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Transmodel – NeTEx – EPTIS:

A European Standard for Modelling and Exchanging Fares

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Abstract
Interoperability between fare systems is an important step towards “seamless travel” and is a necessary condition for the efficient provision of passenger information on fares across transport modes. Achieving this goal presents a technical challenge and to help reach it the European project NeTEx/EPTIS proposes a standardised data exchange format for fares that can be used across Europe. The project specifies how to model the complexity of European fare structures, using a data model based on generic concepts that can represent the core elements of any fare system, independently of any specific set of concrete fare products offered for sale, and then derives a standard interface as an XML schema implementation. The European Reference Data Model for Public Transport (Transmodel), extended to cover the requirements of heavy rail, is used as a basis for the proposed fare model. An early implementation of NeTEx is achieved by the project BIPEx.

KEYWORDS:
Data Model, Public Transport Fares, Data Exchange

Introduction

Providing “seamless travel” is nowadays one of the main objectives - and challenges - of Public Transport operation. To make it possible, a number of developments are taking place as to payment methods and electronic travel documents. Most of these developments involve the “collaboration” of separate fare systems, each having its own description of fare structures and fare products. Information about the fare products and the conditions of their use is expressed in many different ways, usually specific to each fare system. This heterogeneity makes it difficult to construct a database that combines data from multiple sources, and to represent it in a common model that enables the building of standardised fare exchange messages that can be used Europe wide for all modes.

To address this problem, a data model has been built, aiming to provide a generic description of the data objects and elements needed to support functions such as the definition of the fare structure and its parameters, sales operations, the validation of consumption, and the charging of customers. A great deal of variation is found in how these functions are handled in different European countries, and even between the public transport operators within one country. This leads to significant complexity in the concepts that need to be taken into account in any attempt to define a single uniform data model that covers as many existing systems and practices as possible. In order to cope with this complexity, the fare data model concentrates on the generic concepts that form the core of any fare system, independently of how these concepts are implemented by a given set of concrete fare products (e.g. tickets or passes) offered for sale to the public. The key innovation of this approach (see Figure 1) is the definition of fares based on *access rights* rather than simple products or prices. Access rights are defined in terms of rights to use parts of the network or specific journeys on the network. Elementary access rights can then be combined to create immaterial fare products, which are linked to travel documents in order to form sales packages to be sold to passengers. Further steps describe controls that may be applied to these travel documents to validate the utilisation of the public transport system. Price elements are linked to the access rights, fare products and sales packages; they are used to calculate the actual amount to be paid by a customer for a specific consumption (e.g. sale on a vending machine, debiting a value card, post-payment).

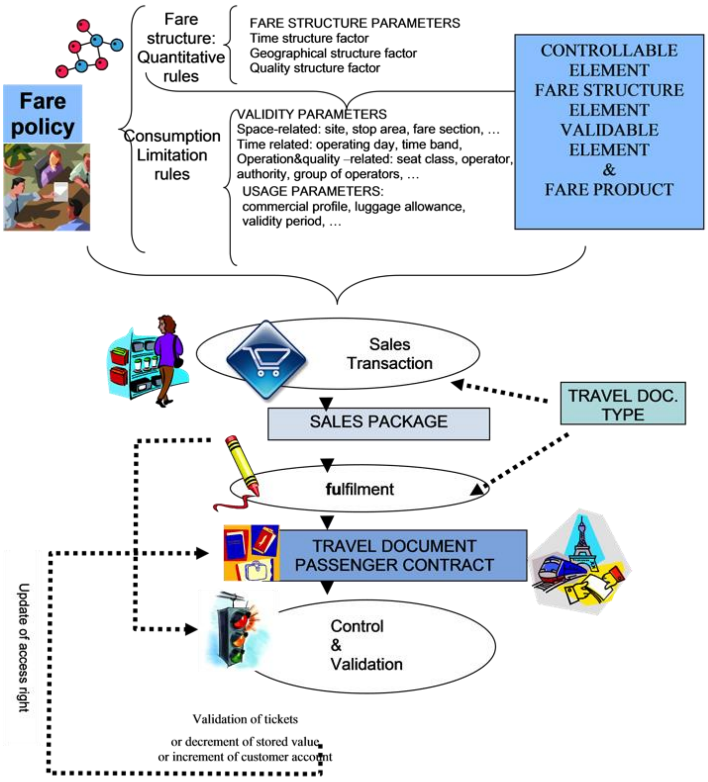

Figure 1 - Main processes in Fare Management

The NeTEx/EPTIS (see [1]) is an example of “model driven design”; development starts from a conceptual model, from which a physical UML model and an XML implementation is derived. The European Reference Data Model for Public Transport, known as Transmodel (see [2]), extended to cover the requirements of heavy rail and the needs modelled by the European standard IFOPT (Identification of Fixed Objects for Public transport, see [4]), is the conceptual basis for the development.

