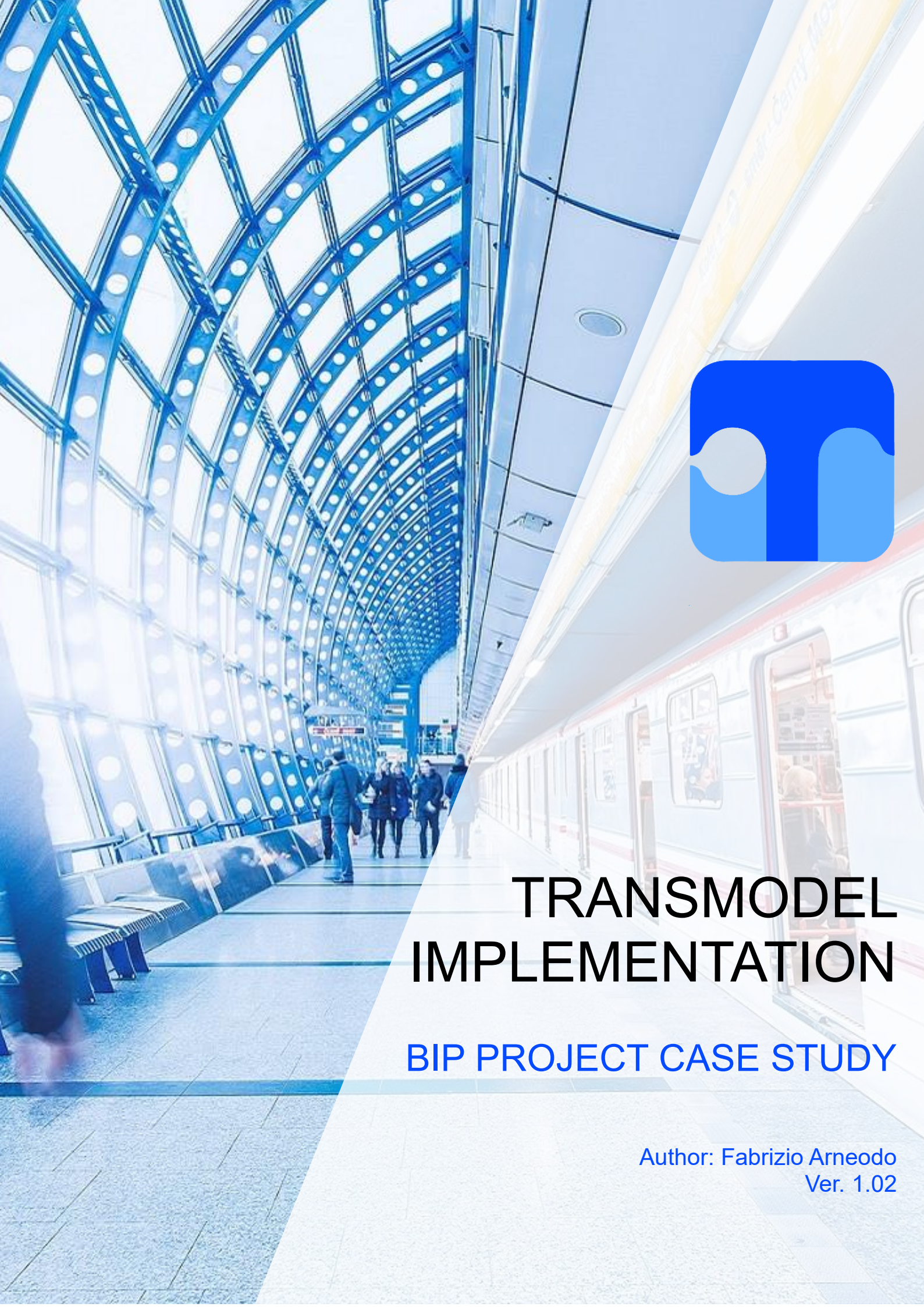

TRANSMODEL IMPLEMENTATION

BIP PROJECT CASE STUDY

Author: Fabrizio Arneodo
Ver. 1.02

Table of contents

1. Introduction

This white paper describes the design and implementation of the Piedmont Integrated Ticketing project, called BIP (*Biglietto Integrato Piemonte*), and its interoperability with any public service already supporting this technology. In particular, how and which parts of Transmodel have been used for the implementation of this solution is described.

