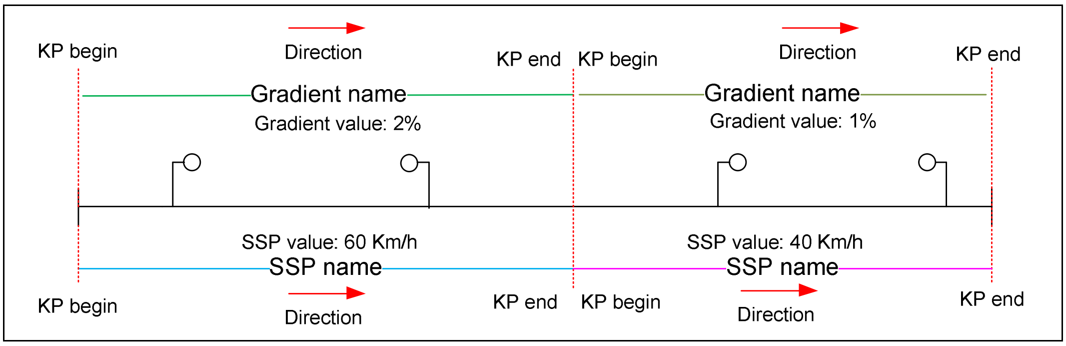

Figure nº: 16 Example of trackElements definitions

ocsElements: contain operation and control system elements, these elements are **train detection elements**, **balises, Stop Posts,** and **signals** of each track with its real localization.

- **trainDetectionElements:** Elements to define the different characteristics of each joint located in the track. It is used to define the limit of the track occupation. This element is defined as follow:

Parameter	Justification
trainDetectionElements	**Contain the different track circuit joint of the track**
trackCircuitBorder	**Each track circuit joint exist in the track**
id	Id of the joint
dir	Direction of the joint
Pos	Position of the joint
absPos	Kilometric point of the joint
absPosOffset	Offset added to the kilometric point of the joint
name	Name of the track circuit

Table 7: trainDetectionElements elements description

```
<trainDetectionElements>
    <trackCircuitBorder id="" dir="" pos="" absPos="" absPosOffset="" name="" />
</trainDetectionElements>
```

Figure nº: 17 Example of trainDetectionElements

- **balises:** Elements to define the different balises located in the track. It is used to locate the trains. This element is defined as follow:

Parameter	Justification
balises	
balise	**Each balise of the track**
id	Identifier of the balise
name	Name appears in the visualization of the balise
countryID	Identifier of the country
groupID	Identifier of the balises group
linkingAccuracy	Margin error between balise
linkReactionAscending	Ascending reaction
linkReactionDescending	Descending Reaction
ndx	Position of the balise inside of the group
dir	Direction of the balise
absPos	Kilometric point of the balise
pos	Position of the balise
baliseGroup	**Each balise group of the track**
id	id of the balise group
name	Name appears in the visualization of the balise group

Table 8: balises elements description

```
<balises>
    <balise id="" name="" CountryID="" groupID=""
    linkingAccuracy="" linkReactionAscending="" linkReactionDescending="" ndx="" dir="" absPos="" pos=""/>
    <baliseGroup id="" name="" />
</balises>
```

Figure nº: 18 Example of balises

- **signals:** Element to define the different characteristics of each signal located in the track. This element is defined as follow:

Parameter	Justification
signals	Contain each signal exist in the track
signal	Signal exist in the track
id	id of the signal
name	Name appears in the visualization of the signal
pos	Position of the signal
absPos	Kilometric point of the signal

Parameter	Justification
dir	Direction of the signal
sigSystem	Type of the signalling system of the signal

Table 9: Signals elements description

```
<signals>
    <signal id="" name="" pos="" absPos="" dir="" sigSystem=""/>
</signals>
```

Figure nº: 19 Example of Signal

- **StopPosts:** Element to define the different stop location exist in the different platforms of the track, It can be in function of length of trains, position of the stairs in the station…etc.