Background of the developments

The system architecture used within public transport companies turns out in many cases to be very complex and involves information exchanges between sub-systems involving data that are not harmonised as regards their semantics. Many different types of data are found (e.g. network topologies, timetables, real-time predictions, fare products, vehicle and crew schedules etc) yet with strong interdependencies; furthermore the data changes continuously at varying rates and involves many different stakeholders. The simplification of "information architecture" was the primary aim of a range of European projects that elaborated Transmodel, a standard Reference Data Model for Public Transport.

An "information architecture" refers to the overall structure of information used by an information system, determining the modularisation and structuring of data held in system databases and/or the structure of data exchanged across interfaces between systems. An information architecture made up of independent modules with well-defined interfaces is easier to maintain and more "future proof". An individual module can be revised or completely replaced without disrupting the rest of the system. The modules can also be more easily reconfigured according to changes in organisational arrangements in transport companies. Technological changes in communications and computing are continuously bringing forward new opportunities for evolving the systems supporting the business and thus inducing adaptations of parts of the system.

Transmodel is concerned with the following Public Transport domains: Network Topology, Timetables, Vehicle Scheduling, Driver Management (Driver Scheduling, Rostering, Personnel Disposition), Operations Monitoring and Control, Passenger Information, Fare Management, Management Information. The project NeTEx (Network and Timetable Exchange) undertook the task to "modularise" parts of Transmodel useful for Network and Timetable exchange and extended the data model for heavy rail needs, taking into account the requirements expressed by UIC (Union Internationale des Chemins de Fer) Leaflets.

NeTEx Part1 (TS16614-1) & Part 2 (TS16614-2) provide in particular the physical data model corresponding to Transmodel relevant UML sub-models (Network Topology, Timetables and Vehicle Schedules) and implements it as XML exchange specifications.

For timetables at least, several standard interfaces based on Transmodel had already been defined prior to NeTEx. Existing national developments include NEPTUNE [8] in France, VDV452 in Germany, TransXChange in the UK, Bison in the Netherlands, NOPTIS in Sweden, AVRIS [9] and TransportXML [10] in Slovenia. Some of them constituted a very valuable input for NeTEx Part 1 & 2, embodying actual data and process requirements for many major European systems.

Another important existing European development is the SIRI standard: SIRI (see [4], Service Interface for Real-time Information, EN15531-1 to 3 and TS15531-4 and 5) is an XML specification created to allow the exchange of real-time Public Transport data, which successfully used Transmodel to create a harmonized European protocol that is widely used to exchange bus and rail real-time data.

The continuation of NeTEx as the EPTIS (Electronic Passenger Transport Information Systems) project follows a similar approach as for NeTEx Parts 1 & 2, but focusing on the domain of Fares and publishing a third section (NeTEx Part 3) as a European Technical Specification (TS16614-3) for Information on Fares, as well as undertaking a number of dissemination activities.

Characteristics of a pan-European approach

A European-wide approach is of course complex, but existing national developments are themselves characterised by several shortcomings: they do not take into account requirements other than for existing locally used features (which may lack support for modern innovations such as demand responsive transport or electronic distribution), and furthermore are not designed for cross-border applications, for example often not allowing for unique global identifiers or multilingual text. As a consequence, a duplication of data often occurs, in particular for networks located near a border. Another disadvantage of current practice is that there is often little reuse of models or data; applications tend to be stand-alone “silos” and interfaces or data bases are developed without taking advantage of the outputs of other Public Transport business areas, i.e. without any consideration of other layers of information. For example the data models used for network topology description are relevant for many applications but are often separately defined in each subsystem. This may generate inconsistencies when an integration of different systems is attempted.

