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**Straßentransport- und Verkehrstelematik –
Öffentlicher Verkehr –
Referenzdatenmodell;
Englische Fassung EN 12896:2006**

Road transport and traffic telematics –
Public transport –
Reference data model;
English version EN 12896:2006

Télématicque de la circulation et du transport routier –
Transports publics –
Modèle de données;
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Nationales Vorwort

Dieses Dokument (EN 12896:2006) wurde vom Technischen Komitee CEN/TC 278 „Straßenverkehrstelematik“, dessen Sekretariat vom NEN (Niederlande) gehalten wird, erarbeitet.

Für die deutsche Mitarbeit ist das Gemeinschaftskomitee GK 717 „Straßenverkehrstelematik“ im Normenausschuss Kraftfahrzeuge (FAKRA) zuständig.

Das Präsidium des DIN hat mit seinem Beschluss 1/2004 festgelegt, dass von dem in den Regeln der europäischen Normungsarbeit von CEN/CENELEC verankerten Grundsatz, wonach Europäische Normen in den drei offiziellen Sprachen Deutsch, Englisch und Französisch veröffentlicht werden, in begründeten Ausnahmefällen abgewichen und auf die deutsche Sprachfassung verzichtet werden kann.

English Version

Road transport and traffic telematics - Public transport - Reference data model

Télématique de la circulation et du transport routier -
Transports publics - Modèle de données

Straßentransport- und Verkehrstelematik - Öffentlicher
Transport - Datenreferenzmodell

This European Standard was approved by CEN on 3 February 2006.

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Contents

Page

Foreword.....	6
Use of the Transmodel standard.....	6
Transmodel origins.....	6
ENV 12896.....	6
Titan 7	
SITP and SITP2.....	7
CEN TC 278 WG 3 SG 4	7
Structure of this European Standard	7
Conformance	8
Future developments.....	9
Introduction	10
Rationale for the Transmodel standard.....	10
Use of the Transmodel standard.....	10
Applicability of the Transmodel standard	11
Introduction	11
Specification of information architecture.....	11
Specification of a database	11
Specification of an interface.....	12
Status of the Transmodel standard	12
1 Scope	13
1.1 General.....	13
1.2 Overview	13
1.3 Network description	14
1.4 Versions, validity and layers	14
1.5 Tactical planning: Vehicle-Driver Scheduling and Rostering	14
1.6 Personnel disposition	15
1.7 Operations monitoring and control	15
1.8 Passenger information.....	16
1.9 Fare collection.....	16
1.10 Management information	17
1.11 Multi-modal operation	17
1.12 Multiple operators' environment	18
2 Terms and definitions	18
3 Requirements	20
3.1 General.....	20
3.1.1 Introduction	20
3.1.2 Modelling Style.....	21
3.1.3 Generic Approach and Abstract Views	21
3.1.4 Structures	22
3.2 Description of the Network	26
3.2.1 Elements of topology	26
3.2.2 Infrastructure Description.....	32
3.2.3 Restrictions	35
3.2.4 Combined Diagram on Topology	37
3.2.5 Additional Aspects to Point.....	39
3.2.6 Generic Network Concepts.....	43
3.2.7 Combined Diagram on Generic Network Concepts	49
3.2.8 Network Linear Features	50
3.2.9 Combined Diagram on Network Linear Features	60
3.2.10 Projection	61

3.2.11	Interface to the GDF Data Model.....	66
3.3	Versions, Validity and Layers	67
3.3.1	Introduction.....	67
3.3.2	General Principles	67
3.3.3	Main Concepts	68
3.3.4	Version Frames.....	69
3.3.5	Versions.....	70
3.3.6	Other Aspects	73
3.3.7	Combined Diagram on Versions.....	74
3.3.8	Explicit Versions.....	74
3.4	Tactical Planning Components.....	76
3.4.1	Days	76
3.4.2	Journeys.....	79
3.4.3	Standard Times.....	84
3.4.4	Journey Times	88
3.4.5	Driver Trips	90
3.4.6	Interchanges	90
3.4.7	Timing Computation of a Journey	93
3.5	Vehicle Scheduling.....	94
3.5.1	Tactical Resource Planning	94
3.5.2	Resources for Tactical Planning.....	94
3.5.3	Vehicle Planning.....	95
3.5.4	Vehicle Requirements	97
3.6	Driver Scheduling.....	99
3.6.1	General Remarks	99
3.6.2	Duties.....	100
3.6.3	Other Aspects of Duties.....	105
3.7	Schedules and Versions	107
3.7.1	Introduction.....	107
3.7.2	Main Types of Schedules and Versions	109
3.7.3	Combined Schedules and Versions	111
3.8	Rostering.....	112
3.8.1	General Remarks	112
3.8.2	Roster Matrices.....	113
3.8.3	Roster Cycles.....	115
3.8.4	Roster Designs	115
3.8.5	Roster Assignments.....	116
3.9	Personnel Disposition.....	117
3.9.1	Introduction.....	117
3.9.2	Driver Assignments.....	118
3.9.3	Driver Accounting	121
3.10	Operations monitoring and control	125
3.10.1	Introduction.....	125
3.10.2	Dated Operational Plans	126
3.10.3	Resource Detection and Monitoring.....	130
3.10.4	Vehicle Assignments	134
3.10.5	Monitored Operations	135
3.10.6	Control Actions.....	138
3.10.7	Events.....	143
3.10.8	Messages.....	144
3.11	Passenger Information.....	145
3.11.1	Introduction.....	145
3.11.2	Provision of Information	145
3.11.3	Spatial Information	148
3.11.4	Timetable Information	151
3.11.5	Passenger Trip Planning	156
3.11.6	Estimation of Trip Duration	160
3.11.7	Other Information	163
3.12	Fare Collection.....	164

3.12.1	Introduction	164
3.12.2	Access Rights Specification.....	166
3.12.3	Fare Structure	171
3.12.4	Fare Products.....	174
3.12.5	Limiting Fare Parameters.....	175
3.12.6	Travel Documents.....	179
3.12.7	Sales.....	181
3.12.8	Customers	183
3.12.9	Prices	184
3.12.10	Pre-consumption Specification.....	186
3.12.11	Controls and Validation	188
3.12.12	Fare Version	191
3.12.13	Information on Fares	191
3.13	Management Information	191
3.13.1	Introduction	191
3.13.2	Service Journey Performance	193
3.13.3	Recorded Use of Services	196
3.14	Multi-modal Operation in Public Transport.....	198
3.14.1	Domain Definition and Limits	198
3.14.2	Network Description	199
3.14.3	Resource Management	202
3.14.4	Vehicle Coupling.....	204
3.14.5	Operations	206
3.14.6	Other Aspects	207
3.15	Multiple Operators' Environment.....	207
3.15.1	Introduction	207
3.15.2	Owners and Users of Resources and Network.....	208
3.15.3	Information from Different Sources	212
3.15.4	Interchanges.....	214
3.15.5	Fare Collection Functions.....	214
Annex A	(normative) Data Definitions and Main Properties	215
A.1	This Annex.....	215
Annex B	(informative) Additional features of the model	269
B.1	Consistency and Integrity Conditions	269
B.1.1	Introduction	269
B.1.2	Logical Constraints	271
B.1.3	Semantic Constraints	276
B.1.4	Optional Constraints	277
B.2	Introduction to Data Modelling and the Methodology Used	278
B.2.1	Introduction	278
B.2.2	Levels of model.....	278
B.2.3	Examples of Different Relationships	280
B.2.4	The Reason for Data Modelling	288
B.2.5	Optimisation and the Optimised Logical Model	295
B.2.6	Subtypes	295
B.2.7	Further Notation.....	297
B.3	Functional Model	298
B.3.1	Introduction	298
B.3.2	Functional Model	302
B.3.3	Definition of Functional Areas.....	309
Annex C	(informative) Changes in this version of Transmodel.....	316
C.1	Changes between ENV 12896 (Transmodel 4.1) and Transmodel 5.0.....	316
C.1.1	Introduction	316
C.1.2	Impact of the changes on the entities	317
C.1.3	Impact of the changes on the diagram.....	332
C.2	Modifications to V5.0 leading to V5.1	334
C.2.1	Introduction	334
C.2.2	How to read this Annex.....	334

C.2.3	Requests and proposed modifications	335
Annex D	(informative) Transmodel in UML.....	365
D.1	Introduction.....	365
D.1.1	General	365
D.1.2	Differences between the two representations.....	365
D.1.3	Structure of this Annex.....	365
D.2	Class diagrams	367
D.2.1	Network description	367
D.2.2	Versions, validity and layers	385
D.2.3	Tactical planning components.....	390
D.2.4	Vehicle scheduling	395
D.2.5	Driver scheduling	397
D.2.6	Schedules and versions	399
D.2.7	Rostering	400
D.2.8	Personnel disposition.....	402
D.2.9	Operations monitoring and control	403
D.2.10	Passenger information.....	410
D.2.11	Fare collection	415
D.2.12	Management information.....	420
D.2.13	Multi-modal operation in public transport	422
D.2.14	Multiple operators' environment.....	425
D.3	Class dictionary	427
D.4	Generalisations and specialisations	638
D.4.1	Specialisations descent.....	638
D.4.2	Generalisations climb up.....	642
D.5	Comparison of notations	650
D.5.1	Relationships/Associations.....	651
Bibliography		655

Foreword

This European Standard (EN 12896:2006) has been prepared by Technical Committee CEN/TC 278 "Road transport and traffic telematics", the secretariat of which is held by NEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2006, and conflicting national standards shall be withdrawn at the latest by September 2006.

This European Standard supersedes ENV 12896:1997.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Use of the Transmodel standard

This European Standard presents version 5.1 of the European Standard EN 12886, known as "Transmodel". Transmodel 5.1 is a reference standard which provides a conceptual data model for use by organisations with an interest in information systems for the public transport industry.

As a reference standard, it is not necessary for individual systems or specifications to implement Transmodel. However, it needs to be possible to describe (for those elements of systems, interfaces and specifications which fall within the scope of Transmodel):

- the aspects of Transmodel that they have adopted;
- the aspects of Transmodel that they have chosen not to adopt.

For an organisation wishing to specify, acquire and operate information systems, Transmodel may be distilled, refined, or adapted to form a comprehensive data model for the organisation, or specific data models for database design or interface specification.

For an organisation wishing to design, develop and supply information systems, Transmodel may be distilled, refined, or adapted to form a comprehensive data model for the product suite.

Transmodel origins

ENV 12896

The prestandard ENV 12896 was prepared by the work area Transmodel of the EuroBus project (1992-1994) and by the DRIVE II task force Harpist (1995). The EuroBus/Transmodel and Harpist kernel team was established as a subgroup of CEN TC278 Working Group 3. The results of these projects were based upon earlier results reached within the Drive I Cassiope project and the ÖPNV data model for public transport, a German national standard. The prestandard reflected the contents of deliverable C1 of the Harpist task force, published in May 1995, with modifications resulting from the discussion process in CEN TC278/WG3 between May and October 1995.

The different organisations that have technically contributed to the preparation of the prestandard ENV 12896 were the partners of EuroBus/Transmodel and the Harpist task force: Beachcroft Systems (UK), CETE-méditerranée (F), CTA Systems (NL), Ingénieur Conseil Bruno Bert (F), Koninkrijk Nederlands Vervoer (NL),

Leeds University (UK), Régie des Transports de Marseille (F), SNV Studiengesellschaft Verkehr (D), Stuttgarter Straßenbahnen AG (D), TransExpert (F), TransTeC (D) and VSN Groep (NL).

The sponsors of the project were the European Communities (EC, DG XIII, F/5, Drive Programme, 1992-94), the French Ministry of Transportation, the Dutch Ministry of Transportation and the German Federal Ministry of Research and Technology.

Titan

The EC project Titan concerned validation and further development of ENV 12896. The different organisations that have technically contributed to the Titan project were: CETE-Méditerranée (F), Üstra (D), OASA (GR), RATP (F), SLTC (F), Salzburger Stadtwerke AG (A), TransExpert (F), TransTeC (D), Synergy (GR), TRUST EEIG (D).

The sponsoring partner was the French Ministry of Transport (DTT/SAE). The project was co-funded by the European Communities and some of the partners, in particular the pilot sites – Lyon (F), Hanover (D) and Salzburg (A).

SITP and SITP2

The French-led project SITP (Système d'Information Transport Public) was sponsored by the French Ministry of Transport (Direction des Transports Terrestres – DTT), the companies Gemplus (F) and Setec ITS (F), and the Transmodel Users' Support Team EEIG (F and D).

SITP built on the prestandard ENV 12896 (issued May 1997) and the results of the EC project Titan (1996-1998). SITP produced the extensions requested of ENV12896; these were validated during 1999-2000. A successor project, SITP2, developed the standard further during 2001-2002.

CEN TC 278 WG 3 SG 4

During 2002-2003, CEN convened a new subgroup of TC 278 WG3 to consider how Transmodel should be taken forward. It considered responses to previous drafts of Transmodel as well as the work of SITP/SITP2, the German VDV specifications, and a range of UK projects.

SG4 was led by the UK Department for Transport, with participants from VDV (D), RATP (F), HÜR (DK), Setec (F), TRUST E.E.I.G. (Transmodel Users' Support Team) (F and D) and Centaur Consulting (UK).

This document, and additional guidance documents (originally produced under SITP) for how it can be used, may be found at www.transmodel.org. Other sites which make this available include www.sitp.its.setec.fr.

Structure of this European Standard

The present European Standard is composed of two parts:

- the normative part (main document and Annex A);
- the informative part (Annexes B, C and D).

The main document presents:

- the history (Foreword) and the rationale (Introduction) of the proposed standard;
- the executive summary of the reference data model (1. Scope);
- the definitions of the terms as they are used in this document (2. Terms and definitions);

- the technical requirements in form of detailed textual descriptions and diagrams (Clause 3. Requirements).

A series of Annexes provides:

- the definitions of the concepts (entity definitions), together with the main properties of the concepts (main attributes, identifiers, super-types) (Annex A, normative);
- modelling convention: consistency and integrity conditions, introduction to data modelling and the methodology used, and a functional model (Annex B, informative);
- modifications to ENV 12896 (Annex C, informative);
- UML presentation of the reference data model (Annex D, informative).

Conformance

A specification which cites Transmodel needs to include comparisons of the specification against the Transmodel reference data model in at least two conformance levels:

- level 1 (the global level) identifies which data domains within the specification are drawn from the Transmodel data domains, and which are not;
- level 2 (the detailed level) compares the data model within the specification against the Transmodel entities.

The level 1 conformance statement shall be presented as a table based on one of the following:

- the Transmodel data domains as described in the normative part of the document: description of the network, versions/validity/layers, tactical planning components, vehicle scheduling, driver scheduling, schedules and versions, rostering, personnel disposition, operations monitoring and control, passenger information, fare collection, management information, multi-modal operation, multiple operators' environment;
- alternatively, the corresponding diagrams as presented in this document, either in the forms in the main text or in the equivalent UML forms in the informative Annex (Annex D).

The level 2 conformance statement shall be presented as a table in which the data concepts used in the specification are described as:

- "Unmodified": concepts in the specification which have the same definition, properties and relationships as in the corresponding Transmodel domain;
- "Modified": concepts in the specification which are similar to a Transmodel concept but which differ in the details of certain attributes and/or relationships (e.g. attributes added);
- "Alternative": concepts or groups of concepts in the specification which model the same concepts as Transmodel but in a significantly different way;
- "Additional": concepts in the specification which are not drawn from Transmodel;
- "Omitted": concepts in Transmodel which are not used in the specification.

Future developments

The developers of this standard recognise that there is continual development in the business practice of the public transport industry, and that Transmodel needs to continue to evolve to fulfil its needs. In version 5.1, the particular weaknesses that have been identified during consultation are the following:

- **Metadata.** Transmodel at present does not provide adequate support for data management and data protection. Future versions will aim to identify metadata such as currency, accuracy, ownership and permissions.
- **Long distance and multimodal journeys.** Transmodel focuses on city-based travel. For longer journeys, aspects such as check-in time or seat reservation will need to be covered, including travel preferences such as aisle/window seat, smoking/non-smoking, dietary needs etc.
- **Fares and tickets.** Transmodel splits passenger information and fare collection into separate areas and therefore does not deal with the issue of ticketing as a whole. This should be reviewed against the provisions of other emerging standards, including as the CEN work in EN 1545 and on IOPTA Data Structures. Further loyalty schemes are not addressed, ie the accumulation of transferable and redeemable 'points'.
- **Journey add-ons.** Transmodel does allow user-definable components to be added to sales products. However it does not make provision for specific common add-ons to journeys, such as inclusive meals or newspapers.

These areas form the basis of work items to extend and refine the standard in the next phase of Transmodel development. Additionally, CEN welcomes input from users of this standard as to where Transmodel needs extension or refinement.

