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Public transport — Network and Timetable Exchange (NeTEx) — Examples, guidelines and explanatory materials

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National foreword

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Transport Public - Échange des données de réseau et d'horaires (NeTEx)

Öffentlicher Verkehr - Netzwerk- und Fahrplan Austausch (NeTEx) - Beispiele, Vorgaben und erläuterndes Material

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Contents

Page

European foreword

This document (CEN/TR 16959:2016) has been prepared by Technical Committee CEN/TC 278 “Intelligent transport systems”, the secretariat of which is held by NEN.

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Introduction

0.1 General information

NeTEx is a series of CEN Technical Specifications dedicated to the exchange of Public Transport scheduled data (network, timetable and fare information) based on:

— Transmodel V5.1 (see [T1], [T1] and [T3]);

— IFOPT (see [I1]);

— SIRI (see [S1], [S2], [S3], [S4], [S5]);

It supports information exchange of relevance to public transport services for passenger information and AVMS (Automated Vehicle Monitoring Systems). Many NeTEx concepts are taken directly from Transmodel and IFOPT; the definitions and explanation of these concepts are extracted directly from the respective documents and reused in NeTEx, sometimes with further adaptions in order to fit the NeTEx context.

The data exchanges targeted by NeTEx are predominantly oriented towards passenger information and also for data exchange between transit scheduling systems and AVMS. However it is not restricted to these purposes, and it can provide an effective solution to many other use cases for transport data exchange

The NeTEx series of documents is divided into three parts, each covering a functional subset of the CEN Transmodel for Public Transport Information:

— Part 1 describes the Public Transport **Network topology** (see [N1]);

— Part 2 describes **Scheduled Timetables** (see [N2]);

— Part 3 covers **Fare information** (see [N3]).

NeTEX is intended to be a general purpose XML format designed for the efficient, updateable exchange of complex transport data among distributed systems. This allows the data to be used in modern web services based architectures and to support a wide range of passenger information and operational applications.

Most public transport modes are taken into account by NeTEx, including train, bus, coach, metro, tramway, ferry, and their submodes. Moreover, it is possible to describe airports and air journeys, but there has not been any specific consideration of any additional provisions that apply especially to air transport.

While there are a number of existing documents available for Timetables, NeTEx is the first systematically engineered document that also covers multimodal Fares.

0.2 Compatibility with existing standards and recommendations

The concepts covered in NeTEx that relate in particular to long-distance train travel include:

— rail operators and related organizations;

— stations and related equipment's;

— journey coupling and journey parts;

— train composition and facilities;

— planned passing times;

— timetable versions and validity conditions.

In the case of long distance train, the NeTEx takes into account the requirements formulated by the ERA (European Rail Agency) – TAP/TSI (Telematics Applications for Passenger/ Technical Specification for Interoperability), entered into force on 13 May 2011 as the Commission Regulation (EU No 454/2011), based on UIC directives.

As regards the other exchange protocols, a formal compatibility is ensured with TransXChange (UK), VDV 452 (Germany), NEPTUNE (France), UIC Leaflet, BISON (Netherland) and NOPTIS (Nordic Public Transport Interface Standard).

The data exchange is possible either through dedicated web services, through data file exchanges, or using the SIRI exchange protocol as described in Part 2 of the SIRI documentation (see [S2]).

This Technical report is to be used in conjunction with the following documents:

— EN 15531-1, Public transport - Service interface for real-time information relating to public transport operations - Part 1: Context and framework (see [S1]);

— EN 15531-2, Public transport - Service interface for real-time information relating to public transport operations - Part 2: Communications infrastructure (see [S2]);

— EN 15531-3, Public transport - Service interface for real-time information relating to public transport operations - Part 3: Functional service interfaces (see [S3]);

— CEN/TS 15531-4, Public transport - Service interface for real-time information relating to public transport operations - Part 4: Functional service interfaces: Facility Monitoring (see [S4]);

— CEN/TS 15531-5, Public transport - Service interface for real-time information relating to public transport operations - Part 5: Functional service interfaces - Situation Exchange (see [S5]);

— EN 12896, Road transport and traffic telematics - Public transport - Reference data model (see [T1]);

— EN 28701, Intelligent transport systems - Public transport - Identification of Fixed Objects in Public Transport (see [I1]).

0.3 NeTEx exchanged information

NeTEx provides a means to exchange data for passenger information such as stops, routes timetables and fares, among different computer systems, together with related operational data. It can be used to collect and integrate date from many different stakeholders, and to reintegrate it as it evolves through successive versions.

All three parts covered by NeTEx use the same framework of *reusable components*, versioning mechanisms, validity conditions, global identification mechanisms, etc., defined in a NeTEx framework in Part 1. NeTEx also includes, container elements called "version frames" to group data into coherent sets for efficient exchange.

NeTEx schema can thus be used to exchange:

— public Transport schedules including stops, routes, departures times / frequencies, operational notes, and map coordinates;

- routes with complex topologies such as circular routes, cloverleaf and lollipops, and complex workings such as short working and express patterns. Connections with other services can also be described;
- the days on which the services run, including availability on public holidays and other exceptions;
- composite journeys such as train journeys that merge or split trains;
- information about the Operators providing the service;
- additional operational information, including, positioning runs, garages, layovers, duty crews, useful for AVL and on-board ticketing systems;
- data about the Accessibility of services to passengers with restricted mobility;
- data are versioned with management metadata allowing updates across distributed systems;
- fare structures, (flat fares, point to point fares, zonal fares);
- fare products (Single tickets, return tickets, day, and season passses etc);
- fare prices that apply at specific dates.

0.4 NeTEx exchanging data modality

Data in NeTEx format is encoded as XML documents that should conform exactly to the defined schema, and conformance can be checked automatically by standard XML validator tools. The schema can also be used to create bindings to different programming languages to assist automating part of the implementation process for creating software that supports NeTEx formats.

In this perspective, a NeTEx service need only to implement those elements of relevance to its business objectives – extraneous elements present in the binding can be ignored. Parties using NeTEx for a particular purpose will typically define a "profile" to identify the elements that have to be present and the code sets to be used to identify them.

Documents in NeTEx format are computer files that can be exchanged by a wide variety of protocols (http, FTP, email, portable media, etc). NeTEx publication documents can be used to define files suitable for the bulk exchange of XML documents representing whole data sets (for example all the timetables for an operator).

In addition, a SIRI based NeTEx protocol is specified for use by online web services. It defines NeTEx request and response messages that can be used to request and return data in NeTEx format, and also publish/subscribe messages for push distribution. The responses return a NeTEx XML document that satisfies the request criteria (and also conforms to the NeTEx schema). There is a WSDL binding for this NeTEx service to make it easy to implement services.

NeTEx XML thus serialises complex PT models into a standard flat file format that can be processed cheaply and efficiently using mainstream modern computer technologies.

0.5 Motivation

0.5.1 Business drivers

Modern public transport services rely increasingly on computerised information systems for passenger information; for example for timetables, for real time data and for ticketing. The increased use of online engines and electronic ticket products in particular requires the representation of timetables, products and fares as digitalised data sets. Such data are typically both inherently complex (since the real-world domains it describes are complex) - and subject to a complex workflow. Data are typically assembled from many different stakeholders with different responsibilities (for stops, timetables, real time, fare products, pricing etc) and is continually changing - at intervals ranging from the intermittent periodic change of network and timetable data, to the second by second changes of real-time systems. Standardization seeks to provide effective data models that both capture these complex domains as reusable components and to support a workflow that involves continuous integration and validation of data under many different possible configurations of participants.

Well-defined, open interfaces therefore have a crucial role in improving the economic and technical viability of Public Transport Information systems. Using standardised interfaces, systems can be implemented as discrete pluggable modules that can be chosen from a wide variety of suppliers in a competitive market, rather than as monolithic proprietary systems from a single supplier. Furthermore, individual functional modules can be replaced or evolved, without unexpected breakages of obscurely dependent function. Interfaces also allow the systematic automated testing of each functional module, vital for managing the complexity of increasing large and dynamic systems.

0.5.2 Technical drivers

Increasing complexity is itself a barrier to the development and uptake of systems, and it is not uncommon to find that organisations develop multiple and sometimes conflicting models to handle different aspects of their business processes, and also to find that the difficulty of changing the system impairs development of the business. Because PT data sets are complex and shared by so many participant, they are especially hard to change and they thus represent a strategic investment. It is thus is important to design them for long term use so that they are expressive enough to capture business requirements and flexible enough to evolve to meet to changing business requirements and use.

0.5.3 CEN documents context

NeTEx has been developed under the aegis of CEN and is the most recent development stage in over 15 years work to systemise and harmonize European passenger information data. The work draws on a number of existing national standards applying systematic principles of information architecture to construct flexible models that correctly separate the different concerns of representing and managing data. The keystone is the Transmodel standard (see [T1]), a conceptual model which names and represents PT info concepts for a wide set of functional areas and can be used to compare and understand different models. Transmodel project outputs have been used both to underpin a number of CEN concrete data standards such as SIRI and IFOPT, and to rationalize national standards to allow for harmonization and interoperability. Transmodel has been used to develop NeTEx and is itself being updated to include NeTEx additions. While there are a number of standards available for Timetables, NeTEx is the first systematically engineered document that also covers multimodal Fares.

CEN (European Commitee for Standardization) is Europe's standardization body. It divides its work under into committees covering different aspects of industry and technology. NeTEx, as a transport Technical Specification is formally produced by Technical Committee 278, Work Group 3, Sub Group 9. Other TC278 WG3 sub groups handle the related standards Transmodel (SG4), SIRI (SG5 Service interface for real-time information) and IFOPT (Identification of Fixed Objects in Public Transport. NeTEx has thus both a concrete series of Technical Specifications, and an open consultative process for maintaining that document.

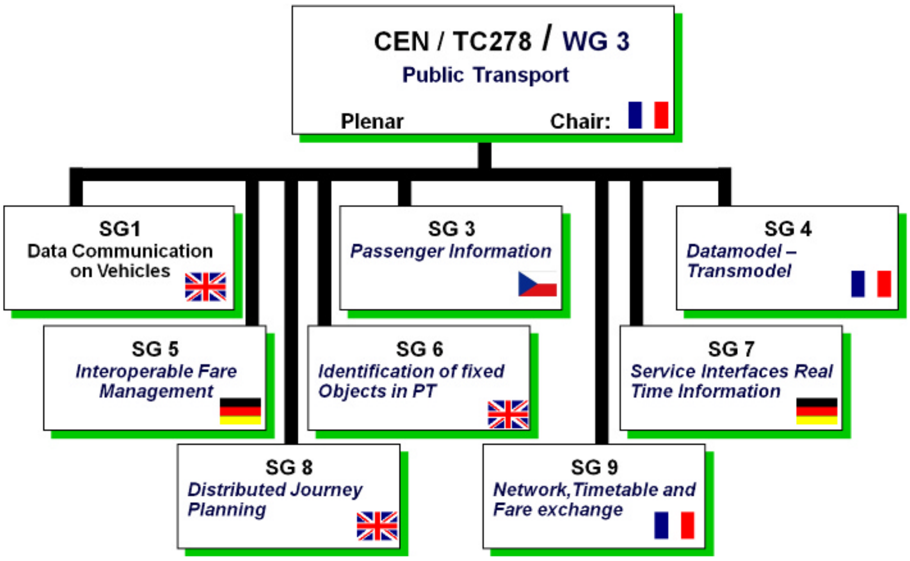

Figure 1 — CEN TC278 WG3 Sub-groups

0.5.4 CEN process and participants

Work on NeTEx has involved delegates from Austria France, Germany, Hungary, Italy, Netherlands, Slovenia, Sweden, Switzerland, UK, and the European Rail Authority. Part 1 and Part 2 were approved in 2013 and Part 3 is being finalized at the moment.

Evolution of EU PT standards and NeTEx for rail with TAP/TSI compatibility

0.5.5 Evolution of EU PT standards and NeTEx

The development of NeTEx has drawn on existing national and legacy standards such as VDV 452 (DE). BISON (NL) Neptune (FR) and TransXChange (UK) in particular to validate the NeTEx model by establishing mappings with established national standards.

The development of NeTEx also coincided with an interest by the European Rail Authority and other stakeholders in seeking a degree of data interoperability between different modes of public transport such as rail, metro and bus, that is, the ability to exchange data about routes, timetables and fares between systems, and also to supply external third party users. To this end a study was undertaken to compare the TAP/TSI B1, B2 and B3 models with the original Transmodel fare model used as the basis for NeTEx Part 3 and a number of gaps were identified and addressed. (A successful informal mapping of the MERITS data for stop and timetable data had already been achieved in Part 2).

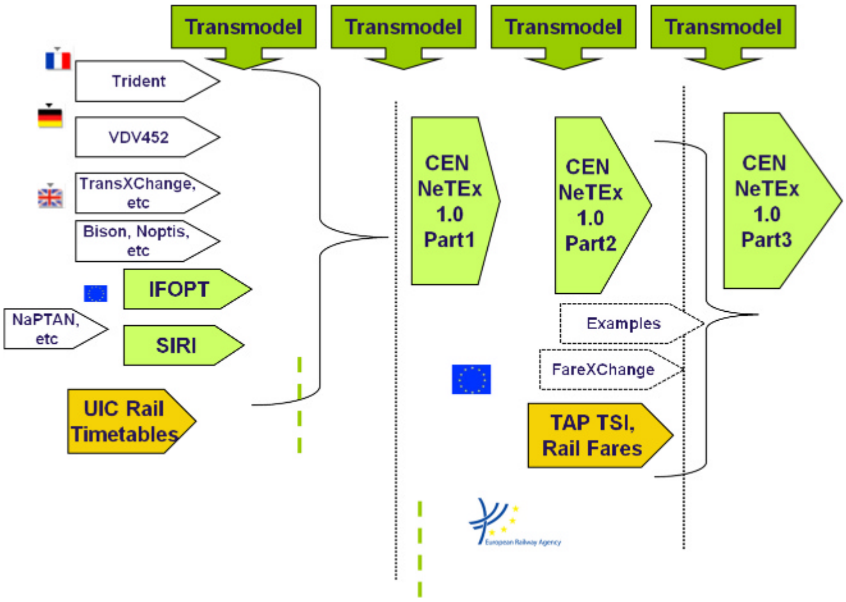

Figure 2 — Evolution of NeTEx documents

0.6 Term of Use

NeTEx is published as a series of CEN Technical Specification, (Part 1, Part 2 and Part 3). These are CEN copyright publications and are available for purchase from the shops of the respective National Standards Organisations of each CEN country: AFNOR (fr), BSI (uk), NEN (nl), SIST (si), UNI (it), DIN (de), etc).

The NeTEx XML Schema and UML models are free to use under a GPL version 3 Licence, so the use of schema and models is possible without necessarily purchasing the CEN NeTEX publications.

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The CEN NeTEX Schema and UML models are free software: you can redistribute them and/or modify them under the terms of the GNU General Public License as published by the Free Software Foundation, either version 3 of the License, or (at your option) any later version, see < http://www.gnu.org/licenses/>.

The CEN NeTEX Schema and UML models are distributed in the hope that they will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for more details.

1 Scope

This Technical Report provides a set of examples, white papers and explanatory material that makes it easy to understand how to use and deploy all parts of NeTEx. This will help EPTIS system providers and acquirers, providing functional scope, guidelines and terminology explanations needed to implement a system. It will also ease formalizing the requirements for the context of a procurement process.

This Technical report provides an explanatory material that makes it easier to understand how to use all parts of NETEX. This will help EPTIS system providers and acquirers, providing functional scope terminology explanations needed to implement a system. It will also ease formalizing the requirements for the context of a procurement process

2 Frequently Asked Questions (FAQ)

2.1 Introduction

In this paragraph, a set of Frequently Asked Questions (FAQ) is reported. FAQ are also maintained updated in the relevant NeTEx website section (see http://netex-cen.eu/?page_id=111).

2.2 Basic Commercial questions

2.2.1 Do I have to pay for using NeTEx?

The formal documents describing NeTEx are available as Technical Specifications (TS) from your national standardization body. A fee in the national currency is charged for such documents by each standardization body. However the actual formats and designs described by the TS may be used without charge, and without necessarily purchasing the CEN NeTEx publications. You may use the schema and models for free under a GPL license as described on NeTEx website (http://netex-cen.eu/?page_id=20). This ensures that the IPR is in the public domain and may be safely considered as a long term strategic investment.

2.2.2 What skills do I need to deploy NeTEx?

The NeTEx schema itself is a W3C XML schema, so XML technical skills are typically required to build applications to create or process data in NeTEx format. General XML skills can be used to process XML documents containing data in NeTEx format, for example, to run validators or to amend content.

At a design level, NeTEx uses a “Model Driven” approach, that is, the fundamental design is described as a high level conceptual model that tries to represent the problem domain as entities and relationships that have been identified by a set of use cases, many taken from existing systems covering the desired business scope. To understand the high level model underlying the XML schema (which is valuable for building applications) requires data modelling skills and an understanding of the UML notation. Public Transport domain knowledge will of course help (additional information available at http://transmodel-cen.eu/).

2.2.3 What tools are available to support NeTEx?

General purpose XML tools can be used to work with the NeTEx XML schema and XML documents that conform to it, for example either the proprietary XML SPY (http://www.altova.com/xmlspy.html), or Oxygen (http://www.oxygenxml.com/) or see free tools at http://www.garshol.priv.no/download/xmltools/. A wide variety of mainstream XML tools are available to validate XML and to create bindings to specific programming languages (NET, Java, PHP, C++).

To look at the design models, an interactive UML viewer such as Enterprise Architect (http://www.sparxsystems.com/)is extremely helpful, although a set of static web pages is also available.

To import or export transport data in NeTEx format, a number of suppliers are developing support for NeTEx for their existing products. New open source NeTEx products are also being developed such as CHOUETTE (http://www.chouette.mobi/en/). Sample mappings to a variety of national formats (VDV, BISON, etc) as well as GTFS have been developed and are included in the NeTEx documents. Further information on NeTEx implementations are available at http://netex-cen.eu/?page_id=65.

2.2.4 How do I get new features added to NeTEx?

CEN working groups provide a consensual process to evolve standards and have formal procedures and timeframes managed through the standards bodies of the European nations. New feature proposals can be submitted to the NeTEx working group by sending an email at info < at > netex-cen.eu and will be considered along with other suggestions for a future enhancement to the documents. Under the CEN process a New Work Item request is created to manage the enhancements to a specification, with a versioning process to identify sets of changes.

Adding new features specific to country, supplier or any smaller area can be done using NeTEx extension mechanisms (Key Value extensions/ Extension Tag). These can also be used to develop new candidate features ahead of formal incorporation. See also 'Can I add my own codes to NeTEx'?

2.2.5 What is a profile?

Although NeTEx is a large document, a NeTEx service needs only to implement the specific elements relevant to its business objectives – extraneous elements present in the model can be ignored. Parties using NeTEx for a particular purpose will typically define a "profile" to identify the subset of elements that have to be present, as well as the code sets to be used to identify them. A machine readable form of this profile may be created using the NeTEx TYPE OF FRAME element, specifying which elements have to be present; this can be used to enable automatic validators for local profiles.

Following are some profile examples:

— Network-profile: http://netex-cen.eu/wp-content/uploads/2015/06/Network-profile.pdf

— Timing-profile: http://netex-cen.eu/wp-content/uploads/2015/06/Timing-profile.pdf

— Stop-profile: http://netex-cen.eu/wp-content/uploads/2015/06/Stop-profile.pdf

— Shared-Element-profile:http://netex-cen.eu/wp-content/uploads/2015/06/Shared-Element-profile.pdf

— Stop-Identification-profile:http://netex-cen.eu/wp-content/uploads/2015/06/Stop-Identification-profile.pdf

— Concept-selection-profile:http://netex-cen.eu/wp-content/uploads/2015/06/Concept-selection-profile.pdf

2.2.6 What if I find a bug in NeTEx?

Any issue on NeTEx can be communicated to the working group sending an email at info < at > netex-cen.eu. NeTEx schemas are in GITHUB and corrected versions, identified by an interim version number, can be created if necessary.

2.2.7 How do I get support for my NeTEx development?

Some basic support for NeTEx development can be get sending an email at info@netex-cen.eu.

2.3 Basic scope questions

2.3.1 Is NeTEx a GIS standard?

Spatial location is important for a number of NeTEx elements, for example to locate stops, but NeTEx is not of itself a GIS standard; rather it defines additional public transport related layers of information that may be projected onto a GIS data set. Thus for example a typical application such as a Journey Planner will seamlessly combine NeTEx data with map data address data to allow a user to plan travel from any location to any location.. NeTEx uses a GML based coordinate system to reference GIS data, allowing a wide variety of GIS formats to be used (WS84, National Ordnance Survey Grid, Lambert, etc). This should make it easy to combine NeTEx data with other data sets, and to support different GIS reference systems.

NeTEx also includes distinct concepts of topographic place and of administrative jurisdiction – again distinct from GIS location, but which can be mapped to other systems that give a spatial projection for reference. Thus stops can be located a serving a particular town or region (even as is sometimes the case for major interchanges, they are not physically contained within the geospatial boundaries).

2.3.2 Is NeTEx a database?

No, NeTEx defines an exchange format to exchange data between systems; it does not constrain the internal representation used by a given system to store or process the data, nor require the use of a specific database design. That said, any database supporting NeTEx data will need to have corresponding elements that can be mapped into the elements in the subset of NeTEx supported.

For more information refer to Transmodel for database modelling (http://transmodel-cen.eu/)

2.3.3 Is NeTEx for real-time applications?

NeTEx can usefully be used to provision systems with the reference data needed to support real-time data, such as stops, lines, routes, timetables etc, but is not envisaged as a real-time data protocol. Real-time applications typically need to be optimised to exchange the data very quickly, very efficiently and specific protocols such as CEN SIRI are designed to do this. The NeTEx model can however be used to understand how the real-time data content of SIRI messages relates to the NeTEx and Transmodel models.

NeTEx model includes additional data elements specifically to support stop and on board real-time systems, for example the headings to show on a vehicle at each stop, the stop announcements etc, that are not needed for simple timetable exchange such as by GTFS.

2.3.4 Can I use NeTEx for Rail?

Yes, NeTEx covers stations, networks, timetables and fares for Rail. The development process has involved experts from Rails (ERA, UIC, SNCF, ATOC, etc.) to make sure specific rails requirements are taken into account. The NeTEx design process included consideration of the B1, B2 and B3 Tap/TSI data models for European Rail fares as well as various national urban and suburban rail systems. NeTEx includes support for complex aspects of rail passenger information, such as journeys that join and split, train makeup, boarding positions on platforms, station and on-board facilities, accessibility and complex fare products. High value rail fare products often have complex conditions of use and NeTEx can describe these in a representation that gives both machine readable and human readable forms. Restrictions on routing (as in Tap/TSI 'Series') can be described. Multimodal products with rail components can also be described.

2.3.5 Does NeTEx provide web services?

Yes, NeTEx include some SIRI based http protocols that can be used to request and return data in NeTEx format, embedding XML documents in the requests and responses.

NeTEx offers predefined SOAP and REST WEB Services.

2.3.6 Does NeTEx cover ticket sales?

The NeTEx's scope doesn't include the actual retailing process – it covers only the products and fares that can be sold, along with all conditions of sale and use that accompany them. It can include information about available distribution channels and fulfilment methods needed to direct users towards the available retailing services. NeTEx can represent many of the ancillary elements relevant for retailing, since they are also relevant for some product definitions. For example passes and season tickets typically require a customer and a contract and because some modern products, are usage based such as pay as you go fares with capping, it also includes a basic record of travel purchases for account based product use.

NeTEx doesn't describe standards for the media used for tickets (for example the layout and content of a rail ticket), though it includes a 'Travel document concept that can be used to link to downstream retail systems that prescribe how a product should be materialized.

2.3.7 Can I use NeTEx for mobile applications?

The data in NeTEx is relevant for a number of types of mobile application – for example, stop finding and journey planning. NeTEx includes web services that can be used to support certain mobile applications directly (e.g. stop finding); others such as journey planning or fare finding will typically involve a specialized API to an engine that is populated with NeTEx data. Note that the communication framework shared with SIRI v 2.0 also includes a specification for automatically mapping XML to JSON and other lightweight formats especially suitable for large scale mobile applications.

2.4 Pros and Cons questions

2.4.1 What are the advantages of using NeTEx?

Key benefits of using NeTEx can include:

— **Reducing development and support costs** (see 'How can NeTEx reduce development costs?' below, as well as 'How can NeTEx simplify my software application development'.)

— Inc**reasing function and design quality** See 'How can NeTEx increase capability and improve design quality?' below, as well as various answers on specific functions such as versioning, internationalization, and advanced capabilitys later below.

— **Reducing complexity** See 'How can NeTEx simplify my software application development?' below

— **Protection of investment** See 'How can NeTEx protect my investment' below, as well as 'How can NeTEx increase capability and improve design quality?'

