



**PUBLIC TRANSPORT
NETWORK TIMETABLE EXCHANGE
(NeTEx)**

**REPRESENTING
PUBLIC
TRANSPORT
NETWORKS
IN NeTEx**

CEN TC278/WG3/SG9 NeTEx PT001

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OCTOBER 2015

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INTRODUCTION

The NeTEx (Network Timetable Exchange) is a CEN standard for exchanging public transport data. This white paper provides an overview of how a Public Transport Network is represented in NeTEx. By 'Network' we mean the stops, routes, lines etc that make up the PT transport system regardless of the timetabled journeys that run over them.

AUDIENCE

This paper is intended to convey a high level view sufficient for a technical manager to appreciate the capabilities of the CEN standard 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 Part1 [N1] and is mainly concerned with describing fixed Networks (stops, routes, lines etc). A separate white paper [W6] describes flexible networks. See further reading below for more information.

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]).

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 [W7]) and facilities (see [W8] 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-time measurement and display can all be described precisely, so that a common network representation can be used for 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 also [W6]).

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 Part1 [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 specialised 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 mode [T4].

- STOP PLACES, PARKING, PASSENGER NAVIGATION PATHS, ENTRANCES.
- POINTS OF INTEREST, PARKING PLACES.
- ACCESSIBILITY features (see [5]).

APPROACH

RECONCILING DIFFERENT VIEWS OF THE NETWORK

Public Transport network data may originate from many different departments or sub-systems of an organisation 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 in [W3]).

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.

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.

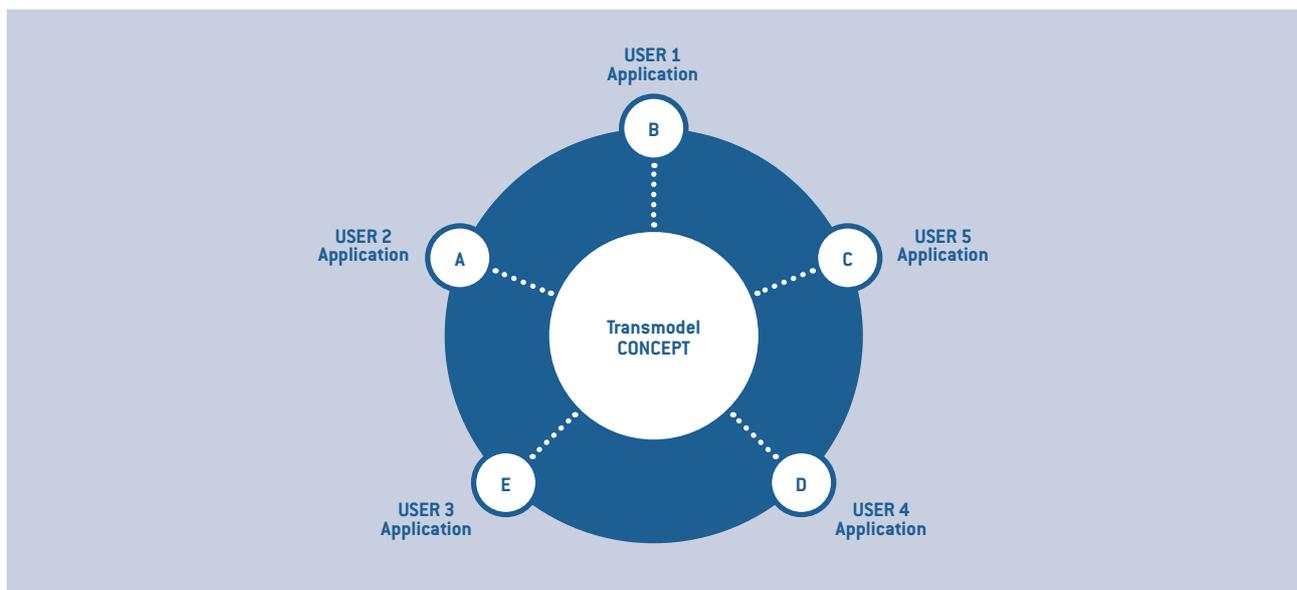


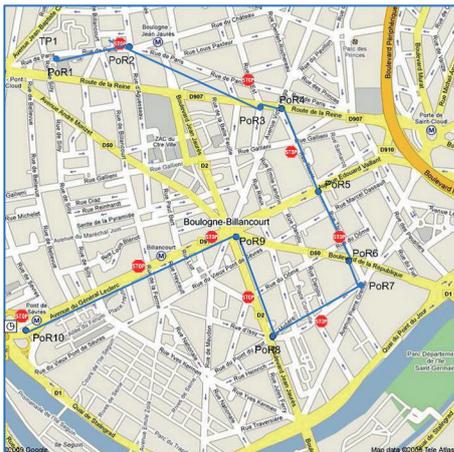
Figure 1 - Generic Concept Approach

BASIC SPATIAL NETWORK ASPECTS

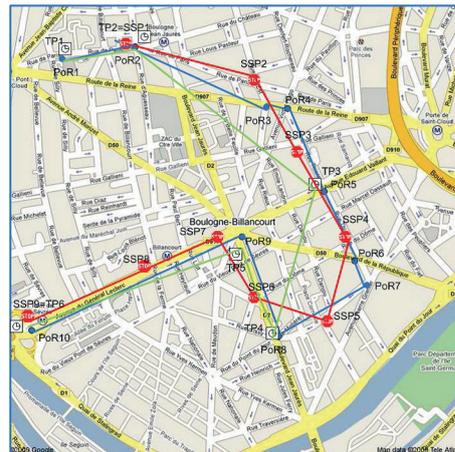
ROUTES AND WORK PATTERNS

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).



