TECHNOLOGIES FOR THE

AUTONOMOUS RAIL OPERATION

Work package 4 –Technologies Supporting Migration to ATO over ETCS

Deliverable 4.2 | Appendix B

Updated GoA3/4 Specification | Digital Map

Due date of deliverable: 31/05/2023
Actual submission date: 18/09/2023

Leader/Responsible of this Deliverable: ALSTOM/RAILENIUM

Reviewed: Y

Document status		
Revision	Date	Description
01	25/01/2023	First complete version
02	05/03/2023	Draft complete version with reviewers remarques and suggestions
03	19/04/2023	Version for TMT/SC approval
04	21/05/2023	First submission
05	18/09/2023	Amended. Final.

Project funded from the European Union's Horizon 2020 research and innovation programme		
Dissemination Level		
PU	Public	X
CO	Confidential, restricted under conditions set out in Model Grant Agreement	

Start date: 01/12/2020 Duration: 30 months

ACKNOWLEDGEMENTS

This project has received funding from the Europe's Rail Joint Undertaking (JU) under the Grant Agreement no. 101014984. The JU receives support from the European Union's Horizon 2020 research and innovation programme and the Europe's Rail JU members other than the Union.

REPORT CONTRIBUTORS

Name	Company	Details of Contribution
Abderraouf BOUSSIF Nadia CHOUCHANI Sekouba TOURE Mohamed GHAZEL	IRT RAILENIUM	Authors
Benoît BIENFAIT	ALSTOM	Document review
Stephane BESURE	ALSTOM	Document review
Benoît ABISSET	ALSTOM	Document review
Bastian SIMONI	ALSTOM	Document review
Jerome LALOUETTE	SNCF	Document review
Merve NALBANT	DB Netz	Document review

DISCLAIMER

EXECUTIVE SUMMARY

The purpose of deliverable is to provide the semi-formal modelling and specification related to the digital map logical block of GoA3/4 autonomous train. This includes the logical architecture, its interfaces, and the collection of track plan data which are required for ATO (up to GoA4).

ABBREVIATIONS AND ACRONYMS

AI	Artificial Intelligence
ATO	Automatic Train Operation
APM	Automatic Processing Module
DM	Digital Map
GoA	Grade of Automation
TAURO	Technologies for the AUtonomous Rail Operation
MD	Mission Data
OE	Operational Execution
PER	Perception
REP	REPository
SCV	Signal Converter
TCMS	Train Control and Monitoring System
TD	Train Data

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 SEMI-FORMAL MODELLING AND SPECIFICATION OF DIGITAL MAP

1.1 INTRODUCTION

In the context of X2Rail-4 project, one of the main objectives is to deliver a semi-formal standard specification (in terms of logical architecture) for GoA3/4 autonomous train (ATO over ETCS up to GoA4). As a complementary project, WP4 of TAURO project aims to upgrade the semi-formal specification of GoA3/4 autonomous train considering the use of ATO on non ETCS area. Particularly, WP4.2 aims to provide a semi-formal specification of the digital map module for GoA3/4 autonomous train.

Figure 1 shows the logical architecture of the signaling system supporting the ATO (up to GoA4)[1]. In this logical architecture, the REP building block is collecting, from trackside, all data required by the on-board building blocks. The categories of data that shall be available from the trackside are:

- MD: Mission Profile Data probably delivered by the RU operating the train unit (hereafter defined as MP);
- TD: Train Data probably delivered by the RU operating the train;
- OE: Operation Execution containing the Journey Profiles probably delivered by the IM operating the line;
- DM: Digital Map containing the digital infrastructure representation probably delivered by the infrastructure manager operating the line.

The DM contains the Track Plan Data which are needed to operate the train according to the Operation Execution Data (e.g., Journey Profiles). The Track Plan Data are split in segments containing the required data. The Segment Profiles defined here are not "*stricto sensu*" the same as the ones used for GoA2 in the SUBSET-126 from the TSI 2022. The Segment Profiles application for ATO (up to GoA4) contain additional data comparing to GoA2 version. Those segments data are extracted from the Digital Map.

The purpose of this deliverable is to provide a semi-formal modelling and specification of the DM building block, its interfaces, and exchanged data, with the support of Capella modelling tool.

[1] This Figure 1 refers to the architecture as it is currently defined in SRS 0.1.4 which is still in the process of development.