2.4.2 How can NeTEx reduce development costs?

A CEN document enables a European-wide economy of scale in developing products and tools that handle transport data, as well as a much higher degree of supplier independence for those purchasing systems. Use of a standard format reduces the number of different interfaces that have to be developed and supported to exchange data between diverse systems, NeTEx uses mainstream XML technology for which there is a large skill base and many toolsets. The NeTEx XML schema includes data and referential integrity checks that reduce development time. The presence of these checks increased data quality automatically throughout the life of the standards.

2.4.3 How can NeTEx increase capability and improve design quality?

NeTEx offers a degree of protection of investment in that not only does it use mainstream technologies and have a process to support future evolution, but it also already includes in its design a high degree of functionality. Because it has been systemised from and validated against leading National Standards it covers most of the commonly found features of public transport information systems and represents a significant amount of free, ready to use IPR in how to abstract the separate concerns of a transport information system into coherent a software model. There is a high degree of reuse of elements. The model also considers a full consideration of many advanced features, such as frequency based services, flexible services, capped fares, etc not full accommodated in many existing national standards. Not all of the features need to be implemented in a given deployment, but their presence in the design gives a clear roadmap for where to include such function if it is needed at any time.

NeTEx is the only document to put forward a comprehensive fare data standard, one that covers not only classic multimodal fares, but also modern products such as card based pay as you fare products, relating them to a common transport model.

2.4.4 How can NeTEx simplify my software application development?

NeTEx can help to reduce complexity at the design level in that it is based on Transmodel, using a well-established set of well-defined concepts with an official terminology set in different European languages. Careful abstracted to separate different design concerns. For example NeTEx separates out the concepts of a route (a sequence of possible stops), a journey pattern (a specific set of stops on the route), the timings to traverse the links of the journey pattern, and the resulting passing times at the stop making up a given timetabled journey, thereby allowing many different journeys to be computed simply by specifying a starting time, As a result of this approach, NeTEx achieves a high degree of reuse, using the same core elements in all three parts and building Part 3 from part 2, and Part 2 from Part 2 elements, reducing the overall number of elements needed. A small number of design patterns are used very consistently reducing the overall cognitive burden needed to understand a large number of different functional areas.

The existence of high level models with transforms to the detailed implementation gives developers a full documented overview of the design, making it easier to understand the purpose of specific components and to assess the impact of changes.

NeTEx can help to reduce complexity at the implementation level in that it takes a uniform approach to many common aspects of data handling, for example, versioning, data frames, data identifiers, validity conditions, etc, greatly simplifying the implementation of such features and allowing a high degree of code reuse for common services. NeTEx includes explicit mechanisms to allow the continuous, repeated large scale integration of data from different sources as is found in modern internet based environments.

2.4.5 How can NeTEx protect my investment?

As a CEN document with international support independent of any one supplier, and a process to support future evolution NeTEx offers an inherent degree of protection of investment. The use of mainstream technologies, such as UML and XML means that design and content is available in robust form with widely available skill sets.

Assembling and managing public transport content models represents a significant long term investment for a Transport Operator Much of the data are inherently complex (e.g. timetables or fares) and is changing continuously. Accurate coherent data sets need to be created to integrate many different types of data and be kept up to date though many different workflows. NeTEx is concerned precisely with such a content model including the necessary metadata to manage it, and gives a long term strategic model for exchanging data between many different systems, one that is already ‘future proofed’ by the inclusion of many advanced features and additional functional modules.

A significant part of the lifetime expense of a system comes from maintenance and support to meet changing business needs. Whereas with modern web technologies new web services to request data can be constructed with relative ease, (e.g. adding new syntactic views as different APIS,), changing the underlying data model is harder and shall be managed in a distributed context – different systems will upgrade at different times, so multiple versions have to be able to exist concurrently and without confusion. The NeTEx model is strictly versioned and designed to allow a managed evolution. Successive versions can easily be regression tested against existing XML documents to ensure compatibility and correctness.

2.4.6 What are the disadvantages of using NeTEx?

NeTEx is not a panacea and there are also a number of potential disadvantages to using it:

— additional complexity from using a large, generalized model. See 'Is NeTEx hard to understand?';

— fragmentation of semantics from generality see '*Does increased generality make NeTEx is harder to work with?*';

— addition computational expense for processing large XML models with extensive integrity checks;

— limited expressiveness of XML;

— slow speed of standards process.

2.4.7 Is NeTEx hard to understand?

NeTEx is undoubtedly large and quite complex, and uses a sophisticated model that has been evolved over more than 15 years to cover the requirements of many different types of system – this imposes a significant learning curve, especially if you are unfamiliar with Transmodel, or with software engineering notations such as UML. However, it is also highly modular, so only the required modules need to be considered and once the core principles have been assimilated, the use of a consistent terminology and a uniform set of design patterns facilitates learning of new areas of functionality. The provision of reusable components such as calendar conditions, stops, etc also reduces the effort needed to understand the system.

2.4.8 Does increased generality make NeTEx is harder to work with?

NeTEx in some cases abstracts concepts into several separate elements in order to separate concerns, this in turn increases reusability and gives greater flexibility. This can make it harder to understand which combination of elements should be used to represent a solution, and even in some cases allows alterative representations. This can be mitigated by a profile setting out how NeTEx should be used for a specific set of data and by examples.

Although it is possible to omit most unwanted functions, certain core properties are required and this can make implementations of simple functions more complex.

2.4.9 Does NeTEx require more computing resources that other standards?

NeTEx uses XML technology; large documents require more processing power to handle than some formats with a lower semantic content, especially if extensive validation and integrity checking is done (though noted that the referential integrity checks can be omitted if documents are known to be correct). In mitigation, computer power continues to get cheaper whereas the cost of skilled resource to resolve issues arising from unchecked data errors has not.

XML is verbose, with both start and end tags being required, and NeTEx documents can be large. Various feature help to reduce size notably; the ability to declare default value at a frame and other levels, and the ability to reference data from other frames, and the ability to exchange just elements that have changed. Bandwidth can be saved by sipping documents for transmission.

2.4.10 Are there missing validity checks in NeTEx ?

Where possible NeTEx enforces validity checks in the XML schema so that data are correct and consistent. XML schema can provide data typing and useful identity and referential integrity checks, so for example it is possible to ensure that not only are fields in the right format (as say for dates, times, email addresses or enumerated values) but also that a document is complete (every referenced element is present) and unique (a given identifier is only used once). However schema cannot describe a number of more complex integrity constraints (for example; that passing times on successive stops in a journey are monotonically increasing) and such checks need to be implemented programmatically by validation or import tools.

A deliberate decision has been made to leave out one type of validity check. In XML schema, it is also possible to specify whether an element will be present or is optional. However in order to allow a single XML schema to be used for many different uses case, NeTEx makes the majority of schema elements optional, and leaves it up to the individual application to check for completeness. (Note that NeTEx profiles can be used to express this requirement also).

2.4.11 Is it quick to add new features in NeTEx?

International standards process are consensual, with periods for review and voting. This makes it relatively slow to incorporate official changes. As an interim measure, the NeTEx extension mechanisms can be used to include additional elements informally prior to ratification.

2.5 Further Specific questions of Scope

2.5.1 Can NeTEx describe journey connection times?

In order to provide accurate journey plans, it is valuable to be able to specify realistic connection times between journeys at interchanges that take into account the mode of transport, the detailed topology of the interchange and even the mobility of the user (for example a path suitable for a wheelchair using a lift may take longer). NeTEx allows both default and specific transfers time to be specified for any connection.

NeTEx also permits complex operational rules about journey interchanges to be described so that that planned and guaranteed connections can be managed and so that real time systems and real-time journey planners can give accurate advice to users.

2.5.2 Does NeTEx support accessibility?

Yes, NeTEx supports the specification of accessibility attributes on both the fixed infrastructure (drawn from the CEN IFOPT standard) and on vehicle types used for specific journeys, so that full accessibility aware journey planning can be provided, including micro-navigation through interchanges. Both accessibility properties and equipment for different disabilities (e.g. wheelchair spaces, navigability, tactile strips etc) and accessibility services (e.g. boarding assistance) can be defined. Furthermore, NeTEx defines a set of user needs (e.g. wheelchair, blindness, push chairs, etc) that a journey planning engine can use to set criteria to find the optimal journey for a given set of accessibility criteria.

2.5.3 Can NeTEx handle frequency based services?

Frequency based services are typically specified as operating at a given interval, rather than particular times. From a passenger point of view multiple journeys will typically be presented as a single journey running at an approximate interval, for example “every six to 10 minutes”. NeTEx uses TEMPLATE VEHICLE journeys to describe such journeys. From an operational point of view there will still need to be specific service journeys scheduled to fulfil the required frequency of service and NeTEx can also include these to support real time journeys.

2.5.4 Can I have different journey timings for different times of day?

Part 2 of NeTEx includes reusable components for constructing timetables of journeys from reusable components, NeTEx separates the concerns of where the timing of a PT route takes place (The TIMING PATTERN made up of TIMING POINTs and TIMING LINKs) from the actual timing values (which are held separately as RUN TIMEs and WAIT TIMEs). Different sets of timing values belong to different TIME DEMAND TYPEs (Peak, off peak, late night etc) can be used with the same TIMING PATTERN to generate accurate timetables for journeys at different times of day.

2.5.5 Can NeTEx describe zone based fares?

NeTEx can be used to describe zone based fare systems of any topology ranging from a simple patchwork (adjacent zones) to the complex, (honeycomb, doughnut) etc). The TARIFF ZONE allows zones to be associated with stops and stations. Mixed zonal and stage systems are also possible. Fare pricing may be a flat fare system per zone, or zone to zone using a (DISTANCE MATRIX ELEMENT), or be differentially priced for particular sequences of zones (using FRAE STRUCTURE ELMENTs in SEQUENCE).

2.5.6 Can I restrict certain products to certain classes of user?

Among the many different usage conditions that can be specified for NeTEx fare products are restrictions on the type of user – child, senior, student, disabled, etc using a USER PROFILE that may be given precise eligibility criteria (e.g. on age, membership, domicile, etc). A GROUP PROFILE allows the number and makeup of groups to be specified; it can also be used to specify companion criteria for disabled users and other special cases.

2.5.7 Can I specify time based constraints on travel?

Some fare products only allow travel at particular times – such constraints can be expressed using USAGE PARAMETERs. Others only allow travel for a particular duration; FARE STRUCTURE ELEMENTs with TIME STUCTURE FACTORs can be used to describe the different durations. Furthermore, sometimes journey time is related to journey length, so for example a longer time is allowed for a two zone trip than a one zone trip; all this can be precisely specified in NeTEx.

Temporal conditions may also apply to the purchase or refund of tickets, likewise expressed as USAGE PARAMETERs attached to fare products.

As well as the routine examples given above, NeTEx can also handle more complex cases. For example, in the periphery of a large city, off peak times may start at different times in each station since by the time a journey to the centre starting from the station ends, the peak period will have ended.

2.5.8 Can I integrate data from different countries with NeTEx?

Yes, one of the strengths of NeTEx is that it takes a global view of data identification, allowing data elements from different name spaces to be exchanged in the same schema.

2.5.9 Does NeTEx support dynamic/ yield managed pricing?

For long distance travel, especially on-rail, there is increasing used of yield managed fares with dynamic pricing, provided by web services. Note that such applications increase rather than decrease the need for documents such as NeTEx as such applications nonetheless require a machine readable definition of the access rights fare structure and usage conditions that apply to the products for which prices are supplied. Furthermore the search parameters used to find the best fare for a user (such as age, possession of rail cards, fulfilment method etc) need to correspond to the properties of the fare product. The NeTEx Part 3 specification and UML model includes an annex showing a sample fare query which shows all the NeTEx model elements relevant for constructing a Fare API.

2.5.10 Can NeTEx define products for modern e-card based ticketing?

Yes. Electronic payment cards such as OV Chipkart (NL), Oyster (London region), Navigo (Paris region) Sube T (Madrid), BIP Card (Turin) are becoming increasingly common and etc transport operators are able to devises increasingly sophisticate products . For example Oyster has fares that adjust according to consumption, capping the cost of trips made in a day to that of a day pass. NeTEx is able to describe the fare structures and scope and conditions for such complex products, as well as to supporting an record of consumption for account based products. (A NeTEx SALES TRANSACTION records an individual PRODUCT SALE).

As products on cards are physical invisible to the user, the ability to create user readable representations become increasingly important – such applications require a machine readable format with corresponding human readable rendering, such as is available through NeTEx.

2.5.11 Does NeTEx support Flexible and Demand Responsive Travel?

Yes, unlike classical route and timetable standards, NeTEx is also designed to support FTS (Flexible Transport Service) and DRT (Demand Responsive Transport). DRT and FTS often cover similar services; FTS being more generic since flexibility may not be directly linked to the demand, but may be related to some operating needs or cost optimisations.

The flexibility can be applied to the line, route and stop structure (areas, corridors, hail and ride, etc.) or to their scheduling (dynamic and/or demand responsive passing times, with all necessary booking arrangements and contact details).

2.5.12 Can I create applications to run in different national Languages?

Yes, NeTEx includes full support for internationalization. All text elements may be created in multiple languages so that place names and other names and descriptions can be provided in one or more languages. Other aspects important for multiregional use are parameterized such as time zones, currency, etc and the Calendar functions allow conditions based on different national holidays to be described.

2.5.13 Can I have different version of data for the same element extant at the same time?

Yes, every NeTEx data element can be versioned, and multiple versions can coexist. Coherent sets of data are assembled for exchange using a ‘version frame’, which itself has a version and knows the version of the elements in it. There are specific types of version frame for different type of data that ar commonly exchanged together (SERVICE, TIMETABLE, FARE etc).

2.5.14 Can I create Network maps with NeTEx?

Yes, one of the additional capabilities of NeTEx is the ability to define and exchange the full topology of a network as presented in simplified view to a user (often with presentational attributes such as colour), with non-directional network segments, loops etc, while also retaining a projection onto the actual underlying stops and route. This allows automatic creation of interactive map applications.

— The LINE element names the line and sets basic properties;

— the LINE NETWORK and LINE SECTION elements can be used to described the topology;

— the ROUTE, ROUTELINK, and ROUTE POINT elements can be used to define the directional elements of the underlying line;

— the SCHEDULED STOP POINT can be used to define the stops of a line.

All these objects can have their own geographic positions and geometry or an be projected onto a custom drawn map using a SCHEMATIC MAP element.

2.5.15 I have my own classification for Stops/ Lines / etc. Can NeTEx handle this?

Ye.s NeTEx allow arbitrary user defined code classifications for elements using the has TYPE OF STOP, TYPE OF LINE and other 'Type of Entity' elements that . In addition NeTEx, to encourage standardised use, also provides fixed enumerations of many commonly found classifications of specific elements, including types of equipment, on-board facilities, etc.. The 'Key Value' extension mechanism allows Also allows additional user defined attributes to be added, which can include classifiers.

2.6 Comparison with other documents

2.6.1 How does NeTEx relate to Transmodel?

NeTEx is primarily dedicated to data exchange, i.e. an XML message format and a protocol are specified. The content model of the NeTEx message structure is based upon the NeTEx physical data model and is derived directly from Transmodel, the CEN Public Transport Reference Data Model developed at a conceptual level and independent of an implementation in any specific technology.

As regards functional domains, NeTEx covers only a subset of Transmodel; the *Network Topology, Timing Information, Vehicle Schedulin*g and *Fare Information* domains, whereas the full scope of Transmodel is broader, including in addition: *Operations Monitoring and Control*, *Fare Management* (sales, validation, control), *Management Information and Statistics*, *Driver Management: Driver Scheduling, Rostering*, and *Driving Personnel Disp*osition.

The Transmodel conceptual model is broken down into modular packages with a mostly linear dependency graph between modules. The same organization of packages is used in the Phsyical model and XML schema so that there is a direct correspondence between the modules for each functional domain. This makes it straightforward to relate the high level design to the implementation.

2.6.2 How does NeTEx relate to IFOPT?

IFOPT, similarly to Transmodel specifies a data model, whereas the primary aim of NeTEx is to define data exchange format. IFOPT has been integrated into the latest version of Transmodel (v6) and thus (see above) builds the basis for the NeTEx physical submodel dedicated to Fixed Objects for Public Transport. This data domain is concerned with particular different types of sites (and their components), such as points of interest, parking or stops and related objects like equipment, for instance, but also pedestrian navigation paths and takes into account accessibility characteristics. NeTEx specifies the exchange of the data defined by the IFOPT model.

2.6.3 How does NeTEx compare with VDV?

Since NeTEx was influenced by existing European national standards and reference exchange protocols it also ensures compatibility with VDV452 ("VDV Standard Interface Network / Timetable" reference exchange protocol in Germany) at the level of conceptual and physical model. The aim of the VDV452 is to transfer network definitions and timetables from a source system into a target system, i.e. the timetable data from a scheduling program is transferred to consumer systems for the purpose of transit operations. NeTEx's physical model provides specific elements (i.e. ExternalStopPointRef, ExternalJourneyRef, ExternalInterchangeRef, etc.) for VDV compatibility, specifically for use in AVMS systems.
A comparison between NeTEx and VDV452 is available at: www.vdv.de/netex.

2.6.4 How does NeTEx compare with TransXChange?

TransXChange, the UK national timetable standard, together with NaPTAN, the UK stop data standard, provides a functional equivalent subset of to the NeTEx stop and timetable elements in NeTEx Part 1 and NeTEx Part 2 and it is straightforward to map these to the contents of a NeTEx timetable frame. Both documents are based on Transmodel and allow the exchange of structural information such as timing information and journey patterns, The NeTEx representation is in many respects simpler, but is less specific about which elements shall be present, and what the restrictions of values are. NeTEx also includes many additional elements in Part 1 and Part 2 that are not in TransXChange, including support complex for rail journeys, interchanges rules, . schematic maps, etc. TransXChange does not support fares and nearly all of NeTEx Part 3 is outside of its scope. The result of 2004 FareXChange study of UK Bus Fares was a significant input into NeTEx.

TransXChange also includes a small number of additional registration elements to support the Electronic Bus Service Registration process of the UK Vehicle Licensing authority (VOSA). Some of the registration concepts (such as administrative areas) have equivalents in NeTEx, but a few of them are specific to the UK regulatory context and are not supported by NeTEx. It would be possible to add a separate UK extension to NeTEx to include these.

2.6.5 How does NeTEx compare with NEPTUNE?

NEPTUNE is a French standard for data exchange in the domain of Network Topology and Timetables. It is based upon a draft EN version of Transmodel and incorporates several features of IFOPT as regards stop typology, equipment and accessibility characteristics. It is comparable as regards the functional coverage to NeTEx-Part 1&2, but smaller regards to number of data covered.

2.6.6 How does NeTEx compare with NOPTIS?

The Transmodel based Nordic Public Transport Interface Standard (NOPTIS) provides a consistent set of XML-exchange protocols covering both planned and real time aspects. One of these exchange protocols is the Data Input Interface (NOPTIS DII). This exchange protocol is optimised to transfer version-managed information concerning Network, Timetable, Vehicle Schedule, Services and other data to a PTA integrator system and is used extensively in Sweden and Denmark. NOPTIS DII was a significant input to NeTEx. There exists a mapping between NeTEx and NOPTIS DII covering the Calendar, Timetable and Vehicle Schedule aspects showing how to use NeTEx in a way that supports parallel partial data deliveries as in NOPTIS.

2.6.7 How does NeTEx compare with IFM?

Interoperable fare management (IFM) encompasses all systems and processes designed to manage the distribution and use of fare products in an interoperable public transport environment. Such systems are called interoperable when they enable the customer to use a portable electronic medium (e.g. a contact/contactless smart card) with compatible equipment (e.g. at stops, with retail systems, at platform entry points or on board vehicles).

IFM-Part 1 is an ISO standard (ISO 24014-1) aiming at the definition of a reference functional architecture for Interoperable Fare Management System(s) and at identifying the requirements that are relevant to ensure Interoperability between several actors in the context of the use of electronic tickets. The exchanges between IFM actors are described from the functional point of view by the IFM standard, without the specification of data exchange format.

NeTEx- Part 3 describes fare elements as specified in public transport fare systems (zonal fares, flat fares, progressive fares, distance matrix, etc) and the resulting fare products using a conceptual data model, specifies a detailed physical data model for fares and derives data exchange message formats for fare exchange. The exchanges are concerning the information on fares (abstraction being made from any particular medium), on the conditions of use of fare products, on associated fare product distribution channels. Parameters necessary for the price calculation of fare products are also provided.

IFM is a process description and NeTEx is a data exchange format.

2.6.8 How does NeTEx compare with BISON ?

The official start of BISON, the platform for *Beheer Informatie Standaarden Openbaar Vervoer Nederland* (Management Information Standards Public Transport Netherlands), took place on 16 September 2008. The BISON platform is the result of an earlier decision on the part of the National Mobility Deliberations

(NMB) to set up a management organization for the further development of collective standards and the incorporation of these standards, insofar as possible, in existing concessions.

The main function of the BISON platform is to formulate, manage, harmonize and monitor all of the information standards that facilitate the exchange of information within the public transport sector.

BISON considers NeTEx to be the standard of choice for the future. Parts of NeTEx have been applied and used within BISON (e.g. Part 3 – Fares). In due time BISON will migrate from its national PT information exchange standard to NeTEx, and in due time NL specific BISON profile(s) will be developed which will help to exchange travel information with other countries such as Germany and Belgium.

2.6.9 How does NeTEx compare with the Taap/TSI standards?

There are three different TAP /TSI standards for fares; m – B1 (standard fares) B2 (Integrated Reservation fares) and b3 (special fares), each using different models (with some common elements between B1 and B3) rand quite different representations of the classes of user conditions, NeTEx is able to represent the elements and attributes of all three models with a single uniform model, based on access rights, using in particular DISTANCE MATRIX ELEMENTs to describe the point to point fares and USAGE PARAMATERs to describe the different conditions applying to the the rail products. Only a small number of .FARE PRODUCTS are needed to describe the standard rail products. A number of sales conditions also relate to rail products and can be describe using SALES PACKAGES with NeTEx DISTRIBUTION CHANNELs and FULFILMENT elements. The mapping of most elements is straightforward and it is straightforward to create transformations using simple mapping tools such as those found in the XML SPY product suite.

The TapTSI standars make used of a number of UIC code sets (all represented in NetEx as either sets of enumerated values or 'Types of value' or in the case of station and oboard facilities as various types of Facility or Equipment. . Stations (Locations in UIC terminology) can be uniformly represented in NeTEx as Scheduled Stop points.

For details on the Tap/TSi model see the UML model of the mapping and the mapping specifications.

2.6.10 How does NeTEx compare with GTFS?

Google General Transport Feed Specification (GTFS) is a widely used format for distributing timetables to third parties. The NeTEx and GTFS formats should be considered as complementary, covering different stages in the data management process: NeTEx is "upstream", GTFS is "downstream". NeTEx differs from GTFS in that it has a much wider scope, and that it is intended for use in back office use cases under which data are generated, refined and integrated (requiring the exchange of additional elements used to construct the timetable), rather than just for provisioning journey planning systems (the prime purpose of GTFS).

GTFS covers stops, lines, and timetabled journey information (Gtf trips) sufficient to answer basic journey planning queries. It supports only a few simple types of fare product . GTFS data identifiers are specific to each data set and require registration of an identifier with Google.

NeTEx covers many other aspects of Public Transport Information apart from timetables (e.g. network descriptions, fare products,), as well as supporting a richer timetable model for export including journey patterns, timing patterns, joined journeys, train makeup, connection timings, etc. . This makes it able to exchange the data sets used to build tinetables as well as the resulting timetables themselves. NeTEx includes the additional information needed to provision real-time systems (such as destination displays) and to link to operational systems (such as blocks) It also includes versioning and validity condition mechanisms to support the repeated peer-to peer integration of many data from many different parties.

Because it uses XML, NeTEx is able to package a complete data set as a single coherent document that can be managed and validated.

GTFS uses a traditional flat file format; this is compact and efficient but requires multiple files to describe the different types of element and thus additional rules for naming and packaging the files as a zip. Custom written tools are need to interpret and process the data.

It is possible to generate a full GTFS data set from NeTEx but not vice versa. The NeTEx UML includes a GTFS mapping package which shows how each GTFS element may be populated from the corresponding NeTEx element.

3 NeTEx covered areas description

3.1 Introduction

NeTEx covers different areas that fall into two main groups: General areas and Specific functional areas.

3.2 General areas

— NeTEx Getting Started [Annex A];

— NeTEx Design Methodology [Annex B];

— NeTEx Framework [Annex C];

— NeTEx Reusable Components [Annex D];

3.3 Specific functional areas

— NeTEx Networks [Annex E];

— NeTEx Flexible Networks [Annex F];

— NeTEx Accessibility [Annex G];

— NeTEx Timetables [Annex H];

— NeTEx Fares [Annex I].