The presentation of this European Standard has also been reviewed. A UML version has been included in this version as an informative Annex (Annex D). It is expected that future versions of this standard may be developed and presented using UML normatively.

Introduction

Rationale for the Transmodel standard

Public transport services rely increasingly on information systems to ensure reliable, efficient operation and widely accessible, accurate passenger information. These systems are used for a range of specific purposes: setting schedules and timetables, managing vehicle fleets, issuing tickets and receipts, providing real time information on service running, and so on.

To operate most effectively, such systems increasingly need to exchange information with each other. This integration can be difficult when systems are provided by different suppliers. This difficulty is usually not for technical reasons, since the widespread usage of technologies such as the Internet Protocol Suite and Relational Database Management Systems have allowed data exchanges to be configured fairly simply. Rather, it is because one system will often not understand the meaning of the data that is used by another.

Thus, it will be much easier to achieve the goal of interoperating systems, if all the systems in question are using similar definitions, structures and meanings for their data. This applies both to connecting different applications within an organisation, and also to connecting applications between interworking organisations (for instance, a public authority and a transport operator).

The Transmodel standard presented in this European Standard provides a framework for defining and agreeing data models, and covers the whole area of public transport operations. By making use of this European Standard, and of data models derived from it, it will be possible for operators, authorities and software suppliers to work together much more easily towards integrated systems. Moreover, the breadth of the standard will help to ensure that future systems developments can be accommodated with the minimum of difficulty.

Use of the Transmodel standard

Transmodel may prove of value to:

- organisations within the public transport industry that specify, acquire and operate information systems;
- organisations that design, develop and supply information systems for the public transport industry.

For an organisation within the public transport industry wishing to specify, acquire and operate information systems, Transmodel may be distilled, refined, or adapted to form a comprehensive data model for the organisation. This will enable the organisation to specify its database structures and/or its system interfaces, in such a way that separate modules can be openly tendered but will still integrate easily. The organisation also has a greater likelihood that information exchange interfaces with external organisations will be easily achieved.

For an organisation wishing to design, develop and supply information systems for the public transport industry, Transmodel may be distilled, refined, or adapted to form a comprehensive data model for the product suite. This will enable the organisation to develop its products in such a way that separate modules will integrate easily, but also so that they may be sold separately to clients seeking Transmodel-compliant systems.

Transmodel is a large and complex model, and allows for great flexibility. Consequentially it takes some skill and resource to apply it effectively. For this reason it is expected that, in many circumstances, many organisations will cooperate to develop a data model or specification for a particular aspect of information systems – perhaps for a particular interface, as between a ticket machine and a management system, or a particular organisational boundary, as between two connecting transport operators.

For such a body, Transmodel provides a wider setting and a starting point. The body can refine specific elements of Transmodel, or develop a specific subset or 'profile' of the Transmodel data model. The resulting specification will then be easier for user organisations to build into a coherent overall systems framework, since it will coexist more readily with other Transmodel-based specifications.

For all of these potential users, the adoption of Transmodel as a basis for development means a common language is being used. Thus, users will understand and assess the claims of suppliers better, and specification developers will be more likely to be working in alignment with each other.

Applicability of the Transmodel standard

Introduction

Transmodel may be applied to any framework for information systems within the public transport industry, but there are three circumstances to which it is particularly suited:

- specification of an organisation's 'information architecture';
- specification of a database;
- specification of a data exchange interface.

Specification of information architecture

An 'information architecture' refers to the overall structure of information used by an information system, which is used to determine:

- the structure of data held in system databases;
- the structure of data exchanged across interfaces between systems.

It may be used as a strategic guide to system planning and evolution, and as the basis for the specification and acquisition of individual systems.

An information architecture made up of independent modules with well defined interfaces is easier to maintain. A malfunctioning module can be taken out of service or completely replaced without disrupting the rest of the system. This is particularly beneficial for on-line or safety critical systems. The modules can also be more easily reconfigured on to hardware located elsewhere on the network to fit in with changes in organisational arrangements for managing the business and data administration processes.

The information architecture itself should be evaluated from time to time to make sure that it is still meeting the needs of the organisation. Technological changes in communications and computing are continuously bringing forward new opportunities for evolving the systems supporting the business.

Specification of a database

At a more technical level, an organisation's systems will have a collection of data in one or more databases, which may be associated with individual applications or may be common to many applications.

In either case, Transmodel can serve as a starting point for the definition of a database schema, which will be used for the physical implementation of databases. Whether applications access a common database built to this schema, or have their own databases and exchange data built to consistent schemas, the use of an overall reference data model assists integration.

Technical constraints (such as memory capacity restrictions of smart cards) may affect the detail and complexity of the data models that can be used in particular data storage devices. Transmodel does not itself specify a level of detail to adopt.

Specification of an interface

Public transport organisations may require different applications to exchange data with each other. Also, public transport organisations may exchange data with other organisations. In either case, the reference data model can be used to help design the interfaces.

Again, technical constraints (such as bandwidth limitations of radio communications links) may affect the detail and complexity of the data models that can be used for particular interfaces. Transmodel does not itself specify a level of detail to adopt.

Status of the Transmodel standard

Transmodel 5.1 is a reference standard which provides a conceptual data model for use by organisations with an interest in public transport information systems. As such, it is a full standard.

The status of Transmodel as a reference standard means that it is not necessary for individual systems or specifications to implement Transmodel. However, it needs to be possible to describe (for those elements of systems, interfaces and specifications which fall within the scope of Transmodel):

- the aspects of Transmodel that they have adopted;
- the aspects of Transmodel that they have chosen not to adopt.

Thus, the status of Transmodel as a ratified standard is not a constraint on those developing, acquiring or operating systems. They are free to use Transmodel to the extent appropriate to their particular circumstance.

It is expected that many developers and users will choose to use specific Transmodel-based specifications, rather than refer directly to Transmodel. To facilitate this, those bodies developing specific standards and specifications based on Transmodel should document particularly carefully how their output uses (and differs from) Transmodel.

1 Scope

1.1 General

The European reference data model for public transport is an offer to public transport companies and other providers of services related to the process of passenger transportation and information, to suppliers of software products supporting these processes, and to consultants and other experts acting in the field of public transport in the widest sense.

The reference data model can support the development of software applications, their interaction or combination in an integrated information system, and the system's organisation and information management which rules the utilisation of the existing telematics environment in a company (or group of companies) running computer applications supporting the different functional areas of public transport.

Although primarily designed to document the information needs of a public transport company in a well defined and structured way, the reference data model can also serve as a starting point and reference for the definition of a database schema. A database schema is needed for the physical implementation of data storage systems to be used by applications directly, or for exchange of data between applications via interfaces. Apart from that, such a database will often additionally be used as a source of information for the company management and/or as an information pool for all employees who may need access to the information basis of the company.

1.2 Overview

The data model describes elementary data needed for

- network description; and
- versions management.

that are used in several functional domains as basic concepts.

The data model describes the information needs related to the following functional domains:

- tactical planning (vehicle scheduling, driver scheduling, rostering);
- personnel (driver) disposition;
- operations monitoring and control;
- passenger information;
- fare collection;
- management information and statistics.

The standard takes into account the:

- multi-modal public transport operation;
- multiple operators environment.

1.3 Network description

The reference data model includes entity definitions for different types of **points** and **links** as the building elements of the topological network. Stop points, timing points and route points, for instance, reflect the different roles one point may have in the network definition: whether it is used for the definition of (topological or geographical) routes, as a point served by vehicles when operating on a line, or as a location against which timing information like departure, passing, or wait times are stored in order to construct the timetables.

The **line network** is the fundamental infrastructure for the service offer, to be provided in form of vehicle journeys which passengers may use for their trips. The main entities describing the line network in the reference data model are the line, the route and the journey pattern, which refer to the concepts of an identified service offer to the public, the possible variants of itineraries vehicles would follow when serving the line, and the (possibly different) successions of stop points served by the vehicles when operating on the route.

The functional views of the network are described as **layers**. A **projection** is a mechanism enabling the description of the correspondence between the different layers. This mapping between the layers is particularly useful when spatial data from different environments (sources, functional domains) have to be combined. An example of such a situation is the mapping of the public transport network on the road network.

The Geographical Data Files (GDF) standard includes a data model for the geographical description of road networks. It provides a basic network description upon which various layers describing specific aspects of the use of the infrastructure network may be placed. Public transport companies or providers of other associated services may want to couple their applications and information basis to geographical information. In this case, the exchange of data between a Geographical Information System and the public transport applications concerned will become necessary. For this purpose, an interface between the GDF data model and the relevant part of the topological network representation in the reference data model for public transport has been defined.

1.4 Versions, validity and layers

This part of the standard describes a way to handle data **versions**, i.e. data **modifications**, such as modifications of the planned service.

A mechanism to handle parallel hierarchies of elementary data groups (e.g. schedules) and the way to represent relationships between the different hierarchy levels is described, using the concept of **validity conditions**.

This part of the model shall be considered as a user guide for system design.

1.5 Tactical planning: Vehicle-Driver Scheduling and Rostering

The tactical planning (or scheduling) domain of the reference data model describes all the information that is necessary to define the vehicle journeys to be provided as a part of the public transport service, and to schedule (logical) vehicles and drivers to work the blocks and duties necessary to provide the defined service offer to the passengers.

The work of the vehicles necessary to provide the service offer advertised to the public consists of service journeys and dead runs (unproductive journeys necessary to transfer vehicles where they are needed, mainly from the depot into service and vice versa). Vehicle journeys are defined for day types rather than individual operating days. A day type is a classification of all operating days for which the same service offer has been planned. The whole tactical planning process is seen on the level of day types in the reference data model, with all entities necessary to develop schedules. These include a series of entities describing different types of run times and wait times, scheduled interchanges, turnaround times etc.

Chaining vehicle journeys into blocks of vehicle operations, and cutting driver duties from the vehicle blocks, are parts of the main functions of vehicle scheduling and driver scheduling, respectively. The corresponding entities and relationships included in the reference data model allow a comprehensive description of the data needs associated with this functionality, independently of the particular methods and algorithms applied by the different software systems.

The process of ordering driver duties into sequences in order to obtain a balanced work share among the driving personnel over the planning period, and to keep the resulting work time in harmonisation with legal regulations and internal agreements between drivers and the company management, is known as rostering. The reference data model offers a model part covering the information needs associated with some classical rostering methods, widely used in European countries. There may, however, be other (particularly more advanced, dynamic) methods applied in some cases, which would probably need additional, or other entities than described in the rostering part of the reference data model. This part of the model is therefore informative.

1.6 Personnel disposition

The **personnel disposition** domain of the reference data model covers the data needs of the relevant driver management functions with respect to the two major tasks of

- assigning *physical* drivers to the *logical* drivers identified in the scheduled duty plan;
- recording the performance of drivers on the actual day of operation.

The assignment of drivers for the actual operating day to the duty plan set up for the whole planning period is usually done in a staged procedure. The assignment will mostly start from default assignments for the whole period in question, which can be continuously overridden by changes and adjustments due to regular absences of drivers from work, changes initiated by drivers according to their preferences or by the control staff according to operational needs. Short-term adjustments may become necessary to balance unplanned absences and other circumstances principally not known in advance.

Records to document the actual driver activities are usually taken to control the driver performance and compare it with the original plan, and to prepare these data in a suitable way for wage accounting. This mainly refers to the specification of the time worked by each driver on the individual day for each type of activity, and some additional classifications which may result in appropriate modifications of the amount to be paid for the recorded activity in question.

This part of the model is informative.

1.7 Operations monitoring and control

The domain of operations monitoring and control concerns all activities related to the actual transportation process. It is also known as real-time control, or operations management.

The supply basis for each operating day is known as a production plan, composed of the planned work of each available resource (e.g. vehicles and drivers). It includes for instance all dated journeys planned on the considered day, including occasional services.

The transportation control process supposes a frequent detection of the operating resources (in particular vehicle identification and location tracking). Such collected information is compared to the planned data (e.g. work plan for a vehicle or a driver), thus providing a monitoring of these resources.

The monitored data is used for:

- controlling the various resource assignments (e.g. vehicle assignment to a dated block);
- assisting drivers and controllers to respect the plan (e.g. schedule adherence, interchange control);
- alerting on possible disturbances (e.g. delay thresholds, incidents);

- helping the design of corrective *control actions* according to the service objectives and overall control strategy; the model describes a range of such control actions (e.g. departure lag);
- activation of various associated processes (e.g. traffic light priority, track switching);
- passenger information on the actual service (e.g. automatic display of the expected waiting time at stop points); and
- follow-up and quality statistics.

Other aspects, such as communication between actors, are taken into account.

1.8 Passenger information

In its passenger information model part, the reference data model does not only describe the data which are needed for applications providing passengers with the relevant information on the planned as well as on the actual service, but also the data resulting from the planning and control processes which may result in service modifications possibly to be made known to the public. Consequently, the passenger information data model includes data descriptions which go far beyond the planned timetable, which is the main source for the classical timetable information, but does not take into account any dynamic issues.

These additional concepts refer to

- passenger information facilities and their utilisation for passenger queries;
- detailed description of all conceptual components of a passenger *trip*, as possibly needed by an interactive passenger information system when answering a passenger query;
- basic definitions of run times and wait times needed to calculate trip duration;
- planned, predicted, and actual passing times of journeys at individual stops;
- service modifications decided by the schedulers or the control staff, resulting in changes of the vehicle journeys and blocks, compared to the original plan.

Basically, all types of passenger information generally use many elements of the topological network definition, the lines and journeys which form the service offer, the definition of run and wait times, and other fundamental definitions. Geographical information may possibly be provided in some cases, if corresponding application systems are available. Specific types of passenger queries may be related to fares, where the relevant information elements are included in the fare collection sub-model of the reference data model.

Thus, the information basis for passenger information systems is widely spread over the whole reference data model, and the genuine passenger information data model covers only those elements which cannot be derived from, and are not explicitly included in other parts of the model.

1.9 Fare collection

The **fare collection** data model aims at a most generic description of the data objects and elements needed to support functions like definition of the fare structure and its parameters, operating sales, validating the consumption and charging customers. These functions and their underlying data structures are handled differently between European countries, and even between the public transport operators within one country. This situation leads to a considerable complexity of the concepts to be taken into account in the attempt to define one single fare collection data model, which aims at covering as many existing solutions and practices as possible.

In order to cope with this complexity, the fare collection data model concentrates on the abstract, generic concepts that form the core of any fare system, independently of how these abstract concepts are implemented by a set of concrete fare products (e.g. tickets or passes) offered for sale to the public. The starting point for the description of these fundamental concepts is the definition of theoretical access rights. These can be combined to immaterial fare products, which are linked to travel documents in order to form sales packages to be sold to passengers. Controls may be applied to these travel documents to validate the utilisation of the public transport system. Prices components are linked to the access rights, fare products and sales packages; they are used to calculate the price to be paid by a customer for a specific consumption (e.g. sale on a vending machine, debiting a value card, post-payment).

1.10 Management information

The data model part supporting management information and statistics provides some additional data descriptions which may be needed apart from the information elements already included in the scheduling, operations management and control, passenger information and fare collection sub-models. Statistical information may of course be provided for any object of interest that is included in the company's specific data model and for which information is recorded in a database, whether for the company management or for other organisational units.

However, some additional information needs and sources are necessary, which cannot be derived from the model parts mentioned above and are specifically related to the evaluation of the operational process, especially to the evaluation of the current timetable and the comparison between the scheduled performance and actual performance. These include:

- events and recordings describing the actual course of vehicle journeys and the resulting service performance;
- the actual status of the planned and advertised interchanges and the resulting service quality; and
- recordings of the actual use of the service offer, i.e. actual passenger rides and trips.

1.11 Multi-modal operation

The multi-modal public transport domain is the co-operation of different public transport modes. The present standard addresses the needs of the following public transport modes:

- bus;
- trolley bus;
- light rail (tramway, metro).

Specific requirements of other transport modes are taken into account whenever possible.

The most significant needs addressed by the data model are dealing with:

- network description;
- resource management;
- operations;
- passenger information; and
- fare collection.

Numerous aspects of multi-modal operation refer to general data structures developed in the other parts of the present standard. They are recalled therefore with the reference to the corresponding data model part. However, specific characteristics, such as restrictions (in meeting or overtaking) or vehicle coupling for rail operation, are detailed in this subclause.

1.12 Multiple operators' environment

The standard takes into account the situation where several operators are present in one geographical area. This leads to solve problems related to the management of the different responsibilities for resources and services, between authorities and operators (and their organisational units). Problems related to the provision of information to passengers when the timetable data comes from different sources are also solved (merged timetables). The problem of interchanges in this situation is also described.

As regards to the fare collection aspects, the reference data model for fare collection is developed in a way to associate data from different operators, using various transport modes or even providing other services. It is therefore designed to meet requirements of an integrated fare collection system.