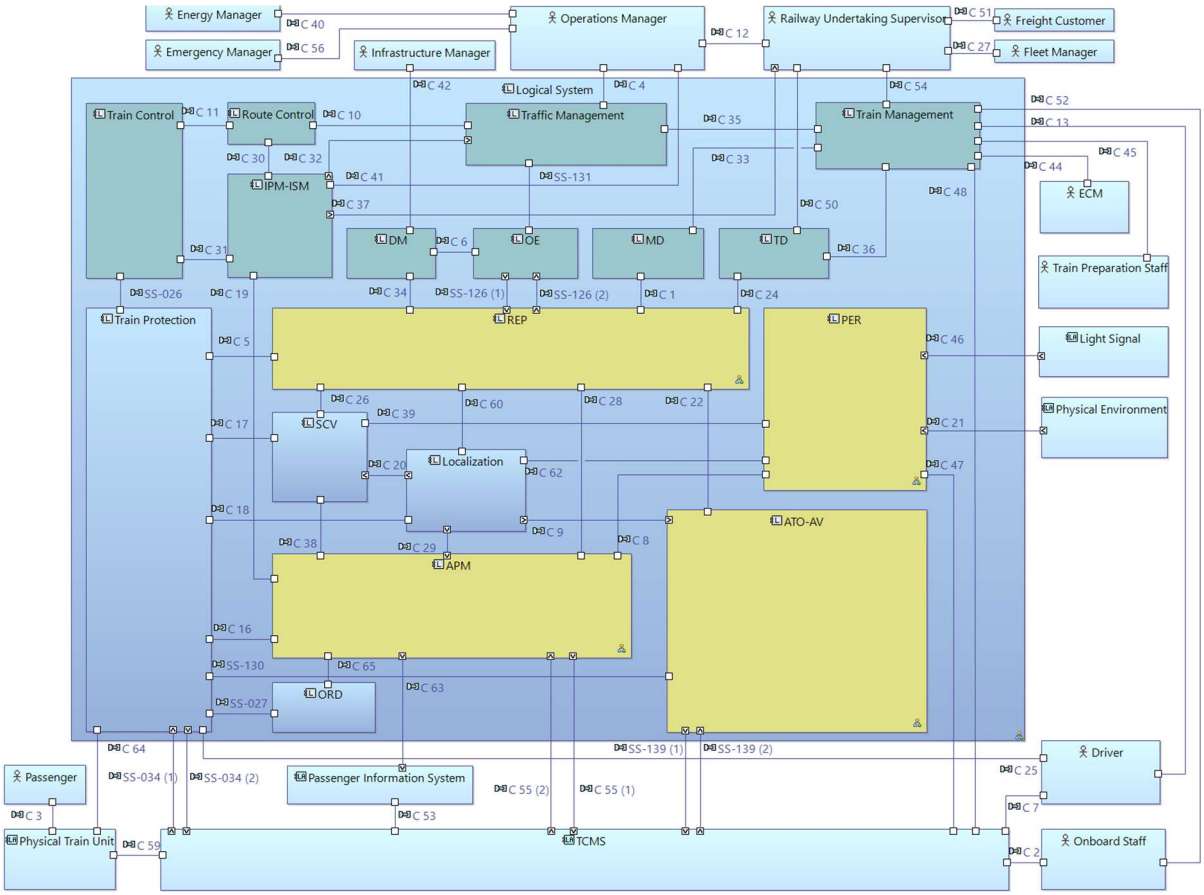

Figure 1: ATO (up to GoA4) logical architecture.

1.2 LAYERED ARCHITECTURE FOR DM

In this section, we propose a layered architecture for the DM, structured around 5 principal layers. Each layer represents a profile description from a given use-case perspective.

1.2.1 DM architecture

Figure 2 depicts the main five layers of the DM. Here below, a succent description of each layer is provided (from down to top).

Layer 1: Common Topology Profile

This layer allows for a topological description of train guidance made up of segments of track identified by unique identifiers. Notice that all infrastructure elements must be located from the beginning of the corresponding track segment to ensures the uniqueness of the positioning reference.

Layer 2: Geometry Profile

This layer describes the track layout geometry. Each track segment is represented by into straight lines (polylines) with track vertices sampling used for navigation and positioning. These points are generally described by 3D geometric coordinates.

Layer 3: Environment Profile

This layer describes the infrastructure areas of interest such as tunnels, level crossings, and bridges, etc [see X2RAIL4_Track Conditions]. It is used for perception and environment monitoring.

Layer 4: Driving Profile

This layer provides an infrastructure description (intended for the ATO) by extending the Subset 126 format. Such a layer is intended for the ATO and is necessary for the train driving operations in GoA4.

Layer 5: Signaling Profile

This layer describes the line side signaling components (fixed and mobile signaling). Such a layer is mainly related to the function of detection and interpretation line side signaling information. It could contain also virtual signaling information.

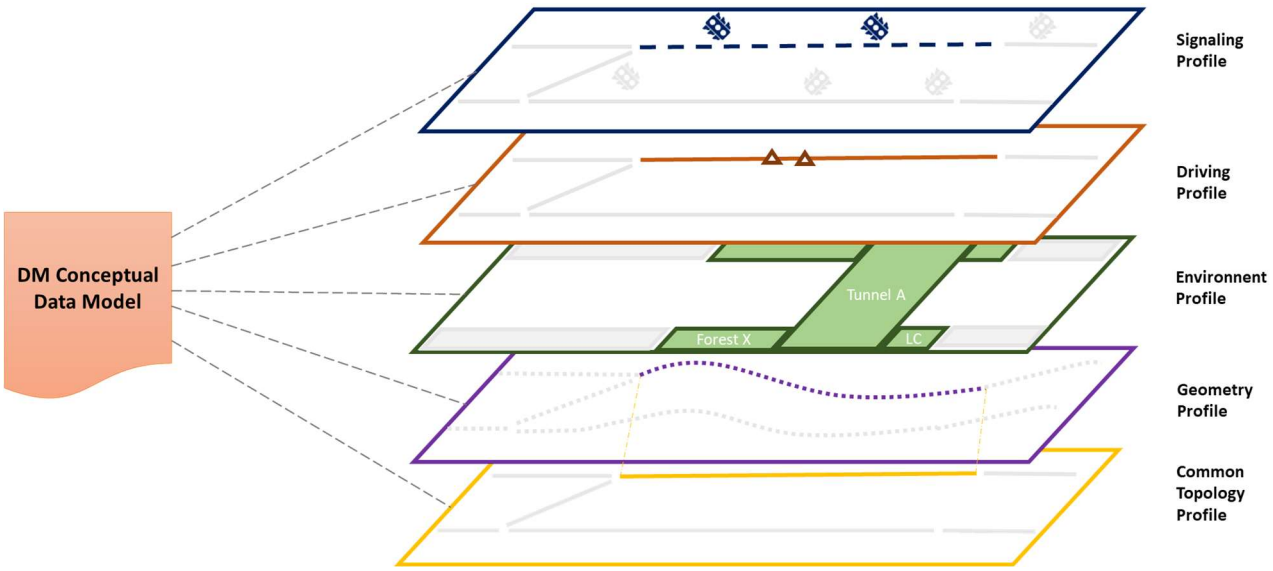

Figure 2: DM layered architecture.

1.2.2 REP data structure

The REP building block (see Figure 1) has the function of acquiring, collecting from the trackside and maintain all updated data required by the on-board building blocks involved in ATO up to GoA4. The data that shall be available from the trackside are mainly coming from the following building blocks:

- MD: Mission Profile Data probably delivered by the RU operating the train unit (hereafter defined as MP);
- TD: Train Data probably delivered by the RU operating the train;
- OE: Operation Execution containing the Journey Profiles probably delivered by the IM operating the line;
- DM: Digital Map containing the infrastructure digital description probably delivered by the IM operating the line.

Figure 3 represents a class diagram showing the data structure collected and maintained by the REP logical block. It includes the Mission Profiles, the Journey Profiles, the Train Data Sets, and the 5 profiles related to the Digital Map.

Each profile related to the Digital Map includes a Static Part and a Dynamic Part. The static part contains the data to be extracted from the Digital Map; while the Dynamic Part contains the current state of the objects (elements) defined in the Static Part.