The interoperation among different service operators is assured by means of a single Regional Service Centre, called "CSR-BIP", sharing data about services and customer usage with transport operators and the Public Administration by means of a standardized transfer data protocol, called BIPEx, compliant with the most up-to-date international standards. The same informative content is used to feed dedicated informative services.

Moreover, all services compliant with the BIP system are accessed by users through a pure contactless smart card, with its Card Data Model, defining its content and the rules to access it. Customers are able to change between Public Transport operators or other transport systems (i.e. bike sharing) and even university and cultural services (Students card or Card for young) or regional museums, without the need to acquire a dedicated "ticket" for each.

The Main macro characteristics of this project are the existence of *one centre*, *one protocol* and a single *smart card*, enabling one of the most integrated ticketing and informative service system ever.

In order to reach such level of integration and interoperability, the design phase chose to create a system compliant with Transmodel CEN standard and other derived standard like NeTEx (see [N1], [N2], [N3]) and SIRI (see [S1], [S2], [S3], [S4] and [S5S5S5S5]). The following Figure depicts the Transmodel parts implemented in the BIP Project.

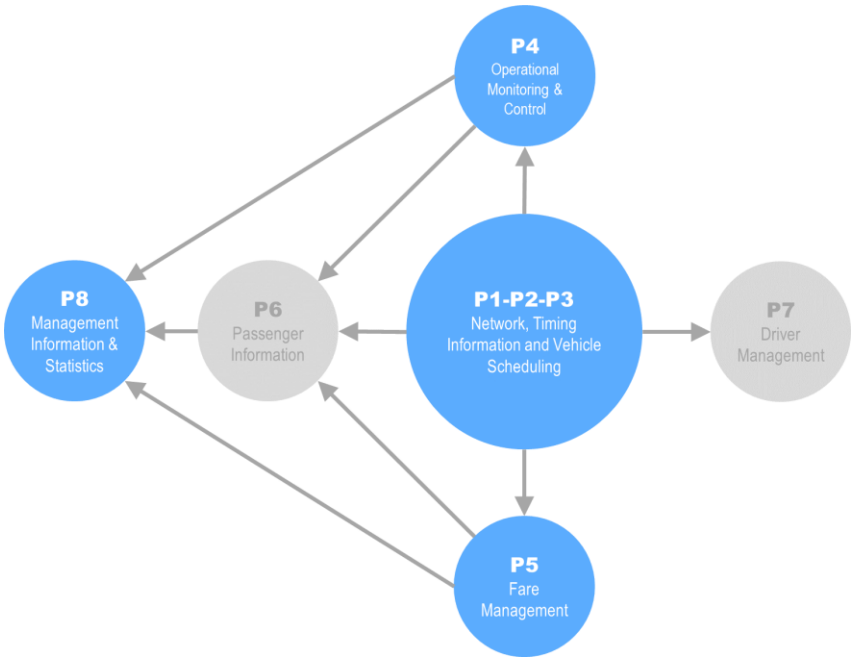

Figure 1 – Transmodel implemented parts

2. Audience

Transmodel covers a large and complex domain, and is itself a large standard. This report is intended only to provide a high-level description of one major Transmodel implementation for technical managers; for further resources see *Further Reading* at the end.

3. BIP project in a Nutshell

BIP project is an innovative integrated ticketing system for public transport, for railways and virtually for all other transport systems and it can even be integrated with cultural services. The project involves over 100 transport operators, nearly 3,400 vehicles, more than 8,600 stopping points, nearly 400 train stations, between 1 and 4 million people, and with a total investment of 50 million euro.

In order to be compliant with the project, the Public Transport (hence called PT) companies have to design and implement an electronic contactless ticketing system based on Calypso technology, an Automatic Vehicle Monitoring system (AVM) enabling real-time and off-line monitoring of executed service, and a video-surveillance system for passengers safety.

Other (non-PT) services, on the other hand, only require compliance with the exchange protocol and with the unified smart card that can host all service contracts and can act as Electronic Purse (with pre-paid credit) to access services without contract subscription.

Obviously, a system with this high level of complexity requires a central system able to exchange data from and towards all these service operators (with dedicated system to store and analyse all these data). Aiming at this, Piedmont Region has created the Regional Service Centre CSR-BIP (hence defined “CSR”): 5T (Telematic Technologies Transport Traffic Turin) company was chosen for these duties and will act as CSR.