2 Terms and definitions

For the purposes of this European Standard, the following terms and definitions apply.

**2.1
attribute**
property of an entity

**2.2
conceptual data model**
description of a real world domain in terms of entities, relationships and attributes, in an implementation independent manner. It should provide a structure on which the rest of the development of an application system can be based

**2.3
conceptual level**
in the context of data modelling, the conceptual data model

**2.4
database**
collection of data; often used in the sense of the physical implementation of a data model

**2.5
data domain**
data structure (in this European Standard, a part of the Reference Data Model for Public Transport) made up of data related to each other, through the fact that there is a functional area or group of functions using this data set as a whole

**2.6
data model**
description of a real world domain in terms of data

**2.7
entity**
object (data) that has its own existence (as opposed to an attribute)

**2.8
entity-relationship (E-R) methodology**
methodology allowing for the representation of a data model in terms of entities and relationships

2.9

fare collection

all activities related to the collection of money from passengers

2.10

function

activity. In this European Standard, a sub-activity of a functional area

2.11

functional area

arbitrarily defined set of activities, used, in this European Standard, to define the objectives and limits of the data model

2.12

GDF

standard defining the contents and format of Geographical Data Files, used for the description, classification and encoding of road networks and road environment features

2.13

GDF database

database containing geographical information on the road network in a particular application area, possibly including information on the location of public transport points, links and services (routes)

2.14

interoperability

ability of (sub)systems to interact with other (sub)systems according to a set of predefined rules (interface)

2.15

logical data model

data design, that takes into account the type of database to be used, but does not consider means of utilisation of space or access

2.16

logical denormalised model

relational data model that is not fully normalised, i.e. does not completely follow the normalisation rules and thus may be redundant

2.17

logical level

in the context of data modelling, the logical data model

2.1

management information

all activities allowing the company management to collect the information necessary to meet problem-solving needs. Data of operational systems are filtered and aggregated for this purpose, and made available to the user interactively, or in form of pre-defined reports and summaries. Such functions are in principle related to all functional areas of a company, with particular reference to the management of statistical results

2.18

oracle CASE-tool

computer aided tool (developed by Oracle), used as a support for the data modelling process

2.19

oracle methodology

conventions described in [1] by Barker, based upon the E-R methodology, used to represent a conceptual data model, dedicated specifically to the Oracle CASE-tool

2.20

operations monitoring and control

all activities related to the transportation process, i.e. real-time functions related to the driving and transportation of passengers according to given instructions, including the monitoring of the driving process and its control in case of deviations, as well as all activities that support the driving process (traffic light priority, track switching, bay selection, advance/delay advice etc.). Such functions are often assisted by computer-aided tools, known as Automated Vehicle Monitoring (AVM)

2.21

passenger information

all activities related to informing the users either on the planned or on the actual transportation services

2.22

personnel disposition

all activities related to the mid term and short-term management of drivers

2.23

real-time control

see Operations monitoring and control

2.24

relational data model

type of logical data model giving the information as series of tables (relations) and attributes. It must have the following characteristics: 1. all attribute values are atomic, 2. all "tuples" (rows/occurrences) are distinct, 3. no part of the primary key may be null, 4. foreign key values must correspond to an existing primary key in another relation or be null

2.25

scheduling

see Tactical Planning

2.26

tactical planning

all activities related to the tactical planning of transportation, splitting into vehicle scheduling, driver scheduling, rostering

3 Requirements

3.1 General

3.1.1 Introduction

The present subclause describes the requirements of the reference data model for public transport. It consists of textual explanations related to a number of entity-relationships diagrams. Each diagram is drawn according to the conventions of the chosen method for entity-relationship conceptual modelling (i.e. in "Oracle notation"). The accompanying text presents the main functional requirements for each domain, the concepts represented by entities and relationships and the ways to use them in a real application.

[1] Richard Barker, "CASE*METHOD - Entity Relationship Modelling", Addison-Wesley Publishing Company, Wokingham, England, 1989

Textual explanations and diagrams are presented in fourteen subclauses, each referring to a domain:

- description of the network;
- versions, validity and layers;
- tactical planning components;
- vehicle scheduling;
- driver scheduling;
- schedules and versions;
- rostering;
- personnel disposition;
- operations monitoring and control;
- passenger information;
- fare collection;
- management information;
- multi-modal operation in public transport;
- multiple operators' environment.

Reports extracted from the data dictionary, which completes the diagram information, are presented in Annex A (normative). It gives for each entity its definition (description), the main attributes as well as the primary key and the possible super-types.

A description of the methodology used for conceptual modelling is provided in Annex B (informative).

A list of constraints expressing consistency and integrity conditions is provided in Annex B (informative).

3.1.2 Modelling Style

3.1.3 Generic Approach and Abstract Views

The reference data model for public transport has to be considered as a generic model. This means in particular that this model:

- represents the practices of most public transport operators and authorities considered as representative throughout Europe, rather than some particular solutions, specific to an operator or inspired by a software product for instance;
- includes the semantics of a variety of practices and takes into account a range of specific needs.

On numerous aspects, the reference model is made up of concrete concepts, which means practical concepts, close to the daily practice of operators and authorities and often specific to public transport. This point of view is judged necessary to facilitate the understanding and the use of the model by the public transport world.

However, the search for a certain generalisation has lead to consider abstract views for various model parts. This effort appears very clearly for the modelling of the public transport network, of versions and of the fare collection domain.

Such abstract views or model patterns have been introduced with the objective

- to clarify some of the data model parts and to simplify some of the diagrams, and
- to show that other instantiations than the most classical may have similar structures, even if those instantiations are not made explicit in the model.

The reference model is therefore a compromise between abstract concepts and concrete concepts. Whenever similar data structures appear in the real world for different functions, priority has been given to abstract concepts. In such a case however, the most classical concrete concepts are also presented, in addition to the abstract views representing in an abstract way the same reality.

The abstract concepts and their relationships may also be used in many cases to develop a particular application in domains that are not covered by the present version of the reference model. The report provides numerous example of such a development.

3.1.4 Structures

The reality represented by the reference model may be described according to different views, each reflecting the genuine information needs depending on a considered purpose. These views may correspond to the point of view of different public transport modes, different functional domains etc. For instance, a public transport network may be described according to such different views.

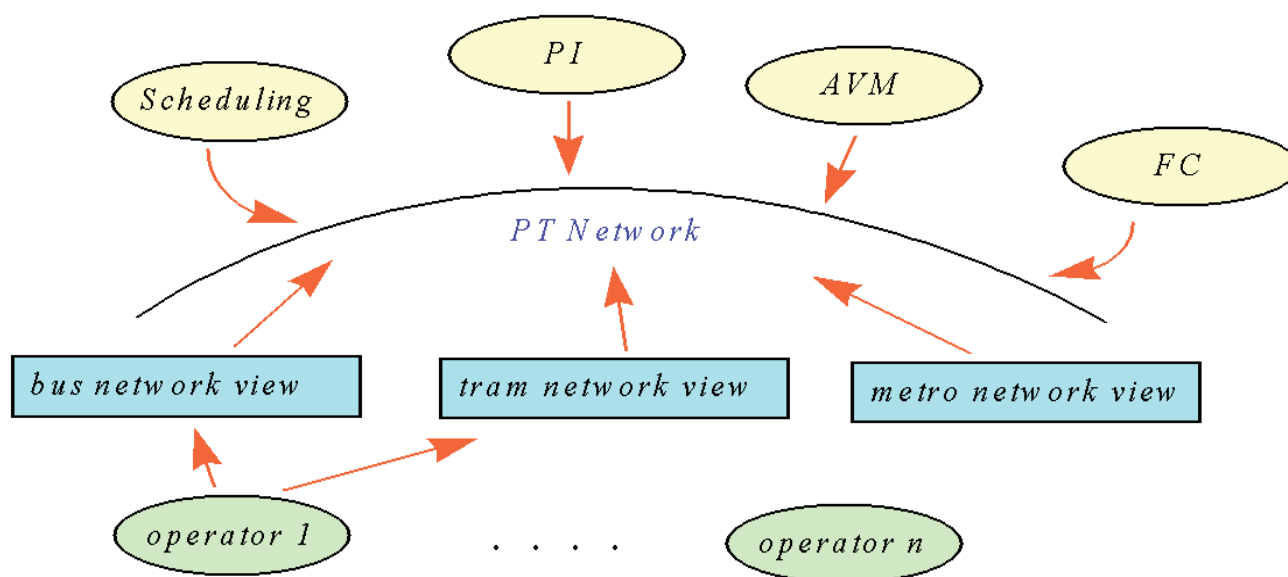


Figure 1 — Functional views of the public transport network

The different views of a specific domain are called structures. A structure is a user-defined collection of objects characterising a data domain, dedicated to a specific functional purpose. For instance, if some functions operated in a company require different representations of the network (e.g. for scheduling, passenger information, track management etc.), different structures are created.

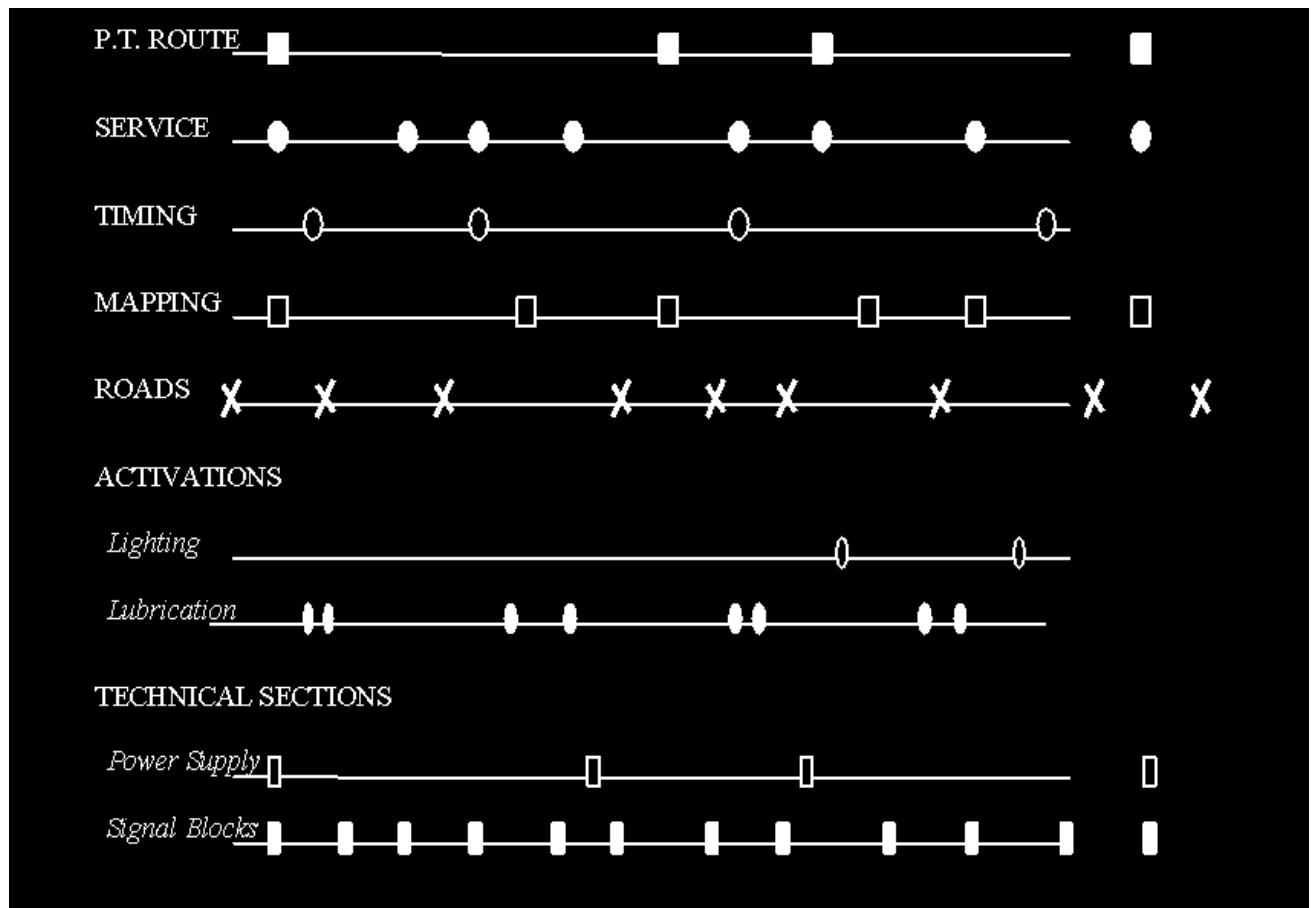


Figure 2 — Examples of structures

Within the reference model, the main following structures, each characterised by some entities, may be identified:

- generic topology: POINT, LINK, LINK SEQUENCE, ZONE etc.;
- road network structure: ROAD ELEMENT, ROAD JUNCTION;
- rail network structure: RAIL ELEMENT, RAIL JUNCTION;
- wire network structure: WIRE ELEMENT, WIRE JUNCTION;
- supply structure: STOP POINT, STOP AREA, ROUTE, SERVICE LINK, JOURNEY PATTERN etc.;
- running conditions structure: TIMING POINT, TIMING LINK, TURN STATION etc.;
- technical equipment structure: ACTIVATION POINT, BEACON POINT etc.;
- passenger information structure;
- etc.

3.1.4.1 Abstract Views of Structures

Some parts of the network description model play the role of an abstract view for objects having common characteristics. For instance, the POINT and LINK entities are abstract views of various other types of points and links used in various functional domains.

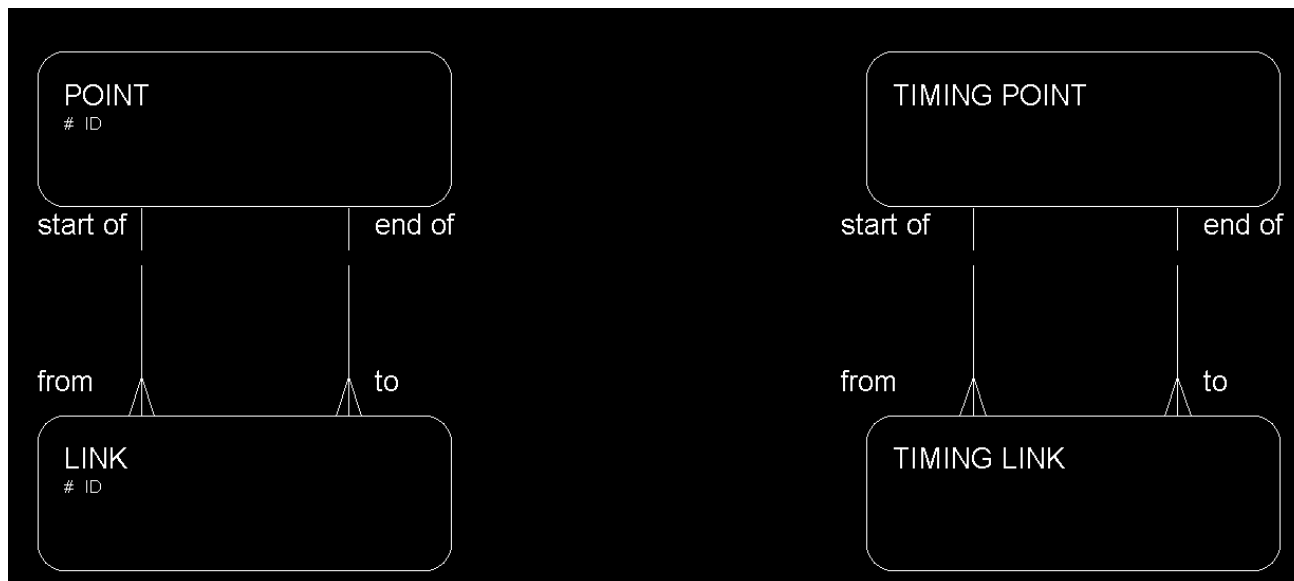


Figure 3 — POINT and LINK Abstract View instantiated in a Concrete View: TIMING POINT and TIMING LINK

Such abstract objects may be instantiated in concrete views, the most classical being explicit in the reference model. For instance, the TIMING POINT and TIMING LINK entities are concrete views of the abstract POINT and LINK entities.

Many other examples can be mentioned: ROUTE is an instantiation of LINK SEQUENCE, TARIFF ZONE is an instantiation of ZONE, STOP AREA is an instantiation of GROUP OF POINTS, DRIVER SCHEDULE VERSION is an instantiation of VERSION etc.

The entities describing abstract concepts may or may not be implemented explicitly at the logical level (e.g. as tables) of a particular application of the reference model. This choice, to be made by the users, will probably depend on the number of different concrete instantiations of an abstract concept. For instance, the POINT concept will probably need in most cases to be implemented as a table, whereas only the concrete applications of the LINK SEQUENCE entity will be implemented.