Transmodel/NeTEx approach has developed a model that is fully multi-modal, covering both the many different aspects of transport data, such as network, timetable and fare structures, for bus, metro, water, rail etc, and including the additional requirements of pan-European heavy rail (such as train make up, journeys that join and split, and complex conditions of use and sale of fare products). Detailed requirements submitted by the European Railway Agency have been thoroughly studied in the three NeTEx areas and taken into account, extending the existing Transmodel Reference Data Model. Drawing on experience of national data sets, the NeTEx format is designed for use in automated processes (essential for lowering costs) and includes uniform metadata for versioning, responsibility, etc, as well as mechanisms for grouping coherent sets of data. NeTEx also reduces complexity by using well abstracted standardised elements for complex concepts found across applications; a particular example is the way temporal conditions are defined (such as when a service operates or when a fare

product may be used); NeTEx systemises such commonly found elements as reusable components, making it easier to integrate and compute over data sets.
To sum up, the use of Transmodel principles, namely the definition and use of generic data concepts, independent from the user, country, application system or business area, facilitates an integrated, coherent system architecture. By carefully defining a standardised terminology for each distinct semantic element (such as “vehicle journey”, “day type”, “fare price”, etc.), a coherent model of unambiguous concepts is built which can then be implemented. This is especially valuable in the context of Public Transport, where many terms have overlapping or fuzzy meanings in vernacular usage (consider for example what is meant by a “route” (a specific path though the network or a line and all its branches?), a “journey” (the course of a vehicle or of a passenger?), or a “child” (infants, young children, any young person?). The modelling also helps to identify certain non-intuitive additional abstractions and to parametrise those elements which require necessary variation, which greatly simplifies the design.The Transmodel/NeTEx approach to fares is also flexible as the model is based upon the concept of access rights and not prices and is thus independent from pricing algorithms and thus adaptable to different organisations, countries and modes.

Applicability
The Public Transport Reference Data Model is used as a basis for specifying the concrete data exchange standards that define data formats and protocols for data exchange. This delivers a coherent series of standards Transmodel/NeTEx/SIRI. However, the model driven approach is also useful for systems using *different* Public Transport concepts and semantics, after an *alignment* of concepts and development of *data converters*.
A proof of the worldwide usefulness of several Transmodel concepts (for instance in the domain of network topology and timetables) has been seen in the ISO group dedicated to Public Transport (ISO TC204 WG8) where mappings of standards from the USA, South Korea and Japan have been studied.
As already mentioned above, Transmodel-based implementations have been implemented in several European countries (France, UK, Sweden, Italy, Germany, Slovenia, etc.) and also SIRI is used in a range of countries in Europe, but also in Israel, Australia and USA.
NeTEx Parts 1 & 2 implementations are currently under way in several European countries (e.g. NeTEx profiles have been developed for the Greater Paris Region). An early version of NeTEx Part1 was used to describe the complex accessibility and travel arrangements for the London 2012 Olympic sites.
The NeTEx Part 3 (NeTEx/EPTIS) data model for fares is based on Transmodel, refined by a further consideration of existing fare systems, (e.g. Oyster Card in the UK, Greater Paris Region fare structure, Berlin tariff system, European Rail Agency specifications for fares) including those with state of the art mass electronic payment systems that introduce new concepts such as fare capping. The standard has been published very recently and it is too

early to mention implementations using NeTEx fare formats. However the Italian BIPEx project is already based upon early versions of NeTEx/EPTIS. This innovative development describes a wide range of multimodal fares.

Use cases and actors

The NeTEx/EPTIS work identifies use cases to characterise the requirements that must be supported. The use cases are mainly oriented towards the provision of information on fare products and fares, and not towards the price calculation, which is the task of price calculation algorithms.

However, the approach does not ignore the necessity of calculating the prices. Fare products are modelled using a parameter-based approach: the different parameters linked to the fare structure elements may be instantiated for particular fare products in order to be taken into account by algorithms dedicated to price calculation.

The main use cases depend of course on the business context, the actors and the type of information involved. In the fare planning process, the most common use cases involve the creation and provision of information regarding the Fare Structure (i.e. the rules and their parameters used to determine the qualitative, quantitative and pricing conditions for accessing Public Transport) and the Fare Products (i.e. generic description of a set of marketable access rights, e.g. single way ticket from A to B or free travel in 3 adjacent zones) and their attendant conditions of use.