For example, the Static Part of the Signaling Profile defines the fixed and mobile signals; while the corresponding Dynamic Part determine the current state of those signals.

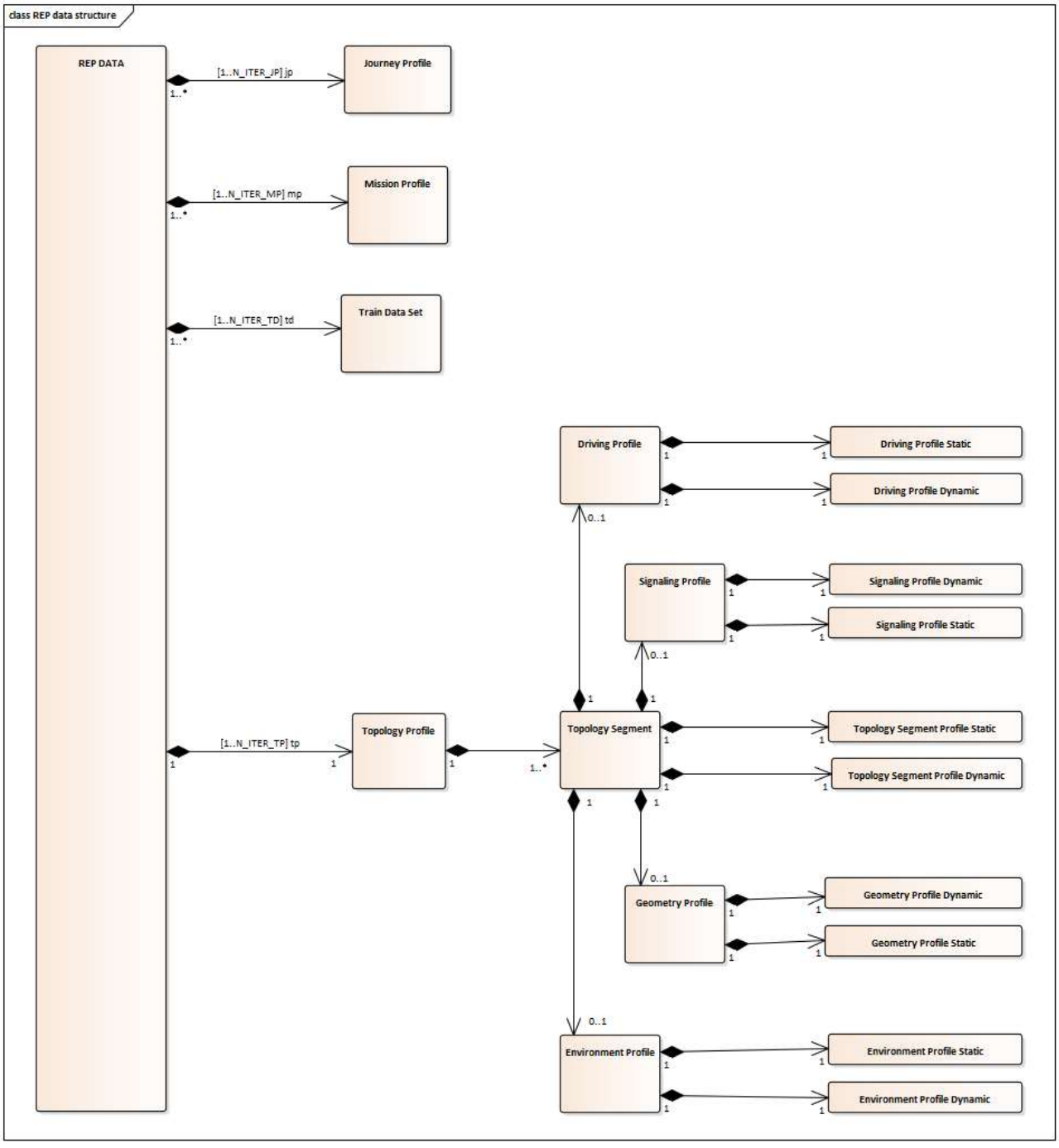

Figure 3: REP data structure.

Figure 4 provides a schematic representation of the data flow between trackside and on-board subsystems. “AT” is the acronym of “Autonomous Train” and represents several on-board sub-systems. DM provides static data through output services. Each service is dedicated to one layer. However, the dynamic data is provided by OE. All these data are then integrated in REP and transmitted to the on-board building blocks. Note that DM, OE, and MD shall be consistent with the common topology profile.