4. The BIP general architecture

The BIP system has been conceived as a “galaxy” of operators (or operators consortia) interacting with each other in order to allow their users to access transport and cultural services with a single smart card. Since this interaction generates a huge amount of information, it was modelled as a “stellar system” with its gravitational centre on the CSR (see Figure 2).

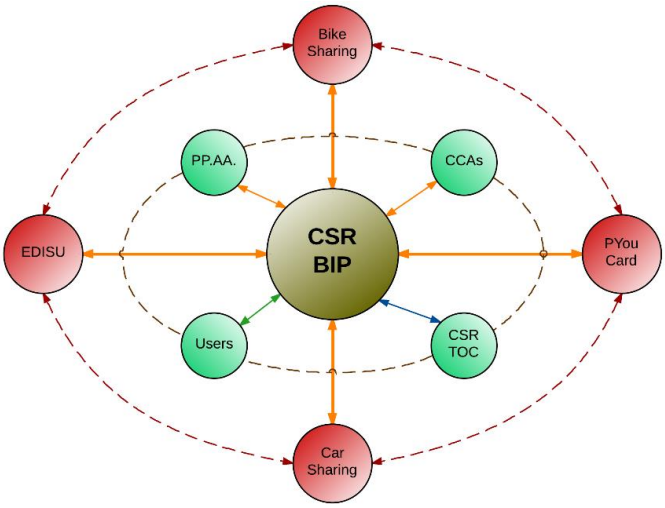

Figure 2 - BIP "gravitational model"

All "planets" are on 2 different "orbits" with different level of interaction:

- the "external interoperability orbit" is occupied by service providers: here we can find cultural services (EDISU and PYOU CARD) and bike/car sharing services;
- the "internal service orbit": here we have consortia of PT operators, Agency Control Centres (CCAs), Public Administration and users that are, of course, the final customers of the whole integrated service. A world apart, is CSR-TOC that is charged by Piedmont Region with monitoring and controlling private traffic across the whole Piedmont Region.

Data exchange between service providers or Public Administration and CSR is performed using BIP Exchange Protocol (BIPEx) (orange arrow in figure). The "dialogue" between CSR and TOC requires a dedicated different protocol (blue arrow in figure) because it is outside the aim of BIPEx protocol. Different service providers can also exchange data with each other, either by direct communication (with proprietary protocols – red dashed arrows) or by accessing the common data hosted in CSR database (BIPEx protocol). Finally, users receive informative services about the PT service, with planned timetables (see [W8]), real-time bus arrival at stopping point and real-time travel planning (green arrow).

5. Regional Services Centre (CSR)

CSR represents the central informative system of Piedmont Region aimed at controlling the whole BIP project and at managing all the relations among Public Administration, Service Operators and users. These relations are analysed by 3 main CSR "modules":

1) *Local Public Transport (LPT)* that stores all data related to the planned transport service, including all static and real-time data of the different operators and transport graph;
2) *Electronic Ticketing System (SBE)* that is devoted to fare system and to solve possible clearing disagreement among various operators; it also manages data security;
3) *Business intelligence (BI)* that is devoted to reporting and Public Administration analysis functions.

Since CSR is the only coordinator for several operators, each one built with its own architecture, structure and technology, it has been developed in order to have *high reliability* and *a modular architecture*, open and service oriented, to be *technology independent* and *easy to monitor,* with *maximum logical software security*.

Finally, the system has been designed with "Process Oriented" architecture compliant to ARTIST (Architettura Telematica Italiana per il Sistema di Trasporto - see [A1]) Italian national model for ITS systems integration.

CSR receives PT data (such as Service Planning, Network description, etc) mainly from CCA, through a specifically designed data exchange protocol called BIPEx. All retrieved data are stored into an internal specific database called CSR-DB, designed and implemented starting from the Transmodel standard.

6. Central Control Agency (CCA)

In order to perform a PT service for Piedmont Region, every PT Company has to be aggregated in a consortium covering a specific geographical area. In order to gather all the hardware and software required to be BIP compliant, a consortium creates a CCA that is its informatics counterpart. The CCA transfers all the data related to PT service (planned and performed) and to Electronic ticketing (sales, travel documents, customers, validations) to CSR in BIPEx protocol.