3.1.4.2 Abstract View of Object Complexity

Another example of abstract view is the pair of entities SIMPLE FEATURE and COMPLEX FEATURE. These entities represent elementary objects referring to a spatial description of the network (SIMPLE FEATURE) and combinations of these elementary concepts (COMPLEX FEATURE). A SIMPLE FEATURE may be a POINT, a LINK or a ZONE, while a COMPLEX FEATURE is composed of one or several SIMPLE FEATURES possibly combined with one or more COMPLEX FEATURES. For instance, a train station may be an instantiation of a COMPLEX FEATURE, composed of SIMPLE FEATURES (STOP POINTs, RAILWAY ELEMENT, platform area etc.) and other COMPLEX FEATURES (e.g. STOP AREA).

In this case, the SIMPLE FEATURE and COMPLEX FEATURE entities are introduced to show at a certain level of abstraction some repetitive characteristics (e.g. relationships). In most real applications of the reference model, only the concrete instantiations will be implemented.

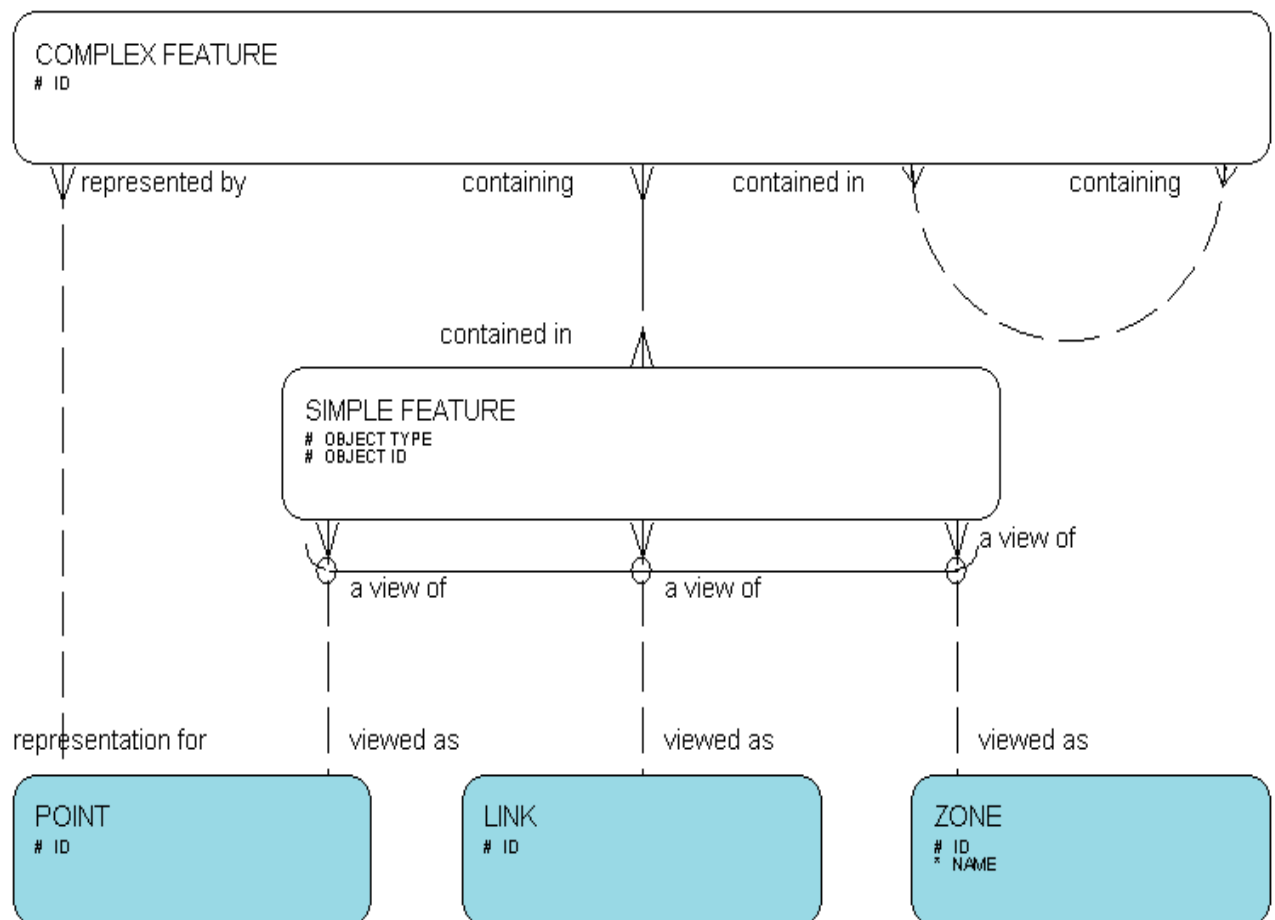


Figure 4 — Abstract View of Simple and Complex Objects

3.1.4.3 Layers and Correspondence Between Layers

As explained above, the users of the model may define different structures. This distinction is particularly meaningful when there is a need to exchange data between different application systems. In such a case, important requirements are:

- to manage in a coherent way versions of objects in each structure;
- to locate in space the objects of a given structure, i.e. to represent them according to a location referencing system;
- to manage and to represent independently objects of different structures.

The layer concept addresses such requirements. A layer is a set of objects belonging to a particular structure, using a specific location referencing system and subject to different versions.

The objects from different layers shall be related to each other with a sufficient integrity to allow an application interfaced to the system to carry out requests, of which the results mix objects from different layers. For instance, a bus control system displays on a screen a layer describing the frame of road infrastructure, another layer describing the PT patterns and a third layer showing the bus located.

A typical example of the needs this construction is able to address is the connection of a database with a geographical information system (GIS). It is not an objective of the reference model to specify a GIS layer, but to allow the users to relate the objects of their own system to various forms of standard GIS description (such as nodes, edges, raster map, complex linear features etc.).

This example shows that the layers have to be defined independently from each other, in particular because the location referencing system will often be different in the various layers. In such a case, the definition of a correspondence between layers is a crucial point, as otherwise it would be impossible to keep significant correspondences when merging layers in a common representation, such as with the previous quoted screen.

The spatial correspondence between objects belonging to different layers is described by another abstract construction, the projection mechanism. This allows to map objects from a source layer onto objects from a target layer.

3.1.4.4 Conventions

In the present report, the entities defined in the reference model are typed in capital letters (e.g. ROUTE). For very common terms, the same wording typed in lower case means that it does not refer expressly to the entity.

In the textual explanation, attributes of entities are typed in simple quotes (e.g. 'departure time'). The # sign means that an attribute is (or is part of) the entity identifier (e.g. # ID).

3.1.4.5 Implementation Guidelines

The reference model for public transport is a conceptual data model, which means that it can be implemented at the logical and the physical levels of a particular application system in various ways, depending for instance on the system used or local conditions. The textual explanation includes a number of guidelines or recommendations for implementing the reference model. Such recommendations are not normative. They are resulting from experiences of pilot sites having implemented the reference model and shall be considered as examples.

3.2 Description of the Network

3.2.1 Elements of topology

3.2.1.1 Points and Links

One of the most important aspects of information systems dealing with public transport is the representation of the networks on which the services are operated. Such a representation describes the objects composing a network (e.g. stations, lines) using simplified and conventional topological objects: points, links or possibly zones. Specific roles are assigned to these simple objects, according to the functional purpose of the description.

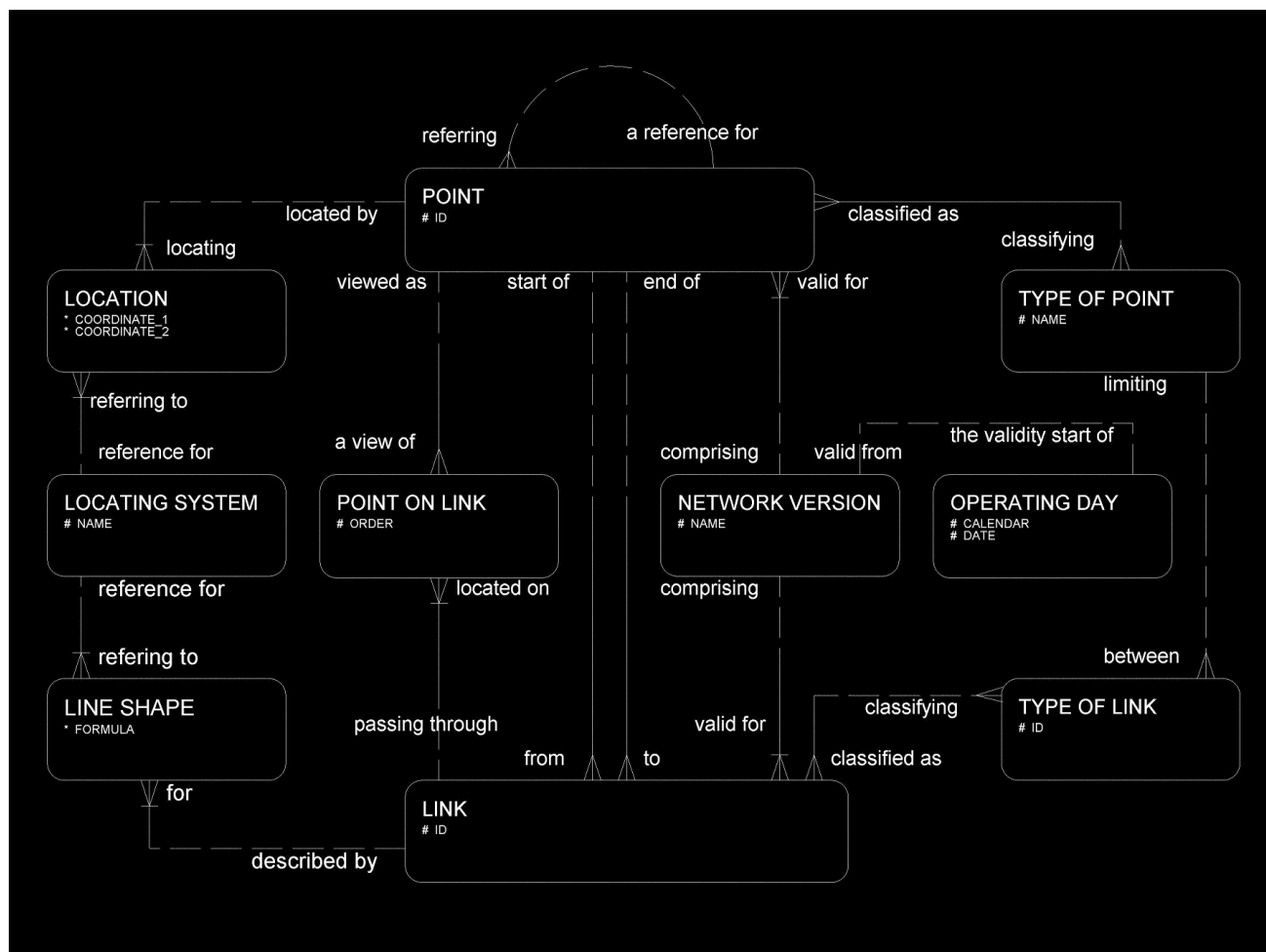


Figure 5 — Points and Links

Topological descriptions of the spatial structure of a public transport network are generally built with points. Thus, an entity POINT is defined as the most basic entity of the network model. A POINT represents a 0-dimensional node of the network. It marks the location of bus stops, parking places or other types of POINTs.

A TYPE OF POINT is defined as an entity to describe common roles played by a number of POINTs. Each POINT is functionally classified as being of one or more types, according to the specific information needs of a particular functional domain.

Certain TYPES of POINT are regarded as important enough to be additionally represented by a separate entity. The most important of these are the STOP POINT, TIMING POINT and ROUTE POINT entities, described in a further subclause. Other examples are ROAD JUNCTION, ACTIVATION POINT etc. The types not explicitly defined by an entity of the reference model may be specified by the generic entity TYPE OF POINT. Any POINT may be of more than one type. For example, the same POINT may be a ROUTE POINT, a TIMING POINT and may be an ACTIVATION POINT as well.

Some functions require that a POINT is chosen as being a hierarchical reference for one or several other POINTs. It may be the case for instance when the referenced POINTs are represented by the reference POINT, in some simplified descriptions. This is expressed by a circular relationship on the entity POINT.

Between two POINTs of any type, a LINK may be defined to store spatial information (e.g. the distance a vehicle will cover crossing this link). LINKs represent 1-dimensional connections between POINTs. There shall be no LINKs without one limiting POINT at each end. Two relationships between the POINT and the LINK entity specify the limiting POINTs of a LINK.

A LINK is oriented from its start POINT to its end POINT. This order has to be interpreted in a rather abstract sense of an artificial orientation, to be possibly used for expressions like “left of” or “right of” the LINK. The order does not necessarily express the direction of the traffic flow, for instance, which shall be defined by appropriate entities, relationships or attributes, depending on the functional context.

The network structures used by different functions may be subject to different conditions and constraints. In some structures, the ordered connection between two POINTs may have to be unique. This means that there cannot be more than one LINK between the two same end POINTs. In other words, such a link is logically a straight line (if it has a curvilinear shape, it is only for a drawing purpose). In other structures, there may be two or more different connections between the same start and end POINTs. This means that such alternative LINKs follow different paths between the two POINTs, therefore have different shapes. In this case, the shape is implicitly associated to a LINK. For instance, between two TIMING POINTs, there may be different TIMING LINKs if the vehicles covering these links follow different paths (ROUTEs).

The LINK entity is therefore identified by an own ID attribute, which allows multiple LINKs between the same pair of POINTs (e.g. TIMING POINTs). This ID does not represent explicitly the path followed by the LINK. The projection mechanism (see 3.2.10) allows to make it explicit. For applications in which a LINK shall be identified by its limiting POINTs, these may be used as an alternative unique key, or the artificial ID may be implemented as a combination of the two end point identifiers.

The entity TYPE OF LINK expresses the different functional roles of a LINK. For instance, this classification may include a distinction between “commercial links” to be used for passenger carrying journeys and “connecting links” to be used by dead runs or turnarounds at the terminals. It may be useful to express a difference between LINKs with separate bus lanes and without, or to describe activation specifications (to control announcements, ticketing devices etc.) that are identical for each LINK of a given TYPE OF LINK.

Each LINK is functionally classified as being of one or more types, according to the specific information needs of a particular functional domain. As for the TYPE OF POINT, certain TYPEs OF LINK are explicitly defined by an entity in the reference model (e.g. SERVICE LINK, TIMING LINK, ROUTE LINK).

The main property of a LINK is often its ‘length’. Further attributes may be added, according to the considered TYPE OF LINK.

In most cases, LINKs of a given type shall be only between POINTs of a corresponding TYPE OF POINT. For instance, SERVICE LINKs shall only be used to connect STOP POINTs (however, other TYPEs OF LINK may be defined between STOP POINTs). An optional relationship between TYPE OF LINK and TYPE OF POINT expresses that only points of the specified type must be used as limits for links of a given type (or several types).

3.2.1.2 Main Types of Points and Links

A STOP POINT is the location of a bus stop where passengers can board or alight from vehicles. This may be restricted to boarding only or alighting only. A STOP POINT is a conventional representation of such a stopping place, as used to build the schedules or to provide broad traveller information. More detailed stopping positions may be necessary for dynamic platform management and the corresponding traveller information. Such aspects are described in 3.2.10.2 and 3.14.2.5.

Any pair of STOP POINTs may be related by a SERVICE LINK, which expresses the possibility for a service to run from one of these STOP POINTs to the other. This possibility may be restricted to one direction only, thanks to the order of the end STOP POINTs and possibly an additional attribute.

A TIMING POINT is a location for which timing information necessary to build schedules may be recorded. A classical way of using TIMING POINTs is to relate them by a LINK. Such a TIMING LINK, relating a start TIMING POINT to an end TIMING POINT, may be used to store standard run times against it.

In some cases, it is necessary to store standard waiting times at some selected TIMING POINTs. A flag attribute ‘waiting point’ allows to specify such points.

Some operators may want to define run times between any pair of STOP POINTs related by a SERVICE LINK. In such a case, probably all STOP POINTs of the network will also be classified as TIMING POINTs. Other companies will define run times only for a selection of STOP POINTs. The times related to the rest of the stops would then be derived by process (e.g. interpolation). In addition, some POINTs that are not STOP POINTs are classified as TIMING POINTs. It is often the case for garage entry or exit points.

The path to be followed by services is described thanks to ROUTE POINTs, related by ROUTE LINKs. A ROUTE POINT may be an end point of a route ("terminus") or a point chosen to express that a route is passing "via" this ROUTE POINT. If there are several possible paths between two ROUTE POINTs, the most common practice is to create such "via" ROUTE POINTs, in order to distinguish the various paths. Therefore, the entity ROUTE LINK is identified by the two end ROUTE POINTs that it relates (unlike the TIMING LINK, for instance). This expresses that there shall be no more than one ROUTE LINK between two particular ROUTE POINTs. A more detailed description of the modelling of routes is provided in 3.2.8.1.