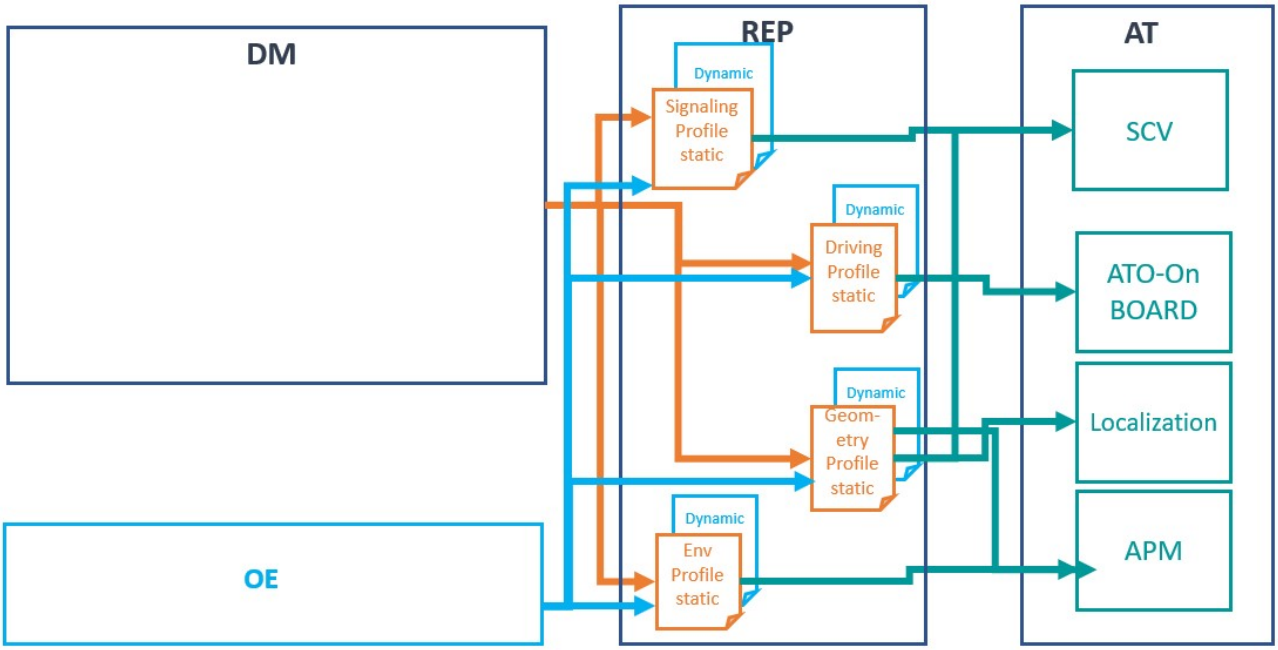

Figure 4: Data flow between the logical building blocks.

1.2.3 Data specification

The data contained in each profile of the DM needs to be specified. Table 1 provides a first attempt to represent and specify the data related to the Geometry Profile.

Table 1: Data specification – case of Geometry Profile.

Level	Variable	Type	Length	Description
1	**Header**		sum<=5 byte:	contains required information to identify and interpret transmitted packet
1	NID_PACKET	INT	8 bits	ID of packet
1	L_PACKET	INT	13 bits	Length of packet
1	Q_GEOREF	INT	2 bits	Geographic Coordinate System for absolute coordinates (WGS84 by default)
1	Q_SCALE_OFFSET	INT	2 bits	Unit for diatance/offset (e.g. cm)
1	Q_SCALE_LEN	INT	2 bits	Unit for length (e.g. cm)
1	N_SEGMENT	INT	5 bits	Number of segments in packet
2	**Data per segment for each N_ITER_SEGMENT :**		<= 5 bytes	Contains all the segments of the topology that are transmitted in the packet
2	SEGMENT(Segment.ID)	INT(UUID)	32 bits	Unique id of referenced segment
2	N_ITER_POINT	INT	5 bits	Number of points on segment
3	**Data per elemnet**		>= 11 bytes	contains the data per element
3	TrackVertices_ID	INT	32 bits	Unique id of Track Vertice
3	Ref_Segment	REAL	15 bits	Offset/distance to define the relative start position of the point
3	Position	INT	5 bits	Position of the referenced point along track polyline
3	Latitude	INT	2 bits	Absolute latitude of the point acoording to the geographic coordiante syste
3	Longitude	INT	2 bits	Absolute longitude of the point acoording to the geographic coordiante syst
3	Altitude	INT	2 bits	Absolute altitude of the point

1.3 SEMI-FORMAL MODELLING AND SPECIFICATION OF DM

This section provides the semi-formal modelling for DM building block and its interfaces. It also provides a specification of the exchanged data.

1.3.1 Environment of the Digital Map

In its role of providing infrastructure map data to concerned building blocks, the DM interacts with several components through different interfaces. These interfaces are listed in Table 2, and showed in Figure 5.

Table 2: Interfaces related to the DM building block.

Building block	Interface
REP	C34
OE	C6
SCV	C26 via REP
APM	C28 via REP
ATO-AV	C22 via REP
Localization	C60 via REP

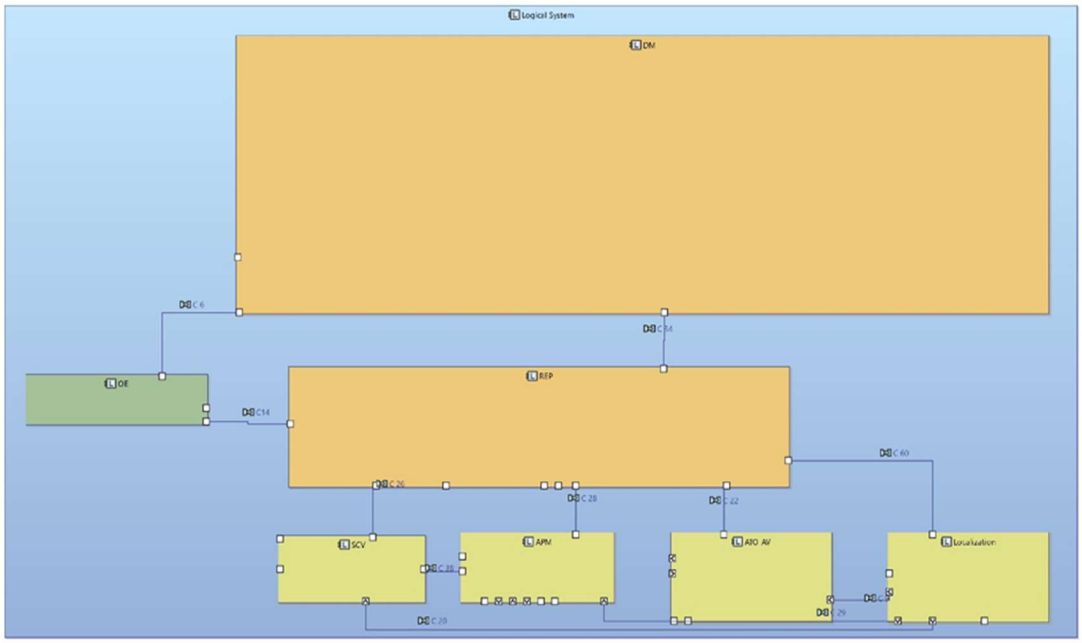

Figure 5: DM Environment.