7. BIPEx exchange data protocol relations with Transmodel

BIPEx protocol has been designed together with CSR-DB starting from Transmodel specifications; the protocol transmits PT data from CCA to CSR. The protocol is an XML based protocol divided in several parts constituted by several entities with a framed structure (see [W3]), similar to the one of Transmodel. Versioning is performed through attributes derived from Transmodel Part 1 Common concepts (see [T1]]). It consists mainly of 2 parts:

- *BIPEx_Publication.xsd* devoted to all static and semi-static data in planned service and fare system; this XSD is derived from Transmodel and NeTEx
- *BIPEx_Report.xsd* devoted to the description of PT service really performed (even in real-time) and to the electronic ticketing system final balance; this part is derived from Transmodel and SIRI

BIPEx_Publication.xsd is divided in:

- *ResourceFrame* contains information about CCA, operators and company resources (i.e. vehicles, service contracts); this part is derived from:
  - Transmodel Part 1 – CC Explicit Frames MODEL - CC Resource Frame MODEL for companies hierarchy
  - Transmodel Part 3 – TI Journey Accounting MODEL for contracts

- *ServiceFrame* describes transport network (i.e. stopping points, links, journey patterns, lines); this part is derived from:
  - Transmodel Part 1 – CC Generic Framework MODEL – for points and links description
  - Transmodel Part 2 – NT Line Network MODEL for Line description
  - Transmodel Part 2 – TP Tactical Planning Components MODEL for journey pattern description
- *ServiceCalendarFrame* contains validity period definition for PT service; this part is derived from Transmodel Part 1 – CC Explicit Frames MODEL - CC Service Calendar Frame MODEL
- *TimeTableFrame* contains all planned vehicle journeys, each one referred to a specific service contract; this part is derived from Transmodel Part 3 – TI JourneyAndJourneyTimes MODEL for vehicle journey and stop points arrival times.
- *FareFrame* describes the electronic ticketing fare system and all the related devices; this part is derived from Transmodel Part 5 – Fare Frame MODEL.

BIPEx_Report.xsd is divided in 2 sections:

- PT monitored service; this part is derived directly from SIRI StopMonitoringDelivery and VehicleMonitoringDelivery parts and comprises:
  - *DatedVehicleJourneyDelivery* contains the description of performed vehicle journeys (with details on real stopping points arrival times) and evidence of every service disruptions;
  - *StopMonitoringDelivery* contains arrival time forecast for every PT vehicle;
  - *VehicleMonitoringDelivery* contains real-time positions of every PT vehicle;
- Electronic ticketing monitoring and accounting; this part is derived from Transmodel Part 5 – Fare Frame MODEL and comprises:
  - *BlackListDelivery*: contains a list of blacklisted smartcards and security modules;
  - *CustomerDelivery*: contains details on new BIP customers for every PT operator;
  - *SaleTransactionDelivery*: contains a description of every fare sale performed by PT operators;
  - *TravelDocumentDelivery*: contains details on smartcards sold to Customer by PT operators (during a Fare Sale);
  - *ControlEntryDelivery*: contains details of every fare validation on PT vehicles.

8. BIP Portable Object (PO)

Since the BIP project is essentially an interoperable transport service system, it can operate correctly only if all actors share also a common “ticket” support: the BIP Portable Object (smartcard, app, etc.). Based on common standards and technologies, this support is as simple as functional: all the complexity has been transferred to CSR systems. It uses Calypso technology, one of the most comprehensive and secure standard for fast, off-line, contactless ticketing transactions available today that is based upon international standards ISO 7816 and ISO 14443 and is driven by the Calypso Network Association work groups. Its security is granted by two main functionalities: the secure session that ensures that the PO, the terminal, and data are genuine (thanks to mutual authentication) and the ratification function that leaves the card in a safe state if the communication link is broken. Calypso’s high level of security is reached using microprocessor cards, Security

Modules on terminals (SAM), and fast symmetric cryptographic algorithms using hardware accelerators (DESX, TDES). In the BIP project, every operator has a dedicated set of keys, so every operator has personalized SAMs: every SAM has all the sets of keys “on board” in order to verify all operators’ signatures, but only the specific operator set of keys can sign data.

The Card Data Model (CDM) is designed and managed to meet the needs of all transport operators. The data structure differs little from the standard one, since it has 8 contract records. This allows hosting multiple travel tickets. A workgroup is constantly active to develop and evolve the CDM.

Since in Italy PT pricing is determined by Public Administrations, each entity can apply its rates especially with regard to discounts category (unemployed, retired, etc.), thus generating complex tariffs which, at times, can be hard to handle. The decision to have a contactless-only PO allowed ensuring, a good longevity in normal use (for example for the smartcard > 4 years), thus limiting the need for replacement and the costs for the users. Calypso technology allows also using the Electronic Purse (EP): it is essential to the aim of achieving interoperability in the Piedmont region, not only from a technical point of view, but also with a simplification of transport usage.