Annex A
(informative)

Getting Started

A.1 Introduction

This Annex is intended to convey a high level view sufficient for a technical manager to appreciate some of the issues involved in implementing NeTEx, omitting many detailed considerations - for a detailed description please see the full CEN NeTEx specification, in particular Part 1 [N1] from which sections of this Annex are taken. Indication for getting started in the NeTEx protocol usage are reported.

A.2 Three common use cases

In practice, any new implementation of NeTEx is likely to be following one of three different use cases:

1) Adding support for **export in NeTEx format** from an existing PT data system that already has similar data content (but does not use the exact NeTEx model).

   — In this case the implementer is constrained by her existing repository model, and the task will be to map the data into the equivalent NeTEx elements in the output documents. It is likely that only certain elements and attributes will be populated, and the level of detail on the versioning of the exported will depend on what is supported in the originating system. A globally unique namespace or namespaces will need to be chosen for the identifiers and added to the exported content.

   — The NeTEx specification includes appendices with mappings into a number of European National standards such as VDV452 (de), NEPTUNE (fr) and BISON (nl) and also GTFS see [G1].

2) Adding support for **import in NeTEx format** into an existing PT data system that already has similar data content (but does not use the exact NeTEx model.

   — The implementer is also constrained by the existing repository model, and the task will be to map the data *from* the equivalent NeTEx elements into the internal format. It may be necessary to extend the existing database model to handle additional elements or attributes present in NeTEx, especially if a lossless round trip exchange is envisaged (otherwise, additional information provided by NeTEx but not required may just be ignored). The importing system may use NeTEx version data present in the document to identify differences in data sets. The import may be limited to the specific namespaces and identifier sets supported by the existing system.

3) Creating a **new system** based on parts of the Transmodel / NeTEx functional model, with **import and export** capabilities for the NeTEx XML schema. The implementer will be free to choose an internal repository model with a direct or straightforward mapping to the NeTEx model as shown in the Physical UML mode. Only those features that will be in the functional scope of the system need to be implemented – unsupported elements can be ignored.

In all three cases the implementer should be able to use automated tools to create an initial binding and NeTEx object model from the NeTEx XML schema (see below).

A.3 Basic Steps

A.3.1 General

This section sets out some basic considerations for using NeTEx.

A.3.2 Agreeing a profile

A.3.2.1 General

NeTEx covers many types of transport data, and can be used in a many of different workflows and to support different levels of detail in the data exchanged. However a given group of stakeholders using NeTEx are likely to be using only a subset of the schema for an agreed purpose. Furthermore they may have more explicit requirements as to which namespaces and identifier sets are used and which elements and attributes are mandatory in the exchanged data. For example, users might just be exchanging stop data for the different modes of a country, or rail timetables for a region.

Using NeTEx therefore requires number of choices to be made. The set of choices may be described more formally as a ***profile*** – a set of decisions as to how NeTEx is to be used by a set of stakeholders who have agreed to exchange data in NeTEx format for a particular purpose.

A.3.2.2 Profiles

A profile will typically covers:

— *Which data elements are to be exchanged* ? For example stops, routes, journey patters, timetables, fare structures, etc. This depends on the functional scope of the systems and the use cases for exchanging data.

— *Which types of version frame are to be used to exchange the data ?* In many cases, a single type of frame (e.g. TIMETABLE FRAME) has all the elements needed for the function (since the frames is chosen to group related elements). However sometimes elements from several different frames are needed; in this case a COMPOSITE FRAME is also used to group the frames into a coherent set with common validity conditions and compatible versions.

— *Choose the name spaces and identifiers to use to identify instances of elements as unique*. NeTEx allows you to declare a globally unique context for each identifier (see Annex C), but it is up to the implementer to allocate specific domains for this purpose and to decide the semantics of the codes within the namespace. In some cases it may also be useful to include legacy identifiers as aliases on elements when they are exported, allowing two way exchange with legacy systems.

— *Select the specific attributes of the elements which shall, may, or shall not be present* (other than the attributes which are mandatory in the NeTEx schema and shall always be present)

— *Determine the granularity of elements within the frame.* When outputting data elements within a given frame in some cases the implementer has a degree of freedom to the exact organization of elements within the frame (since they are walking a complex object model in order to serialize it, expressing some relationships by containment and others by explicit reference) For example, in some cases it is more convenient to nest related elements in-line within another containing element in other cases it is more convenient to declare the related elements separately and add a reference to them from the 'containing' element. This choice should make little difference to an importing system, as the parser technology available for XML in any case does most of the work to reassemble the serialize objects from the document using the information provided by the schema, regardless of the actual encoding, but in some cases it may materially affect the size of the resulting document.

— *Determine the level of versioning to be exposed in the exchanged data*. All NeTEx objects can hold detailed versioning attributes, and the data attributes may be exposed in the exchange format so that importing and exporting systems can use them to process changes efficiently. However many legacy systems do not support fine grained versioning and the fine grained version data may be omitted or ignored if it is not to be used.

— *Select the protocol to use to exchange NeTEx XML documents.* The content of a NeTEx document is independent of the method used to transfer it – and in fact the latter may vary according to the application. (e.g. SIRI http exchange of XML documents, asynchronous FTP of documents, SOAP, etc). A messaging protocol using SIRI allows arbitrary dynamic queries to be formulated – but typically only some query capabilities will actually be implemented. A group of stakeholders using NeTEx will need to decide which method of transmission i.e. protocol they wish to use, and also ensure that the bandwidth and processing capacity are appropriate to the data content and frequency of exchange that is envisaged.

A.3.2.3 Describing a profile with a Type of Frame

A FRAME is a concept used to group related and consistent elements. NeTEx includes a mechanism, the TYPE OF FRAME, which allows version frames to be formally marked as conforming to a given profile. A TYPE OF FRAME can list the elements and attributes that shall be included in an instance of a version frame as well as various descriptive attributes and properties. SITE, SERVICE, TIMETABLE, FARE and other VERSION FRAMES can then reference the TYPE OF FRAME to indicate they are constrained to the profiles requirements. Additional validation programs may use the information from the TYPE OF FRAME to apply automatic validation tests over and above those enforced by the XML validators.

A.3.3 Choosing a Version frame

Data shall be exchanged in one or more version frames; the version frame groups together compatible data meeting a given set of selection criteria and validity conditions (e.g. “Berlin bus stops”, “Todays timetable”, “Paris Metro Fares Winter 2015”) There is a special version frame for each the of functional data, as well as several general purpose frames. A COMPOSITE frame is used to group other frames. See Table A.1.

Table A.1 — NeTEX version Frame type

Part	Name	Description
Part 1 Framework	RESOURCE FRAME	Used to exchange common reference data such as operators, modes, facilities, day types, calendars, equipment, vehicle types, etc
	GENERAL FRAME	Can be used to exchange any arbitrary user defined set of coherent elements
	COMPOSITE FRAME	Used to group other frames for exchange as a single unit.
Part 1 Functional	INFRASTRUCTURE FRAME	Used to exchange details of the road and rail elements making up the underlying network, along with restrictions on using them with specific vehicles,. Also locates different points dedicated to the vehicle and crew changeover
	SERVICE FRAME	Used to exchange the basic description of a transport network; stops, lines and routes of a transport including stops and connection, along with the timing
	SITE FRAME	Used to exchange information detailed places and sites such as stations, points of interest parking, including navigation paths and access restrictions.
Part 2 Functional	TIMETABLE FRAME	Used to exchange timetables, including journeys, linked journeys, planned interchanges, service facilities etc.
Part 3 Functional	FARE FRAME	Used to exchange fare data, including fare structures, fare products, fare restrictions, sales packages, pricing parameters, prices
	SALES TRANSACTION FRAME	Used to exchange descriptions of customers and their purchases.

A.4 Implementing a NeTEx System

A.4.1 Implementation Technology

NeTEx systems can be implemented using any technology (JAVA, C#, C++, Visual Basic, Python, PHP, Ruby, etc.) that can process XML documents; pragmatically it should be one that has an object orientated programming mode and tools to automatically create a binding to XML. NeTEx makes use of inheritance.

A.4.2 Implementation of NeTEx interfaces

— **To create an import interface,** typically an implementer will first create a binding for the chosen language from the NeTEx XML Schema using a tool, this will create an object model that an XML parser will populate when it reads a NeTEx XML document. The implementer will then write a mapping of the elements of this model to his own internal representation, including any logic to resolve references to link to the appropriate version of object.

— **To create an export interface**, an implementer will write a program to process a query request (as specified by an XML document) to assemble a collection of elements that meet the selection criteria and validity conditions, and then walk the results to output the elements as XML elements wrapped in a specific version frame. Conditions as to the validity of the data may be attached to individual elements and to the whole frame. The output XML document should be validated against the NeTEx schema to check that it is correct.

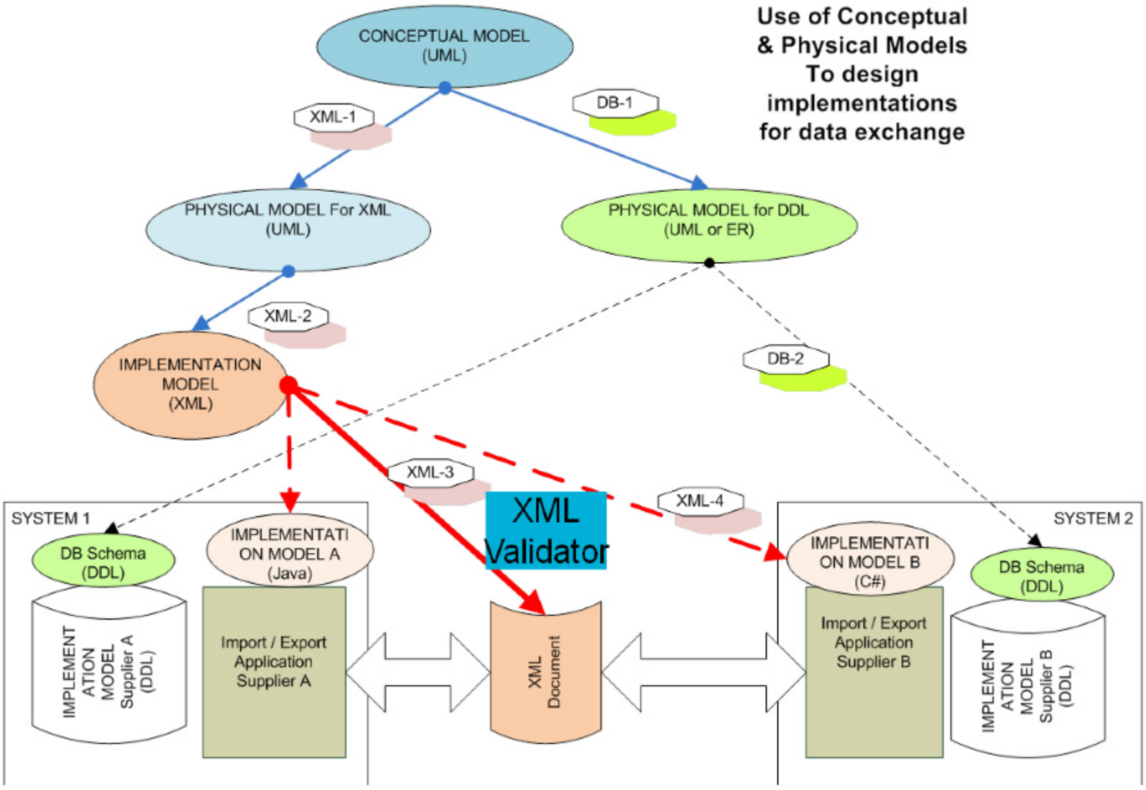


Figure A.1 — Use of conceptual and physical models

A.4.3 Version Lifecycle for Data Elements

Systems that allow the creation and maintenance of NeTEx data elements and that provide full support for the versioning of the elements (allowing the concurrent handling of one or more different versions of the same component within the same repository) should follow the uniform "Edit, Version, Release" cycle inherent in NeTEx versioning model.

— In order to edit a component a new "open" version is created; changes are then made to the open version; and then when these are complete, it is versioned.

— In order to version a subcomponent (for example a point within a journey pattern) an new open version of the parent component shall also be created, and the new subcomponent version be released into it before the parent can be versioned.

— Once versioned, no further changes can be made; a new version of the component shall be made first.

— Only versioned components can be exported.

A.4.4 Validation and Conformance of XML documents

One of the goals of NeTEx is to improve data quality and to automate the routine checking of documents for errors using the normal XML validators and parsers, without the need for explicit programming.

— The use of XML data types allows content strings to be checked for conformance to type (e.g. dates shall be valid dates, periods shall be valid durations, email addresses valid email addresses, etc.)

— The use of XML identity and reference constraints allows identifiers to be checked for uniqueness and references to be checked for completeness (i.e. referenced entities shall be declared in a document in which there are referenced).

A NeTEx document *shall* validate against the schema before it is deemed fit for import. Together these measures help catch many types of routine error, saving time and improving data quality. However not all integrity conditions of the model can be checked by the XML validator and an implementer may want to consider which additional tests of imported data should be performed. For example, "*every QUAY and other area in a STOP PLACE should have at least one entrance*" (otherwise it cannot be reached by a path); "*the passing times on a vehicle journey should be monotonically increasing over the course of the journey*", etc. In many cases it is possible to make an auto correction – but note that any change to the data should be reflected by creating new versions as well.

A.4.5 Schema versions and schema compatibility

NeTEx is intended as a strategic interface; the schema and subschemas are versioned and it is likely there will be future versions from time to time. Successive schema versions will be **forwards compatible**, that is, documents that conform to an earlier version will also conform to a later version. They will also generally to be ***backwards compatible***, that is documents that conform to the latest schema *that do not use new features* will also conform to earlier schema. Schemas include a version number that can be used to detect schema levels automatically.

A.5 Resources

The following are resources for finding out more about NeTEx:

A.6 NeTEx CEN Technical specifications,

NeTEx is formally described as set of PDF documents that may be purchased from CEN national bodies such as VDV, AFNOR, BSI, NEN,

— NeTEx Part 1: Network description [N1];

— NeTEx Part 2: Timing information [N2];

— NeTEx Part 3: Fare description [N3].

The CEN Technical specifications are large and somewhat unwieldy documents prepared in accordance with CEN rules.

A.7 NeTEx UML Models

NeTEx provides models in UML notation of all the NeTEx entities and relationships as electronic artefacts. The models are modularised and provide a convenient way of browsing and studying the NeTEx models. The UML physical model includes many additional diagrams and views that are not present in the CEN Specification that help to understand the model and its dependencies.

The NeTEx UML model includes two distinct models:

— NeTEx UML *Conceptual* Model;

— NeTEx UML *Physical* Model.

Ancillary models showing a mapping to TAP/TSI B1, B2 and B3 specifications and to GTFS are also available (see [N1], [N2]).

In order to view the UML models you need an appropriate tool, such as the Enterprise Architect viewer (www.sparxsystems.com.au) or an XMI enabled UML viewer.

The NeTEx models are free and are available from www.netex-cen.eu (from the *Download* page).

A.8 NeTEx XML Schema

The primary software resource from implementing a NeTEx interface is the NeTEx XML schema which is available at the www.netex-cen.eu.

Two main variants of the schema are available each providing a different protocol for embedding the same content model subschemas.

a) **Simple NeTEx documents exchange:** *(NeTEx _publication.xsd*). A schema to use with NeTEx documents input or output by a system that are exchanged as files using FTP, email etc.

b) **NeTEx document exchange using SIRI http requests**: *(NeTEx_siri_SG.xsd*). A schema that embeds the NeTEx elements in a sequence of http messages that define request/response and publish/subscribe interchanges for exchanging NeTEx data. Requests used NeTEx elements to specify the desired data. Responses are wrapped in version frames. The messages are specializations of the SIRI framework.

The schema is modularized into smaller subschema, corresponding to the NeTEx modules and includes complex integrity constraints. The schemas are versioned to allow for concurrent support of successive versions. Use of a tool such as XML SPY or Oxygen to view the schemas is strongly recommended.

A.9 NeTEx WSDL Bindings

Three different SIRI WSDL bindings are available for NeTEx, with separate **consumer** (the system requesting data) and **producer** (the system supplying the data) messages.

Table A.2 — SIRI WSDL bindings

	Producer	Consumer
WSDL2	NeTEx_wsProducer-WSDL2.wsdl	NeTEx_wsConsumer-WSDL2.wsdl
Document	NeTEx_wsProducer-Document.wsdl	NeTEx_wsConsumer-Document.wsdl
RPC	NeTEx_wsProducer-Rpc.wsdl	NeTEx_wsConsumer-Rpc.wsdl

The bindings are also versioned to allow for concurrent support of successive versions.

A.10 Tools and Technology

General purpose XML tools such as parsers, validators and binding tools can be used with the NeTEx schema.

A number of different open source implementations and tools are under development including:

— CHOUETTE available on https://github.com/afimb (see http://www.chouette.mobi/developpeurs/formats-supportes/).

Annex B
(informative)

Design Methodology

B.1 Introduction

This Annex is intended to convey a high level view sufficient for a technical manager to appreciate the capabilities of NeTEx, and omits all detailed considerations - for a detailed description please see the full CEN NeTEx specification, in particular Part 1 [N1] from which sections of this annex are taken. Indications on followed Design Methodology are reported.

B.2 Model driven design

B.2.1 General

NeTEx uses a “Model Driven” approach to design, that is, the fundamental design is described as a high level **conceptual model that** represents the problem domain as entities and relationship that have been identified by a set of use cases and existing systems covering the desired business scope. This conceptual model is implementation independent, but is then elaborated to create a more detailed design for a **physical model** that can subsequently be transformed into a software implementation, either automatically or semi-automatically, using a specific technology – in NeTEx’s case XML. (Other implementation languages are also possible.)

The use of high level models allows designs to be reviewed and validated by interested parties and to be fully documented with narrative text that describes the intention of the design. Implementing a data exchange format represents a significant investment by many different stakeholders and having such a model and documentation facilitates long term use of the model and schema by many different parties. Modelling in particular helps identify common abstractions and components that simplify the implementation. It also allows dependencies between components to be understood so that the system can be modularised in a way that minimises coupling and optimises flexibility. This in turns makes it easier for implementers to select just those components needed for a given purpose. It is also valuable for future evolution as the dependencies between components can be properly understood and the effects of a change evaluated.

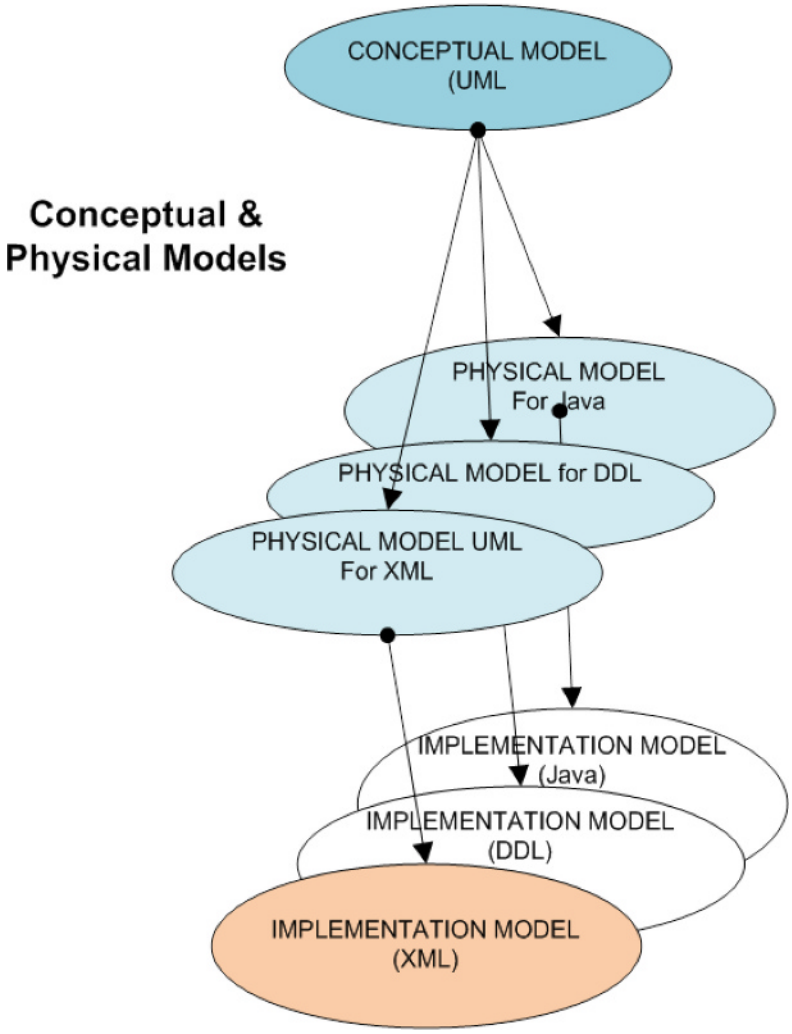


Figure B.1 — Conceptual and Phisical models

B.2.2 The Transmodel Conceptual model

The conceptual model used in NeTEx is based on Transmodel, the CEN Reference model for Public Transport [T1], [T2] [T3], [T4], developed over the course of the past two decades from a harmonization and systemisation of a number of proven European National standards. Transmodel focuses on Transport concepts at a high level design level and as an object model. It does not need to address detailed implementation points such as the use of namespaces, or how elements should be organized when serialised in a linear format such as XML.

NeTEx, as a concrete physical format which can be implemented, shall make technology specific decisions on such points and also adds in functional attributes for a number of elements based on existing European transport systems.

B.3 Consistent Terminology

One of the design goals of NeTEx is to uphold a consistent set of terminology for a given Public Transport data concept wherever it is used. The names of public transport concepts in everyday language are often fuzzy, the same word having different meanings in different contexts depending on whether one is discussing the passenger, the vehicle or the timetable, or describing a process or an entity. For example, consider “Stop”, “Service”, “Route”, “Journey”, etc, each of which has multiple meanings in English. This problem is compounded at a European level since different languages may have further differences in their semantic categories as well (that is to say a given term may cover a subtly different set of connotations in each specific language – as say with *Reise/ Viaggio/ Voyage/ Journey/ Potovanje/ Reis* etc). Transmodel tries to follow a restricted, consistent terminology, using a single term for a single concept each with its own well-defined description. Quite often this results in a rather cumbersome technical vocabulary, for example a VEHICLE JOURNEY, SCHEDULED STOP POINT, ACCESS RIGHT ASSIGNMENT (Transmodel terms are given in uppercase by convention), and sometimes a term is used somewhat artificially to exclude some colloquial senses (for example in Transmodel TRIP is used only for passengers while JOURNEY is used only for vehicles), but the approach has significant advantages in precision and, once understood and adopted, in reducing overall complexity. Readers should however to be aware of this convention in reading NeTEx documents.

B.4 UML Notation

NeTEx represents the underlying model using **Unified Modelling Language** (UML) class diagrams [U1], stored alongside an electronic representation of the model in a repository. UML is an industry standard notation for describing complex software models and supports a number of different types of relationship between software components (associate, aggregation, inheritance etc). Two levels of UML model are provided – A high level conceptual UML model which is implementation independent, and a physical model which includes detailed attributes and details needed to support implementation as XML schema. Textual definitions are attached to the NeTEx schema elements as well.

Each model is carefully modularised into packages within the NeTEx Part 1, Part 2, and Part 3 parts, with a given package having correspondences at each level. (UML dependency diagrams are provided to document the relationship between modules).

In practice, the use of a UML model requires the use of modern design tool (such as Enterprise Architect) that offer powerful navigation and visualization capabilities to examine a model and its documentation interactively in many different views. Such views may be included as illustrations in a document such as this but represent only a static snapshot. For in depth study of NeTEx use of a tool is recommended

B.5 XML schema

B.5.1 General

NeTEx uses W3C XML schema to describe data. XML Schema Definition (XSD) is a general purpose language for describing data model elements in a form that can be serialized and transmitted between different computer system.

B.5.2 XML Benefits

XML allows for a semantically rich representation of data and has several important advantages over a flat file technology.

— **Validity checking**: a schema allows not only the structure of the model to be described but also many integrity constraints. These can cover not only basic data types (dates, times, numbers, allowed values for enumerations, etc) but also complex referential integrity conditions that can be used to ensure that a coherent data set is delivered, such as unique identifiers and satisfied cross references. This automates much of the data quality checking process and assists problem resolution between different participants.

— **Reuse mechanisms:** XML is a modern Object Orientated Language and includes powerful mechanism such as inheritance and embedded groups that simplify representations and improve the maintainability of implementations.

— **Programming language and Software Tool support:** There is widespread support for XML in many different tools and programming languages, making it relatively straightforward to implement import and export procedures. In particular the complex task of parsing and reassembling data are largely done by the standard XML parsers without any further programming effort being required.