1.3.2 Functions allocated to DM building block

The Digital Map executes several functions in order to deliver the required mission. The main functions (depicted in Figure 6) are:

- *Manage Map data request.*

Once the REP block has identified the segment id from the Journey Profile, it sends a request to the DM to get the map data of the identified segment. The DM the manage the received request and proceed to gather the related data of the identified segments before sending them back to the REP. The data gathering functions are:

- *Gather Signaling data for identified segments.*
- *Gather track geometry data.*
- *Gather related Driving profile data.*
- *Gather Environment data.*

After gathering the related data, the Digital Map sends the data to the REP (as shown in Figure 6) using the function:

- *Provide infrastructure database.*

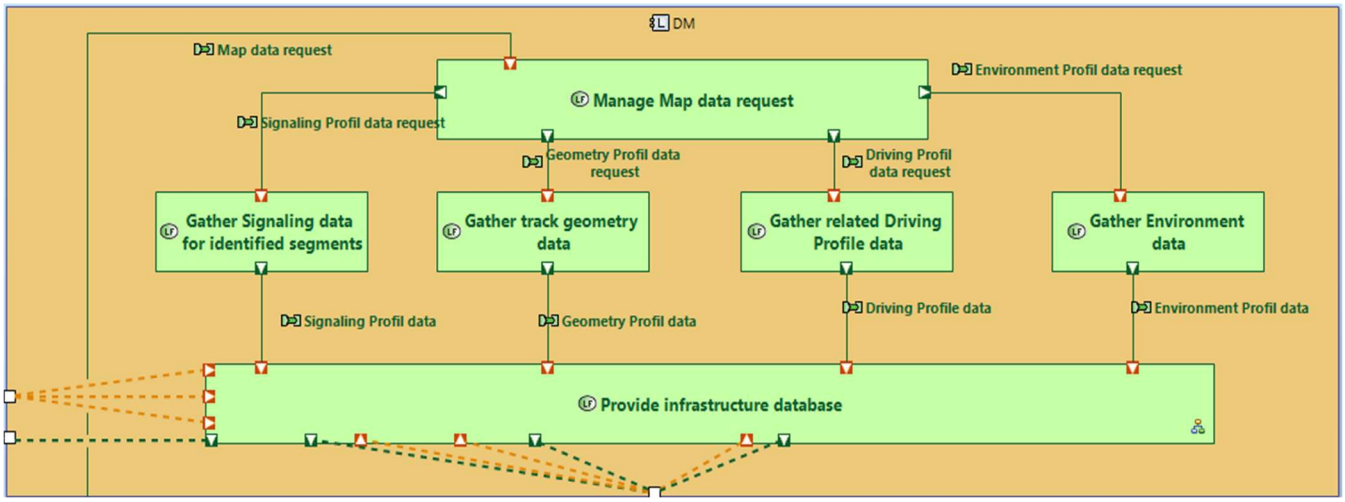

Figure 6 : DM functional allocation.

1.3.3 Allocated functions to related buildings blocks

The functions allocated to the building blocks which interact with the DM are presented in Figure 7 and listed in Table 3.

Table 3: Functions related to the building blocks in interaction with DM.

Components	Functions
DM	- *Manage Map Data request.* - *Gather Signaling data for identified Segments.*

	- *Gather track geometry data.* - *Gather related Driving Profile data.* - *Gather Environment data.* - *Provide infrastructure database.*
REP	- *Read and synchronize the infrastructure database.* - *Request map data for identified segments.* - *Determine Segment id from JP.* - *Acquire JP and MP.* - *Manage reporting.* - *Map REP with route.* - *Provide train parameters.*
SCV	- *Receive Signaling infrastructure data.*
APM	- *Receive Environment data.*
ATO-AV	- *Receive Driving data.*
Localization	- *Receive track geometry data.*
OE	- *Determine/verify and transmit JP data.* - *Transmit Dynamic data.*

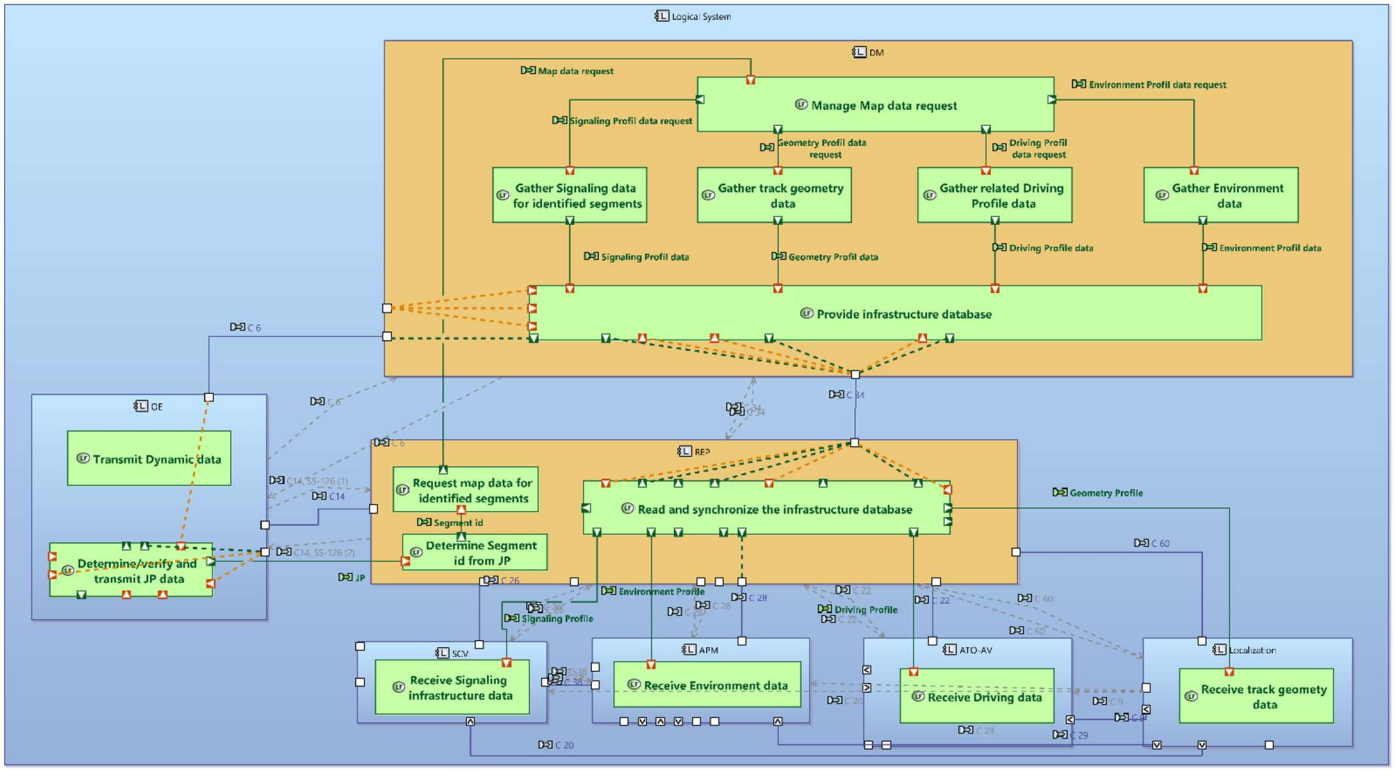

Figure 7: Logical functions in interaction with DM functions.