The most common use cases can be summarized as follows:

- to distribute general planned information on fares for publication;
- to distribute general planned information on fares for use by other relevant service providers, such as Public Transport Operators (PTO's), as a basis for derivation of information flows that facilitate operational processes,
- to provide general planned information on fares to online passenger information systems;
- to provide information on fare products and their rules and restrictions for a specific passenger trip: this is a refinement of the previous use case, taking into account a specific trip context, i.e. vehicle journey, date, time, interchanges, trip duration, distance, etc.;
- to identify shortest travel times and conditions for the lowest fare, taking into account possible combination rules of several fare products, so that passenger information can propose the actual fare products needed and available for travel;
- to show fare zones on topographical and schematic maps,
- to exchange fare information between long distance (i.e. heavy rail) and local public transport;
- to provide up to date fare parameters for price calculation: the necessary parameters enabling the price calculation are provided, not the calculation algorithms themselves.

The following table gives an overview of systems for Public Transport that are likely to use the NeTEx/EPTIS fare interface. Actors are organisations that might operate such systems.

Table 1 - Use Case Examples

Systems	Organisations
Service tendering and timetable registration systems	Public transport authorities
Fare Management and Planning Systems	Public transport authorities & operators
Journey planning systems	Public transport authorities & operators
Ticket selling systems	Public transport authorities & operators
Automated fare collection (AFC) systems (automatic ticket barriers (gate, turnstile) with fare collection (mechanical, infrared, magnetic))	Public transport operators
Passenger information systems (i.e. on-board fare displays)	Public transport operators
Demand responsive transport (DRT) or Dial-a-Ride Transit (DART) systems	Demand responsive transport operators
Mapping systems	Commercial/non-commercial service providers
Strategic planning systems	All levels of public transport authorities

Approach and methodology

The approach chosen by NeTEx/EPTIS is that already implemented for NeTEx Part 1 & 2. Starting from a conceptual model (extended Transmodel), a physical UML model is developed and then an implementation using XML (Figure 2).

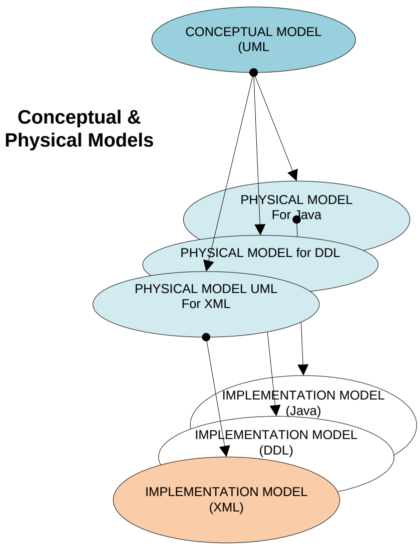

Figure 2 - NeTEx Methodology

Such an approach has the advantage of defining a coherent set of standards: Transmodel, NeTEx (and SIRI).

Data Model Contents

The NeTEx/EPTIS data model for fares (Figure 3) and its XML implementation rely on the underlying Transmodel-based representation of the network and journeys found in NeTEx Part 1&2 (Network and Timetable Exchange), together with the abstractions of the Transmodel Fares sub-model in particular the concept of "access rights".

The definition of the access rights needed to use a Public Transport service is linked to:

- space, time or quality related rules, determined by a range of parameters, called fare structure parameters, describing generic elements of the service offered for consumption (FARE STRUCTURE ELEMENTs). For instance, the parameters that determine the possibility of riding on a service journey from one stop point to another on one single vehicle,
- validity limitation rules, determined by validity and usage limitation parameters, specifying the particular conditions of the consumption of the generic access, for instance, the restriction to a particular tariff zone, particular line, etc. or to the type of user (user profile, commercial profile, the maximum duration of a particular trip or set of trips, to the accompanying objects, such as luggage allowance, specific permissions, such as interruption of the use of the right, use of specific route, etc.),
- the definition of means to materialise the access rights on travel documents (e.g. a throw-away ticket, an electronic travel card, etc.) and to control their consumption (e.g. using validators, turnstiles, manual controls, etc.).

The set of access rights granted by a travel document represents a FARE PRODUCT, i.e. a set of VALIDABLE ELEMENTs, determined by fare structure parameters, validity parameters and usage parameters and may be considered as being combinations of FARE STRUCTURE ELEMENTs.