The typical customer of Public Transport is likely to have a contract that will allow him to travel on the necessary routes through few operators. In case the user is located outside of his usual context, he can buy the EP that is valid throughout the region: the user only has to validate on any vehicle, which will charge the exact amount of the ride, without the need of a specific ticket. Authenticity and integrity of PO data are guaranteed in two ways depending of the origin of the data communication:

- from vehicle and/or access points terminals to CCAs: data are signed before being sent by Calypso SAM modules with a provided key; a specific module (SAM-DV) is used by CCAs and CSR to verify the signature. Thanks to this process, the public authority could also certify the service for funding purpose;
- from CCAs to CSR: a PKI infrastructure will be used; CSR is the Certification Authority for all systems interoperating with it and is responsible for certificate release and issue.

The CSR is responsible for overseeing supply of the PO from manufacturers that must obtain a certification from a test laboratory that verify physical, electrical/electronic characteristics (ISO 10373) and certify the compliance of the PO to standards (ISO 14443-B). Moreover, CSR is equipped with modern testing tools for the assessment of compliance of the operating system of the smart card to the Calypso specification (revision 3).

Thanks to the guarantee of uniqueness of the serial number given by the Calypso technology, other (non-PT) circuits may alternatively decide to take advantage of this feature to authenticate the users and enable them the use of its services. As a result, this decreases the complexity of infrastructure which does not need SAM modules and increase the reading speed of the cards since it is sufficient for a single command to read the serial number, for example for an entrance to an event or for use of bike sharing. The BIP is also evolving towards on-the-Host Card Emulation technology, thus digitizing within the Android smartphone the data structure provided by the BIP Card Data Model.

9. Regional Informative Platform and Business Intelligence

CSR database contains a huge amount of information that can be used to develop a new Regional Informative Platform capable of transferring the "interoperability" concept from the real service to the information world. Travellers receive a web based regional travel planning with updates on vehicle stopping point arrival and service disruptions, in real-time, by means of every possible media (internet, mobile, television and radio broadcasting). It is also available by means of mobile dedicated services and through informative panels with vocal announcement.

All different kinds of data, stored on CSR-DB, can also be used to implement an effective Governance through a Management by Data approach; a classical Business Intelligence architecture has been implemented (see Figure 3), but tailored to reach the CSR purposes:

1. Extracting Transforming and Loading (ETL) module: aimed at retrieving data from available sources, mainly the On Line Transitional Process (OLTP) databases and load them into DataWarehouse;
2. DataWarehouse (DW) module: builds the DW to store data and create structures for multi-dimensional analysis (hypercube);
3. Analysis and Elaboration data module: stored data are elaborated to feed dedicated Dashboards and Decision Support Systems (DSS), aimed at mobility analysis and control.

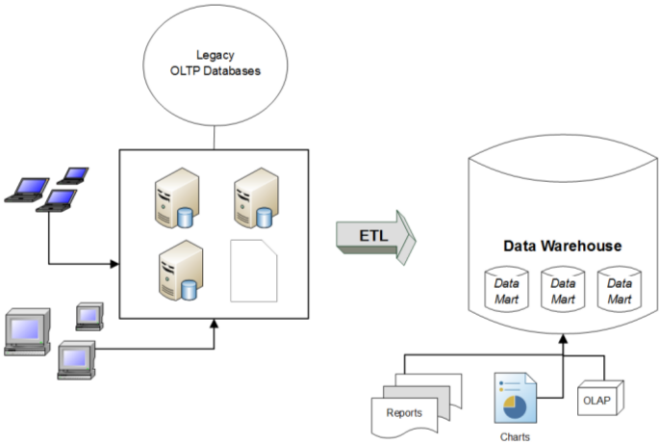

Figure 3 – BI architecture

The Management by data in based on gathering, storage and elaboration of raw data to calculate indicators aimed at (see [T8]):

- **Situation analysis**: this covers all the analysis to examine and study the operating status (e.g. delays because of traffic lights, road construction, traffic jams, etc.). It requires some recording of aspects of the operational context and of events along with the real-time data performance;
- **Contractual reporting**: this group covers the analysis and control mechanisms needed by Public Administration to provide funds for PT when the actual service must be accounted towards the local, regional or national administration body responsible for providing Public Transportation. It requires some representation of the accounting of undertaken services;
- **Providing data for Quality-of-service** analyses and processes: based on the planned timetables and the exchanged data, quality-of-service (QoS) analyses may take place, including delays and cancelled vehicle journeys; this aspect is fundamental for passengers.