Parameter	Justification
StopPosts	**Contain each stop exist in the track**
StopPost	**Stop location in a platform**
id	id of the stopping point
name	Name appears in the visualization of the stopping point
dir	Direction of the stopping point
absPos	Kilometric point of the stopping point
PlatformEdges	Reference id of the platform in the infrastructure file

Table 10: StopPosts elements description

```
<StopPosts>
    <StopPost id = "" name "" dir="" absPos="" PlatformEdges=""/>
</StopPosts>
```

Figure nº: 20 Example of StopPost

```
<ocsElements>
    <signals>
        <signal id="" name="" pos="" absPos="" dir="" sigSystem=""/>
    </signals>
    <balises>
        <balise id="" name="" CountryID="" groupID="" linkingAccuracy=""
        linkReactionAscending="" linkReactionDescending="" ndx="" dir="" absPos="" pos=""/>
        <baliseGroup id="" name="" />
    </balises>
    <trainDetectionElements>
        <trackCircuitBorder id="" dir="" pos="" absPos="" absPosOffset="" name="" />
    </trainDetectionElements>
    <StopPosts>
        <StopPost id = "" name "" dir="" absPos="" PlatformEdges=""/>
    </StopPosts>
</ocsElements>
```

Figure nº: 21 Example of ocsElements structure

With the previous elements a basic track layout of the line is defined. **The visualization of the states of the line** and its different element in real time are covered with the previous elements.

For the **operation management**, the previous elements shall be complemented with the elements provided by the interlocking. The elements are:

- **Track Circuits:** represents an area for which its occupation status is provided by Interlocking.
- **Routes:** Each route normally is defined between two signals. The status of each route is provided by interlocking.

To define the route it is necessary to add another file, because with railML files it is not possible. The definition of the route is as follow:

Parameter	Justification
Tgm-Routes	Describe the train
Tgm-Route	Id of the train
RouteDescription	It includes all the elements of the route (signals and switches)
Mask	It is the id of the information providing for Interlocking

Table 11: Tgm-Routes elements description

```
<Tgm-Routes>
    <Tgm-Route RouteDescription="" Mask=" "/>
    <Tgm-Route RouteDescription="" Mask=" "/>
</Tgm-Routes>
```

Figure nº: 22 Example of Tgm-Route

Timetable

TrainParts: Includes the actual information regarding the path of all the trains.

- **trainPart**: Includes the actual information regarding the path of the train as well as the corresponding schedule information. This element is defined as follow:

Parameter	Justification
trainPart	Describe the train
id	Id of the train
name	Name appears in the visualization of the train
operator	Operator of the train
trainNumber	Number of the train

Table 12: trainPart elements description

```
<TrainParts>
<trainPart id="" name="" operator="" trainNumber="">
    <OcpsTTs>
        <OcpsTT ocpRef ="">
    </OcpsTTs>
</TrainPart>
</TrainParts>
```

Figure nº: 23 Example of trainPart

OcpsTTs: works as a container element for defined OcpsTT.

OcpsTT: Element to define the different characteristic of the trip of the train.

- **Times:** This element describes arrival and departure times with their scope. This element is defined as follow:

Parameter	Justification
Times	Describe the different times of the trip
arrival	Arrival time of the train
arrivalDay	Arrival day of the train
departure	Departure time of the train

Parameter	Justification
departureDay	Time in Hours/Min/Seconds

Table 13: Times elements description

```
<Times arrival="" arrivalDay="" departure="" departureDay=""/>
```

Figure nº: 24 Example of Times

- **SectionTT:** This element describes data concerning the way from one OcpTT to the next one in the order of the sequence. This includes references to the used infrastructure as well as run times in function of the operational mode.
  - The sub element **track Ref** is referencing the track elements used by the train and described in detail in an infrastructure branch of the railML file. This element is defined with the id of the element located in Infrastructure file.
  - The sub element **Run Times** describes the structure of the run time to the next ocpTT. This element is defined as follow:

Parameter	Justification
SectionTT	**Each different point of the trip. With the concatenation of SectionTT, the trip is built.**
section	Identifier of the SectionTT
RunTimes	**Time to past for the corresponding SectionTT**
minimalTime	Minimum time to cover this section
operationalReserve	Operational time margin
additionalReserve	Additional time in degraded mode
TrackRef	**Element taking from the infrastructure file as reference**
ref	Id of the element taking from the infrastructure file

Table 14:SectionTT elements description

```
<SectionTT section="">
    <RunTimes minimalTime="" operationalReserve="" additionalReserve=""/>
    <TrackRef ref=""/>
</SectionTT>
```

Figure nº: 25 Example of SectionTT

- **StopDescription:** This element describes data concerning the stop a certain ocpTT. This element is defined as follow
  - The sub element **Stop Times** describes the composition of the stopping durations a train spends in a station.
  - The sub element **Platform Edge Ref** is referencing the Stop Post element used by the train and described in detail in an infrastructure branch of the railML file.