1.3.4 DM data specification

The data exchanged by the DM is specified according to each profile considered in its layered architecture.

1.3.4.1 Driving profile

Driving profile contains the set data that is provided from the DM to ATO-AV. In the current work, only static data from the driving profile is specified.

Figure 8, 9 and 10 show the data dictionary used by the driving profile. The data are sent through interface C34 to REP.

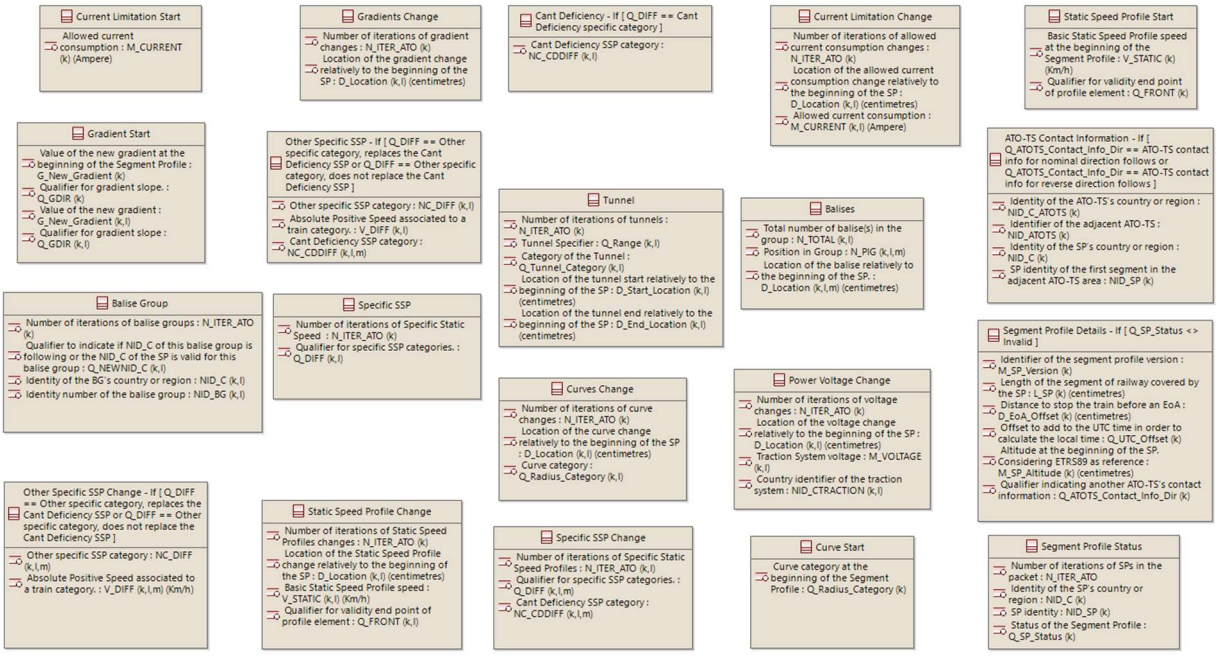

Figure 8: Driving profile (part 1).

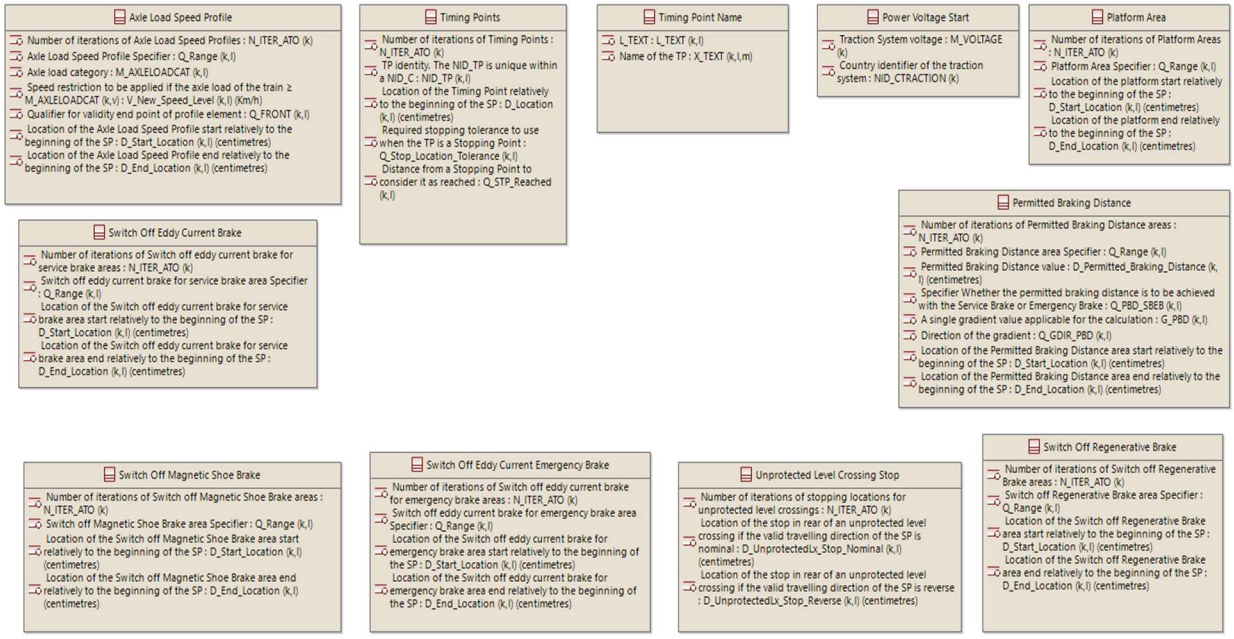

Figure 9: Driving profile (part 2).