A ROUTE (in blue) determining a unique path of a vehicle



ROUTE (blue), TIMING PATTERN (green) and SERVICE PATTERN (red)

Figure 2 – Route, Timing and Service Patterns

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.

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 SYSTEM 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:

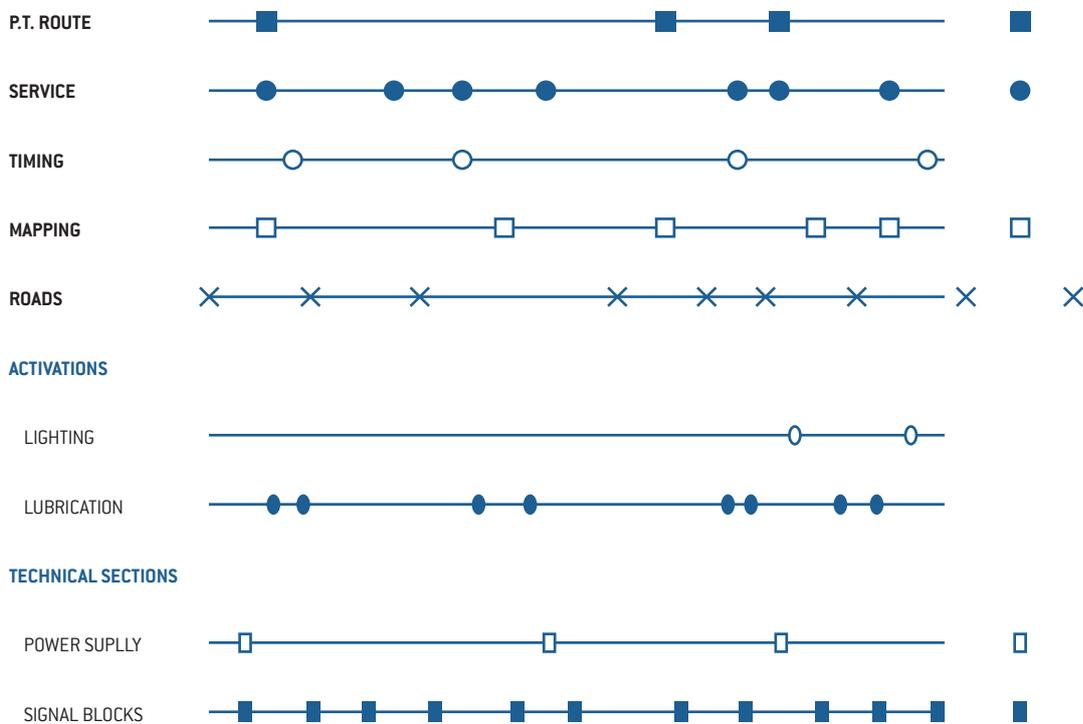


Figure 3 - Schematic view of possible LAYERS

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.

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:

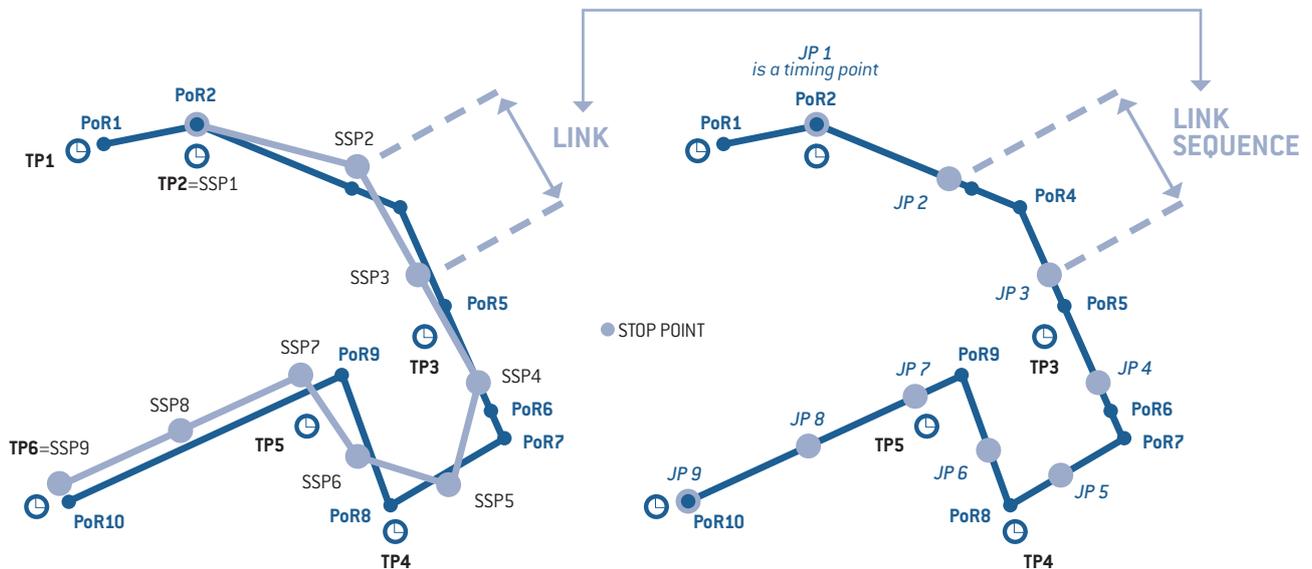


Figure 4 - Projection example of a link on a link sequence

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.

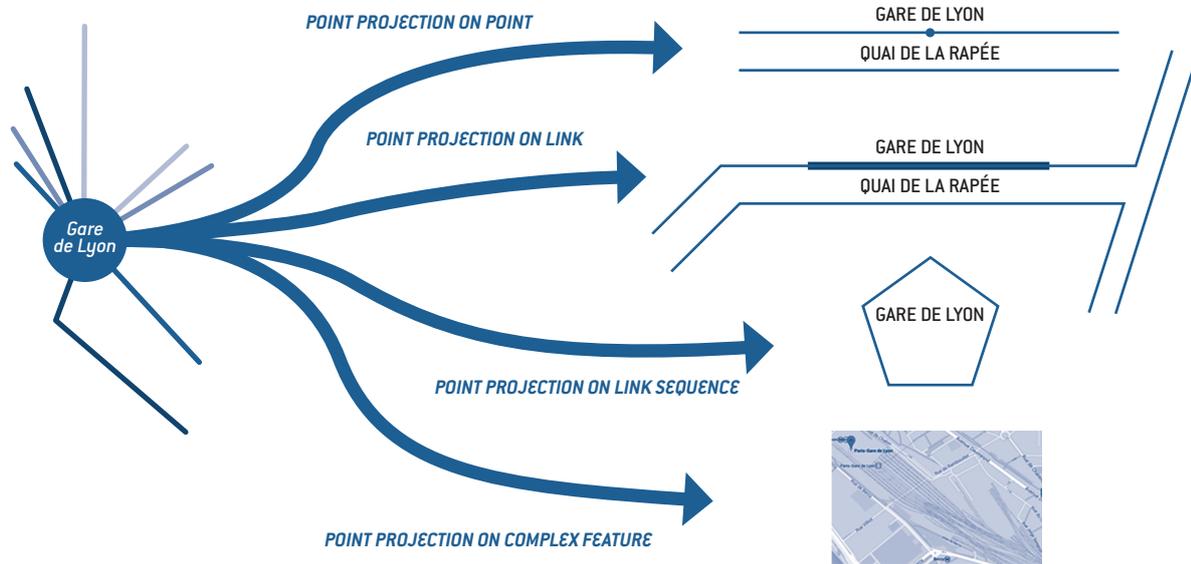


Figure 5 - Projections examples of a point

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

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.

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 visualisations 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.

ACKNOWLEDGEMENT

This White Paper has been produced thanks to the support of Fabrizio Arneodo (5T srl), Kasia Boureé (KBIC), Christophe Duquesne (Aurige), Nick Knowles (Steam Intellect), Andrej Tibaut (University of Maribor), Jan Tijmensen (InTraffic , Connekt).

FURTHER READING

THE NeTEx STANDARD

- [N1] NeTEx-Part 1: *Public Transport Network Topology exchange format, CEN/TS 16614-1:2014*
 - [N2] NeTEx-Part 2: *Public Transport Scheduled Timetables exchange format, CEN/TS 16614-2:2014*
 - [N3] NeTEx-Part 3: *Fare Information exchange format, CEN/TS 16614-3:2014*
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OTHER NeTEx WHITE PAPERS

- [W1] NeTEx *Introduction* - White Paper
 - [W2] NeTEx *Getting Started* - White Paper
 - [W3] NeTEx *Design Methodology* - White Paper
 - [W4] NeTEx *Framework* - White Paper
 - [W5] NeTEx *Reusable Components* - White Paper
 - [W6] NeTEx *Flexible Networks and Multimodality* - White Paper
 - [W7] NeTEx *Accessibility* - White Paper
 - [W8] NeTEx *Timetable* - White Paper
 - [W9] NeTEx *Fares* - White Paper
-

OTHER REFERENCES

- [T1] *Public Transport Reference Data Model – Part 1: Common Concepts (Transmodel)*, EN12896-1
 - [T2] *Public Transport Reference Data Model – Part 2: Public Transport Network (Transmodel)*, EN12896-2
 - [T3] *Public Transport Reference Data Model – Part 3: Timing Information and Vehicle Scheduling (Transmodel)*, EN12896-3
 - [T4] *Identification of Fixed Objects for Public Transport*, EN28701
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FURTHER INFORMATION

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