Parameter	Justification
StopDescription	Stop of the trip
StopTimes	**Time of the stop**
minimalTime	Time in Hours/Min/Seconds
PlatformEdgeRef	**Platform where the stop is located**
ref	Id of the platform taking from infrastructure file

Table 15 StopDescription elements description

```
<StopDescription>
    <StopTimes minimalTime=""/>
    <PlatformEdgeRef ref=""/>
</StopDescription>
```

Figure nº: 26 Example of StopDescription

```
<TrainParts>
<trainPart id="" name="" operator="" trainNumber="">
    <OcpsTTs>
        <OcpsTT ocpRef ="">
                <Times arrival="" arrivalDay="" departure="" departureDay=""/>
                <SectionTT section="">
                    <RunTimes minimalTime="" operationalReserve="" additionalReserve=""/>
                    <TrackRef ref=""/>
                </SectionTT>
                <StopDescription>
                    <StopTimes minimalTime=""/>
                    <PlatformEdgeRef ref=""/>
                </StopDescription>
        </OcpsTT>
    </OcpsTTs>
</TrainPart>
</TrainParts>
```

Figure nº: 27 Example of trainParts structure

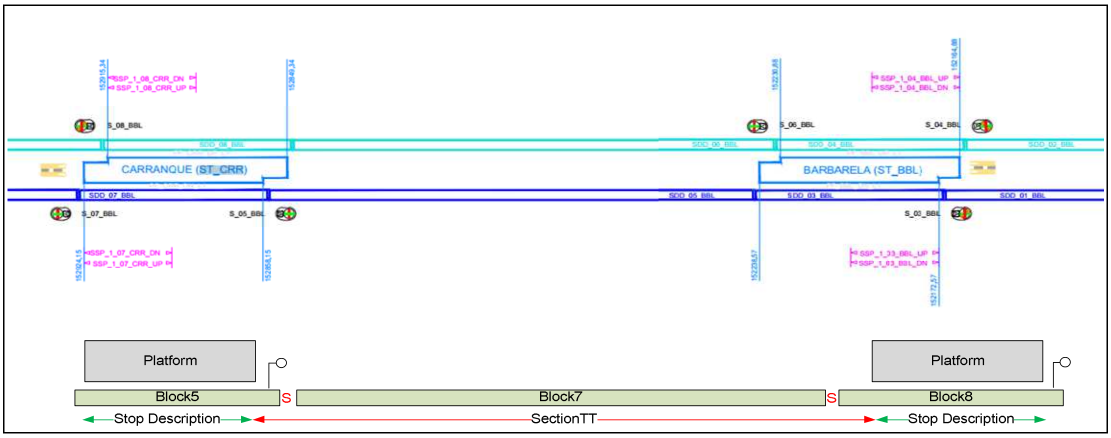

Figure nº: 28 OcpsTT

With the previous information is possible to build a complete timetable of the line and it is possible to take the information for the passengers.

Train

vehicles: works as a container element for each defined vehicle.

vehicle is used to identify each vehicle. Inside of this element should be possible define:

- **MaintenanceIntervals** allows describing a particular maintenance task for the vehicle. This element is defined as follow:

Parameter	Justification
vehicles	**Contain each vehicle of the line**
vehicle	**Contain the maintenance characteristic of one vehicle**
id	Id of the train
name	Name of the train appears in the visualization
MaintenanceIntervals	**Maintenance interval of the Vehicle**
id	Identifier of the maintenance
name	Name of the maintenance appears in the visualization
description	Description of the maintenance
maximumIntervalDays	Time between maintenance
maximumIntervalDistance	Kilometres between maintenance

Table 16: Vehicles elements description

```xml
<vehicles>
    <vehicle id="" name="">
        <MaintenanceIntervals id="" name=""  description="" maximumIntervalDays="" maximumIntervalDistance=""/>
    </vehicle>
</vehicles>
```

Figure nº: 29 Vehicles structure

With this information it is possible define the timetable for maintenance and provides this information to the maintenance staff.

Chapter 5. CONCLUSION

5.1 CURRENT STATE OF THE ART OF TRAFFIC MANAGEMENT LAYER

A complete studio of the state of the art appears in §3.3. At the beginning of the ERTMS initiative started the OPTIRAILS project. Its objective was to specify the architecture of the ETML. Finally this project eventually became Europtirails project. The objective of this project was more specifically, “improve the effectiveness and efficiency of train running on European rail corridors in the operational range”.