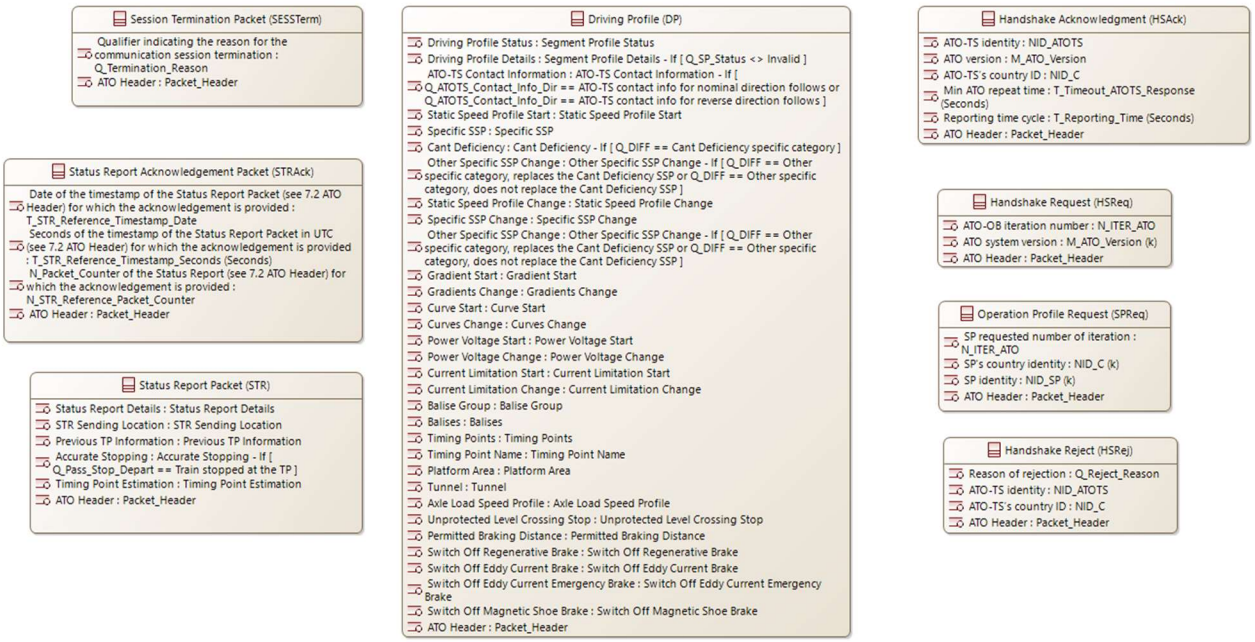

Figure 10: Driving profile (part 3).

1.3.4.2 Geometry Profile

The Geometry Profile regroups the data set transmitted to the Localization module to improve the localization function. Figure 11 shows a list of the data related to the Geometry Profile.

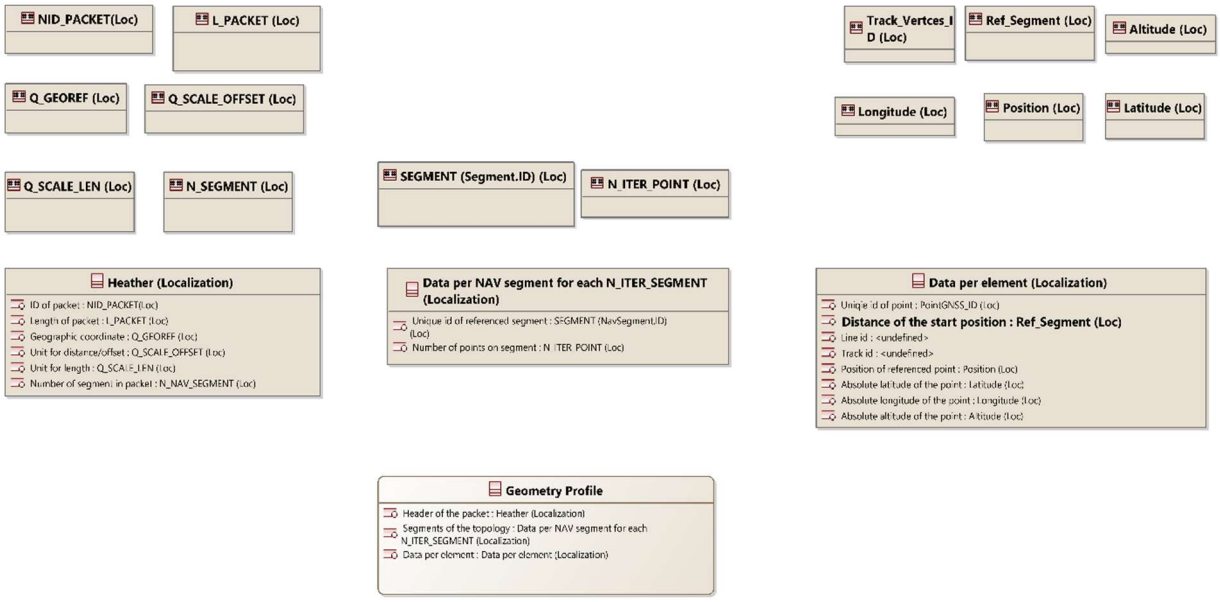

Figure 11: Geometry profile data.

1.3.4.3 Signaling Profile

The Signal Profile regroups the data set transmitted to the SCV module in order to enhance the detection and conversion of trackside signals [see SCV specification in TAURO WP4.1]. Figure 12 shows a list of the data related to the Signal Profile.