— **Flexibility:** Normally standards need to be able to evolve over time to support changes in the business requirements. XML is a self-describing format that can include optional elements and it is possible to have successive, but backwards compatible versions in concurrent use, distinguishable by different schema version attributes: This is valuable in a distributed implementation where there are many different systems using different versions of the system at the same time and that will choose to upgrade to new releases at different times.

B.5.3 XML Drawbacks

Use of XML schema technology also has some drawbacks.

— **Document size:** XML implementations are relatively verbose compared to flat file formats, requiring more bandwidth to transmit and greater computational resource to process. In mitigation, the semantically richness may also be used to condense content to avoid unnecessary repetition (as is found say in TAP price data) and data can in any case be compressed for transmission using normal zip techniques. Where size is critical additional optimisations can be made. ("It is easier to make a correct model fast than a fast model correct").

— **Multiplicity of components:** the use of discrete, functionally orthogonal, reusable components, implemented with the various inheritance mechanism of XML (subtyping, embedding of groups etc) so as to be highly modular, means that the specification is quite fragmented and has a large number of small elements, making it harder to comprehend. This can be mitigated by the use of powerful editing and visualization tools (such as XML SPY or Oxygen) which are able to reassemble the elements into views for users to inspect and edit schemas.

— **Complexity of interpretation:** The semantic richness of NeTEx means that sometimes there is more than one way of potentially encoding a concept. When the difference is purely syntactic this does not matter in practice (for example, in-lining elements rather than declaring them separately and cross-referencing them), as the parser technology available for XML in any case does most of the work to reassemble the serialize objects from the document using the information provided by the schema, regardless of the actual encoding. A more serious problem is that in certain cases there may appear to be more than one plausible way of encoding data. Usually there will be a preferred "more correct" way, but deciding exactly the correct representation to use may involve expert consideration of subtle aspects of the model. For example, does a temporal condition apply to a whole SALES PACKAGE or just to one particular parameter such the PURCHASE WINDOW? Or should a condition be attached to a FARE PRODUCT or to a SALES PACKAGE based on the FARE PRODUCT? To mitigate this, users concerned to exchange a particular set of data (for example VDV timetables or TAP /TSI fares) typically specify a "profile" that spells out the preferred choice of elements, and examples (as cited in this document) are also valuable. A profile can be further described by a TYPE OF FRAME which is can indicate as "metadata" which elements should or should not be present.

— **Limited constraints:** Although XML schemas support many important types of integrity constraint to check data, certain more complicated constraints cannot be expressed and shall be checked programmatically in an incoming program. For example, for the sequence of stops making up the calling pattern of a vehicle journey, it might be required that there is only a departure time at the origin, only an arrival time at the destination; but at least one departure or arrival times for all the intermediate stops. NeTEx in fact makes most properties optional in the schema so that the same schema can be used for many different applications, in effect not even using all of XML's capabilities to express multiplicity of occurrence.

B.6 Tools and Technology

NeTEx's technology choices (XML, UML) represent mainstream technologies with widespread tool and platform support and a large pool of people with the necessary technology skills.

B.7 Modularisation of the framework

A large conceptual model and schema such as NeTEx (which has several hundred entities) needs to be modularised into smaller submodels in order to be manageable; both to understand it; to implement and test systems based on it; and to allow the separate evolution of unrelated subdomains over time. NeTEx encapsulates model elements into small packages of just a few related elements concerned with a particular function, each with their own self-contained diagrams and documentation. The core framework elements and common components are included in the base packages in Part 1 and then referenced by the dependent packages that deliver the actual concrete functional of NeTEx.

Dependencies are linearized as far as possible, so that base packages can be used independently of other packages. To help users navigate the models the documentation includes both high level and low level dependency diagrams, and also uses a consistent set of colours for components from different functional.

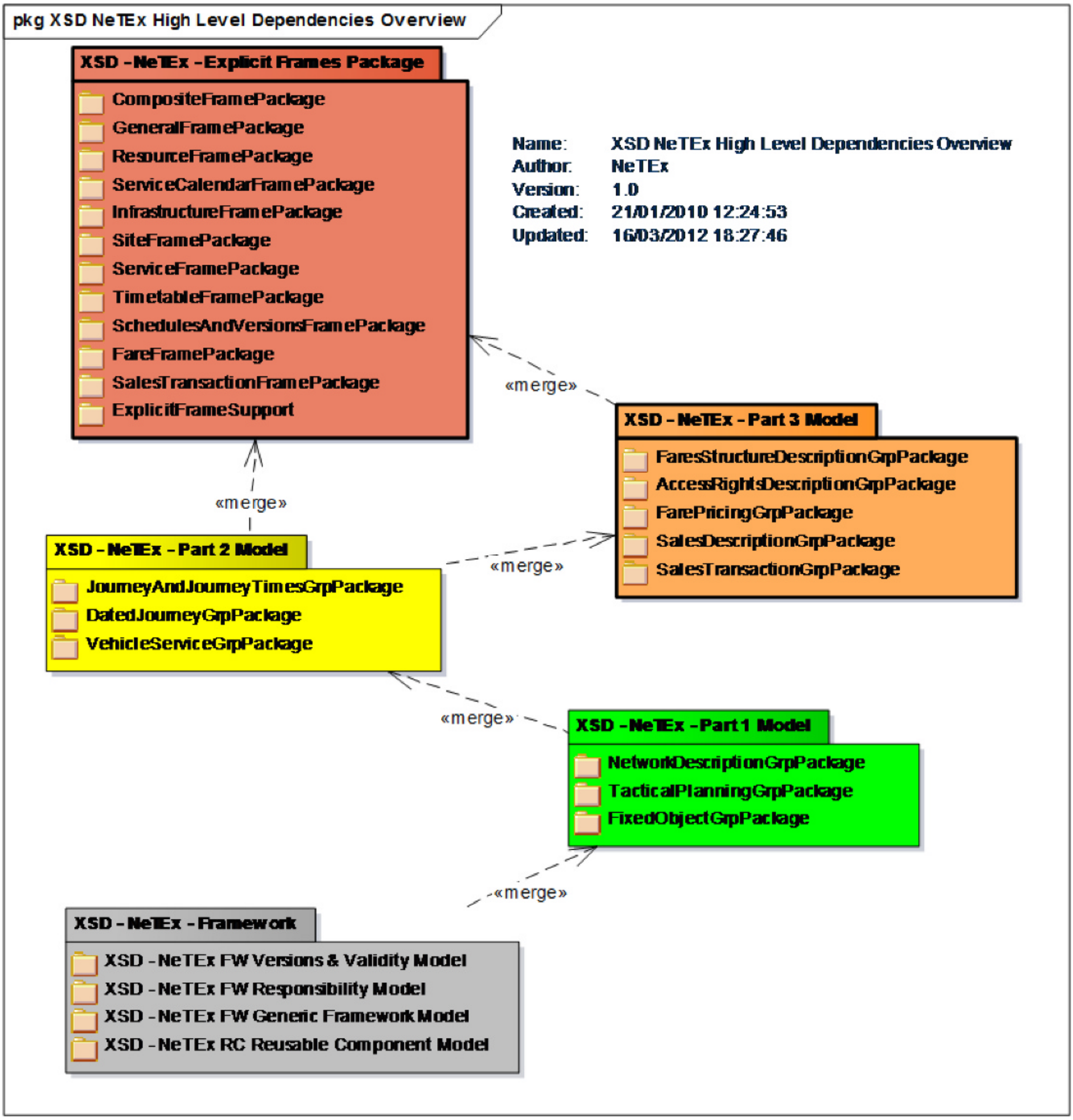


Figure B.2 — Dependency overview

Annex C
(informative)

Framework

C.1 Introduction

This Annex is intended to convey a high level view sufficient for a technical manager to appreciate the capabilities of NeTEx, and omits all detailed considerations - for a detailed description please see the full CEN NeTEx specification, in particular Part 1 [N1], from which sections of Annex are taken. Indications on Framework components usage are reported.

C.2 The NeTEx Frameworks

The NeTEx schemas provide a modular format for exchanging transport data from many different stakeholders. Since any useful description of transport services is multifaceted in time and space, such data are inherently complex, requiring many interdependent model elements some of which are composite, and furthermore subject to change over time, requiring metadata to manage a continuous integration of compatible versions. In order to simplify both the implementation of systems, and also to reduce the cognitive load of understanding the format, NeTEx adopts a uniform approach to many common aspects of data management such as versioning, identity (the means of uniquely distinguishing each element within and between systems), data aggregation, etc., all variously described through a *framework*. The uniform approach makes it straightforward to enforce important integrity checks, such as for uniqueness and for referential integrity, using built in XML mechanism, reducing the amount of programming needed to validate data exchanged in NeTEx format.

The framework provides both common universal properties for all elements (such as identity and versioning), and a number of different design patterns of abstract object types for specific purposes which are specialized to create coherent elements with common properties. An example of a simple framework object, is the ***point***; many different types of *spatially located element* are found in transport; such as route points, stops, vehicle monitoring points, points of interest, etc. The framework provides a *generic* POINT type with standards based GIS coordinates; such points are specialized variously in the NeTEx functional domains to create different specific point types such as a SCHEDULED STOP POINT, a ROUTE POINT, etc. A slightly more complex example is the ***point and link sequence***; different types of paths through the transport networks can all be described as sequences of points and or links of different types, for example routes, route timings, vehicle journeys etc. NeTEx provides a number of specializations of POINT AND LINK SEQUENCE, each describing a specific type of path and each of which has additional specific properties (and semantics), but is subject to common design pattern constraining its use. For example, a JOURNEY PATTERN is a point sequence of the stops visited by a vehicle executing a timetabled service – it can be considered as both an ordered set of SCHEDULED STOP POINTS, and as an ordered set of SERVICE LINKs, where each link shall connect between two different successive stops.

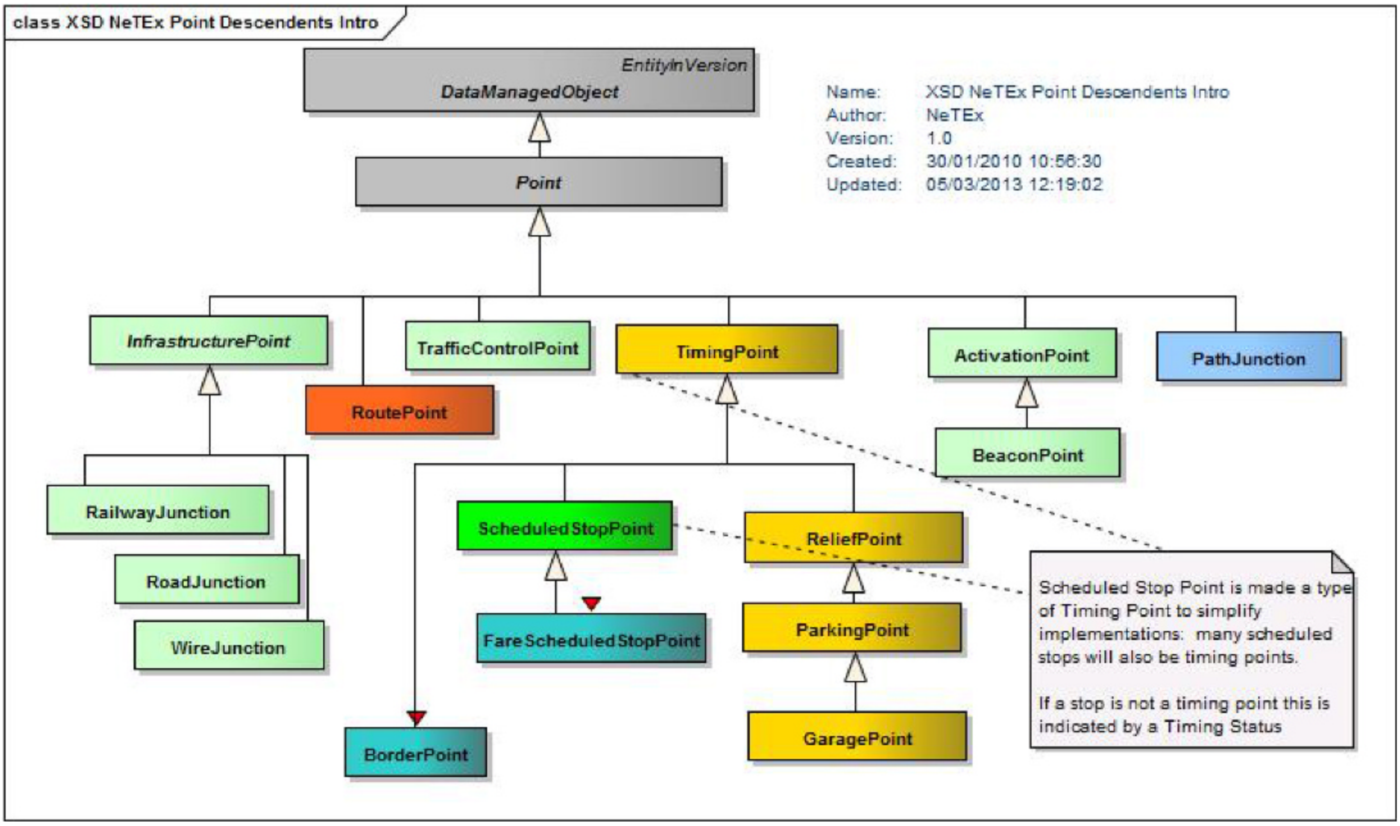


Figure C.1 — Framework properties

The primary advantage of using a framework is simplicity; only a relatively small number of components and common design patterns need to be grasped in order to understand much of the model, and elements need be described only by their differences from the base elements. Implementation is similarly simplified. Furthermore, evolution of the model at the framework level is extremely powerful in that changes made to the framework apply automatically everywhere they are resolved in the model. The framework also prescribes consistent naming conventions for elements, attributes and relationships, making it easier to identify entities and relate them to the specification.

C.3 NeTEx framework features

C.3.1 Versioning

C.3.1.1 General

Information systems for public transport operation typically require the exchange of many different types of data, produced by different organisations or operating divisions, and are subject to a multi-stage lifecycle, from planning through to production and the realization of the transport services in real-time. For example, in an urban network, stop data might come from the authority, bus timetable data from the bus operators contracted to provide bus services, metro data from the metro operators of each line, rail timetable data from the rail operators, etc. These data are continuously evolving and are subject to a variety of different validity conditions as to when they are current, and as to which data are needed for a particular purpose. NeTEx includes uniform **versioning** and **validity** mechanism to address these requirements; the mechanisms are part of the NeTEx framework and that can be applied to all data elements throughout their various lifecycles.

The NeTEx **versioning** model allows successive versions of data elements to be identified, allowing the fine grained identification of just those elements that have changed, and the auditing of changes. All NeTEx elements are specializations of DATA MANAGED OBJECT, an abstract element with detailed version attributes so that every single object can be individually version managed if desired, with its own *creation date, last modification date, version number* etc recorded, supporting the exchange and retention of complete histories of objects. Furthermore, references to other objects can also be versioned so that for composite data sets that comprise a number of related elements it is possible to be precise as to which version of each referenced element is required (even if the referenced element is omitted), and giving an importing system the ability to resolve version references. The use of explicit versions also makes it possible to use XMLs built in referential integrity mechanisms to check for completeness of XML documents without any additional implementation programming.

The NeTEx **version frame** mechanism provides a versionable container that allows a coherent and complete set of related elements to be exchanged, that is, compatible versions of elements that do not contain unresolved references. For example, “all the stops making up the Berlin transport network”, “all the journeys making up the London - Paris timetable”, or “the Autumn 2015 network tariffs”. NeTEx provides a number of different types of frame each for a different type of data, for example SITE FRAME for stop date, TIMETABLE FRAME for timetable date, FARE FRAME for fare data, etc., that. The generic version frame provides common properties, and each different type of frame follows a common design pattern as to what how the elements contained in the frame shall behave. Frames can themselves be aggregated using a COMPOSITE FRAME, allowing frames of several different data types to be treated as a single coherent whole.

Since pragmatically, actual systems that contain data to be exchanged differ in the sophistication of their support for versioning, the NeTEx mechanisms are furthermore designed so that they may be used either just in a course grained manner at the level of the whole data set (as when say the timetable as a whole has a version number but the journeys and stops in it do not), or if full version support is available, in a more powerful way at the level of the individual data element, with every change tracked.

The NeTEx **validity** model allows conditions to be attached to elements as to when they are current or the circumstances in which they should be used. Validity conditions can be attached to specific elements and also, through version frames, to whole sets of objects so that it is possible to be explicit about the exact conditions governing the coherence and relevance of data. This makes it possible for systems both to express the currency conditions for data they require when requesting data, and to describe the validity of data that is returned by a system. Validity conditions can be expressed using a number of reusable temporal elements, for example “valid on weekdays”, “valid in the winter season”, or as specific properties of elements, for example “valid when train classification is an express train”, “valid on market days” - or a combination. The rovision of a uniform system of temporal validity conditions greatky simplifies the integration of data .

C.3.1.2 Summary of NeTEx Version Frame Types

When data are requested from a system that supports NeTEx, it is output as an XML document containing one or more version frame elements. NeTEx provides nine different types of version frame, one of these, the composite frame is used to aggregate other frame types, the others are each concerned with exchanging a particular type of functionally related data.

Table C.1 — NeTEX version Frames

Part	**Name**	**Description**
Part 1 Framework	RESOURCE FRAME	Used to exchange common reference data such as operators, modes, facilities, day types, calendars, equipment, vehicle types, etc.
	GENERAL FRAME	Can be used to exchange any arbitrary user defined set of coherent elements – an extension mechanism.
	COMPOSITE FRAME	Used to group other frames for exchange as a single document.
Part 1 Functional	INFRASTRUCTURE FRAME	Used to exchange details of the road and rail elements making up the underlying network, along with restrictions on using them with specific vehicles. Also locates different points dedicated to the vehicle and crew changeover
	SERVICE FRAME	Used to exchange the basic description of a transport network; stops, lines and routes of a transport including stops and connection, along with the timing.
	SITE FRAME	Used to exchange information detailed places and sites such as stations, points of interest parking, including navigation paths and access restrictions.
Part 2 Functional	TIMETABLE FRAME	Used to exchange timetables, including journeys, journey parts and couplings, planned interchanges, service facilities, etc.
Part 3 Functional	FARE FRAME	Used to exchange fare data, including fare structures, fare products, fare restrictions, sales packages, pricing parameters, prices
	SALES TRANSACTION FRAME	Used to exchange descriptions of customers and their purchases.

C.3.2 Identifiers, uniqueness of reference and Namespaces

The task of gathering, collating and aggregating data for a public transport network necessarily shall be distributed among many different organisations, especially when creating data sets for large cities, regions, or whole countries. Computer systems require unique identifiers to distinguish each individual data element as it appears serialised in an exchange format. The data sets covered by NeTEx are large and belong to many different stakeholders, each of whom may have their own system of identifying elements.

In order to be able to integrate data repeatedly from many diverse systems, it shall be possible to give each object a globally unique persistent identifier regardless of its data source. NeTEx is designed to support large scale data integration, and supports uniqueness though the use of namespaces, based on domain and path strings (as familiarly seen in urls), a readily available and well established existing global document to provide domain names which may be used as the prefixes of labels. Thus for example, a UK bus stop might be identified within the NaPTAN domain, as "naptan.org.uk://21407867", or a German rail timetable as "farhplan.db.de://1234" (or perhaps "db.de/fahrplan:1234". Every NeTEx element in a document is given a unique identifier and NeTEx XML schema enforces well defined uniqueness constraints. To avoid verbose repetition, namespaces can be declared at a version frame level and overridden on individual elements only as necessary.

Identifiers are unique within each type of NeTEx object. Thus for example, the TIMING POINT with id of ”hde:123“ is different from the ROUTE POINT with an id of ”hde:123”, since they are different classes of element. Multiple identifier aliases, for example to support mappings to legacy system identifiers are also supported, so it is possible to make repeated “round trip” exchanges of data without ambiguity.

Here data management is distributed, some degree of central coordination is needed to agree who is responsible for which type of data, to agree common interfaces, and in certain cases to agree the partition of code namespaces so that data coded to a common standard can be aggregated without clashes as to the unique identifiers. This can be done through the NeTEx responsibility model.

C.3.3 Responsibility Management

NeTEx data will be used in data management environments that may have a complex organisational structure. For instance, different organisations may be responsible for different types of data, and different organisations or departments may each add, change or remove information in a complex workflow. Plans may be made, revised, forwarded, enriched, combined with other plans and forwarded again to other users for execution and distribution. The participating organisations may be strictly PT concerns such as bus operators, or be external entities, such as governmental departments or management agents. To address this, NeTEx has a flexible organisational and responsibility model that can be configured to enable a wide variety of different workflows. The model in effect defines metadata as to the ownership and use of data that can be used to help manage the data – NeTEx does not of itself define processes or tools for implementing workflows.

The *responsibility* model allows each data object to be give an owner and a data source, and a set of rights associated with various organisations. Responsibilities can in turn be associated with an administrative model of organisations and departments defined using NeTEx's *reusable components* (see Annex D).

The responsibility model makes it possible:

— to define operational responsibility for the real-life entities that are described by the information. For example it can specify which organization is responsible for planning and maintenance of the physical stop, or the services at the stop;

— to define data management related responsibilities for the information itself. E.g. functional or technical IT data management regarding a set of produced, collected or forwarded plan information. This can be used to identify who needs to be contacted to correct or amend data.

If used, the responsibility model can be applied to achieve the following goals:

— provide as part of the passenger information the contact information of agencies or help-desks to turn to in case of reservations, questions, complaints, etc.

— provide IT and PT related responsibility information for the purpose of management, assessment, etc. activities concerning quality management of data.

— associate Intellectual Property Rights with individual data elements or groups of elements.

— implement the delegation of data management: a receiving system can check the authorizations in relation to responsibility for provided data and see if the provider is authorized to manage that data. This concept can be used to protect data from being changed by the wrong parties.

C.3.4 Summary of GENERIC Framework Components

C.3.4.1 General

The NeTEx framework has a small set of abstract elements which are specialized to create the actual concrete elements of the NeTEx format. The elements specify common attributes and imply the existence of specific behaviour in their subtype elements.

C.3.4.2 Generic Framework elements

The following provide basic abstract elements for NeTEx function:

— DATA MANAGED OBJECT element: Provides common version management and responsibility properties. It is the ur object for all NeTEx elements.

— VERSION FRAME element: Provides a properties and behaviour of a version frame, a container for holding other elements for exchange. It is specialized as a number of different concrete frames as listed in Table C.1 above.

C.3.4.3 Design pattern Framework components

The following abstract elements can be specialized to create elements with particular desired properties that will interact in specific roles with other elements:

— GROUP OF ENTITies element: Provides abstract properties for elements that reference a set of other entities, (for example a ZONE includes a set of POINT references) a means of grouping elements and is used as abstract supertype for many different aggregates.

— The POINT and LINK model provides abstract elements for defining 0D points and 1D links.

— The LINK SEQUENCE model provides elements to defining graphs of points or links as commonly found in layered PT models.

— The ZONE model provides a model for defining 2D zones (with possible 0D point centroid).

— The PROJECTION model provides a means of defining mappings between different graphs of POINTs and LINKs, so that for example a transport route (a schematic view of a vehicle path) may be mapped to a road infrastructure element.

— The PLACE element provides a model for defining named places and links between them, including their relationship to COUNTRies. It can have spatial and navigation properties.

— The ASSIGNMENT element provides common behaviour for dependent ancillary elements which assign additional and often alternative sets of attributes to other entities.

— TYPE OF VALUE is used where the choice of values of attributes is restricted to a discrete “code set” of named values but the set itself needs to be extensible; this is specialized to create specific sets of values whose use can be validated using the XML validator. A VALUE SET is used to group value definitions.

Annex D
(informative)

Reusable Components

D.1 Introduction

This Annex is intended to convey a high level view sufficient for a technical manager to appreciate the capabilities of NeTEx, and omits all detailed considerations - for a detailed description please see the full CEN NeTEx specification, from which sections of Annex are taken. Indications on Reusable Components usage are reported.

D.2 The NeTEx Reusable Components

As well as achieving reusability by specializing abstract framework components (see Annex C), NeTEx also provides a number of *reusable components* to represent common concepts found in various transport data functional models; these may be used as objects without further specialization.

The elements are used throughout NeTEx Part 1 (see [N1]), Part 2 (see [N2]) and Part 3 (see [N3]); for example transport OPERATORs, transport MODEs, DAY TYPEs, OPERATING DAY, etc. Standardized versions of these common objects are provided, which include a wide range of attributes to support the different functions of NeTEx (and drawn from proven European national standards). NeTEx sub-schemas reuse these existing components rather than introducing separate elements in each different application context. Also, in line with normative CEN standardization principles, NeTEx references existing underlying standards where appropriate, such as GML for GIS coordinates, or ISO country codes to identify countries.