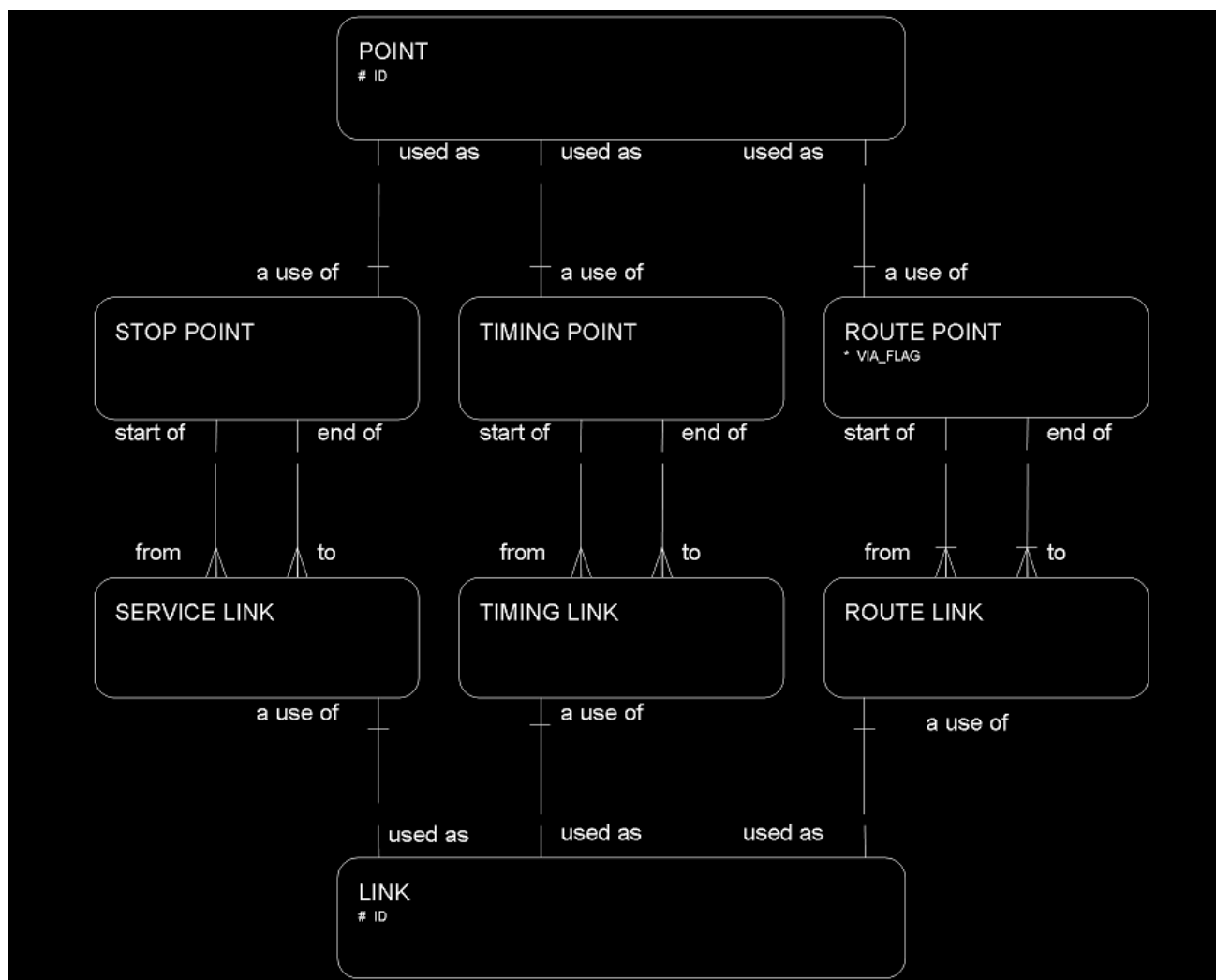


Figure 6 — Main Types of Points and Links

3.2.1.3 Network Versions

From time to time, public transport companies may want to alter their networks, in order to comply with changes in transport demand or in the infrastructure (e.g. road) network. Some POINTs in the network will perhaps have to be shifted to other locations, or a couple of POINTs will need to be defined, in addition to already existing POINTs, to cover a completely new service area. A company will probably have to record different sets of POINTs, which are the skeleton of its network model, at the same time. These different

network models will be valid for different periods of time, but shall be accessible in parallel for the network planning process.

An entity NETWORK VERSION is introduced to allow for this practice. Crucial network data, and other data logically related to them, are defined depending on a NETWORK VERSION. A set of network data that will be valid for the same period of time is kept separate by membership of the same NETWORK VERSION.

The most fundamental entity owned by a NETWORK VERSION is the POINT. All the entities dependent on the POINT are also dependent implicitly on the NETWORK VERSION, e.g. LINK, ROUTE POINT, ROUTE LINK, TIMING POINT or TIMING LINK.

The starting validity of a NETWORK VERSION is often given by a specific date, which is expressed by a relationship to the OPERATING DAY entity. In such a case, the end of the validity period can be derived as the latest date that is earlier than the start date of the next NETWORK VERSION recorded. This practice prevents any two NETWORK VERSIONs from overlapping in time. Other solutions may be chosen to define the validity of a NETWORK VERSION. A more generic modelling of versions is shown in 3.3.

The reference model does not mandate the limits (VERSION FRAME, see 3.3.4) of a NETWORK VERSION. It may be applied to only one line, or to all lines served by the same depot etc. Several levels of NETWORK VERSIONs can be defined (e.g. one for the whole network, one for each line) in a hierarchy (line versions referring to a network version). This allows in particular to distinguish simulation versions from production versions.

3.2.1.4 Structures and Layers

A topology is a way to represent (on a map, on a diagram, on a screen...) objects from the real world according to conventional representation rules. In the reference model, most spatial objects are represented by POINTs and LINKs.

There may be a different set of objects for each different specific purpose (e.g. scheduling, passenger information, track management). Such a combination of user defined objects for a specific purpose or function is called a "structure". One of the main properties of a structure is the functional purpose it is designed for.

A LOCATING SYSTEM may be attached to a structure, in order to fix the representation rules. A LOCATING SYSTEM may be a cartographic system, a screen mapping system, an addressing system (street name and house number), or even a simple schematic implicit system.

Each structure may be managed with one or more LOCATING SYSTEMs. Each single LOCATING SYSTEM may be shared between different structures. In contrast to the term "structure", the term "layer" represents one single structure using one single locating system.

In addition, each structure may be defined for several versions, for example a layer may exist under some temporal conditions that will define a version of this layer.

3.2.1.5 Use of Layers

A layer is defined by the user of an information system. Several layers will be created if some functions operated in the company require different representations of the network (e.g. different representations for scheduling, passenger information or track management).

The layering should fit with the needs and constraints addressed by the system, in particular the exchanges it provides with other systems. For each of these interfaced systems, at least one layer will be defined to describe the data provided by or to this other system. For instance, the data describing the road structure, acquired from an external geographical system, will constitute a layer in the operator system; another layer may describe the bus lanes or the sections that are outside the road network.

The objects from different layers have to be related to each other with a sufficient integrity, in order to allow an application interfaced to the system to carry out requests, of which the results mix objects from different layers.

For instance, a bus control system displays on a screen a layer describing the frame of road infrastructure, another layer describing the PT patterns and a third layer showing the bus located.

In the reference model, no particular layer is identified as being a “basic” layer, to which all other layers should refer. It is a matter of users’ choice to decide whether such a basic layer should exist in implementations of the model, and to choose which one.

The main objective in introducing layers within the reference model is to face the increasing complexity of data handled by PT organisations, in particular the management of data coming from various sources. It is important to maintain the consistency and the integrity of such complex information, while the management of data by the end users should remain relatively simple. The modelling organised by modular layers is aimed at providing independent data systems for each structure a PT organisation may define, as well as the tools to exchange data between layers without affecting this independence.

The key mechanism relating layers to each other is the projection, which allows the representation of an object on another layer, other than the one it has been designed in (see 3.2.10). A typical example of the needs this construction is able to address is the connection of a database with a geographical information system (GIS). It is not an objective of the reference model to specify a GIS layer, but to allow the users to relate the objects of their own system to various forms of standard GIS description (such as nodes, edges, raster map, complex linear features etc.).

In real implementations, the use of explicit layers is not necessary when the considered systems includes only a limited number of them (e.g. 2 or 3). It becomes much more useful when the number of layers increases. A typical example in this respect is the management of several layers of links. With two or three layers, there is no difficulty in assigning one of the layers as being basic: the LINKs defined in this layer will include the position of the end POINTs of the LINKs from other layers. However, if the number of layers is high, this simple solution would lead to cut these basic LINKs into too numerous small parts, which is not suitable for an efficient data management.

A LAYER represents a set of space-related data grouped together within a functional structure. It is depending on one LOCATING SYSTEM and one DATA SYSTEM.

A LAYER is subject to one or several LAYER VERSIONs. A TYPE OF PROJECTION (see 3.2.10.3) uses a LAYER VERSION as source and another as target.

The detailed modelling of layers is to be found in 3.3.6.2, as it uses abstract concepts described in the corresponding subclause.

3.2.1.6 Location and Shape

An important property of a LOCATING SYSTEM is to specify the location of represented objects (e.g. POINTs and LINKs). A LOCATING SYSTEM includes in particular methods to represent elementary objects (e.g. POINTs and LINKs), their shapes (shape of a curvilinear LINK), their position related to a reference (e.g. axis) and their relative distances (distance between two POINTs). These methods and rules vary in general from one LOCATING SYSTEM to another.

The location of a POINT is dependent on the LOCATING SYSTEM used. Given a LOCATING SYSTEM, every POINT may be located in this system by a LOCATION. One of the classical ways to locate a POINT is to assign to it coordinates. The LOCATION is hence defined by two coordinates in a two-dimensional representation and possibly by a third coordinate relating the point to a surface. Examples of coordinates are x- and y-values in a plane graphic or diagram, degree of longitude and latitude on a globe, GPS-coordinates, the angle to the North and the distance from an origin etc.

Every LOCATION shall be referring to one and only one LOCATING SYSTEM and shall be locating one and only one POINT. Every POINT may be located by one or more LOCATIONs, each of which referring to only one LOCATING SYSTEM.

Within a number of layers, a LINK is described as a straight line. However, a shape may be assigned to a LINK, in order for instance to draw curves on a map. The intersection entity LINE SHAPE, similar to LOCATION, describes the graph to be drawn between the limiting POINTs of the LINK, using a 'formula' recorded against this entity.

For instance, the model addresses several possibilities of assigning a shape to a LINK:

- the locating system of a layer may allow describing a LINK as a curve (formula etc.);
- the projection modelling allows to project the LINK onto a sequence of consecutive straight segments (called "edge" or "segmented line", for instance) which belongs to another layer;
- the projection modelling allows projecting the LINK onto a curvilinear feature, described in another layer.

In the first example, the shape of the LINK is included in the considered layer; in the two other examples, the LINK follows the shape of a linear feature described in another layer.

The LOCATING SYSTEM defines the units measuring the values given in the properties of a LOCATION or a LINE SHAPE. In addition it enables in general to specify relative distances between objects, which makes it possible to describe the position of an object within another object that has more dimensions.

It is often necessary to define POINTs that are simply located on a LINK of a certain type. For instance, on a LINK defined for activation of traffic light priority, some intermediate points may be necessary, at which a vehicle should confirm or cancel the priority request. If a platform is described by a LINK, it may be necessary to define the different coach stopping positions as POINTs on this LINK. Such a POINT ON LINK is a POINT that is defined on a LINK belonging to the same layer.

Each POINT ON LINK is identified by the LINK it is located on and by an order on that LINK. The distance from the start point of the LINK is only optional information, but the order attribute ensures that all the intermediate POINTs ON a LINK are sequenced in a unique way.

The LOCATION SYSTEM enables to measure distances between objects, in particular the distance from a POINT to another, which will be the length of the LINK between those POINTs, if it exists. Lengths therefore may have to be specified for various types of LINKs, according to different functional purposes or using different LOCATION SYSTEMs. This may generate problems of consistency between the distances defined for different functions. For instance, a PT data base may receive from an external geographical system lengths of road elements (distances between road junctions) for a part of the network, while all distances between STOP POINTs are provided by measurements (e.g. with buses specifically equipped).

It is however necessary to allow distances to be defined independently for each different purpose in the network representation, because it shall be possible to use these functions separately, without the necessity to refer to one common network including the definite distances for all functional purposes. Each time two layers will be interfaced, both providing distance values (because the LOCATING SYSTEM is different, or because the measurement source is different), rules or constraints have to be set up to face such a potential inconsistency (e.g. priority rules, conversion formulas etc.).

3.2.2 Infrastructure Description

3.2.2.1 General Remarks

The subclauses below describe the physical network that is used to provide the service offer. The journeys scheduled during the planning stage are supposed to run along this physical network. Some model elements are borrowed from the GDF standard data model (see 3.2.11) and integrated into the public transport reference model, thus forming a natural data interface between both standard models.

3.2.2.2 Infrastructure Points and Links

Similarly to the journey description that uses POINTs and LINKs (e.g. SERVICE LINK), in a simplified representation of the real world, the infrastructure of the PT network is described by POINTs and LINKs. This does not mean that both descriptions are identical. On the contrary, they shall remain as independent as possible in a data system. The representation of the objects necessary to describe the journeys is used in layers dedicated for operational planning. They may be projected onto the description of the infrastructure, described in other layers, to indicate that they follow a path of infrastructure link sequences.

Any POINT necessary to describe the infrastructure network is defined as INFRASTRUCTURE POINT, which is a generic entity including several subtypes (e.g. ROAD JUNCTION). Similarly, the necessary LINKs are defined as INFRASTRUCTURE LINKs.

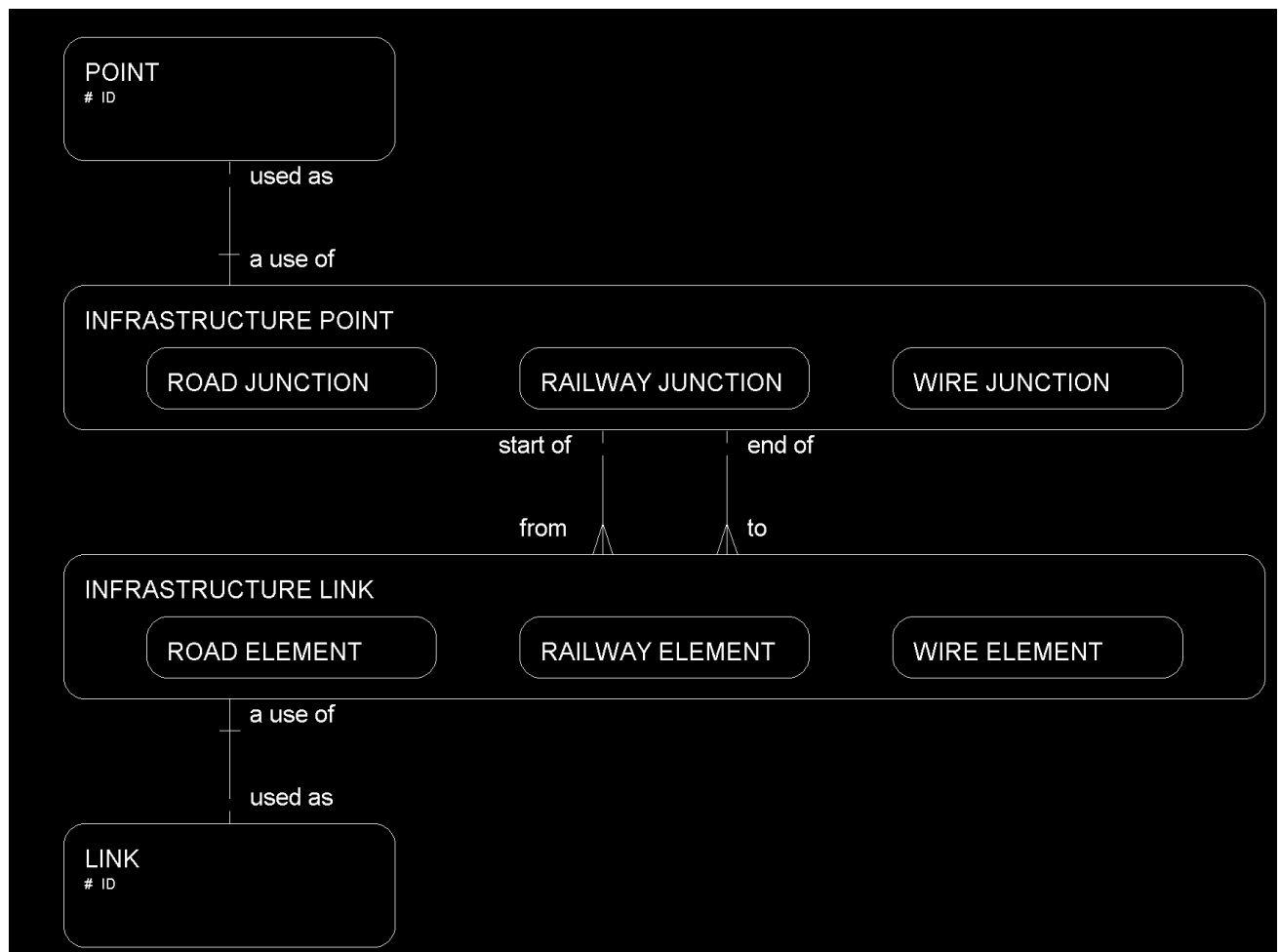


Figure 7 — Infrastructure

Any INFRASTRUCTURE LINK shall be bordered by a start and an end INFRASTRUCTURE POINT. This orientation does not necessarily refer to the direction of the traffic flow, but has to be interpreted as an arbitrary orientation. An optional attribute 'driving direction' may be used to specify such a direction, if necessary.