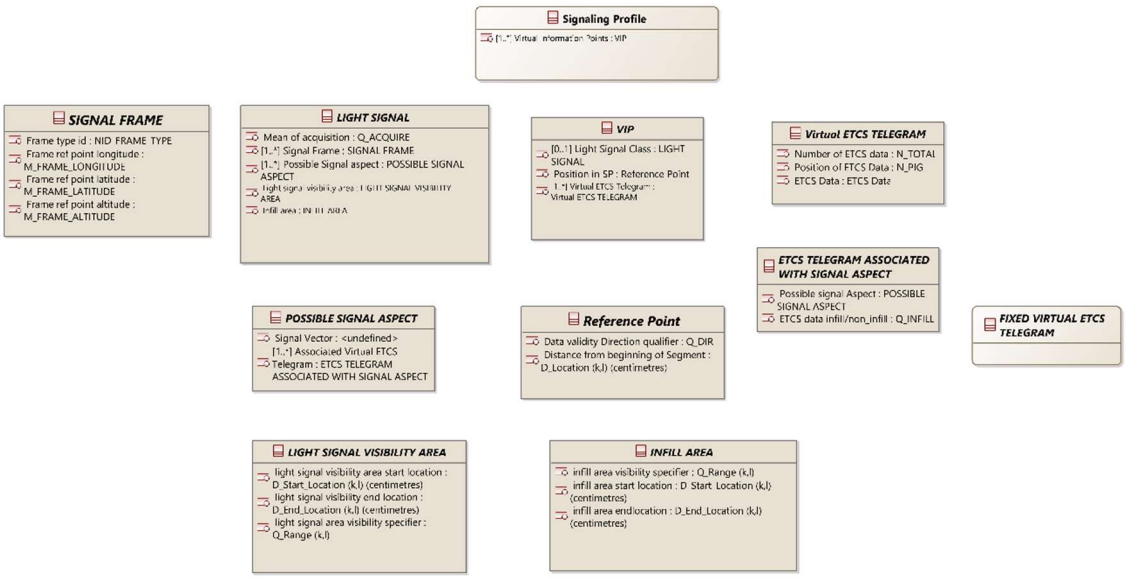

Figure 12: Signaling profile data.

1.3.5 Creation and allocation of exchange items

Using the semi-formal modelling tool Capella, the exchanged data by the DM are created in a library. The library is referenced in the model to allow the allocation of exchange items[2] (See Figure 13). they are created in the model and their types correspond to the data classes from the library are shown in the Figure 14. The exchange items are then allocated to the interfaces through which the data are distributed.

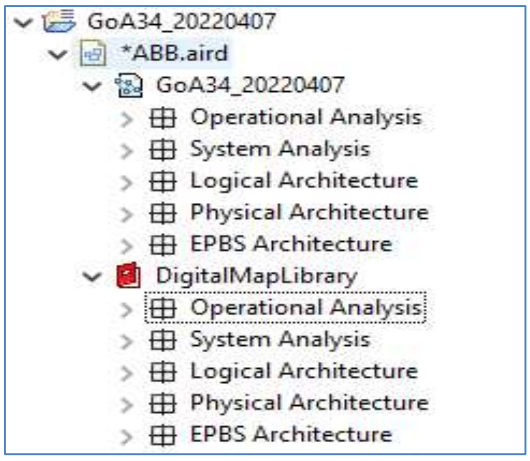

Figure 13: Library referenced.

[2] An "item" in Capella refers to a specific element in a system model (component, data, etc.).

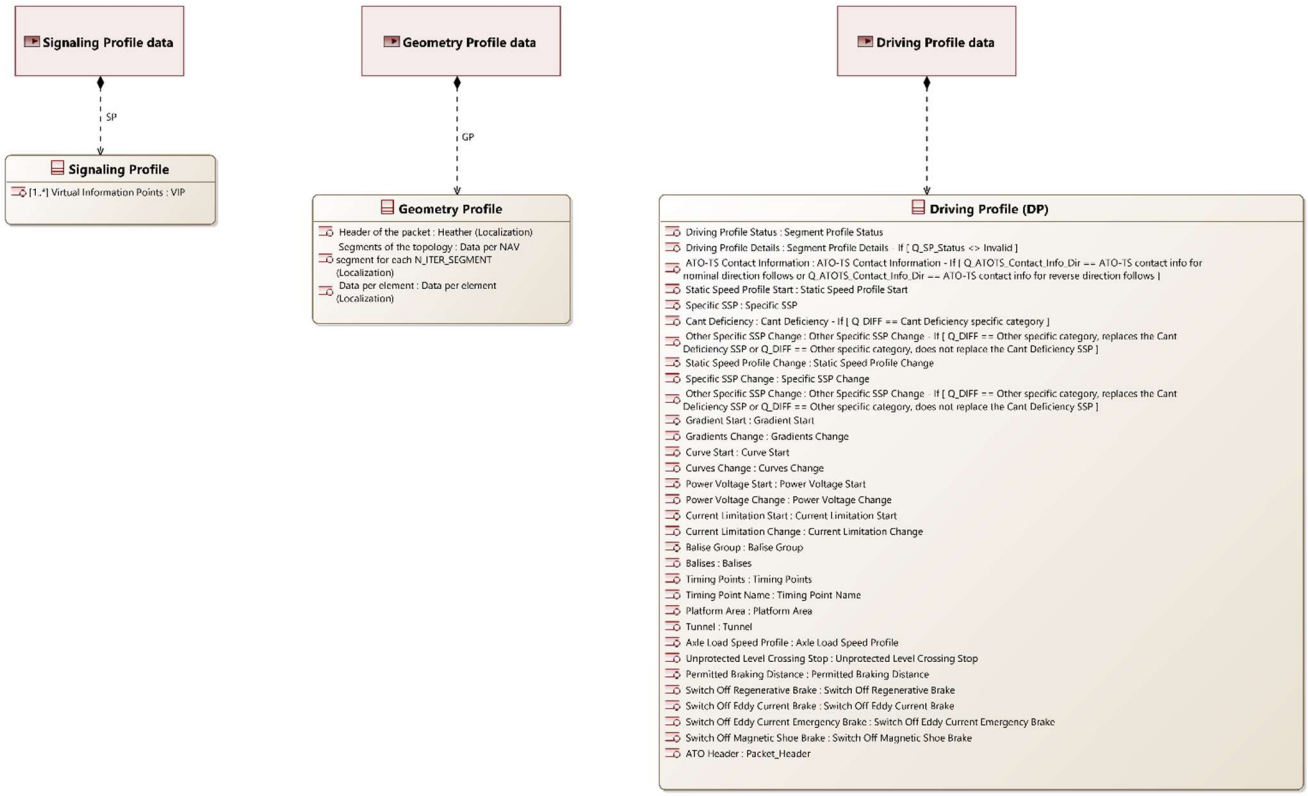

Figure 14: Exchanged items.

To access the entire diagrams and data, please refer to the Capella model (see the D4.3 Appendix B).