When included in a NeTEx document, instances of the reusable components will be grouped with a version frame (see “NeTEx Frameworks - White paper”); the RESOURCE FRAME in particular is used to exchange general-purpose components such as ORGANISATIONs and FACILITIEs. Frames of different types may be grouped within a COMPOSITE FRAME.

D.3 Summary of Reusable Components

D.3.1 General

— The NeTEx reusable components can be grouped under several headings:

— **Framework Components**: ready-made components that support framework level functions, such as VERSION.

— **General functional components**: ready-made components of generic applicability, such as NOTICEs.

— **Transport functional components**: ready-made components that can be used directly, such as OPERATORs., AVAILABILITY CONDITIONs, FACILITIES, etc.

D.3.2 Reusable Component types

The NeTEx framework provides a set of ready made reusable elements that can be used without further specialization. Some of these are ancillary metadata elements to support framework behaviour (for example for automatic comparison of versions):

— VERSION: Versions are reified as explicit elements which can be given descriptions and other properties and be used in conditions.

— VALIDITY CONDITION. Conditions are specified in terms of temporal or other values and can be associated with version frames and other elements to indicate when they apply. An AVAILABILITY CONDITION is specialization of VALIDITY CONDITION that uses a number of predefined elements to specify a temporal condition, for example as a day of the week or occurrence of a holiday.

— DATA SOURCE: Sources indicate the origin system from which a data came.

— RESPONSIBILITY SET: Each NeTEx element can be associated with a Responsibility Set which indicates the owner and other rights and responsibilities. These can be used both to support problem resolution processes and to track IPR rights.

D.3.3 General Reusable Component types

A second group of ready-made components defines useful functional elements that are not specific to transport applications.

— NOTICE Model – Defines footnotes and other NOTICEs that can be associated with elements.

— REUSABLE AVAILABILITY Model – Defines standardised temporal VALIDITY CONDITIONs such as day types for specifying when an event or condition is valid, i.e. in effect.

— TOPOGRAPHIC Model – Defines named TOPOGRAPHIC PLACES that provide a context for SITES, STATIONS, STOPS etc. that may be served by public transport, with an ISO based Country definition.

D.3.4 Transport Reusable Component types

The organisational reusable components describe the basic operator mode and topography context for the various transport data elements.

— TRANSPORT MODE Model – Defines standard Transport modes and submodes.

— TRANSPORT ORGANIZATION Model – Defines OPERATORS, AUTHORITIES and other Transport ORGANISATIONs.

— OTHER ORGANIZATION Model – Defines SERVICED ORGANISATIONs and other non-operator ORGANISATIONs.

The equipment reusable components describe the generic equipment properties, and classifications of servers and facilities that can be associated with services and sites.

— GENERIC EQUIPMENT Model – Defines general EQUIPMENT properties for EQUIPMENT elements that can be associated with VEHICLES and SITEs. EQUIPMENT can be specialized to create specific types of equipment, for example WAITING ROOM EQUIPMENT, STAIR EQUIPMENT, WHEELCHAIR EQUIPMENT etc with complex attributes

— FACILITY Model – Defines simple named service and facility categories that can be associated with stops, timetables and other NeTEx elements. Facilities have a name and code but no attributes.

— CLASSES OF USE (First class, second class, etc), ticket types etc. define classifiers.

The vehicle related components define types of vehicles and vehicle equipment.

— VEHICLE TYPE Model – Defines VEHICLE TYPES, VEHICLE MODELs and VEHICLEs.

— TRAIN model, defines train composition (COMPOUND TRAIN) and the facilities of the carriages (VEHICLE EQUIPMENT PROFILE).

— VEHICLE EQUIPMENT Model – Defines specific VEHICLE EQUIPMENT Types and actual EQUIPMENT usage on a VEHICLE TYPES, VEHICLE MODELS and VEHCILES.

— SERVICE REQUIREMENTS Model – Defines requirements for VEHICLE TYPEs to go on specific services.

Finally the following miscellaneous element provides a general purpose mechanism for creating "smart" maps that link to NeTEx model elements

— SCHEMATIC MAP Model – Defines general purpose SCHEMATIC MAP contents that can be used to link data elements to visualizations such as network maps and interactive displays.

D.4 Summary of Reusable Data types

NeTEx uses a small set of XML data types to specify the attributes of the different NeTEx elements, facilitating validation and type checking of data in implementations. Where possible these are based on existing XML, CEN or W3C standards.

— XML built in data types are used to set specific types for data elements wherever possible, allowing the efficient validation of NeTEx documents by normal XML validators to detect type and grammar (Schema) errors. Examples are, *date, time, number, boolean, duration*, etc. Timestamps are generally given in 24 h format with a time zone suffix to avoid ambiguity. Periods (e.g. 20 days 3 months 1 year, etc.) are defined using the XML *duration* type.

— NeTEx text elements are designed to support international use; the language of all descriptive strings can be specified through the ***MultilingualString*** type and alternative translations in different languages can be associated with key text names. Language defaults can be set at the frame level when exchanging sets of data in a given language.

— To specify spatial coordinates NeTEx uses a core subset of the GML schema, allowing a different alternative well-defined systems of spatial coordinates to be used, including WGS84 as a widely used default.

— Common quantitative unit dimensions such as height, distance and weight are specifically typed using added XML types that can be validated. SI units are generally used by default.

— Common reusable base types such as an email format, time zone, etc., are provided to assist XML validation, and a LOCALE mechanism is provided to set a time zone and other locality specific properties.

— Enumerated types are used to restrict the set of allowed values for data elements that take a fixed set of values, again allowing validation by the XML parser. Where an open ended set of values is needed a TYPE OF VALUE is used (see NeTEx Framework – White Paper).

Annex E
(informative)

Representing Public Transport Networks in NeTEx

E.1 Introduction

This Annex is intended to convey a high level view sufficient for a technical manager to appreciate the capabilities of the CEN document NeTEx, and omits all detailed considerations that can be found in the detailed documentation. NeTEx documentation is divided into three parts [N1], [N2], [N3]; in particular Network representation is covered in Part 1 [N1] and is mainly concerned with describing fixed Networks (stops, routes, lines etc).

E.2 NeTEx Methodology

NeTEx uses a “model driven design”, i.e. the development starts from a conceptual model, from which a physical UML model and an XML implementation is derived.

The European Public Transport Reference Data Model, known as Transmodel, is the conceptual basis for the development (see [T1], [T2], [T3]).

E.3 Scope

The NeTEx public transport network representation can be used for networks for any mode of transport, including rail, bus, metro, ferry, etc. The same model elements can be used in different ways in different views, for example ranging from a high level schematic view of the network for passengers, to a stop by stop sequence of a route for a specific scheduled journey.

Both the different types of locations (stations, airports bus stops etc), their layout and their properties such as accessibility (see Annex G) and facilities (see Annex H) can be described. The relationship between the representation of a stop as a set of physical points (e.g. a station and its platforms); the stop as a point in a timetable (which may be independent of platform) and the stop as point for real-the measurement and display can all be described precisely, so that a common network representation can be reused from both planning and operational purposes.

NeTEx includes representations of rail stations and rail routes designed to be compatible with TAP/TSI and other requirements so that the network model is adequate for representing long distance rail networks. Concepts such as platforms and boarding positions on platforms (and their relation to train makeup) can be covered so that full information for rail passengers can be given.

Basic infrastructure elements, such as road/railway/wire elements are also described together with the constraints on the tactical planning of operations imposed by infrastructure characteristics, e.g. choice of an adequate vehicle type (described in [N1] and [N2]).

Some of the fixed network elements may be used to describe the structure of flexible networks, for Flexible Transport Systems or Demand Responsive Systems (see Annex F).

E.4 Corresponding NeTEx documentation

A detailed specification of NeTEx capabilities as regards the representation of public transport networks can be found in two distinct sub sections of Part 1 [N1]:

Section 1 – Framework, describes concepts and models shared by all NeTEx functional parts and includes three different aspects, namely:

— Common framework mechanisms: such as versioning, validity, grouping, and responsibility metadata, allowing the automated tracking, and processing of successive versions. VERSION FRAME, VERSION, VALIDITY CONDITION (see [2]);

— Generic Patterns: defining abstract components that can be specialized to create concrete elements in the various NeTEx functional domains, in particular the POINT, LINK and SEQUENCE of LINK components used to define network layers;

— Reusable components: certain common components, for example TRANSPORT MODES, CALENDARS, DAY TYPEs, EQUIPMENT etc. that are not specific to any particular functional part of NeTEx but are widely used in several different functional areas (see also [3]).

Section 2 – Public Transport Network Topology, describes the concrete objects for the spatial description of Public Transport networks. As well as their own specific semantics, these objects typically have geometric features giving them common spatial properties. Many of such objects are used for the tactical planning of operations and in the context of passenger information.

The network topology is represented either through simple or complex object classes like:

— Paths through the network: ROUTEs, JOURNEY PATTERNs, TIMING PATTERNs, SERVICE PATTERNs, etc. which are linear features, linked to point features such as:

  — Operational points: TIMING POINTs, GARAGEs, CREW POINTs, BEACON POINTs, etc;

  — Passenger service points: SCHEDULED STOP POINTs, STOP AREAs, CONNECTIONs, etc.

The Network Model includes representations of the physical locations to which passengers may travel using elements from the Fixed Objects for Public Transport model [T4].

— STOP PLACEs, PARKING, PASSENGER NAVIGATION PATHs, ENTRANCEs;

— POINTs OF INTEREST, PARKING PLACEs;

— ACCESSIBILITY features (see [5]).

E.5 Approach

E.5.1 Reconciling different views of the network

Public Transport network data may originate from many different departments or sub-systems of an organization or organisations. When data from different sources (for instance, departments) are put together, inconsistencies may be found in the distances in space used, or in the timings to cross the spaces. An example is the calculation of the distance run by a vehicle: an operation management system may be concerned with the number of kilometres covered by a bus during a time period (e.g. at a particular hour of a particular type of day) along the "itineraries", while an accounting system may be concerned with the number of kilometres as agreed in contractual obligations and computed from distance figures along the "itineraries" for an accounting time period. In many cases, the "itinerary" is not a well-defined concept, and different sets of attribute values are relevant for different purposes.

In the above example the origin of the inconsistency of distances may be twofold:

1) the word "itinerary" is not understood in the same manner by the different departments and/or systems;

2) the basic elements for distance computation are very different: the nature and the coordinates of the different start/end points of the links involved in the computation of the "itinerary" may relate to different location referencing systems; there may be different value sets for different conditions; the precision of the coordinates may also differ considerably.

To address the ambiguity of concept, NeTEx follows the Transmodel data model which introduces distinct elements to represent the precise semantics of each separate concept, in particular of an "itinerary". (See also discussion of Transmodel terminology (see 0).

To manage the second problem in a correct way, i.e. to guarantee the coherence of distances for different purposes, the Public Transport Reference Data Model (Transmodel) defines data sets, called "layers", specified for a particular functional purpose and related to one single location referencing system (that is a coordinate system such as WGS84 used to encode coordinates).

In order to be able to relate objects from one layer to another layer, i.e. to describe the correspondence of objects from one layer to objects from another layer and perform useful computations over the data, a mechanism called "projection" is defined.

E.5.2 Generic concepts

The discussion above highlights two fundamental but different notions of an "itinerary" that need to be accommodated (others are also possible e.g. for fares),

— as a sequence of links between stop points, e.g. as basis of contractual agreements or to describe the available routes to a passenger.

— as a larger sequence of route-defining points, that are not necessarily stop points, e.g. as taken into account by Automated Vehicle Monitoring (AVM) systems (that are responsible for providing registered distance data).

To represent the above, NeTEx provides a number of separate concepts for the various types of ordered sequence of points and / or links needed to describe paths through a network; in particular ROUTE, JOURNEY PATTERN, SERVICE PATTERN and TIMING PATTERN.

Each of these "patterns" is can be considered as an ordered sequence of POINTs or of LINKs; (or both); the specific points and links of each type of pattern making up a linear feature in a particular layer of the network.

The distinct semantics of these separate concepts makes it possible to reuse the various concepts in different business contexts, and the use of uniform properties e.g. for spatial geometry makes it relatively simple to integrate and compute over different data sets.

This is also the "philosophy" followed throughout Transmodel in order to achieve flexibility: to separate concerns into separate abstractions so that each concept is independent of other concerns, and function domains are as far as possible orthogonal.

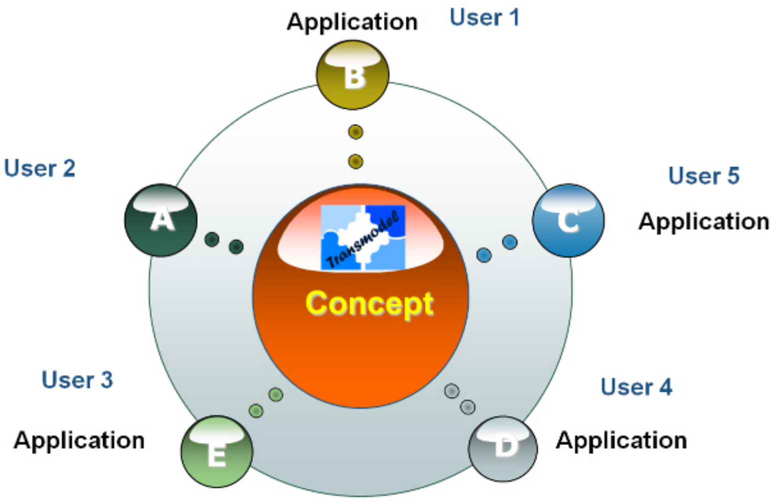


Figure E.1 — Generic Concept Approach

E.6 Basic spatial network aspects

E.6.1 Routes and work patterns

The main linear patterns used to define the spatial structure of a Public Transport Network are: ROUTE, JOURNEY PATTERN, TIMING PATTERN and SERVICE PATTERN.

— A ROUTE is an ordered list of located ROUTE POINTs defining one single path through the road (or rail) network. A ROUTE may pass through the same ROUTE POINT more than once. ROUTE LINKs may be used to specify attributes of a link.

— The ROUTE network does not necessarily correspond strictly to the infrastructure network, represented in the figure below as the “street network” (made up of ROAD ELEMENTs), and as typically defined in a GIS model. However, an obvious correspondence between the ROUTE and ROAD ELEMENT sequences exists: this correspondence describes the exact shape of the ROUTE.

— A JOURNEY PATTERN is defined as an ordered list of SCHEDULED STOP POINTs (i.e. points where passengers can board or alight from vehicles) and TIMING POINTs (i.e. points against which the timing information necessary to build schedules may be recorded) on a single ROUTE, describing the pattern of working for public transport vehicles. A JOURNEY PATTERN may pass through the same point more than once. Again links (SERVICE LINKS, TIMING LINKS etc) can be used to provide a link based representation if needed.

— The sequence of TIMING POINTs of a JOURNEY PATTERN determines a TIMING PATTERN (green in the figure below) and the sequence of SCHEDULED STOP POINTs (of a JOURNEY PATTERN) determines a SERVICE PATTERN (red in the figure below).

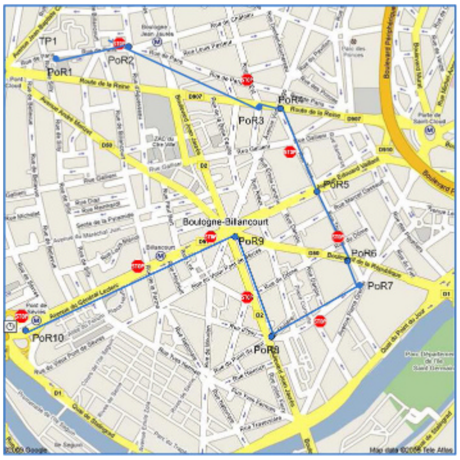


Figure E.2 — ROUTE (in blue) determining a unique path of a vehicle

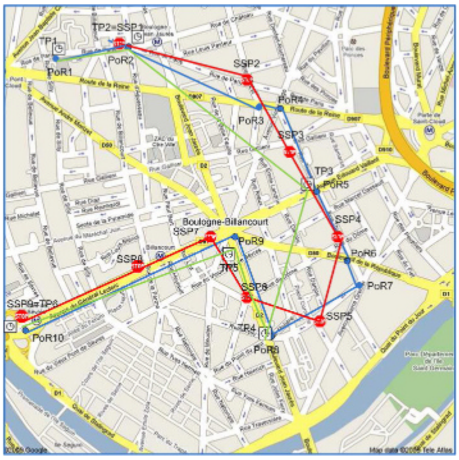


Figure E.3 — ROUTE (blue), TIMING PATTERN (green) and SERVICE PATTERN (red)

All these linear features may be used to represent different aspects of the spatial structure of the Public Transport network. It is, as indicated above, of particular importance to keep in mind which linear objects have to be taken into account when talking about the measurement of distances.

E.6.2 Layers

To avoid the problems of inconsistency of distances, the concept of a LAYER is used, defining groups of linear features (and other elements if appropriate) that are all spatially located using a single location referencing system (LOCATING SYSTEM). A LOCATING SYTEM is a coordinate system such as WGS84 or National Ordnance Survey.

Examples of LAYERs are represented in the figure below, which shows a number of different types of linear feature describing a network:

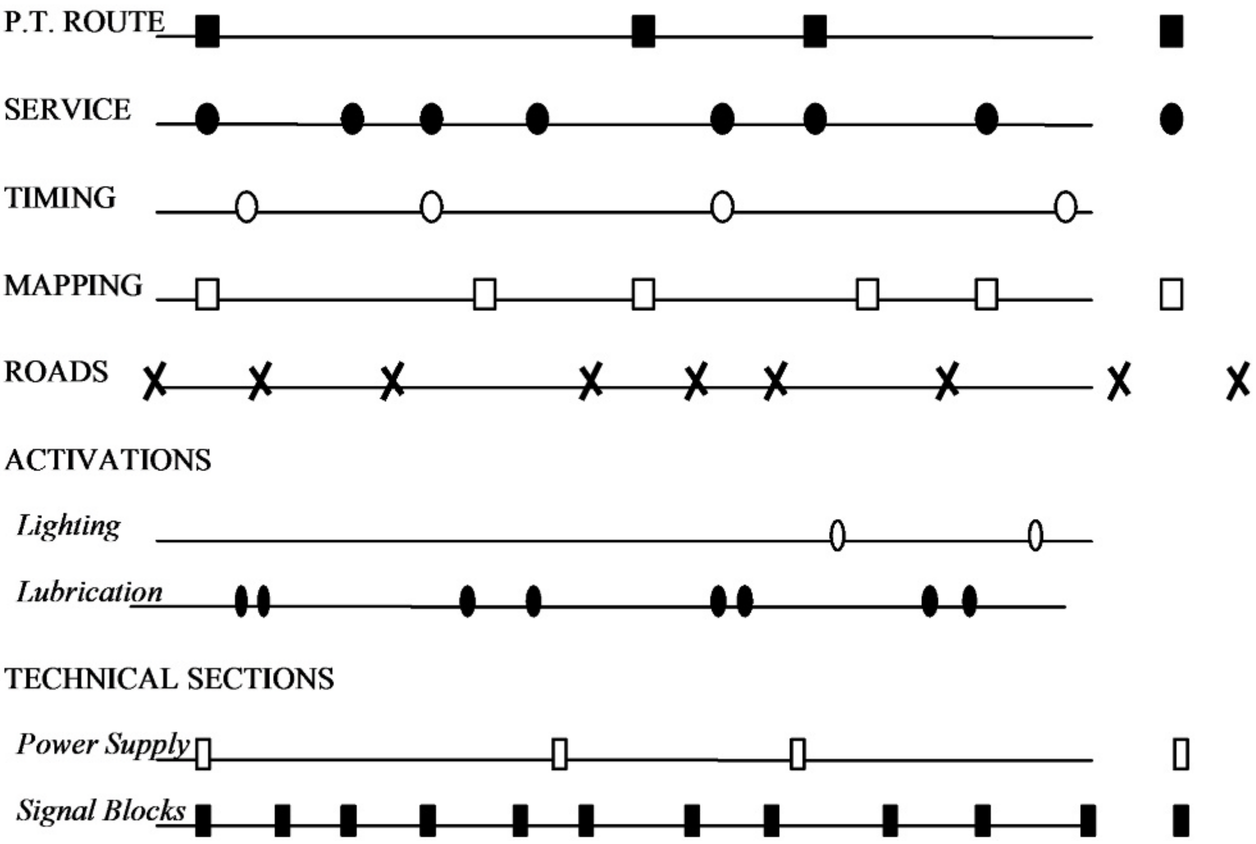


Figure E.4 — Schematic view of possible LAYERs

For example JOURNEY PATTERNs (SERVICE PATTERNs or TIMING PATTERNs), describe different aspects of the work of vehicles, while ROUTEs describe the physical layout of the network. The first three types of objects belong to a "service layer" while the ROUTE belongs to the "PT route layer".

The public transport (PT) network layers may be related to maps and other geospatial layers either simply through their coordinate systems, or semantically, that is individual features in one PT layer such as ROUTE LINKS between ROUTE POINTs may be linked semantically with spatial features such as ROAD ELEMENTS and RAIL ELEMENTs. Thus for example a ROUTE LINK could be associated with a particular lane and direction of a highway, allowing for advanced ITS (Intelligent Transport Systems) applications that integrate road and PT data. To facilitate integration with Geographic Information Systems (GIS) spatial data sets the NeTEx model includes a minimum set of GIS features (the ROAD POINT, ROAD ELEMENT, ROAD RAIL ELEMENT etc) that in practice will normally be populated from a general GIS data set.

E.6.3 Geospatial concerns

In the most general case SERVICE PATTERNs (that is the sequence of stops a vehicle on a journey goes to) and TIMING PATTERNs (sequences of points where time constraints may be indicated) are determined independently (often by different departments); JOURNEY PATTERNs are defined as a sequence of TIMING and SCHEDULED STOP POINTs while, quite separately a "public transport vehicle path network" is defined through ROUTEs.

All these objects represent different aspects of the same public transport network: the problem consists in establishing a correspondence between these objects.

The correspondence between layers is called in NeTEx (and Transmodel) a PROJECTION.

The PROJECTION from the "service layer" to the "PT route layer" is achieved through the definition of a correspondence between:

— each SERVICE LINK and TIMING LINK used for that particular JOURNEY PATTERN; and

— the ROUTE, which is a sequence of ROUTE LINKs.

This correspondence is called in Transmodel a LINK PROJECTION.

The precise definition of a LINK PROJECTION is: an oriented correspondence

— from one LINK of a source layer;

— onto an entity in a target layer: e.g. LINK SEQUENCE, COMPLEX FEATURE, within a defined TYPE OF PROJECTION.

In the example represented below the LINK PROJECTION is of a type where the target is a LINK SEQUENCE.

This may be schematically represented as follows:

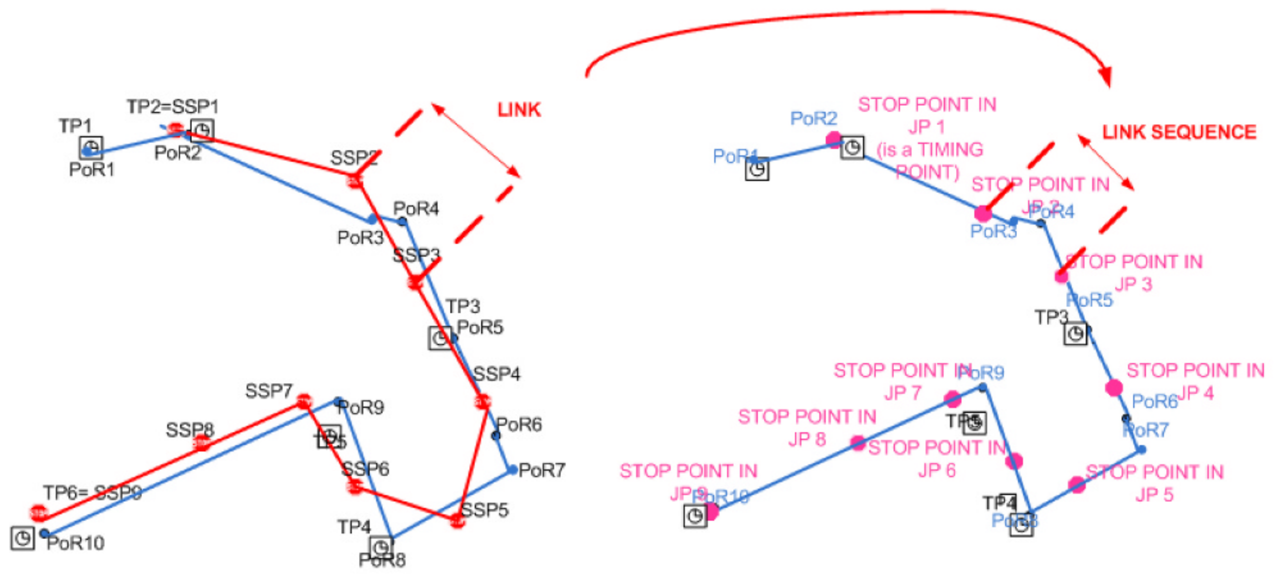


Figure E.5 — Projection example of a link on a link sequence

Also a POINT PROJECTION is defined in Transmodel (and more likely to be used in NeTEx) as:

an oriented correspondence:

— from one POINT of a source layer, onto a entity in a target layer: e.g. POINT, LINK, LINK SEQUENCE, COMPLEX FEATURE, within a defined TYPE OF PROJECTION.