A FARE PRODUCT is immaterial, which means that the same FARE PRODUCT can be materialised on various TRAVEL DOCUMENTs according to a particular type of medium. For instance, a monthly pass may be incorporated on a specific ticket or stored on an electronic card. Classical TRAVEL DOCUMENTs are anonymous, i.e. without any registration of the user. If a registration takes place a CONTRACT is agreed between a customer and an organisation in charge of collecting fares for using services (authority, operator or another service provider). The FARE PRODUCTs are associated with TRAVEL DOCUMENTs in order to form packages suitable for selling. A SALES PACKAGE is defined as a package to be sold as a whole, consisting of one or several FARE PRODUCTs materialised thanks to one or several TRAVEL DOCUMENTs. TRAVEL DOCUMENTs are usually allocated to customers on the occasion of a SALE TRANSACTION (i.e. a log entry recording an elementary sale event).

There is a large variety of methods to calculate the price to be paid and no generic solution to model all possible price generation algorithms. Therefore, the data model includes a set of price entities, which provide the data necessary to calculate the price in each of the use cases. Specific algorithms are responsible for applying the local price calculation rules to these basic price entities.

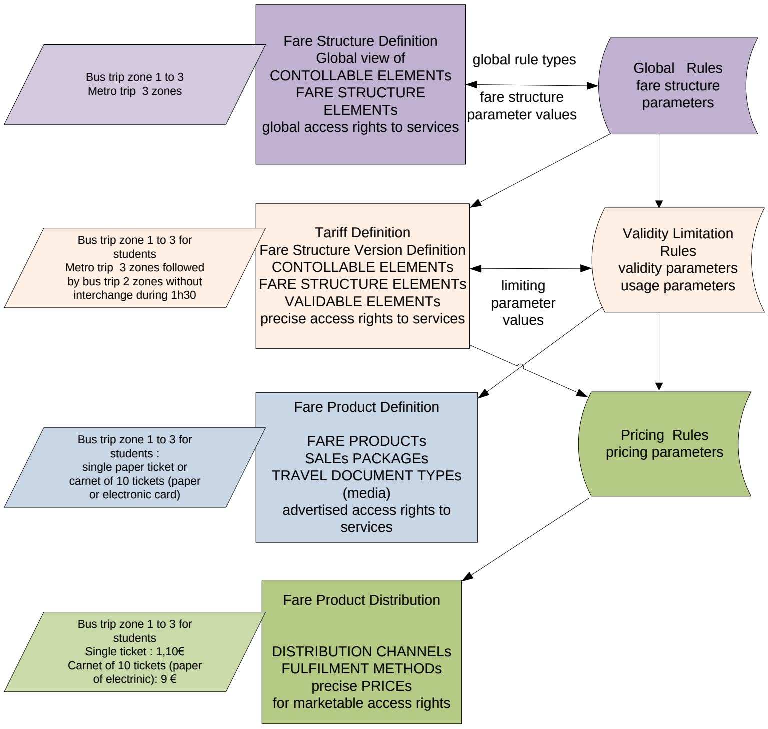

Figure 3 - Overview on Rules Types, Parameters and Concepts

Passenger information may need to include information on where particular products may be purchased. In this perspective, the FARE DISTRIBUTION MODEL specifies rules for where and how products may be purchased, for example over the counter, on-line, from self-service ticket machines, etc. SALES PACKAGEs can be restricted to specific DISTRIBUTION CHANNELs or GROUPs OF DISTRIBUTION CHANNELs. The concerns of DISTRIBUTION CHANNEL – how a product may be purchased - and FULFILMENT METHOD – how a purchase is subsequently delivered – are separated, as they may be distinct. For example, a product purchased on-line might be fulfilled either by e-mail, self-printing, collection from a machine, or automatically added to an on-line account. Where distribution, or the execution of certain functions such as refunds is limited to certain points of sale this can also be indicated.

First Implementations

Many IT implementations for Public Transport explore the concepts standardised in Transmodel and NeTEx. The Italian BIP project is one of the first implementations involving concepts from Transmodel that also uses the new NeTEx format. The project represents an innovative integrated ticketing system for Public Transport, railways and for virtually all other transport systems. The project involves over 100 Public Transport Operators (PTO), nearly 3.400 vehicles, more than 8.600 stopping points, nearly 400 train stations, from 1 to 4 million people with a total investment of 50 million euros.

One of the main goals of the project is to guarantee the interoperability among different PTO's, who all have to adopt a unique 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 passenger safety.

Linking the PTOs in the realized BIP system is a complex task needing the creation of a central system able to exchange data between all stakeholders: PTO's, PTO's consortia (CCA), Public Administration, Service Operator. A Regional Service Centre (called “CSR-BIP”) has been created, to act in the role of an independent judge able to solve issues between different operators (i.e. a “clearing referee”).