Some users will restrict the use of INFRASTRUCTURE LINKs to the following conditions:

- certain types of INFRASTRUCTURE LINKs shall not overlap (e.g. RAILWAY ELEMENT or, as it is the case in GDF, ROAD ELEMENTs);

- certain types of INFRASTRUCTURE LINKs shall not overlap and their end POINTs shall be POINTs where the infrastructure ends (e.g. end of a track) or where three or more LINKs meet (junctions).

The reference data model does not mandate such conditions. It is the responsibility of the user to formulate and to maintain them.

3.2.2.3 Road Network

This part of the reference model contains elements used to describe the physical road network, which represents all carriageways available for buses, and into which the bus line network can be embedded.

The corresponding INFRASTRUCTURE POINTs are defined as ROAD JUNCTIONs, while the corresponding INFRASTRUCTURE LINKs are defined as ROAD ELEMENTs.

According to GDF, ROAD JUNCTIONs may be located:

- at intersections of two (or more) road centrelines;
- at the end of dead end roads;
- at the intersection of a road element and an *Enclosed Traffic Area* (a two-dimensional level-1 feature in GDF);
- at the intersection of a road element and a *Railway Element* (a GDF feature to be introduced in the next subclause);
- at places where the validity of any significant information changes along the road (for instance the width or the number of lanes).

Users of the public transport reference model may implement all or some of these conditions, according to their needs and the geographical systems they are interfaced with.

3.2.2.4 Rail Network

The description of the rail network is meant to be a model of the track network along which vehicles (or trains) can physically proceed, without taking into account security aspects, or regulations and conventions decided by the company staff or other authorities. Railway aspects are developed in this data model for reference purposes and not for control functions.

The corresponding INFRASTRUCTURE POINTs are defined as RAILWAY JUNCTIONs, while the corresponding INFRASTRUCTURE LINKs are defined as RAILWAY ELEMENTs.

RAILWAY ELEMENTs will always have to be interpreted as non-overlapping parts of the rail network. This means that one railway section between two switches or crossings cannot be described alternatively, and in parallel, by two or more different subdivisions into chains of railway elements. Different sequences of railway elements between two switches will principally mean multiple connections, physically separated from each other.

The location where contiguous RAILWAY ELEMENTs are connected is represented by RAILWAY JUNCTION. The two RAILWAY JUNCTIONs bounding a RAILWAY ELEMENT are specified by two relationships between these entities. The names of the relationship ends suggest a direction, which has to be interpreted as an arbitrary orientation, similar to the orientation of ROAD ELEMENTs described in the previous section.

3.2.2.5 Overhead Wire Network

The wire network for power supply of trolley buses (or trams) is modelled according to the same principles as applied for the rail network. WIRE ELEMENTs will be defined as the links between WIRE JUNCTIONs, which may be at places where three or more WIRE ELEMENTs are joined, at locations where only two adjacent WIRE ELEMENTs are connected or possibly at intermediate locations.

3.2.3 Restrictions

3.2.3.1 General

The fact that trains cannot overtake each other or meet each other on the same track is obvious for railway systems, but similar restrictions apply for trolley buses and even conventional diesel buses, under specific circumstances (depending on the number and width of lanes on the street). This type of restriction may be relevant for the scheduling process, because vehicle journeys shall be scheduled in a way to avoid such conflicting events.

The modelling presented in this subclause is not aimed at describing the track and train movement management, for which the concepts to consider are far more complex. It fits with a function often operated in light train operation, which consist in a first verification of the train movements planned in a schedule, in order to check whether there are situations in which the track constraints makes the schedule impossible to run. This function is usually operated with feedback to the scheduling process.

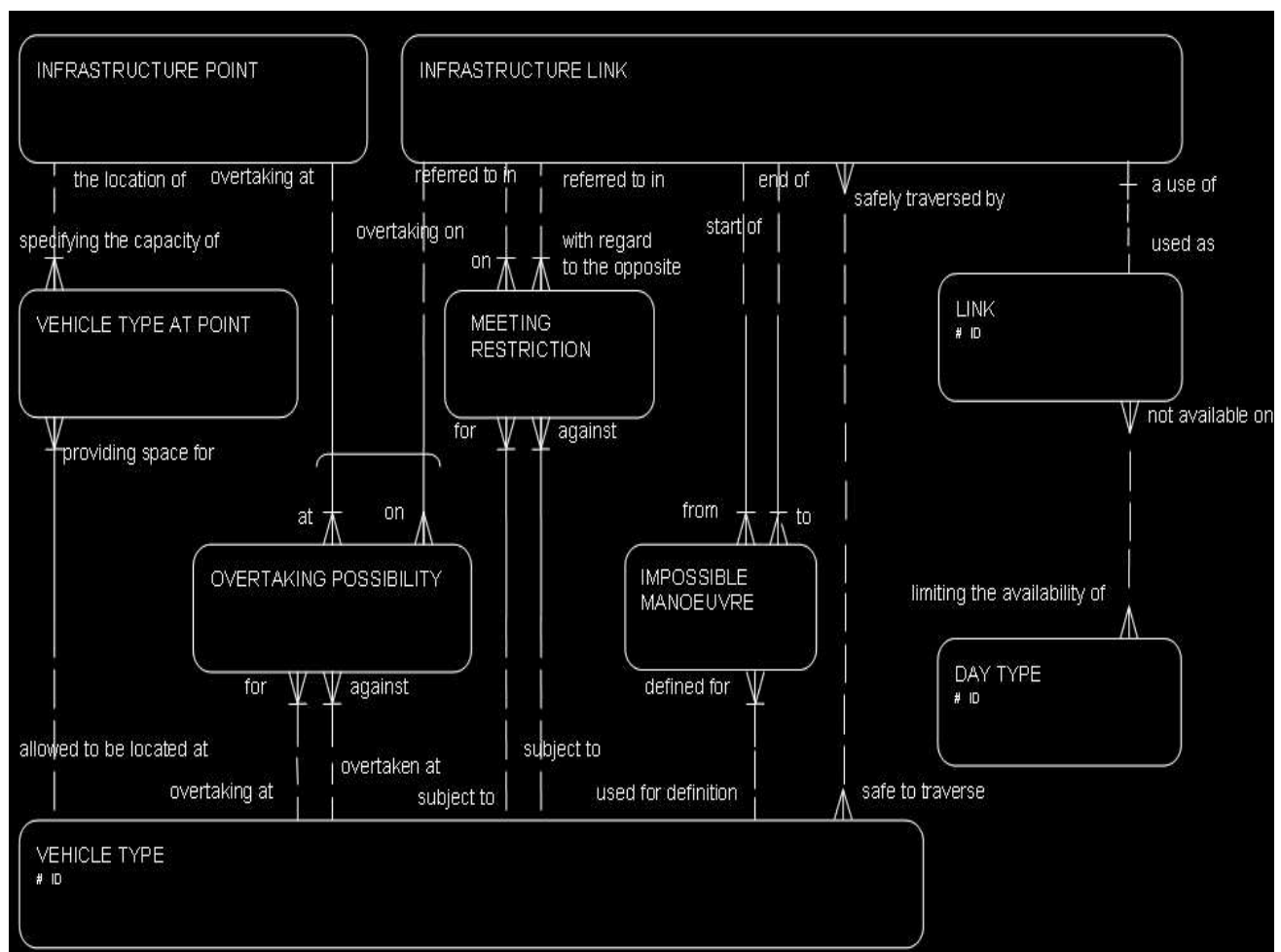


Figure 8 — Restrictions

3.2.3.2 Vehicle Types at Points

A VEHICLE TYPE characterises the common properties of a defined class of public transport vehicles (see 3.5.4.2). Vehicles of a certain VEHICLE TYPE may not be allowed, or physically unable, to stop for any length of time at particular INFRASTRUCTURE POINTs in the network. The entity VEHICLE TYPE AT POINT may be used to express how many vehicles of each type there is space for, at the concerned POINT. This will usually be a STOP POINT. If the number is 0, then vehicles of that VEHICLE TYPE cannot stop at this INFRASTRUCTURE POINT at all. This restriction may sometimes be relevant for checking the timing of overtaking journeys during the scheduling process.

3.2.3.3 Availability of Links

Vehicles of a certain VEHICLE TYPE may not be able, allowed or safe to cross particular INFRASTRUCTURE LINK s in the network. For example, a double-decker bus may not be able to pass under a low bridge. The reference data model expresses this as a positive relationship: a VEHICLE TYPE is safe to traverse a particular INFRASTRUCTURE LINK.

There may be LINKs which are not available at all on certain DAY TYPEs (see 3.4.1.2). While these limitations generally depend only on the choice of the public transport company to offer or not to offer particular services, there may be physical restrictions that prevent particular LINKs to be used on a specific DAY TYPE. For instance, a street may be blocked because of a special event (e.g. market day) which occurs regularly on each day of that DAY TYPE. A relationship between the LINK and the DAY TYPE entity may be used to express this kind of limited availability on parts of the public transport network.

3.2.3.4 Overtaking Possibility

In rail or wire systems, overtaking is only possible if an appropriate overtaking track is available. In bus systems, there are, in theory, more opportunities to plan for buses to overtake each other. Due to physical (e.g. bus lane) or legal limitations, such cases often occur near a POINT. Checking the movement of vehicles before validating a schedule may require a simplified description of the network with all overtaking opportunities registered. The places where overtaking is possible can be described by particular POINTs or LINKs. Most often STOP POINTs will be used for this purpose in operational practice.

The entity OVERTAKING POSSIBILITY is therefore related to either an INFRASTRUCTURE POINT or an INFRASTRUCTURE LINK that allows a vehicle stopping at this POINT or covering this LINK to be overtaken by another vehicle. The OVERTAKING POSSIBILITY specifies that this INFRASTRUCTURE POINT or LINK provides means (for instance a bus bay, or an overtaking rail) for one vehicle overtaking the other. This possibility may depend on the characteristics of the VEHICLE TYPEs in question, so the VEHICLE TYPEs of both the overtaking and the overtaken vehicle are associated with the OVERTAKING POSSIBILITY, by means of identifying relationships.

3.2.3.5 Meeting Restrictions

The entity MEETING RESTRICTION expresses that vehicles of two specified VEHICLE TYPEs are not allowed to meet on a particular pair of INFRASTRUCTURE LINKs (e.g. opposite tracks). In practice, this will probably occur mainly in tram systems, where several generations of tram vehicles are operating on the same rail network, with different vehicle widths leading to conflicting clearance profiles along certain parts of the track network. In metro or light rail systems, such a situation may occur if the network comprises single-track sections.

3.2.3.6 Impossible Manoeuvre

A particular characteristic of railway networks (in contrast to road networks) is the fact that the railway geometry does not always allow vehicle movement between two adjacent railway elements, for instance in the case of switches or crossings. Railway elements may not be suitable to be passed through in any arbitrary sequence and some successions may physically be impossible. This kind of restrictions is expressed by the entity IMPOSSIBLE MANOEUVRE, specifying from which INFRASTRUCTURE LINK to which other (adjacent) element a rail vehicle cannot proceed, due to physical restrictions. Additional information can be attached, for

example the VEHICLE TYPEs for which an IMPOSSIBLE MANOEUVRE would apply (for instance, bi-directional rail vehicles may be able to perform a certain manoeuvre whereas one-directional vehicles are not capable of it).

3.2.4 Combined Diagram on Topology

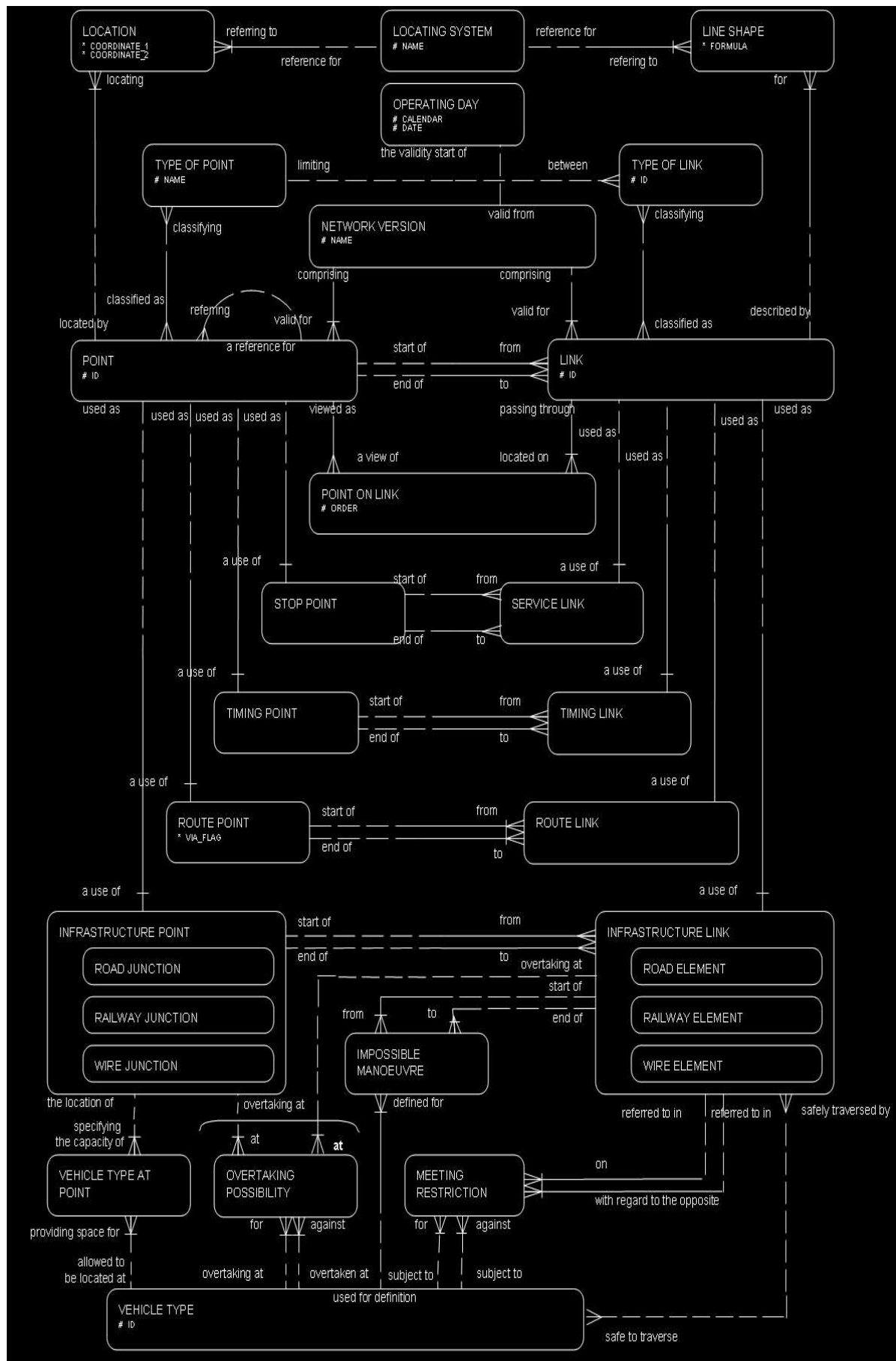


Figure 9 — Combined Diagram on Topology

3.2.5 Additional Aspects to Point

3.2.5.1 Stop Point Equipment

The STOP POINTS are classified according to a TYPE OF STOP POINT, which is often used to characterise the equipment to be installed at stops. In addition, some users may use this entity to distinguish whether passenger information is displayed at stop points of a certain type, if connections are planned or advertised from or to some stop points etc.