This means that a point feature may be brought in correspondence with spatial features of another type, dimension and complexity.

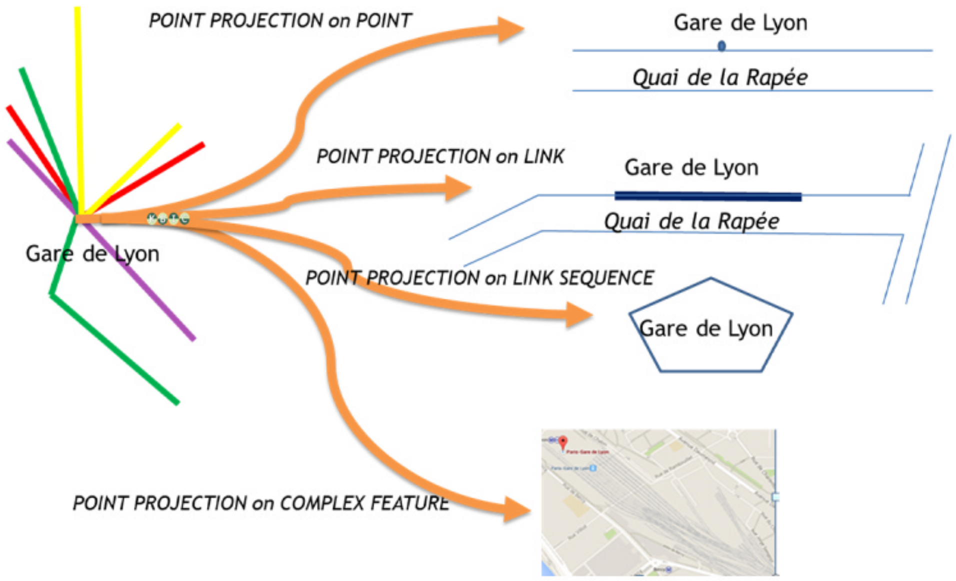


Figure E.6 — Projections examples of a point

By analogy, a ROUTE may be mapped to the "infrastructure layer" in order to get a correspondence with the spatial geographic features.

E.6.4 Lines

In order to make them easy to understand by the public, transport networks are normally marketed as sets of named routes covered by specific services – in colloquial terms a 'route' or 'line'. The actual choice of route names may be quite arbitrary and include services that branch, go round in circles, or barely overlap. NeTEx uses a distinct *LINE* element for this concept, which is independent of the spatial concept (as described by ROUTE, SERVICE PATTERN etc) thus allowing any arbitrary *grouping* (of ROUTEs) to be created.

E.6.5 Schematic maps

The various patterns discussed above are *all directional*, that is separate patterns are used for each direction of travel, with separate links between each point in each direction. High level visualizations of passenger information systems such as route maps (for example the Paris metro map) are often not directional and mostly show simple non-directional links between stops (and sometimes omit intermediate stops). NeTEx allows such high level views to be constructed using SCHEMATIC MAPs, such that individual points and links can be related to the underlying directional elements so that station as well as disruption and other information can be tied in to the map and computed over by applications such as personal navigators or disruption alert tools. Common presentation properties such as the line colour to use for each LINE and font can be described as well, supporting the automatic creation of consistent interfaces.

Annex F
(informative)

Representing Flexible Networks and Multimodality in NeTEx

F.1 Introduction

This Annex is intended to convey a high level view sufficient for a technical manager to appreciate the capabilities of the CEN document NeTEx and omits all detailed considerations - see detailed documentation [N1], [N2], [N3].

F.2 Scope

The NeTEx public transport network representation can be used for any mode of transport, including rail, bus, metro, ferry etc. The same model elements can be used in different ways in different views, for example ranging from a high level schematic view of the network for passengers, to a stop by stop sequence of a route for a specific scheduled journey.

In the NeTEx representation (see Annex E), both the different types of locations (stations, airports bus stops etc), their layout and their properties such as accessibility and facilities can be described (see Annex G). The relationship between the representation of a stop as a set of physical points (e.g. a station and its platforms); the stop as a point in a timetable (which may be independent of platform); and the stop as point for real-time measurement and display can all be described precisely.

The representation of *multimodal features* of topological elements already described in [T4] is extended in NeTEx, fully integrated into the network topology representation and may be used for instance for the description of inter-modal connections.

Alongside a more classical view of network topology, NeTEx can also describe *flexibility features* of topological elements that characterize flexible services. Some of the fixed network elements may be used to describe the structure of Flexible Networks, for Flexible Transport Systems or Demand Responsive Systems. This makes it possible to make Flexible services visible in journey planners and stop finders and other applications.

F.3 Corresponding NeTEx documentation

A detailed specification of NeTEx capabilities as regards the public transport network representation and exchange can be found in [N1]. A short presentation of the public transport network representation is also given in Annex E.

The basic network topology as described in [N1] is represented either through simple or complex object classes like:

— Paths through the network: ROUTEs, JOURNEY PATTERNs, TIMING PATTERNs, SERVICE PATTERNs, etc. which are linear features, linked to point features such as

  — Operational points: TIMING POINTs, GARAGEs, CREW POINTs, BEACON POINTs, etc;

  — Passenger service points: SCHEDULED STOP POINTs, STOP AREAs, CONNECTIONs, etc;

  — Groupings of services for marketing; LINEs.

For network topology, the main Flexible Transport Service (FTS) aspect considered is the flexible line structure, defined through:

— Additional flexible topologies FLEXIBLE ROUTEs, FLEXIBLE POINT PROPERTIES, FLEXIBLE LINK PROPERTIES;

— Additional flexible service areas; FLEXIBLE STOP PLACEs, FLEXIBLE QUAYS;

— Additional flexible aspects for marketing services: FLEXIBLE LINES.

Service related aspects of FTS are defined in [N2]:

— Additional flexible aspects: FLEXIBLE SERVICE PROPERTIEs, BOOKING ARRANGEMENTs.

Certain other aspects of FTS passenger information such as reservation rules are defined in [N3].

F.4NeTEx Methodology

NeTEx uses a "model driven design", i.e. the development starts from a conceptual model, from which a physical UML model and an XML implementation is derived.

The European Public Transport Reference Data Model, known as Transmodel, is the conceptual basis for the development (see [T1], [T2], [T3]).

F.5Flexible networks

F.5.1 Flexible behaviour of public transport services

NeTEx is designed to support FTS (Flexible Transport Service) and DRT (Demand Responsive Transport). DRT and FTS often cover similar services; FTS being a more generic concept since flexibility is not necessarily directly linked to demand, but may be related to other factors such as operating needs or cost optimisations. The term 'FTS' will be used in the following text to cover both concepts.

NeTEx distinguishes two concerns: *flexibility of the network topology* (that is, services that cover a variable area) and *flexibility of the network service*s (that is, services that can run at varying times or to satisfy user demand). Both may be combined to describe a flexible network (though it is possible that a network is flexible only as to its topology or its services and not necessarily as to both).

F.5.2 Defining areas of flexible coverage

Flexible services need be visible alongside fixed services, for instance in journey planners, so that passengers are aware of their existence. Zone based flexible services or a geographical area where flexible services are present (e.g. Hail and Ride services which serve a section of road) can be represented in NeTEx using FLEXIBLE STOP PLACEs and FLEXIBLE QUAYs. This allows the sections or zones to appear as named "stops" in their own right in a journey planner. Flexible services can also use regular STOP PLACEs and QUAYs for all or part or all of their journeys.

The following figure describes a Hail and Ride section along a bus line (in red). It has two separated start and end points, one for each direction. Between start and stop point, the vehicle can be stopped on any point (on passenger demand) for boarding or alighting.

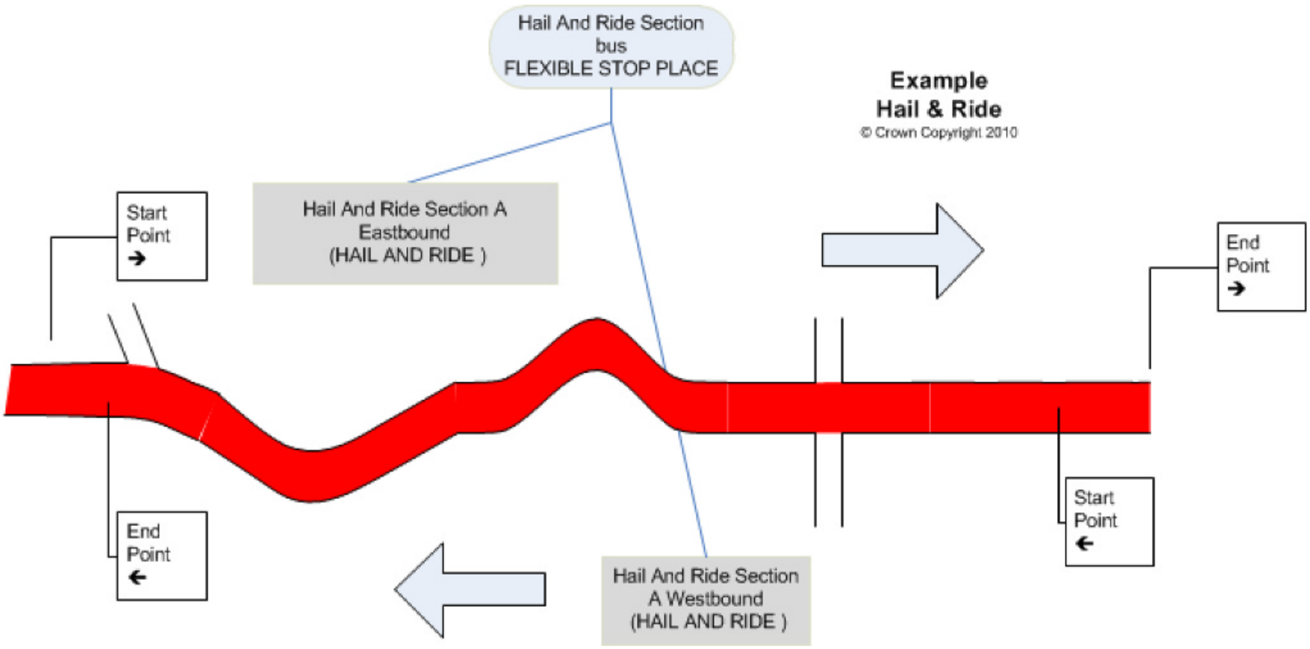


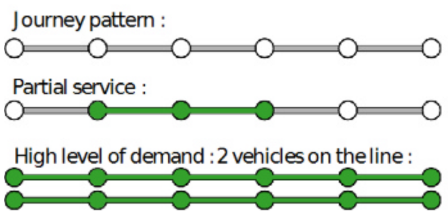
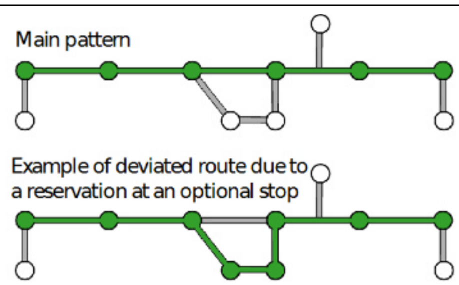
Figure F.1 — Hail and Ride Stop example

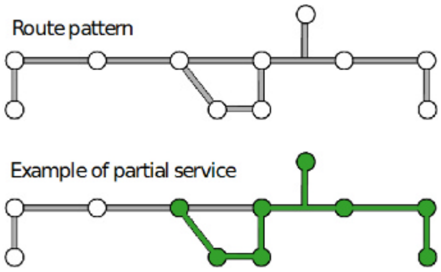
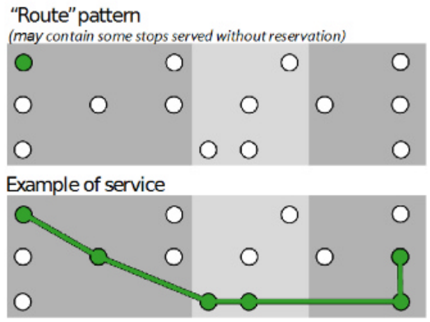
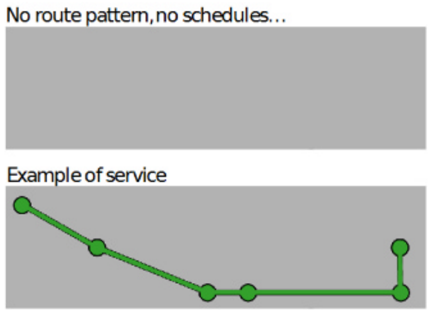
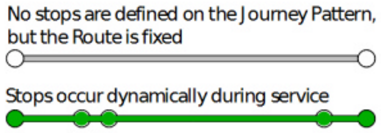
F.5.3 Defining flexible routes

The flexible topologies available in NeTEx are summarized in the table below.

Flexible services can operate on regular line topologies or on a flexible topology. The FLEXIBLE LINE element describes common flexible properties of a LINE and the FLEXIBLE LINK PROPERTY and FLEXIBLE POINT PROPERTY elements can be used to add attributes to fixed elements to describe flexible behaviour.

Table F.1 — flexible topologies available in NeTEx

Name	Description	Figure
Virtual Line (fixed topology)	This case is very similar to fixed line operation: JOURNEY PATTERNs are defined as usual, but stops are served only if there is a passenger booking for it. Virtual line can be operated with fixed or dynamic passing times. The virtual line topology is therefore fixed.	
Flexible line with **main route**	A minimal list and order of stops are defined determining a "main and minimal" journey pattern. Possible additional stops are defined but will be served only in case of passenger reservation. The JOURNEY PATTERN is determined through a stop list and order defined dynamically according to the passenger reservations and	

<table>
<tr><th>Name</th><th>Description</th><th>Figure</th></tr>
<tr><td></td><td>“around” the “main and minimal” journey pattern.</td><td></td></tr>
<tr><td>Corridor (Flexible line without main route)</td><td>The possible stops of the JOURNEY PATTERN are known, and the possible stop sequences are also defined and the real stop list and order are defined dynamically according to the passenger reservations without any reference to a main pattern.</td><td></td></tr>
<tr><td>Flexible zone with fixed stops</td><td>The service is defined by one or several zones (in sequence). Each zone is defined by a set of possible stops.
Stops served, and stop order are defined for each VEHICLE JOURNEY according to the reservations.
PASSING TIMES (entry and exit time) are usually defined for each zone. They may also be defined for each stop.</td><td></td></tr>
<tr><td>Flexible zone without fixed stops</td><td>The service is defined by one or several zones (in sequence). A stop can occur anywhere in each Zone.
Stops served, and stop order will be defined four each VEHICLE JOURNEY according to the reservations.
PASSING TIMEs may be defined for each zone (entry and exit time), or for each stop.</td><td></td></tr>
<tr><td>Hail and Ride</td><td>The ROUTE is defined, but the journey pattern only has a start and an end.
Boarding or alighting is obtained by signalling the driver that one wishes to board/alight, and can occur anywhere along the Route.</td><td></td></tr>
<tr><td>Combination of any of the previous FTS structure</td><td>A lot of FTS services are defined as a sequence of the above described FTS types.</td><td></td></tr>
</table>

F.5.4 Timing of flexible services

Even if a service does not have a fixed timetable, a flexible service will normally operate within a certain time band and on particular day types (weekdays, holidays etc). This operational window can be specified for a FLEXIBLE LINE using NeTEx generic components for specifying temporal conditions (VALIDITY CONDITION etc), allowing journey planners to make intelligent decisions as to when to include flexible services in their results.

The scheduling of flexible services that run to a timetable can be described with the same elements as used for fixed services and described in Annex H. Several types of flexible services are available, for example:

— Fixed PASSING TIMEs: meaning scheduled passing time: there is a timetable, but the service will only run under condition, mainly depending on sufficient demand);

— Dynamic PASSING TIMEs: times at stop will vary according to when the service runs;

— Fixed HEADWAY FREQUENCY: in this case, a maximum waiting time is available through a HEADWAY JOURNEY GROUP, but no passing times are defined, all is done dynamically depending on the demand.

Two additional properties can also be supplied:

— Whether cancellation is possible or not, even after booking, meaning that the operator can decide to cancel a service or a stop, usually because there is not enough demand, or the service is too busy.

— Whether the PASSING TIME and place may be updated or not, even after booking (usually passing times are updated to optimize the service).

F.5.5 Information on using services

FTS require user interaction to invoke the services. Booking arrangements can be associated with a FLEXIBLE LINEs in order to define the contact point (telephone, URL, etc.), the booking authorization, and booking conditions such as:

— the passenger shall/can/cannot make a reservation;

— the reservation shall be done x minutes/days/… before the vehicle departure time;

— etc.

F.6Multimodality

F.6.1 Multimodal network features

NeTEx has a generalized model that allows transport data for all modes to be represented and exchanged. Common representations can be used for most aspects of public transport data, with mode and submode indicated by standard attributes. Certain modes have characteristics specific to the mode (for example rail journeys may involve multi carriage trains that join or split for part of the route) and NeTEx has specific features to cover these (see [M1]). Here we illustrate how a common stop place model is used for all modes of physical transport, making it easier to integrate data from different modes to create a joined up trip planning system.

F.6.2 Multimodal stop places

NeTEx provides a way to exchange a detailed and unambiguous description of the physical layout of stops making possible the *multimodal use of the same stop* – and also allowing detailed accessibility information to be provided (see Annex G or [T1], [T2], [T3]).

The STOP PLACE model describes different aspects of a physical point of access to transport, such as a stop or station. For locations with a complex structure, such as a station, this includes all the component areas of the station: the entrances, concourses, platforms, the levels they are on, the paths through the station and the various types of equipment found in the station, such as ticket machines and lifts, barriers, signs and seating. It also allows detailed accessibility attributes to be recorded at both the element and the station level.

A STOP PLACE may represent a pair of physical stops or a cluster of physical stops. A STOP PLACE may contain other STOP PLACEs.

A STOP PLACE is composed of different spaces, such as platforms (QUAYs), and concourses (ACCESS SPACEs), etc. The physical point of access to transport is always a QUAY. ENTRANCEs describe the internal and external entrances to the STOP PLACE.

An example of a complex STOP PLACE is a large rail station which may contain a metro station as a child STOP PLACE and have associated STOP PLACEs for the stops of the bus routes that pass by it, as shown on the figure below.

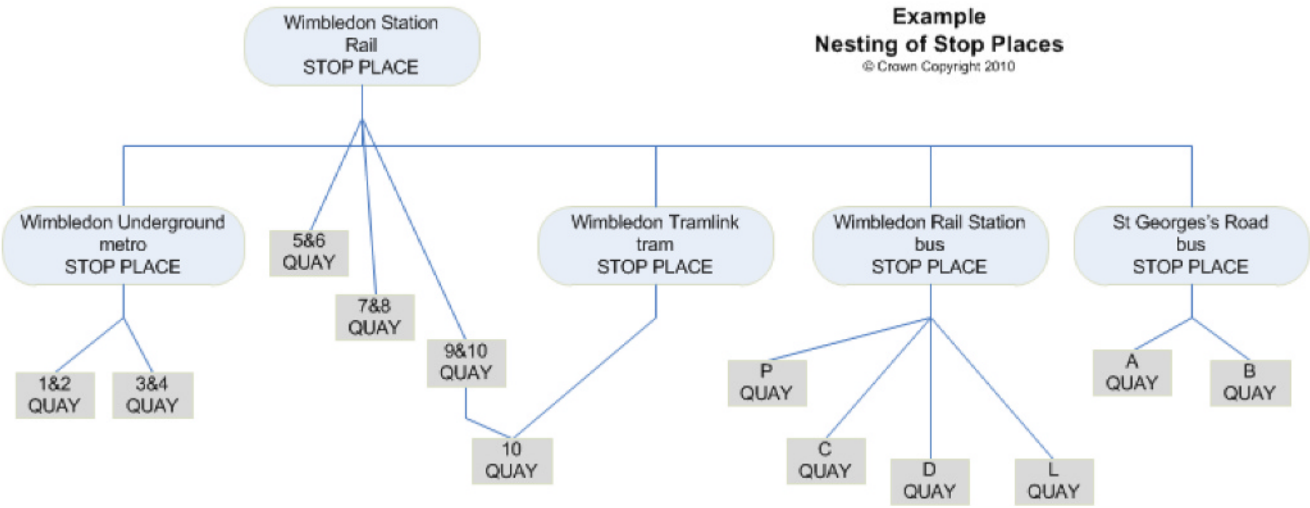


Figure F.2 — Nesting of Stop Places example

In such cases a general recommendation is that

— There should be a separate STOP PLACE for each pair of bus or tram stops (or isolated stop) on street;

— There should be a separate STOP PLACE for each transport mode each with its own QUAYs, and with distinct ENTRANCEs.

Sometimes however different modes may share the same platform, for example between rail, tram or metro, or between bus and coach. In this case it is recommended that:

— A separate STOP PLACE should be created if an area of a station can be referenced as a separate station by a timetable or other passenger information usage;

— Where platforms are shared between modes, a single definition of the platform i.e. QUAY can be made. The STOP PLACE for the major mode (e.g. rail) can contain the QUAY definition. Two alternative approaches are possible:

  1) Create a separate STOP PLACE for the additional mode; the STOP PLACE mode can reference the QUAY definition.

  2) Simply specify multiple modes for the STOP PLACE and the QUAY (e.g. rail, metro).

F.6.3 Physical versus logical stops

A STOP PLACE, a physical description of a location at which public transport stops, is a distinct concept from the representation of the stop (logical stop) in a timetable – the SCHEDULED STOP POINT. The former has a spatial geometry which can be related to the underlying Geographic Information System (GIS) features; the latter is defined within the overall topology of the transport network and its routes as a simple point (thus for example the SCHEDULED STOP POINT 'Gare du Nord' in Paris has long distance, suburban, metro and bus services, corresponding to a number of different STOP PLACEs at a multiplicity of physical locations). The two concepts can be explicitly connected using a STOP ASSIGNMENT. Often there is a one-to-one correspondence between the two, and the same identifier is used for both (amounting to an implicit assignment), but in other cases – as say when a bus stop is moved, or a platform reassigned, or one transport mode uses a different set of identifiers from another mode, the use of separate elements for the separate concepts allows a more precise representation (and also different assignments to be made to cover different circumstances). In also enables detailed passenger information on interchange navigation to be provided (see Annex G and Annex I).

F.6.4 Multimodal connection possibilities

The STOP PLACE model in particular allows the nature of the possible connections between services that may be made at a transfer to be described very precisely and to be related to the physical paths through the station, as well as the paths to access a station. This representation can include timing information for different times of day, allowing more accurate journey planning (see concepts of ACCESS and CONNECTION in Annex G or [T1], [T2], [T3]).

Gathering such a data set for many large transfer locations requires a significant investment, so, as elsewhere, NeTEx allows an incremental approach to be taken. Global default values for transfer possibilities between modes on any SITE or OPERATOR, can be specified for where there is no more specific value for a SITE.

Annex G
(informative)

Support for Accessibility in NeTEx

G.1 Introduction

This Annex is intended to convey a high level view sufficient for a technical manager to appreciate the capabilities of the CEN document NeTEx for describing accessibility, and omits all detailed considerations that can be found in the detailed documentation see- (N1], [N2], [N3]).

G.2 Scope

The NeTEx public transport network representation can be used for any mode of transport, including rail, bus, metro, ferry etc. (see Annex E). The same model elements can be used in different ways in different views, for example ranging from a high level schematic view of the network for passengers, to a stop by stop sequence of a route for a specific scheduled journey (see Annex H). Among the properties that can be described are accessibility and facilities Thus both for of locations on the network (stations, airports bus stops etc), and transport services (on trains, buses etc) it is possible to specify accessibility data, including physical limitations, facilities and assistance services.

G.3 Corresponding NeTEx documentation

A detailed specification of NeTEx capabilities as regards the public transport network representation and exchange can be found in [N1].