The Functional Architecture of the BIP system has been conceived as a universe of stakeholders 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 data, it was modelled as a “solar system” with its gravitational center on the CSR-BIP (see Figure 4).

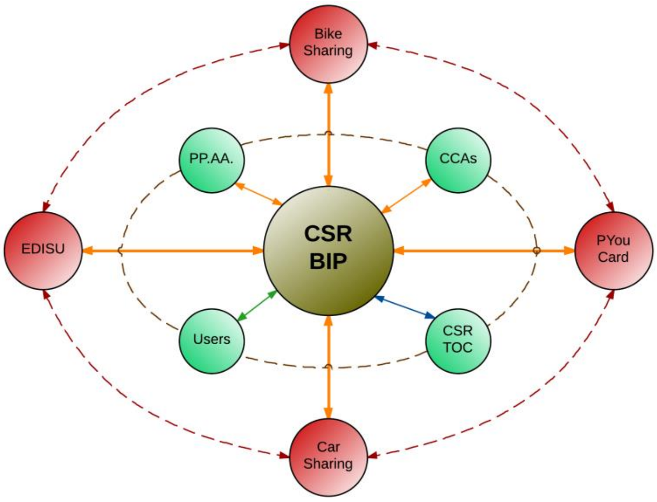

Figure 4 – BIP “gravitational model”

The “planets” of the BIP system are organized into two different “orbits”, with different levels 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 PTO's, Agency Control Centers (CCAs), Public Administration and users that are the final customers of the whole integrated service. Quite separate is CSR-TOC (see [6] - Regional Service Centre – Transport Operation Centre, hence called TOC) that is in charge of monitoring and control private traffic across the whole monitored territory,

- data exchange between service providers, Public Administration and CSR-BIP is made using BIP Exchange Protocol (BIPEx) (orange arrow in the figure).

CSR-BIP is the only center authorized to purchase BIP smart cards and it operates on behalf of CCAs (PTO's consortia) in order to communicate and exchange data with CCAs and Public Administration. An abstract data model has been designed and developed aimed at heterogeneous data migration. This model has been inspired by the standards: Transmodel, NeTEx and SIRI.

The BIPEx protocol implements and augments the above standards, adapting them to the specific project architecture and to an Italian operational context. It is XML based and is divided in 3 main parts:

- Planned service (TPL): is used to exchange planned service of PTO's agencies (with dedicated structures for service network and timetables) directly derived from NeTEx Part 1 and Part 2 protocol;
- Electronic Ticketing System (SBE): is related to PT usage data (tickets purchased, validations etc.); this part was developed by extending the available NeTEx Part 3 protocol with further Transmodel elements and local requirements ;
- Real-time information (see [5]): exchanges real-time positions of vehicles related to their current service state and is used both for info-mobility services and for vehicle monitoring; this part was derived from SIRI.

Conclusions

This paper presents an approach for modelling and exchanging Public Transport fare data in order to enable seamless travel, facilitating a collaboration between multiple fare systems. The approach is *model driven*, using a reference data model that provides a generic description of the data objects and elements needed to support the definition of the fare structure and its parameters. A standard Reference Data Model for Public Transport, called Transmodel, finalized by 2001, became a CEN Norm (EN 12896) around ten years ago. Based on Transmodel, implementation standards like NeTEx or SIRI have been developed, providing technical specifications for network, timetable, fare and real-time data exchange. Transmodel-based implementations have been developed over the past fifteen years and now exist in a number of European countries with - in some cases - entire national timetable data sets now being available in a standard format. Further implementations are found in Israel, Australia and the USA, where some SIRI interfaces are used. The model driven approach can now be measured as both mature and successful. The EPTIS project builds on NeTEx and aims to deliver a technical specification for NeTEx Part 3 on Fare Structure data, including XML schema and other supporting materials that will explain the standard and assist with its dissemination. An early version has been successfully deployed in the Turin BIPEx system.

As a next step, there are currently activities in progress to elaborate NeTEx profiles to undertake concrete implementations (e.g in Greater Paris Region, STIF). An updated

Transmodel documentation (fully coherent with NeTEx) of the Part 1 (Common Concepts), Part 2 (Network Topology) and Part 3 (Timing Information and Vehicle Scheduling) has been achieved and work on the subsequent parts will be completed in the near future, with particular emphasis on modularization of Transmodel, together with some extensions.

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