The entity TYPE OF EQUIPMENT represents particular types of stop point equipment (post, shelter, seats etc.). It may also be used for other types of equipment (e.g. installed onboard buses).

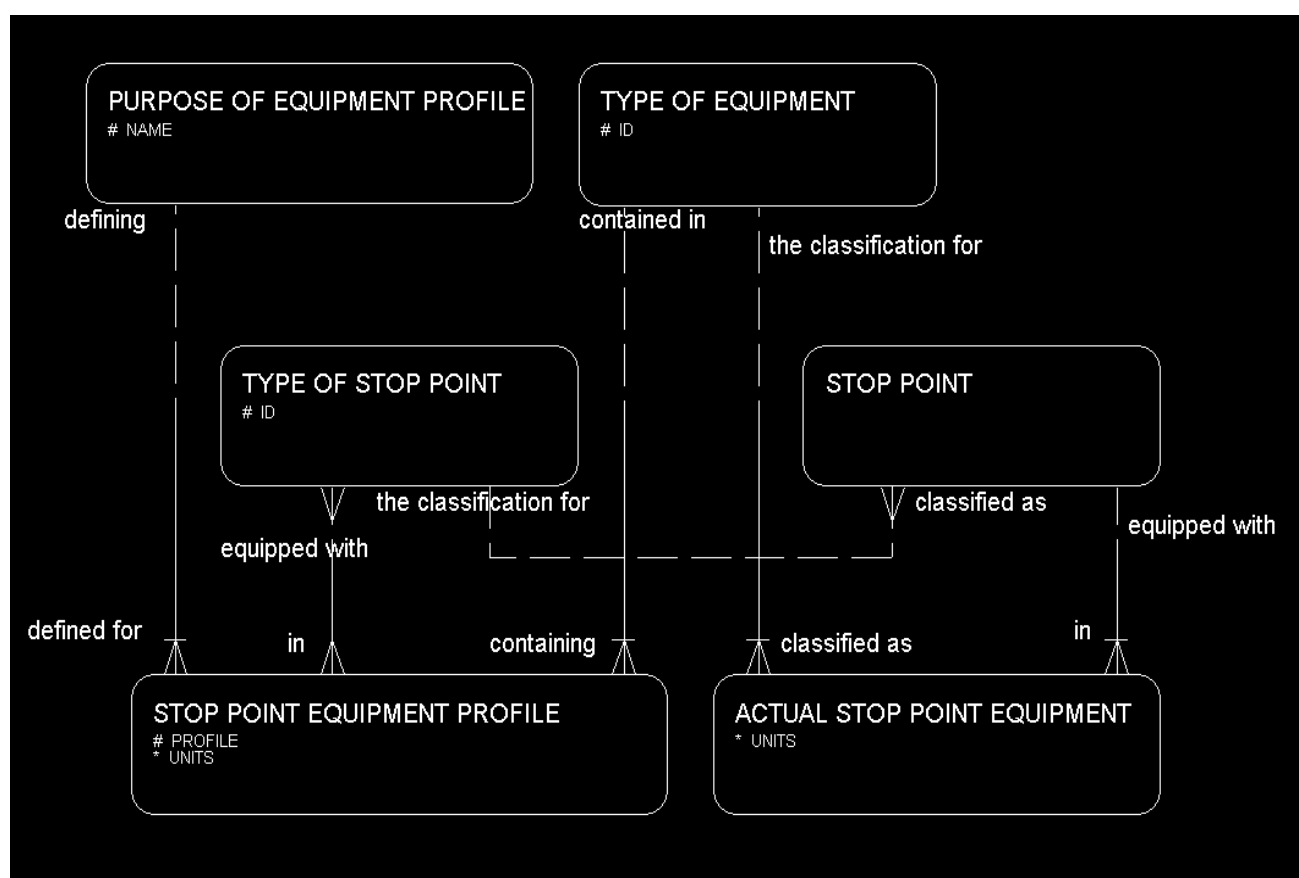


Figure 10 — Stop Point Equipment

The entity STOP POINT EQUIPMENT PROFILE provides the number of items of a certain TYPE OF EQUIPMENT, to be normally installed at a certain TYPE OF STOP POINT, according to a specific PURPOSE OF EQUIPMENT PROFILE. The latter entity describes the functional purpose of equipment (e.g. equipment for displayed passenger information). Various profiles may exist for the same purpose and the same type of stop point, depending for instance of equipment generation.

The entity ACTUAL STOP POINT EQUIPMENT represents the type of equipment actually installed at each particular STOP POINT.

The attribute 'units' of STOP POINT EQUIPMENT PROFILE and ACTUAL STOP POINT EQUIPMENT specifies the number of items.

The above entities only refer to a type of equipment, not to the individual devices.

3.2.5.2 Vehicle and Crew Points

The GARAGES where public transport vehicles are usually parked are considered to be part of the basic network definition. They are the source and destination places where vehicles start and end their operation, and thus are part of the basic infrastructure.

Within a GARAGE, it is often necessary to distinguish several GARAGE POINTs. Such points are not aimed at describing any precise parking place for vehicles, but to specify conventional places where timing information, necessary for planning, may be different. Therefore, different GARAGE POINTs may represent different parking areas, or different entry or exit points. The detailed management of garages is out of the scope of the reference model.

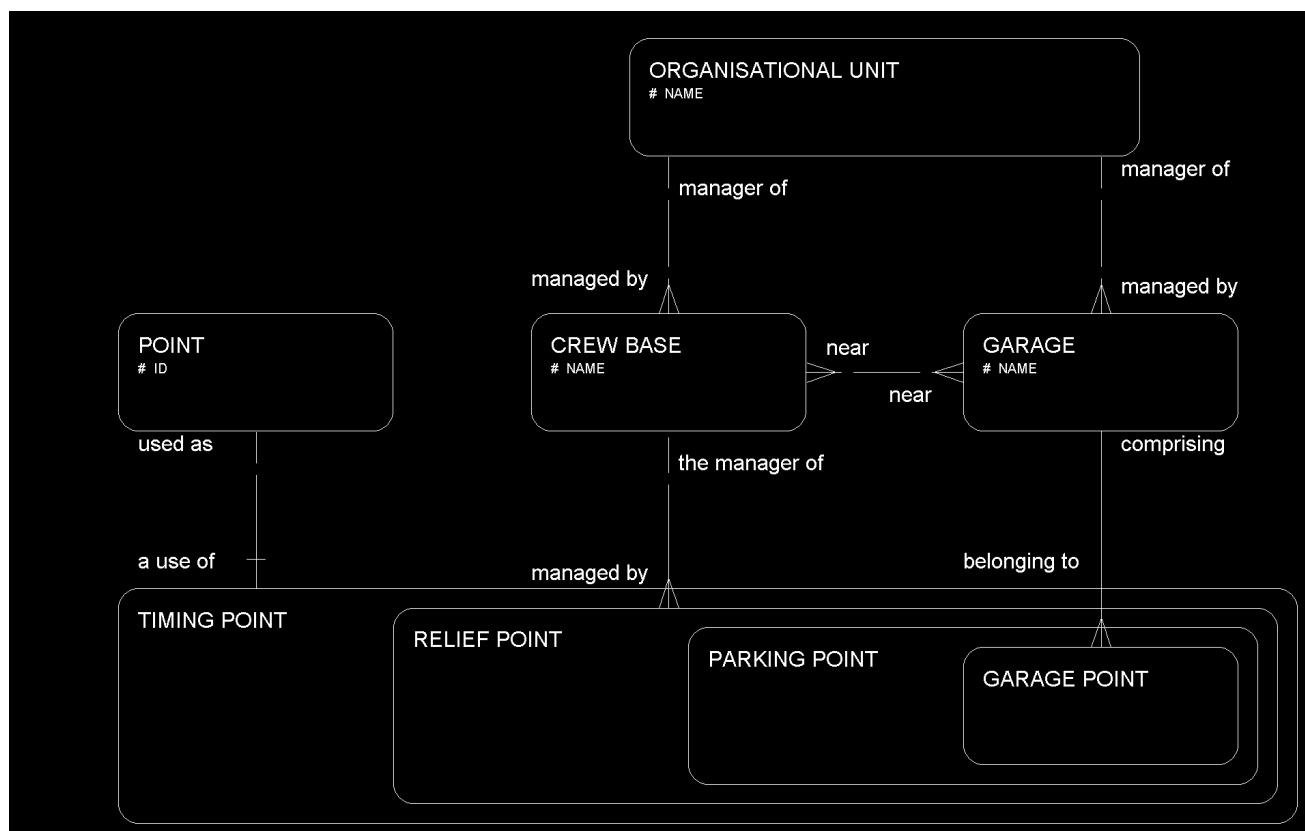


Figure 11 — Resource Management Points

The entity PARKING POINT represents any POINT where a vehicle may be parked for a while. It includes GARAGE POINTs located within a GARAGE, as a subtype. Other PARKING POINTs located at other places may be defined. For instance, in bus operation, PARKING POINTs often exist in central places of the network; buses may be parked there at off-peak hours, or as tactical reserve.

Operating employees of a PT operator, in particular the drivers, are managed at a CREW BASE, where they report, sign on or off, stock up with tickets etc. A CREW BASE and a GARAGE may be near each other (or even in the same "depot"). They may be each managed by one ORGANISATIONAL UNIT (see 3.15.2.2), which may be identical for both.

The driver planning process implies to define in advance the points where the drivers will start or end driving vehicles. Such POINTs are qualified as RELIEF POINTs. They are managed by a CREW BASE. RELIEF POINT is to be understood with an extended meaning, as it includes any point where a driver may pick up an unattended vehicle or park it. Therefore, PARKING POINT (including GARAGE POINT) is a subtype of RELIEF POINT.

As the start or the end of a driving spell necessitates to order fixed times, RELIEF POINT is a subtype of TIMING POINT. PARKING POINT and GARAGE POINT are hence subtypes of TIMING POINT as well.

Most often TIMING POINTs will be defined as end-points of a TIMING LINK, in order to record planned run times on such a link, or planned wait times at such a point. GARAGEs and other PARKING POINTs will be included in that category. For other vehicle scheduling purposes, it may be necessary to specify fixed times (e.g. a JOURNEY MEETING, see 3.4.6.6) at TIMING POINTs that are not necessarily end-points of any TIMING LINK. In addition, some TIMING POINTs are used for driver scheduling purposes: points where drivers start and finish their SPELLs, STRETCHes etc. (including CREW BASEs); points where they spend BREAKs or run TASKs etc. Most scheduling software tools need to isolate those TIMING POINTs to be used for one or several particular functions. Therefore, an attribute 'category' of the TIMING POINT entity is defined to describe the various above categories. In real applications, this attribute may be simply implemented using one or two flags (e.g. 'for driver scheduling').

3.2.5.3 Activation Points and Links

Real-time systems designed for operations control, traffic light priorities, track switches management or passenger information use a range of activation devices. The activation of the corresponding equipment is triggered by the passage of a vehicle at a certain point (e.g. a beacon) or on a certain link (e.g. a rail electrical section). The aim of the modelling is not to specify the various technical devices that may be installed to support different functions, but the representation of the necessary information to manage these devices and systems correctly. Therefore, the emphasis lies on the topology of elements necessary to operate them, rather than on the devices themselves.

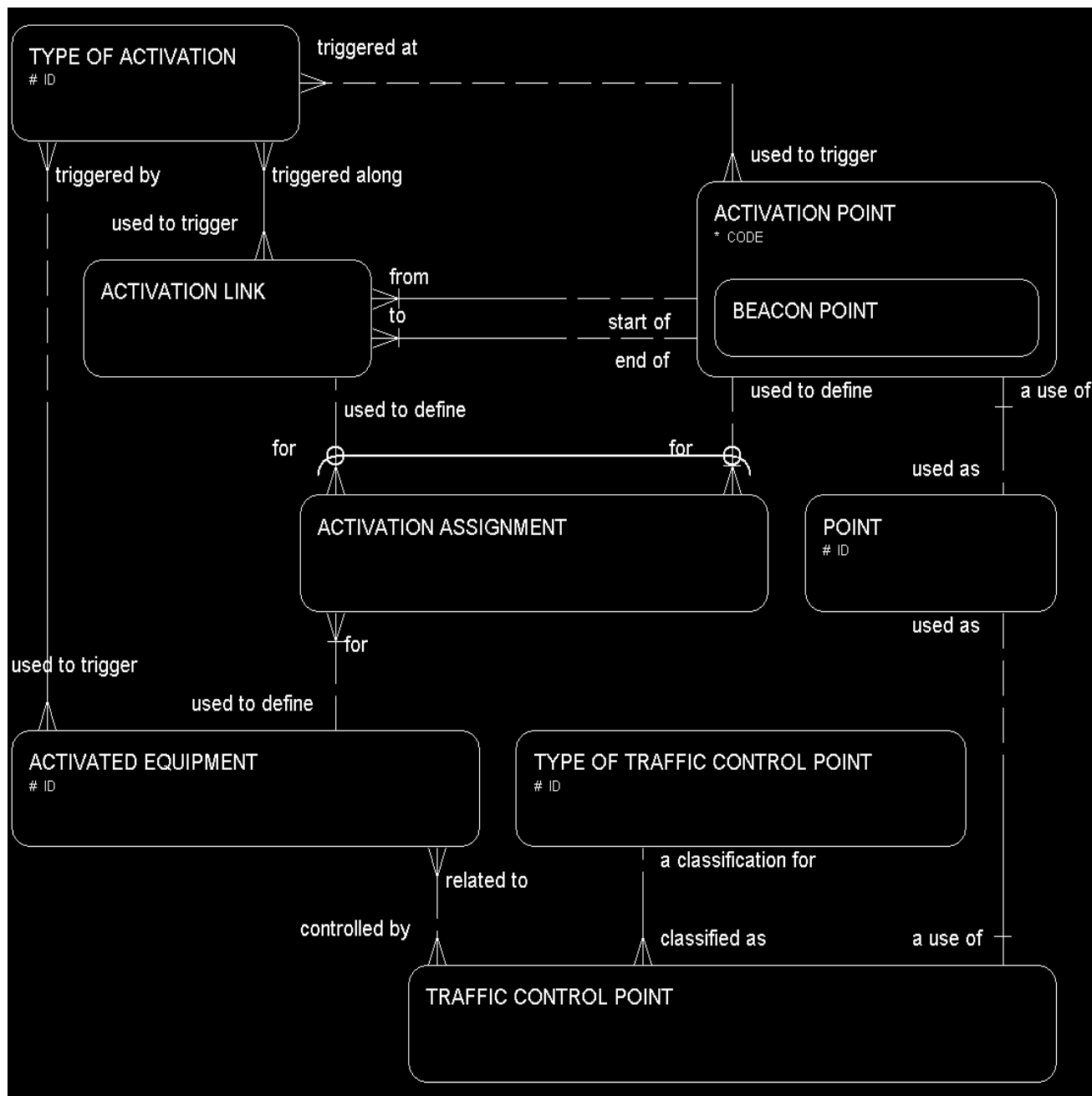


Figure 12 — Activation Facilities

An ACTIVATION POINT represents a POINT in the network that is used to activate some device when a vehicle passes it. Similarly, an ACTIVATION LINK represents a LINK used for such a function. The event of passing by may be recognised by a particular equipment (e.g. beacon), or may be calculated (e.g. by an AVM system). The appropriate control process, or other action, will be hence triggered.

A particular subtype of ACTIVATION POINT is the BEACON POINT. Infrared or electrical beacons are installed at particular locations along the tracks or at stops, for instance. They send out a specific 'code' (permanently or after having been activated by a vehicle passing by) to be used by a vehicle location system to adjust the actual location of vehicles.

Any device to be activated will be identified as an ACTIVATED EQUIPMENT. The entity ACTIVATION ASSIGNMENT is used to specify which ACTIVATED EQUIPMENT is alerted when a vehicle passes either by

an ACTIVATION POINT or an ACTIVATION LINK. The actions triggered by ACTIVATED EQUIPMENT are classified according to a TYPE OF ACTIVATION (traffic light priority or barrier opening request, interior lighting of vehicles in tunnels etc.). In some systems, the activation process consists of several messages. The first message triggers the activation once a vehicle passes a first point, whereas the activation will be cancelled as soon as the vehicle passes the second point. In addition, some systems need to refer to a certain approaching section for a pre-announcement (e.g. in traffic light priorities). Such processes are differentiated by distinct TYPES OF ACTIVATION.

An important case of activation is the process of priority requests sent to TRAFFIC CONTROL POINTs. This entity represents a POINT in the network where a traffic light (or another device used to influence the traffic flow) is located. The traffic lights installed at a TRAFFIC CONTROL POINT will be controlled by one or more traffic light controllers, specified as ACTIVATED EQUIPMENT. Such a controller may control more than one traffic light, all of which may be at the same crossroads, or may be distributed over several consecutive crossroads. TRAFFIC CONTROL POINTs are classified according to a TYPE OF TRAFFIC CONTROL POINT.