After these projects, a lot of numbers of project to create a tool, simulator, software have been developed, but the problem is that these projects are for a specific area of the traffic management or for specific operator or specific country…etc.

5.2 ADVANTAGES UNAMBIGUOUS SET OF DATA

Currently it is being making great efforts in the development of the railway interoperability. All these efforts are in rolling stock, infrastructure and signaling but not the traffic management. Several causes can be mentioned; the number of high-speed lines crossing different countries is not very high and has not yet emerged a necessity in this sense. In the next figures it is possible to compare the number of high-speed lines today with the numbers in the future:

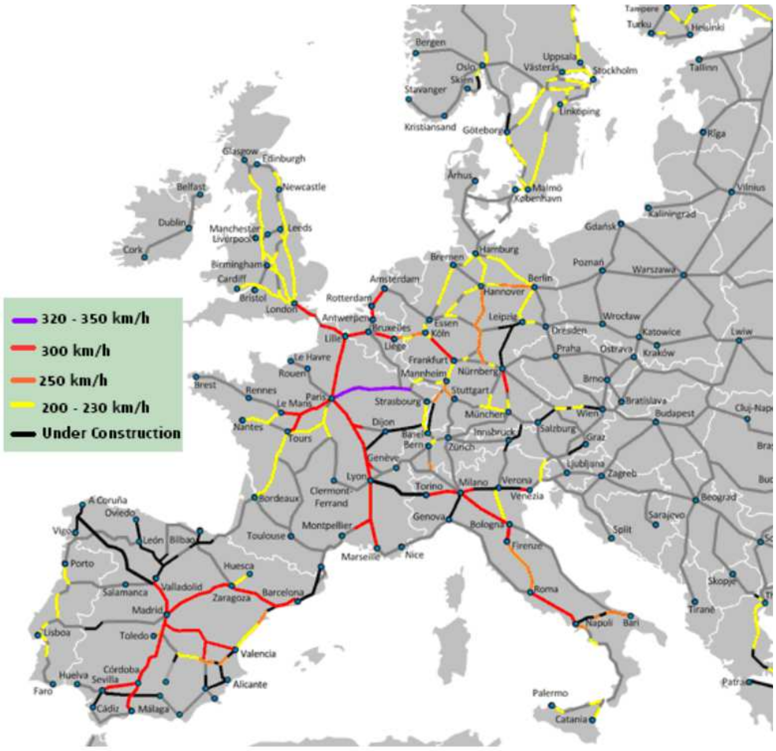

Figure nº: 30 High speed lines with ERTMS exists today

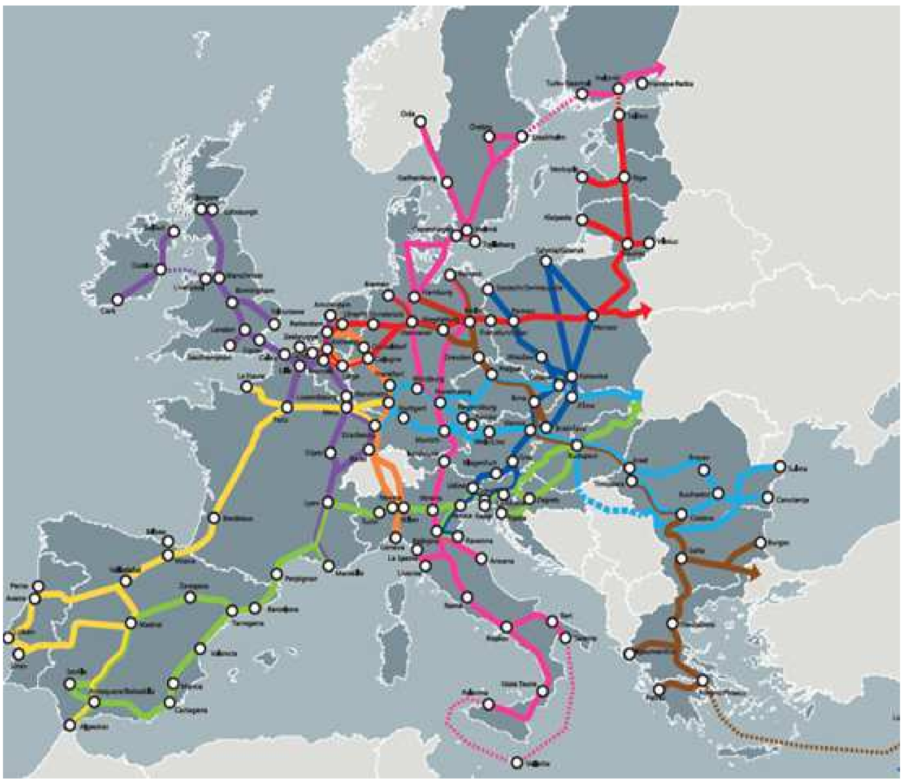

Figure nº: 31 High speed lines with ERTMS in the future

In the future, with the construction of all these lines equipped with ERTMS and which crossed different countries, the need to create a common standard for all these countries for the traffic management point of view will arise.