In particular the accessibility properties of the network are mainly described as additional (space-related) aspects of the basic network (Annex E) and also apply to various (time-related) aspects of the JOURNEYs described in Annex H, as summarized here:

The NeTEx *Framework* (section 1 of [N1]) includes some generic components describing accessibility that are reused in other sections (see also [N2], [N3]), such as:

— Generic accessibility components: USER NEEDs, LIMITATIONS, SUITABILITIES, ACCESSBILITY ASSESMENTs describe different types of user accessibility requirements (Wheelchair, Pushchair, Guide dog, Visual Impairment, Medical condition etc) as a standardized set of categories that can be used uniformly;

— VEHICLEs and VEHICLE TYPEs which can have their accessibility described through an EQUIPMENT PROFILE;

— EQUIPMENT: specific accessibility properties of SITES and VEHICLEs (for example Wheelchair accessible Toilets, Lifts etc.), can be described using EQUIPMENT elements. These can be specialized in other sections of NeTEx to create specific types of equipment;

— VALIDITY CONDITIONs can be used to set temporal and other conditions on availability.

Public Transport Network Topology (section 2 of [6]), describes elements of the Network to which accessibility can be applied:

— Sites in the Network: STOP PLACEs, POINTs OF INTEREST, PARKINGs etc and their subcomponents (QUAYs, ENTRANCES, etc), as well as the paths (NAVIGATION PATHs) within them.

— Transfer points: TRANSFERs, CONNECTIONs, INTERCHANGEs.

Accessibility concepts also apply to some of the journey related entities described in [7]),

— Journeys: SERVICE JOURNEYs and JOURNEY PARTs may have facilities or EQUIPMENT associated with them that describes the accessibility features of a journey or part of a journey.

G.4 NeTEx Methodology

NeTEx uses a "model driven design", i.e. the development starts from a conceptual model, from which a physical UML model and an XML implementation is derived.

The European Public Transport Reference Data Model, known as Transmodel, is the conceptual basis for the development (see [T1], [T2], [T3] and also [T4] which provides a detailed physical model of stops).

G.5 Approach

NeTEx aims to use a uniform and standardized set of attributes to describe the accessibility properties of the network; this makes it possible to use such data in journey planners to compute consistent results across the network.

Specifying all the possible accessibility characteristics of a network requires a sustained long term effort to gather what is a large and quite complex data set; such a set will typically only be gathered incrementally and unevenly over a network. Furthermore, the mandatory requirements for providing accessibility data are subject to different legal requirements in different European countries, so are likely to be achieved at different rates. The NeTEx model is accordingly designed to be usable at different levels of detail; it can be populated sparsely at a high level to achieve a useful basic level of function and then populated more richly to over time. When fully populated it enables a high level of functionality including a detailed step by step representation of a path through an interchange.

To describe accessibility, NeTEx models as separate and distinct aspects:

(a) the description of the USER's NEEDs – for example wheelchair, hearing impaired, vision impaired, lift-averse, etc.; and

(b) the ACCESSIBILITY LIMITATION, of the location i.e. description of the limitations of a SITE ELEMENT to support a specific need, for example *Wheelchair, Step free, Escalator free, Lift free* .

These aspects can be grouped together as an ACCESSIBILITY ASSESSMENT and associated with various NeTEx ENTITies.

G.6 Accessibility of sites

NeTEx/Transmodel supports a detailed description of the accessibility of a SITE, i.e. of a location to which passengers may wish to travel such as a station (STOP PLACE) or POINT OF INTEREST (the latter can be used to describe accessibility of public buildings, parks and other locations that are not public transport nodes.)

The accessibility of SITE components is described using an ACCESSIBILITY ASSESSMENT: this allows any SITE component to be described either in terms of suitability for specific user needs or in terms of accessibility limitations of the SITE, or both.

This can be used in applications in various ways:

— for journey planners when calculating a journey that meets a given set of user criteria, to choose stations or paths that are, for instance, wheelchair accessible when planning a point-to-point journey

— for trip preparation to show the exact properties of a given location, part of a planned trip so that users may make their own judgement about the opportunity to access this specific location.

In addition to the accessibility of SITEs, further information relevant for detailed accessibility is contained on many of the different EQUIPMENT elements, for example, lift dimensions and controls, step heights, handrails and the number of steps in a staircase, ramp gradients, whether barriers are wheelchair passable, etc. LOCATION SERVICEs can be used to describe, ASSTANCE SERVIES, porterage that may be invoked to assist travellers, including information on how to book them.

Information can be specified at a detailed SITE COMPONENT level and also at a summary level so that an overall indication can be given for a SITE

G.7 Accessibility and connections

In order for a journey to be accessible, it shall be possible not only to access a stop despite any mobility restrictions, but also to change services at each intermediate stop where a connection is made between journeys. Users with mobility restrictions may need extra time to make a connection, either because they move slower, or because they have to take a different path within the transfer site. NeTEx allows accessibility and time conditions to be specified on individual connections so that precise journey plans can be computed that reflect the layout of complex interchanges such as major stations, where there can be material differences in the time needed to according to the specific interchange. Generic defaults for a mode be used as a fall-back or useful approximation when exact data are not available.

We note that in colloquial usage, the terms 'interchange', 'transfer', 'connection', 'access' are commonly used in the context of journey planning, but often with overlapping or ambiguous senses. To remove this ambiguity, Transmodel and thus NeTEx (as elsewhere), uses each term for a distinct, well defined concept so that the different aspects of journey interchanging can be modelled and computed over. In particular, the spatial passenger-oriented aspects are clearly separated from operation and time-related aspects.

— The terms TRANSFER, ACCESS and CONNECTION are *passenger-oriented and space–related* concepts against which time constraints for a passenger to change from one public transport vehicle to another to continue the trip are expressed.

— INTERCHANGE is an *operation–oriented time-related* term expressing scheduled time constraints to be respected between vehicle journeys.

Thus, to describe the characteristics of the network and its topology TRANSFER, ACCESS and CONNECTION are used. More precisely, a TRANSFER represents any pair of points located sufficiently near that there is a *possibility* of a passenger moving between them on a timescale which is realistic for carrying out a trip.

— A CONNECTION is a type of TRANSFER between two SCHEDULED STOP POINTs or STOP AREAs.

— An ACCESS is a type of TRANSFER that represents the walking movement of a passenger at the beginning or end of the trip from their origin/destination to a stop where he will board a public transport vehicle.

It is possible to specify detailed timings and accessibility attributes for ACCESSEs and CONNECTIONs so that journey planners can make use of them.

G.8 Accessibility of navigation paths

ACCESSes and CONNECTIONs specify the *possibility* of a transfer but do not define the precise physical paths to be taken. The specific ways of traversing a site are described by NAVIGATION PATHs between any two points; these may be annotated with their accessibility characteristics so that a journey planner can choose an accessible path.

Several different NAVIGATION PATHs may be associated with the same CONNECTION, representing alternative paths by which the CONNECTION can be walked;

Both concepts (CONNECTION and NAVIGATION PATH) allow to record times, but:

— CONNECTION transfer times relate to the timetabled connection times (and can be used without reference to actual platforms)

— NAVIGATION PATH transfer times relate to the known times to traverse between physical stops.

A NAVIGATION PATH is made up of PATH LINKs, each recording the accessibility characteristics of an individual section in the path. These can include information on Lifts, Steps, lighting, handrails, surfaces (cobbled, tactile surfaces for the blind, etc) and other properties of interest to different classes of passenger. In order to make use of the information about accessibility in ACCESSes, the PATH LINKs, shall typically be integrated with information about the wider geospatial context within which the NAVIGATION PATH is connected, i.e. with the characteristics of the related road elements. This part is not considered in detail in the model, only some of the infrastructure-related characteristics are explicitly mentioned.

G.9 Accessibility of journeys

The accessibility of a journey may also depend on the facilities of the actual vehicles used and on the assistance services provided by the operator to mobility impaired users.

SERVICE JOURNEYs and JOURNEY PARTs may have facilities or EQUIPMENT associated with them that describe the accessibility features of a journey or part of a journey. These may be derived from a VEHICLE TYPE and its EQUIPMENT PROFILE, or be specified on a specific journey. If facilities are only available at certain times VALIDITY CONDITIONS can be used to specify this.

— The accessibility of specific services and VEHICLE JOURNEYs, (e.g. low floor access, on board wheelchair spaces, wheelchair hosts) can be described using equipment elements such as VEHICLE ACCESS EQUIPMENT and WHEELCHAIR ACCESS EQUIPMENT. In addition a number of other equipment types have some accessibility attributes. A LOCAL SERVICE can be used to describe assistance services.

NeTEx can cover complex cases such as when only a specific part of the platform gives access to a train, or where a stop is only accessible if a specific vehicle type is used.

Annex H
(informative)

Representing Timetables in NeTEx

H.1 Introduction

The paper is intended to convey a high level view sufficient for a technical manager to appreciate the capabilities of NeTEx, and omits detailed considerations, but is still quite technical. For a complete description, see in particular Part 2 (see [N2]), as well as generic framework concepts (points, links, zones, etc.) and PT network topology concepts (scheduled stop points, lines, routes, etc.) described in [N1].

H.2 Corresponding NeTEx documentation

Conceptually a timetable is a frame that aggregates timetable related concepts from models mainly described in NeTEx Part 2 (see [N2]).

Table H.1 gives a summary of models inside NeTEx Part 1 and Part 2 documentation, which are relevant for the interoperable exchange of timetables in NeTEx.

Table H.1 — NeTEx parts containing frames and models that make up a timetable

NeTEx Part 1	**NeTEx Part 2**
NeTEx Explicit Frames	Journey and Journey Times Model
• Service Frame Model	• Vehicle Journey Model
• Timetable Frame Model	• Service Journey Model
• Service Calendar Frame Model	• Time Demand Times Model
NeTEx Framework	• Journey Pattern Times Model
• Generic Framework Model	• Vehicle Journey Times Model
o Generic Point and Link Model	o Interchange Model
• Reusable Components Model	o Interchange Rule Model
o Service Calendar Model	o Coupled Journey Model
o Notice Model	• Flexible Service Model
o Reusable Availability Model	• Journey Timing Model
• Versions and Validity Model	Journey Accounting Model
o Generic Version Model	• Dated Journey Model
o Generic Validity Model	• Passing Times Model
Network Description Model	• Vehicle Service Model
• Route Model	• Vehicle Journey Assignment Model
Tactical Planning Components Model	
• Journey Pattern Model	
• Time Demand Type Model	
• Service Pattern Model	

H.3 Approach to Timetables in NeTEx

NeTEx uses a consistent model (from Transmodel) to represent PT timetables for all PT modes (train, bus, coach, metro, tramway, ferry, and their sub-modes), including both the journeys of the service, and any interchanges with other services. It also includes support for advanced rail related concepts, such as coupled journeys for trains that join and split, and the makeup of trains for passenger information. Services may be scheduled with fixed departure times, or as frequency based services (say, "every 5 minutes").

The NeTEx representation is designed to support the exchange of schedules throughout the operational processes of a PT operator, and therefore includes components that tie in the timetables and their journeys both to upstream planning and to downstream operations processes, making the NeTEx format richer and more flexible (and more complex) than a mere 'final timetable format' for publishing timetable data to journey planners (such as say GTFS [G1]). Timetables may be created quickly and efficiently from reusable network and timing components, with linkage references to the latter being maintained, so that any changes to the derivation can be propagated automatically into a revised timetable.

Timetables are themselves in effect reusable components as they may be specified independently of any actual dates. Actual dates are assigned to a timetable with a service calendar frame, which specifies a set of day types (e.g. "working weekday"), operating days (e.g. "Wednesday 2015-09-17") with corresponding day type assignments (e.g. "17th September 2015 is a day type 'working weekday' "). By using different service calendars a timetable may be perennial and be reused in different actual periods.

Timetable elements can also include links to data needed to support real-time operational systems including blocks and driver components, as well as additional passenger information such as on-board announcements, stop displays, equipment, etc.; again enabling the automated provisioning of systems (and updating in the case of change).

One of the significant practical considerations in representing timetables digitally (and the cause of the greatest difficulty when integrating different data sets from different sources) is the representation of temporal validity conditions as to when a particular timetable, or service within the timetable, operates. The NeTEx framework provides a uniform model for defining validity conditions that helps to simplify the interpretation of temporal constraints and makes data integration a lot easier – see Annex C and [N1]. A consistent system of conditions is also useful for upstream systems, which may wish to maintain many alternative versions of timetables for different planning or contingency purposes; the validity condition mechanism allows timetables to be tagged semantically for different uses –e.g. 'Winter timetable for heavy snow conditions'.

Timetables can include additional annotations such as notices applying to particular journeys, details of facilities available for all or part of the journey and on-board equipment. Journeys can also be tagged with accounting attributes for contracts between PT organisations.

A NeTEx timetable only needs to be populated as required for a given application – most of the elements are optional, so the same format (and technology platform) may be used for both a sparsely populated summary (equivalent say to GTFS) or a richer representation for planning or operational purposes. There are mappings of timetable elements into major legacy formats such as VDV 452 and NEPTUNE.

Fares for scheduled services are added in NeTEx Part 3, referencing the network and timetable components developed in NeTEx Part 1 (see [N1]) and NeTEx Part 2 (see [N2]).

H.4 The representation of a timetable

H.4.1 General

NeTEx uses a conventional representation for the core timetable, corresponding to that found in various national standards, which we outline in this section:

— A simple timetable is made up of one or more SERVICE JOURNEYs; each journey describing a scheduled journey departing at a specific time. A journey is made up of two or more CALLs, each describing arrival and or departure times at a SCHEDULED STOP POINT in sequence, along with any other information relating to a visit to a particular stop, such as notices, platforms, display headings, accessibility of the service, etc. Validty conditions as to when a particular journey runs are normally specified in terms of DAY TYPEs types which can be separately resolved to an actual calendar date.

— The journeys are grouped explicitly in a TIMETABLE FRAME, which sets global validity conditions and other defaults for all SERVICE JOURNEYs in the timetable. The frame provides a container to hold the journeys and other timetable related elements for exchange. Timetable frames can themselves be grouped in a COMPOSITE FRAME with other types of frame, for example SERVICE FRAMEs (with stop and route details), SERVICE CALENDAR FRAME (with DAY TYPEs and OPERATING DAYs) and/or FARE FRAMEs (with price details) in order to create complete and coherent self-contained data sets. DAY TYPE is used to specify the days one which a given service runs; the temporal constraints on the DAY TYPE can be specified by VALIDITY CONDITIONs that specify the day of week, holiday operation, etc.

NeTEx has many additional features to represent additional aspects of timetables that are found in different circumstances:

— To represent frequency based services; an additional types of service journey, the TEMPLATE SERVICE JOURNEY, is provided. The frequency may be specified either as an interval such as "every five to ten minutes'" (using a HEADWAY JOURNEY GROUP) or a as a regular e.g. "at 05, 25 and 45 minutes past the hour" (using a RHYTHMICAL JOURNEY GROUP). Use of a separate template component clarifies the distinction between the operational view of the timetable (which still involves individual SERVICE JOURNEYs running at specific times in operational blocks) from the passenger view, which is condensed down to a single entry with a frequency.

— PT services will often be planned so as to connect with other services, and information on these connections may be included in passenger information using the SERVICE JOURNEY INTERCHANGE element. The representation can describe interchange times and whether a connection is advertised, guaranteed (i.e. will wait a certain time) and other operational constraints. Additional complex conditions about managing journey interchanges can be specified with INTERCHANGE RULEs.

— Long distance rail may involve vehicle journeys that join or split; this can be modelled by the additional use of JOURNEY PART elements, to represent each segment of the journey which can be combined as JOURNEY PART COUPLEs to indicate a joined segment of the journey. TRAIN and COMPOUND TRAIN ELEMENTS can be used to describe the corresponding train makeup implications (i.e. which carriages go where) so that meaningful passenger information can be provided. The TRAIN NUMBER element allows the correct public identifier used for each journey to be provided, despite any intricacies of joining or splitting or international operation.

H.4.2 Components to create a timetable

The operation of modern PT networks typically involves the use of computer based systems to plan and optimize the provision of services. Planning systems represent (and may need to change) not just the timetable element but also the various elements from which the timetable is built. NeTEx allows such data to be exchanged, as well as the resulting timetables. Here we outline the relationship of such elements to the timetable.

— The central timetable element is the VEHICLE JOURNEY (a generalization of SERVICE JOURNEY), which is a combination of a number of different tactical components: (a) the ROUTE and related JOURNEY PATTERN and SERVICE PATTERN, which dictate the route and sequence of stops (POINTs IN SEQUENCE) to be followed; (b) the TIMING PATTERN, and JOURNEY TIMINGs, which give the timing points and times needed to cover each link of the journey, and (c) the TIME DEMAND TYPE, which specifies the part of day that the journey is taking place, e.g. 'weekday', 'rush hour', etc. and so which set of timings should be used. Thus given a starting time and a SERVICE PATTERN it is possible to integrate information from the other components and automatically compute a sequence of CALLs with PASSING TIMES etc. at each stop.

— The planning of services may also involve the optimization of groups of journeys in driver and vehicle scheduling systems, to create work periods for each VEHICLE TYPE. Such periods are described as BLOCKs, worked from a PARKING POINT to another, composed of sets of VEHICLE JOURNEYs. BLOCKs may be coupled (building COMPOUND BLOCKs, representing the work of a vehicle during the time it is coupled to another vehicle) or separated for a while, building BLOCK PARTs, i.e. the parts of a BLOCK corresponding to the different JOURNEY PARTs of the VEHICLE JOURNEYs in a BLOCK.

— A DEAD RUN is another type of VEHICLE JOURNEY, an out of service journey that send out vehicles and retrieve them back to their depots, these may included to support operational and real-time systems.

H.4.3 Components to operate a timetable

Other types of operational data may be included in the SERVICE JOURNEY representation to provision downstream systems. For example:

— JOURNEY ACCOUNTING elements can be used to apportion costs for providing services for (parts of) a journey for contracts between different organizations.

— DESTINATION DISPLAY elements can be used to drive headsign, on-board displays and next stop announcements along the journey.

H.5 Example of a simple timetable in NeTEx

The example (Figure H.1) shows a simple bus timetable for a linear route modelled in NeTEx. The example originates from a national PT database in Slovenia.

— The timetable includes two ROUTES (outbound – "*Briga to Nova sela"* and inbound – "*Nova sela to Briga")* belonging to one LINE (id = K66, "*Kočevje – Petrina*") with transport MODE "*bus*".

— The timetable includes three stop points (SCHEDULED STOP POINTs) (Briga, Banja Loka and Nova sela) in each DIRECTION (i.e. *Briga smer Petrina, Briga smer Kočevje*).

— The timetable aggregates two SERVICE JOURNEYs (i.e. specific passenger carrying VEHICLE JOURNEYs), each following its own SERVICE PATTERN (boarding/alighting status). Each SERVICE PATTERN refers to a SERVICE JOURNEY PATTERN to derive the exact order of nodes, i.e. SCHEDULED STOP POINTS for its ROUTE; this is reflected in the timetable as the sequence of CALLs

— Each SERVICE JOURNEY also refers to a TIME DEMAND TYPE, which defines a set of vehicle running times for links between stop points for a given TIMEBAND and DAY TYPE. The given TIME DEMAND TYPE is used to calculate the planned vehicle arrival and departure times for each SCHEDULED STOP POINT at the given time of day; the result is included in the CALLs.

— A reference to DAY TYPE, which has property values "*Everyday*" and "*AnyHoliday*", defines operating days for the timetable.

VOZNOREDNI OBRAZEC

Koncesionar: A09 (INTEGRAL STOJNA d.o.o.)
Oznaka linije: K66
Naziv linije: Kočevje - Petrina
Obdobje: 01.01.2009 - 31.12.2009
Vrsta prevoza: MK - Medkrajevni
Stanje: P (Predlog)

Itinerarji:

01	Briga - Nova sela
02	Nova sela - Briga

K66: 01 Briga - Nova sela

POSTAJA (p.točka)	Km	01
		0
BRIGA smer Petrina	0,0	7:00
BANJALOKA smer Petrina	1,9	7:03
NOVA SELA smer Petrina	3,3	7:04

K66: 02 Nova sela - Briga

POSTAJA (p.točka)	Km	02
		0
NOVA SELA smer Kočevje	0,0	7:10
BANJALOKA smer Kočevje	1,2	7:11
BRIGA smer Kočevje	3,2	7:14

REŽIMI:

0	Vozi vsak dan

Odgovorna oseba in žig

Koncedent :

Direkcija Republike Slovenije za ceste

[18.03.2015] [stran 1 od 1] [K66-Kočevje - Petrina]

Figure H.1 — The bus timetable Kočevje-Petrina converted to NeTEx (XML physical model)

The following is a minimal encoding of the outbound part of the above timetable, omitting elements that give additional information and all referenced elements:

```
< TimetableFrame version = ”1” id = ”ao:K66_01” >
    < validityConditions >
        < AvailabilityCondition  id = ”ao:k66_01_01” >
            < FromDate > 2009–01–01T00:00:00Z < /FromDate >
            < ToDate > 2009–31–12T00:00:00Z < /ToDate >
        < /AvailabilityCondition >
    < /validityConditions >
    < Name > Bus timetable for line Kočevje-Petrina < /Name >
    < VehicleModes > bus < /VehicleModes >
    < OperatorView >
        < OperatorRef ref = ”ao:A09”/ >
        < Name > (INTEGRAL STOJNA d.o.o < /Name >
    < /OperatorView >
    < vehicleJourneys >
        < ServiceJourney  id = ”ao:K66_outbound_01” >
            < DepartureTime > 07:00:00.0Z < /DepartureTime >
            < dayTypes >
                < DayTypeRef  ref = ”ao: Everyday-AnyHoliday”/ >
            < /dayTypes >
            < ServicePatternRef  ref = ”ao:K66_outbound”/ >
            < TimeDemandTypeRef  ref = ”ao:offpeak”/ >
            < LineRef  ref = ”ao:K66”
            < JourneyPatternView >
                < RouteRef  ref = ”ao:K66_out”/ >
                < DirectionType > outbound < /DirectionType >
                < DestinationDisplayRef  ref = ”ao:NovaSela”/ >
            < /JourneyPatternView >
            < calls >
                < Call id = ”ao:K66_outbound_01” order = ”1” >
                    < ScheduledStopPointRef ref = ”ao:Briga-p”/ >
                    < Arrival >
                        < ForAlighting > false < /ForAlighting >
                        < /Arrival >
                    < Departure >
                        < Time > 07:00:00.0Z < /Time >
                    < /Departure >
                < /Call >
                < Call id = ”ao:K66_outbound_01” order = ”2” >
                    < ScheduledStopPointRef   ref = ”ao:BanjaLoka-p”/ >
                    < Arrival >
                        < Time > 07:02:30.0Z < /Time >
                    < /Arrival >
                    < Departure >
                        < Time > 07:03:00.0Z < /Time >
                    < /Departure >
                < /Call >
                < Call id = ”ao:K66_outbound_01” order = ”3” >
                    < ScheduledStopPointRef ref = ”ao:NovaSela-p”/ >
                    < Arrival >
                        < Time > 07:04:00.0Z < /Time >
                    < /Arrival >
                    < Departure >
                        < ForBoarding > false < /ForBoarding >
                    < /Departure >
                < /Call >
            < /calls >
        < /ServiceJourney >
    < /vehicleJourneys >
< /TimetableFrame >
```

Annex I
(informative)

Representing Fares in NeTEx

I.1 Introduction

This Annex is intended to convey a high level view sufficient for a technical manager to appreciate the capabilities of the CEN document NeTEx and omits all detailed considerations - see detailed documentation [N1], [N2], and in particular for fares, [N3].

I.2 Scope

NeTEx Part 3 [N3] covers fare data and is the main focus of this white paper; it is concerned with data for the following purposes:

a) To describe the many and various possible fare structures that arise in public transport (for example, flat fares, zonal fares, time-dependent fares, distance based fares, stage fares, pay as you go fares, season passes, etc.).

b) To describe the fare products that may be purchased having these fare structures and to describe the conditions that may be attached to particular fares, for example if restricted to specific groups of users, or subject to temporal restrictions. These conditions may be complex.

c) To allow actual fare price data to be exchanged. Note however that NeTEx does not itself specify pricing algorithms or how fares should be calculated. This is the concern of Fare Management Systems. It may be used however to exchange various parameters required for pricing calculations that are needed to explain or justify a fare, and each price may indicate their derivation from another price using a named method.

d) To include the attributes and the text descriptions necessary to present fares and their conditions of sale and use to the public. The conditions are in a machine readable from that an application program may utilize.

I.3 Functional areas

I.3.1 general

The Transmodel model [T1], [T2], [T3], on which NeTEx is based, breaks down "fare collection" into the following functional areas:

I.3.2 Fare policy specification:

— Characterization of different fare structures through spatial and/or temporal parameters (e.g. sections, zones, time periods, etc.).

— Specification of the access rights allowed on a network, i.e. access to services provided on a transport network (e.g. trip on the metro network, trip on the bus network, access to the 1st class waiting area, etc.) within a fare structure and the ways of using them (e.g. trip on the metro network during a time period of 2 h, without successive on-board validations, trip on an open bus network during 1h30 with mandatory on-board validations and with the obligation to show an entitlement to use this right).