10. Further Reading

I. The NeTEx Standard

[N1] NeTEx- Part 1: Public Transport Network Topology exchange format, CEN/TS 16614-1:2014

[N2] NeTEx- Part 2: Public Transport Scheduled Timetables exchange format, CEN/TS 16614-2:2014

[N3] NeTEx-Part 3: Fare Information exchange format, CEN/TS 16614-3:2014

II. The Transmodel Standard

[T1] Public Transport Reference Data Model - Part 1: Common Concepts (Transmodel), EN12896-1

[T2] Public Transport Reference Data Model -Part 2: Public Transport Network (Transmodel), EN12896-2

[T3] Public Transport Reference Data Model - Part 3: Timing Information and Vehicle Scheduling (Transmodel), EN12896-3

[T4] Public Transport Reference Data Model - Part 4: Operations Monitoring and Control (Transmodel), EN12896-4

[T5] Public Transport Reference Data Model - Part 5: Fare Management (Transmodel), EN12896-5

[T6] Public Transport Reference Data Model - Part 6: Passenger Information (Transmodel), EN12896-6

[T7] Public Transport Reference Data Model - Part 7: Driver Management (Transmodel), EN12896-7

[T8] Public Transport Reference Data Model - Part 8: Management Information and Statistics (Transmodel), EN12896-8

III. The SIRI standard

[S1] SIRI Part 1: Context and framework (CEN/TS 15531-1:2015)

[S2] SIRI Part 2: Communications infrastructure (CEN/TS 15531-2:2015)

[S3] SIRI Part 3: Functional service interfaces (CEN TS/15531-3:2015)

[S4] SIRI Part 4: Functional service interfaces: Facility Monitoring (CEN/TS 15531-4:2011)

[S5] SIRI Part 5: Functional service interfaces – Situation Exchange (CEN/TS 15531-05:2016)

IV. NeTEx White Papers

[W1] NeTEx Getting Started – White Paper: http://netex-cen.eu/wp-content/uploads/2015/12/02.NeTEx-GettingStarted-WhitePaper_1.06.pdf

[W2] NeTEx Design Methodology – White Paper: http://netex-cen.eu/wp-content/uploads/2015/12/03.NeTEx-DesignMethodology-WhitePaper_1.05.pdf

[W3] NeTEx Framework – White Paper: http://netex-cen.eu/wp-content/uploads/2015/12/04.NeTEx-Framework-WhitePaper_1.07.pdf

[W4] NeTEx Reusable Components – White Paper: http://netex-cen.eu/wp-content/uploads/2015/12/05.NeTEx-ReusableComponent-WhitePaper_1.08.pdf

[W5] NeTEx Network - White Paper: http://netex-cen.eu/wp-content/uploads/2015/12/06.NeTEx-Network-WhitePaper_1.08.pdf

[W6] NeTEx Flexible Networks and Multimodality – White Paper

[W7] NeTEx Accessibility – White Paper: http://netex-cen.eu/wp-content/uploads/2015/12/07.NeTEx-Flexible-Network-and-Multimodality-WhitePaper_1.06.pdf

[W8] NeTEx Timetables – White Paper: http://netex-cen.eu/wp-content/uploads/2015/12/09.NeTEx-Timetable-WhitePaper_1.05.pdf

[W9] NeTEx Fares – White Paper: http://netex-cen.eu/wp-content/uploads/2015/12/10.NeTEx-Fare-WhitePaper_1.04.pdf

V. Other References

[A1] *ARTIST (Architettura Telematica Italiana per il Sistema di Trasporto);* hhttps://ttsitalia.it/file/ARTIST/Workshop%2018%20dicembre/ARTIST%20FISICA.pdf

[U1] *Unified Modeling Language:* http://www.omg.org/spec/UML/2.5/

[G1] *General Transport Feed Specification;* https://developers.google.com/transit/gtfs

VI. Further Information

NeTEx Website: http://www.netex-cen.eu

Transmodel Website: http://transmodel-cen.eu/

OpRa Website: http://www.opra-cen.eu/

Calypso Network Association: http://www.calypsostandard.net/

Enquiries: email: info@transmodel-cen.eu