This project believes that this necessity will arise because now day this problem appears in the traffic management of different lines of the same country but equipped with different companies causing extra cost for the operation.

One simple example can be that if a same line cross different countries, and it is built for different companies, the management of this line, now day it is not unique. First of all, each company provides its equipment, its software, its tools…etc and these can be very different respect from the others companies. But the big problem will be that one line that crosses different countries, it will be management by different administrations and will be necessary a standard to unify the traffic management of this line.

Other advantage is that with an unambiguous set of data is the greater ease of reuse and sharing data with other subsystems that are part of the railway world. Also allows the development of tools for configuring equipment of the manufactures univocally and simple.

5.3 THE FEASIBILITY OF TRAFFIC MANAGEMENT LAYER BASED ON RAILML

This project shows that it is possible to implement the functionality of ETML with railML open models. A complete studio of the different elements of railML appears in §4.1.2. In this project, one first approach to specify the ETML elements is done. The functionalities covered are:

- **Visualization of states of the line** is implemented with Infrastructure subschemas it is possible to define the most important elements of the line taking its states from the signaling area.
- **Traffic planning** is implemented with timetable subschemas taking reference of some variables of Infrastructure subschema. All the information about the

different trains and its trips like time of the travel, the time of the stop …etc are defined here.

- **Information for passengers** is implemented from the timetable information of the travels. This information can be the arrivals or departures times of the different trains running in the line.
- **Information for maintenance** is implemented with the timetable subschema, specifically with Maintenance Intervals subgroup. With this group is possible to define the time to maintenance corresponding for each train.
- **Operation Management System** is implemented with the infrastructure subschema taking information received from the interlocking. If the elements define in the ETML can be associated with the signaling variables, the Operation management can be possible.

The traffic management in real time is not covered in this studio, this include the next functionalities:

- **Driver-only and driverless operation:** This area is developing in ERTMS. The idea is to stablish a method to control the train remotely and improve its circulation, archiving energy saving.
- **Power supply and infrastructure:** The energy area of the lines is also operated from the control centers. For this reason, maybe, is interesting to include the energy area in the ETML.

Chapter 6. CONTRIBUTIONS

6.1 CONTRIBUTIONS

Nowadays, the interoperability is the first objective for the railway world. The objective of interoperability is to establish a minimum level of technical harmonization between different national rail systems of the European Union, which allows achieving an open and integrated European rail system.

Stablishing the use of a standard interface for data exchange for railway traffic management, it is a step towards interoperability because today the trend in railway operation is to transport the maximum number of passengers per hour and in the shortest time possible and with the definition of a standard for the traffic management contributing in this objective.

The development of ERTMS-ETML contributes to the coherence of the railway system. The development and production of ETML as a universal standard for railway management layer would be a step towards interoperability looking for this sector, changing the communication between Operator and Supplier.

BIBLIOGRAPHY

1. ERTMS official web: http://www.ertms.net/
2. International Union of Railways (UIC) official web: http://www.uic.org/
3. European Railway Agency (ERA) official web: http://www.era.europa.eu/
4. Adif official web: http://www.adif.es/
5. On time project official web: http://www.ontime-project.eu/
6. InteGrail project official web: http://www.integrail.info
7. railML official web: https://www.railML.org/en/
8. Notes of “Mater Universitario en Sistemas Ferroviarios”
9. Alstom official web: http://www.alstom.com/
10. Siemens official web: https://www.siemens.com/global/en/home.html
11. Oliver Wyman official web http://www.oliverwyman.com/index.html
12. Swiss Federal Institute of Technology Lausanne EPFL, Intermodality and Transport Planning LITEP official web http://railnet2.epfl.ch/
13. Rail Management Consultants GmbH official web http://www.rmcon.de/home-en/
14. Indra official web http://www.indracompany.com/es
15. SMA and Partners Ltd official web http://www.sma-partner.com/en/
16. Opentack official web http://www.opentrack.ch/