— Specification of combinations of marketable access rights, called fare products (e.g. service consumption rights granted through a simple ticket), being possibly combinations of access rights determined by different fare.

— Description of sale principles applied to the fare products (e.g. specification of fare products sold as a sales package, and parameters describing the purchase rights, as for instance the obligation to show an entitlement to purchase a certain fare product).

Sales management:

— Management of the sales network (not covered by Transmodel V5.1).

— Sales operations (including fulfilment) (partly covered by Transmodel V5.1).

— NeTEx for Basic Rail fare data NeTEx and TAP TSI - V0.6-Draft.docx Page 13 Management of customers (partly covered by Transmodel V5.1).

— Collecting funds or accounting (not covered by Transmodel V5.1).

Pricing:

— Pricing parameters specification (partly covered by Transmodel V5.1).

— Exact price calculation (not covered by Transmodel).

Consumption control:

— Access right validation and control (covered by Transmodel V5.1).

— Fraud management (partly covered by Transmodel).

— Collection and aggregation of consumption data (not covered by Transmodel V5.1).

— Management of revenue sharing and clearing house activities (not covered in Transmodel V5.1).

I.4 Provision of information on fares

NeTEx covers only certain of the “upstream” processes of fare management sufficient to provide passenger information on fares; it is not concerned with reservation and ticketing processes. Thus “Fare policy specification” and “Provision of information on fares” are in the scope of NeTEx. “Pricing”, limited to “pricing parameters specification” is part of NeTEx and represents an extension to Transmodel V5.1 (see [T1]). Collection and aggregation of consumption data are also in the scope of NeTEx. Sales Management, Consumption control and other downstream process are outside the scope.

The following diagram summarizes this.

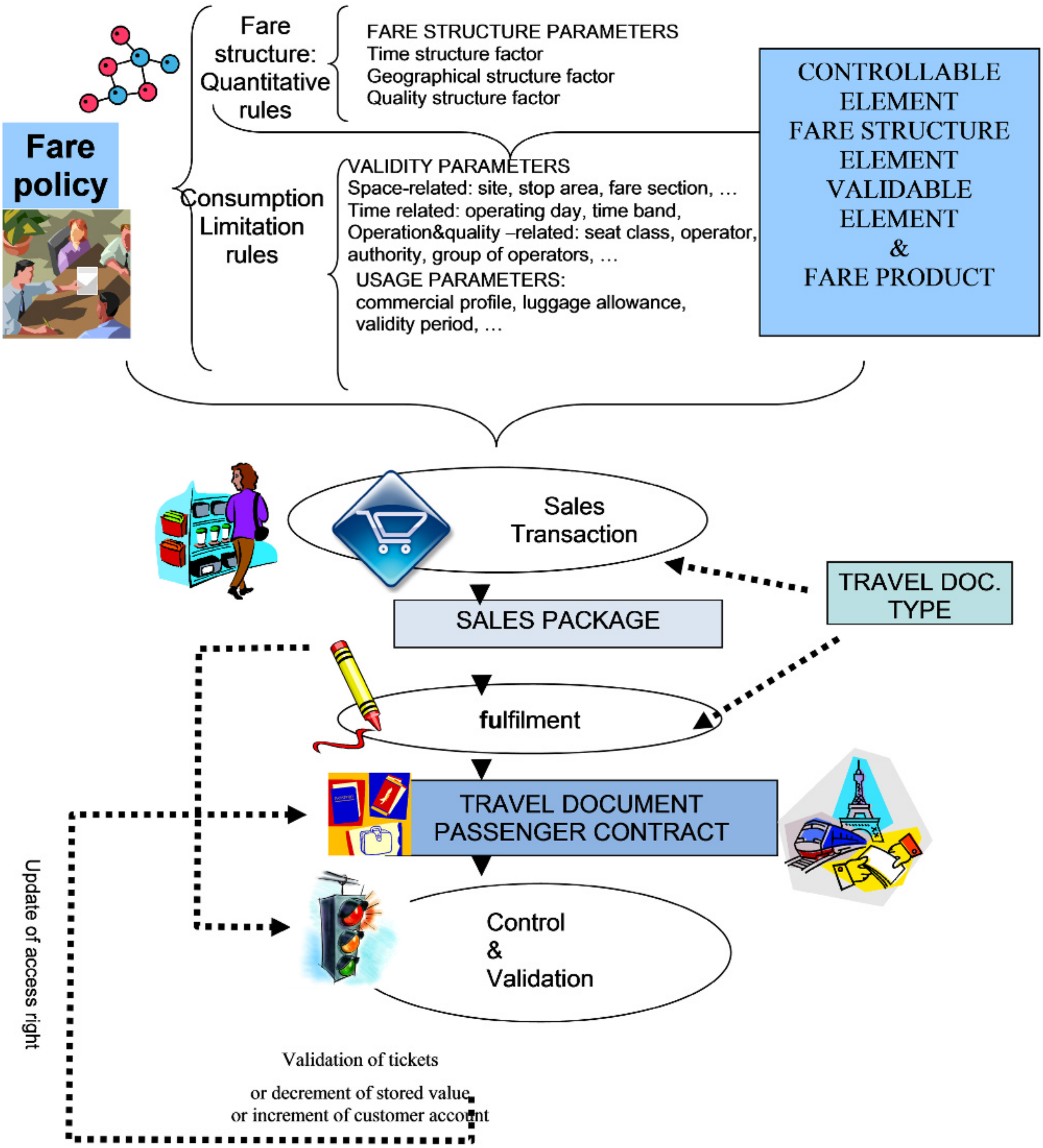


Figure I.1 — NeTEx Fare Overview

I.5 Approach

I.5.1 General

In practice, fares range from the extremely simple – say a simple flat fare for anyone for the whole network, to the excruciatingly complex; for example ones that depend on the route taken, time of travel, length of travel, the type and number of users, time of purchase, method of purchase, amount of other travel made in a given period, and payment method. NeTEx can describe even very com

plex fares, using a uniform set of elements applicable to any mode of transport.

The essence of the NeTEx approach is to break the description of fares down into a number of separate, reusable elements, which can be combined flexibly to create a huge range of different fares.

I.5.2 Fare structure elements

The FARE STRUCTURE describes the underlying basis for the fare, which might for example relate to zones visited, a route, a specific origin and destination, a period of time for which travel is made, a specific journey on a specific service (all defined in terms of elements defined in Part 1 and Part 2).

As a very simple example of using just one type of element to define a simple fare structure, the following figure shows one of the most common (and straightforward) structures – a simple table of point-to-point fares on a transport network with four stops.

Table I.1 — Example Triangular Fare Table with Absolute Prices

Outward (Absolute Fare Price)

Ask Av					
Bath Pl	£0,40				
Cam Sq	£0,50	£0,40			
Dee St	£0,75	£0,75	£0,50		
Ely Rd	£1,00	£1,00	£0,75	£0,40	
	Ask Av	**Bath Pl**	**Cam Sq**	**Dee St**	**Ely Rd**

Each cell can be represented in NeTEx as a DISTANCE MATRIX ELEMENT, which specifies travel between two stops (or two zones) – both stops (SCHEDULED STOP POINTs) and zones (TARIFF ZONE) are network definition elements specified in NeTEx Part 1. This set of elements gives a basis upon which to define products and to associate prices with the cells. In the figure, we show just one simple price – in practice even for a simple standard fare product there are likely to be different sets of prices for different classes of user (*adult, child, senior*, etc), and for single / return tickets. Additional conditions and prices might apply to products intended to encourage different times of travel (rush hour, off-peak), or for bulk products such as monthly passes and season tickets (see conditions and products below). All can still make use of the same DISTANCE MATRIX ELEMENTs.

Other types of FARE STRUCTURE ELEMENT allowed in NeTEx include those based on time intervals, (e.g. for day and week passes), zones; sequence of zones, etc; specific journey elements in prescribed sequence (e.g. parking use, followed by a train ride, then a metro ride); specific routings, etc. In reality, some very intricate 'edge cases' can be found, such the requirement to in a particular sequence of zones or not to get out at particular stops – NeTEx 's separation of concerns generally it possible to express such structure precisely and in a way that can be related to the subsequent control (i.e. of checking) of fares.

I.5.3 Access rights and Fare products

The FARE PRODUCTs that passengers can actually buy are then specified with reference the relevant fare structure elements (using VALIDABLE ELEMENTs) to scope the travel that may be made, further qualified with conditions restricting use, attached as VALIDITY PARAMETERs.

Products are thus defined as *combinations of rights to access the system* as characterized by the fare structure elements. In the following greatly simplified diagram (Figure I.3 — Usage Parameters), an ACCESS RIGHT ASSIGNMENT specifies access rights (i.e. which fare structure elements may be used, possibly with constraints on order, time, or occurrence of use) and other limitations on using the system (USAGE PARAMETERs, such as passenger types as described by a USER PROFILE, or) to apply to specified products.

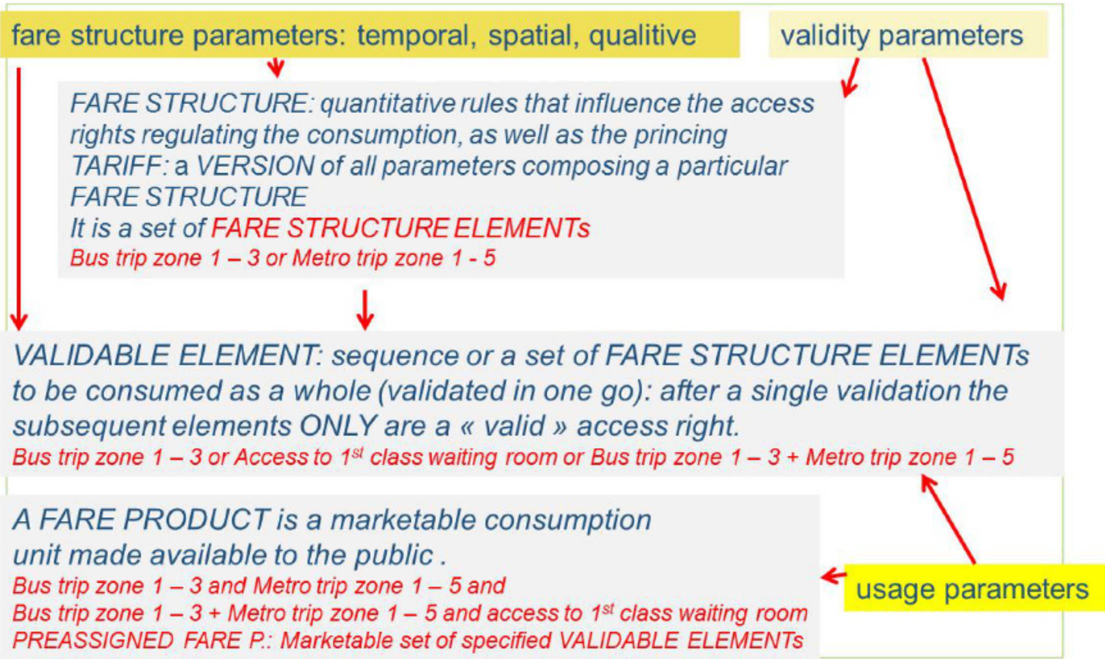


Figure I.2 — Access Rights overview

Access rights allow a very precise expression of conditions along with a high degree of reuse and are one of the key innovations of NeTEx's Fare model. Consumable elements for services other than transport may also be incorporated into composite products, such as rights to use a first class lounge or have a meal.

NeTEx distinguishes a FARE PRODUCT – an underlying product with general conditions of use, from a SALES PACKAGE, which will be a marketed product that applies particular specific sales conditions to a FARE PRODUCT. Thus for example a rail “NRT fare” (Non reservable fare) or a “IRT fare” (Reservation required fare) are two different types of FARE PRODUCTs, each with different commercial conditions. Single person and group tickets might then be marketed as separate SALES PACKAGEs of the respective products, the latter limited to a group of more than a specified number of users travelling together and with differing conditions of purchase. The choice of SALES PACKAGEs is to some extent arbitrary, that is to say, reflects the marketing strategy of a particular operator in a particular context rather than having a necessary logic – NeTEx's approach allows an operator to flexibly define products and packages that reflect their requirements.

I.5.4 Restrictions and conditions

NeTEx supports a large number of different usage parameters, derived from the study of actual fare conditions in a wide spectrum of real-world examples for different modes of travel, including rail. These describe limitations on the product, for example, those governing travel allowed such as USAGE VALIDITY PERIOD, MINIMUM STAY, ROUND TRIP, STEP LIMIT, etc; those stating the prerequisites; such as ENTITLEMENT REQUIRED; or commercial conditions, such as PURCHASE WINDOW, RESERVING, EXCHANGING, TRANSFERABLITY, etc, etc. Some parameters may have prices, discounts or fees associated with them.

Each of the usage parameters has a number of specific attributes describing the various possible properties of the condition. To illustrate this the following diagram shows an example details for just one subset of the USAGE parameters relating to travel restrictions.

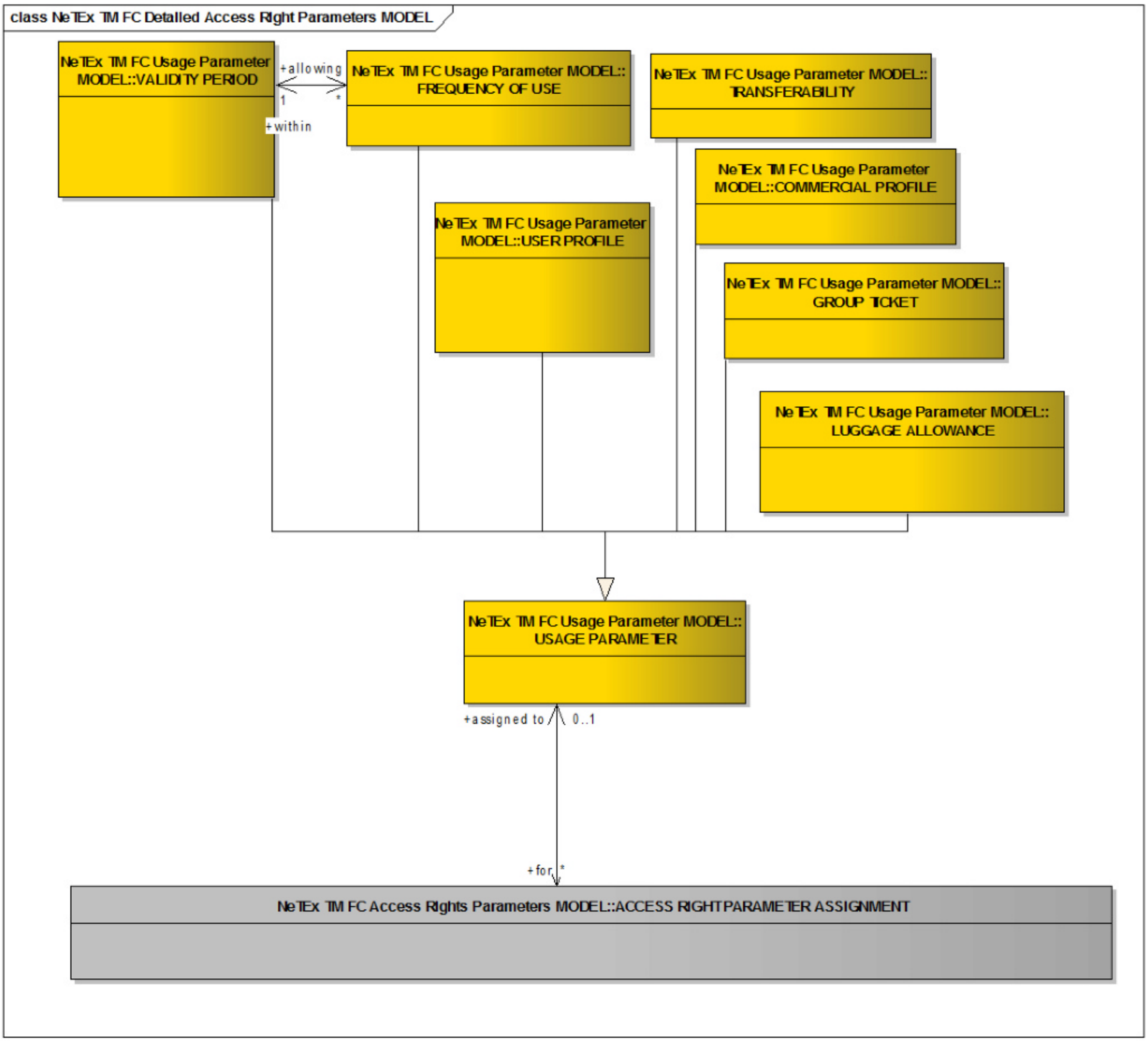


Figure I.3 — Usage Parameters

NeTEx supports a wide variety of **validity parameters** to specify the access rights to use the system, for example TRAIN NUMBER, LINE, FACILITY SET, CLASS OF USE, OPERATOR, etc. The following diagram summarizes these.

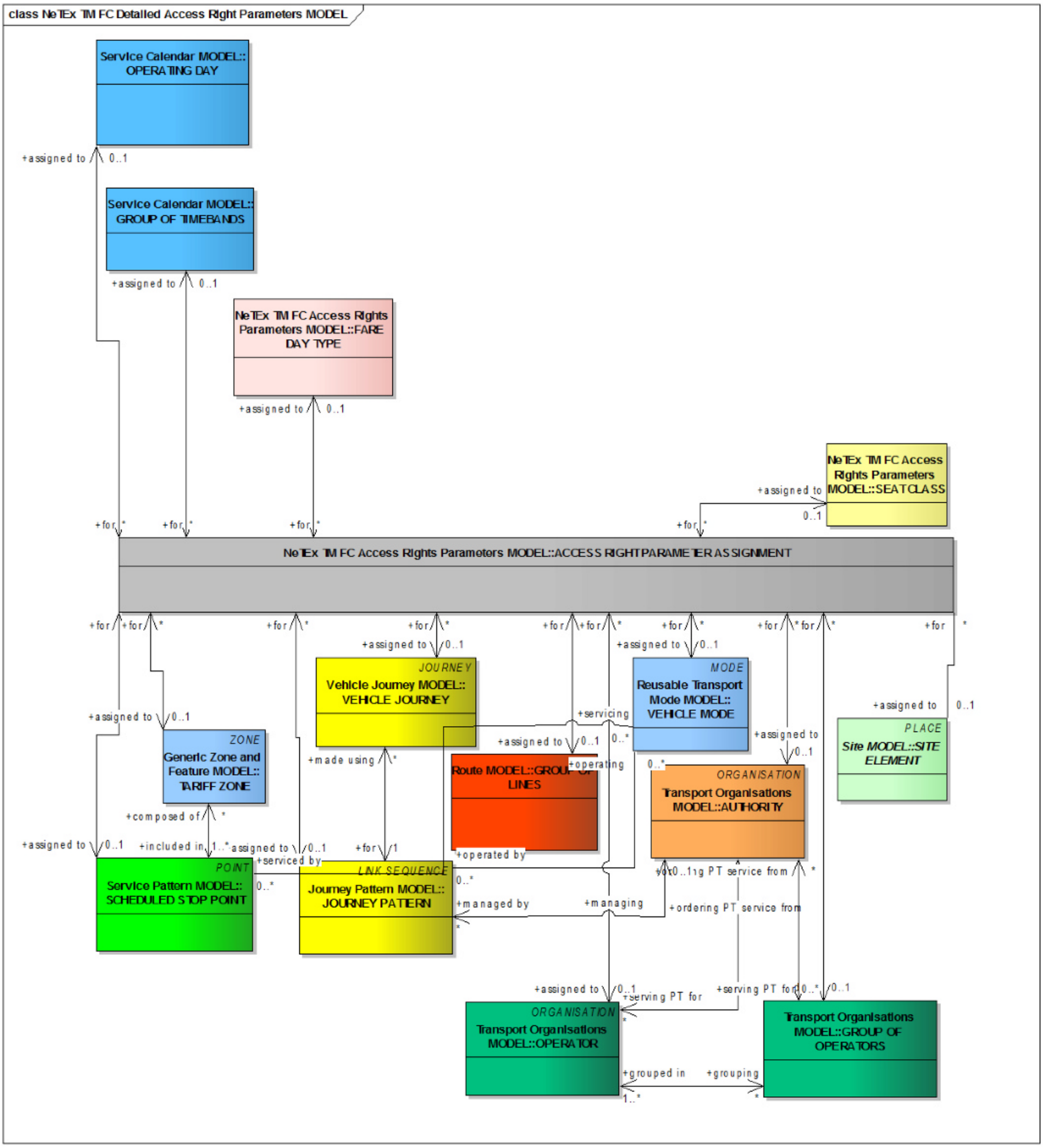


Figure I.4 — Validity Parameters

I.6 Selecting a Fare

I.6.1 General

A given PRODUCT or a SALES PACKAGE does not represent a single combination of elements (say an adult off peak fare between A and B), but rather comprises a whole set of allowed potential combinations that share the same fare structure, and might include many alternate fares such as concessionary fares, full fares and return fares. For example, a single product might be used for all the 10 possible point-to-point fares in the table shown earlier above, as well as for separate concessionary fares for adult, child and disabled USER PROFILEs. When someone selects a specific journey (for example, an adult off-peak fare between C and D). a TRAVEL SPECIFICATION is created, recording the actual choice or origin destination, user type etc, and a price is obtained. The specification can also be used in a SALES TRANSACTION to describe a a record of a payment.

I.6.2 Pricing a Fare

An important principle followed in NeTEx is to hold prices as separate entities from the elements being priced. This makes it possible have multiple prices, or to change the prices without modifying the fare structure.

depending on the application it may be appropriate to hold precomputed set of prices for every possible combination of fare elements and condition, or to compute prices dynamically using a set of base prices and pricing parameters (discount, rounding, etc). NeTEx supports either approach; where a price is derived from another the nature of the derivation can be shown.

NeTEx does not cover the actual computational rules for calculating a price, but can indicate the elements used to derive a given price from another price. It is also possible to indicate the pricing service to use to fetch a dynamically computed price, so that NeTEx may be used in conjunction with yield managed services.

I.6.3 Electronic Fare products and NeTEx

NeTEx supports a number of different types of fare product, allowing not just the description of traditional prepaid travel tickets, but also usage and discount rights (such as a rail discount card), units of value (such as coupon based products) and stored value and pay as you go products. These can also be distinguished by the CHARGING MOMENT, that is, is the product paid for before use, at the beginning of travel, or even after the journey? NeTEx also allows a CUSTOMER and SALES CONTRACT to be represented so that account based products can be described.

The value of this approach can be seen when considering the requirements of modern electronic payment systems. The following table, taken from *The next step in creating Electronic Ticketing Interoperability for Europe*, a Memorandum of understanding issued by ITSO, VDV KA, Calypso Networks, AFIMB and UITP in February 2012, also shows a categorization by charging moment for account based and anonymous card products

Table I.1 — Payment Methods

	Use case	Paper based	Card centric	Back office centric	Payment
		Payment Offline gates/validators and inspection	Payment Off line gates/validators and inspection	On line gates/validators and inspection	
1	**Pre-defined products** Tickets, Concession	Product on paper ticket	Product on media	ID on media. Product in back office.	Payment before usage.
2	**Pay as You Go with prepaid stored value**	N/A	Stored value on media	ID on media. Stored value in back office.	Add-value before usage.
3	**Pay as You Go with customer account giving permission to travel** Standard, Concessionary	N/A	N/A	ID on media. Account in back office Payment means ID in back-office.	Billing after usage according to accounting contract.
4	**Pay as You Go With payment registration at gate**			Bank ID on media. Billing in Back Office.	Payment when usage. Usage may be aggregated by short periods.

These products may be found packaged on Transport cards (Use cases 1, 2 and 3), Contactless bankcards (Use cases 3 and 4) or NFC-enabled Mobile Phone (all cases).

The NeTEx model can describe all the various types of product above since, although NeTEx is not itself concerned with the mechanics of packaging send selling products on media, it is nonetheless necessary to be able to describe the types of product available and their conditions of purchase and use in order to provide accurate fare information in journey planners and elsewhere. NeTEx can also describe where products may be purchased, methods of payment and collection.

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[N2] CEN/TS 16614-2:2014, *Public transport — Network and Timetable Exchange (NeTEx) — Part 2: Public Transport Scheduled Timetables exchange format*

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

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

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[IS3] ISO/IEC 19501-1:2002, *Unified Modelling Language (UML) — Part 1: Specification*

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[U1] UIC recommendations and leaflets

X1 XML. Extensible Mark-up Language (XML) 1.0 W3C Recommendation 04 February 2004, available at http://www.w3.org/TR/2004/REC-xml-20040204

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