3.2.6 Generic Network Concepts

3.2.6.1 Sequence of Links

A path through the network may be defined as forming a sequence of LINKs. The entity LINK SEQUENCE represents a linear feature of which the shape is described by an ordered sequence of LINKs.

There are two alternative ways of describing a LINK SEQUENCE, depending on whether the LINKs used are unique between their end POINTs (e.g. ROUTE LINK) or not (e.g. TIMING LINK).

In the first situation, between two consecutive POINTs in a LINK SEQUENCE, there cannot be more than one LINK (such a LINK may be identified by its two end POINTs only). In such a case, a LINK SEQUENCE is described as a sequence of POINTs, with LINKs in between. The LINK SEQUENCE is defined by an ordered set of POINTs IN LINK SEQUENCE (e.g. POINTs ON ROUTE defining a ROUTE). Each of these POINTs IN LINK SEQUENCE is identified by the attribute 'order'.

As a constraint, between each pair of POINTs used consecutively as POINTs IN LINK SEQUENCE, there shall be a LINK valid for connecting the POINTs IN LINK SEQUENCE under consideration (e.g. TIMING LINK between TIMING POINTs IN JOURNEY PATTERN). As there is no alternative LINK between two consecutive POINTs IN LINK SEQUENCE, this sequence is sufficient for defining the shape of the LINK SEQUENCE.

In other situations, several LINKs may exist between two POINTs in a LINK SEQUENCE (i.e. a LINK shall have its own identifier). In such a case, a LINK SEQUENCE is described as a sequence of LINKs. The LINK SEQUENCE is defined by an ordered set of LINKs IN LINK SEQUENCE. Such a LINK IN LINK SEQUENCE, identified by the attribute 'order', specifies which one of the possible LINKs between the POINTs under consideration is used. As a constraint, any succeeding LINK in a LINK SEQUENCE shall start at the same POINT at which the preceding LINK ends.

The entity TYPE OF LINK SEQUENCE defines the different functions a LINK SEQUENCE may be used for. Some of these types are explicit in the reference model (ROUTE, JOURNEY PATTERN, TRIP PATTERN). Other types may be added according to the user requirements (e.g. "road", "border line").

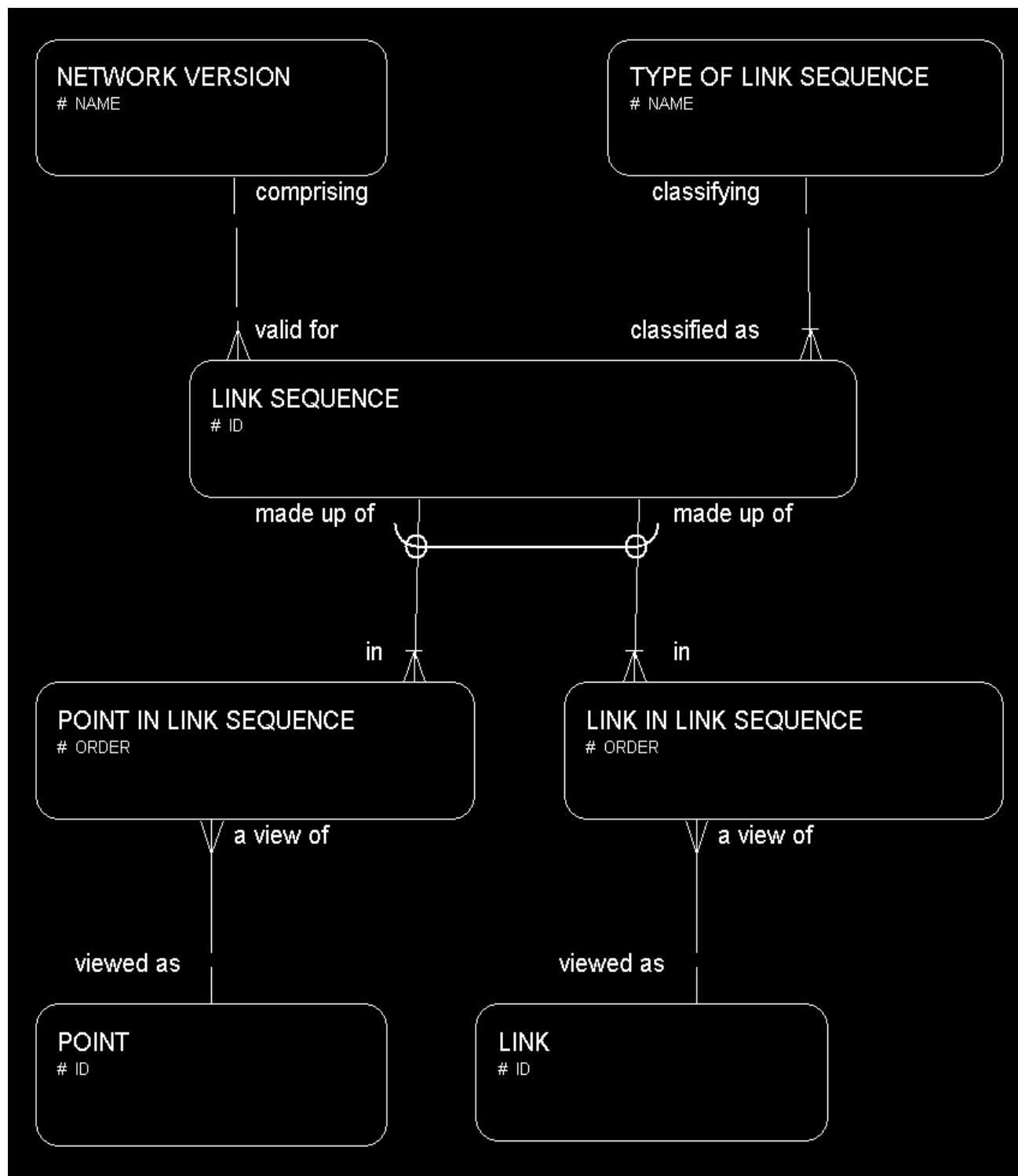


Figure 13 — Link Sequences

3.2.6.2 Grouping

Objects like POINT, LINK, and LINK SEQUENCE may be grouped by the corresponding entities GROUP OF POINTS, GROUP OF LINKS, and GROUP OF LINK SEQUENCES respectively.

Each of these groups shall be classified by only one identifying PURPOSE OF GROUPING. Such a group is the association of specific elements of a given type into a group needed for a particular functional purpose (e.g. WIRE ELEMENTs having a specific power supply type). The PURPOSE OF GROUPING refers to the functional purpose for which the associated groups of elements are defined.

The STOP AREA represents one of the most significant GROUPS OF POINTS. Several STOP POINTs will sometimes be grouped together and referred to by a common name. This will often be at a crossroads where different lines use different stops which are close to each other, or at central stops, for example at a railway station. The STOP AREA entity is defined to model this grouping of STOP POINTs, for scheduling or for passenger information.

The generic concept of grouping POINTs (for instance) may be expressed by explicit entities defined for a particular function in the network, like STOP AREA. However, the necessity of grouping points will also arise with view to various other purposes (e.g. data modelling solutions to cover multi-modal operations). Both the generic and the semantically explicit entities are present in the network description model.

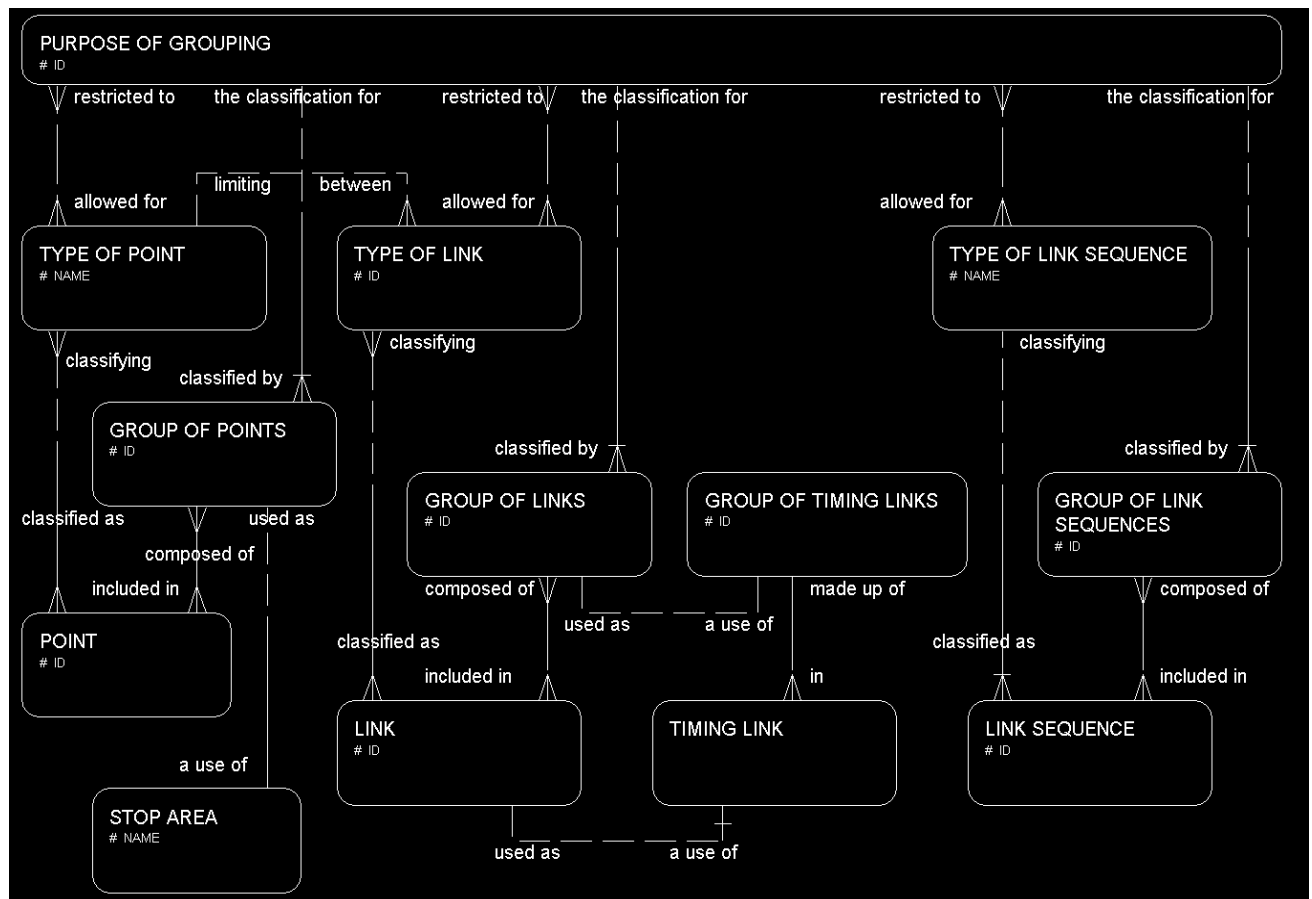


Figure 14 — Grouping

The assignment of elements to groups of such elements is represented by many-to-many relationships. This means that each element may belong to more than one group, not only with view to different PURPOSES OF GROUPING, but also within the same type.

Groups of elements may be restricted to elements of only one type, i.e. of a class of objects grouped together for a specific purpose. For instance:

- STOP AREAs and TARIFF ZONES will be made up of STOP POINTs exclusively;
- GROUPs OF LINKS may be restricted to links of one particular type (e.g. TIMING LINKs in a GROUP OF TIMING LINKS, group of LINKs where the inner lighting is automatically activated etc.);
- a GROUP OF LINK SEQUENCES may be restricted to ROUTEs controlled (or not) by an AVM system.

3.2.6.3 Zones

A certain network structure may consist not only of POINTs, LINKs and LINK SEQUENCEs but may contain in addition two-dimensional objects, i.e. areas, or more complex objects, which are combinations of other objects, for instance of different dimensions.

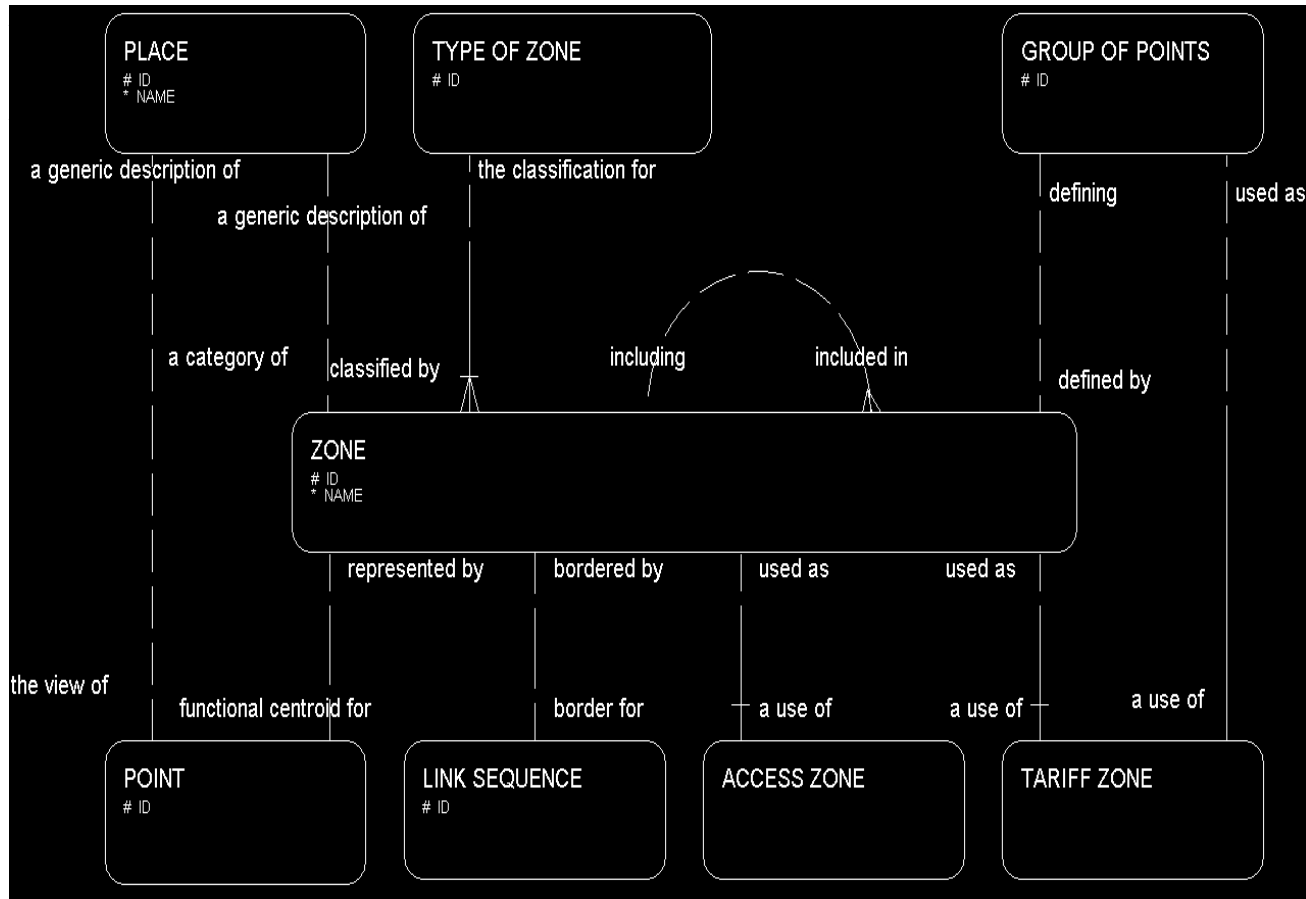


Figure 15 — Zones

A ZONE may also be defined as a geometric area, bordered by a LINK SEQUENCE. In such a case, this LINK SEQUENCE has to be a closed one (i.e. the first and last POINTs IN LINK SEQUENCE shall be a view of the same POINT).

Both definitions may coexist: an ACCESS ZONE, for instance, may include a group of STOP POINTs and be defined as a geometric area around these points.

A ZONE may be defined as including other smaller ZONES. This is expressed by the circular relationship on this entity. This may be the case, for instance, for ZONES such as ADMINISTRATIVE AREAs.

A ZONE may be represented by a single POINT. Within one particular layer, this representing POINT has to be unique.

Due to the variety of solutions offered by the modelling of zones, users of the reference model will select the relevant parts, according to their needs. A specific implementation will require certain constraints in order to maintain the consistency. For instance, the direct relationship between TARIFF ZONE and GROUP OF POINTS may be redundant with the relationship of ZONE with GROUP OF POINTS.

3.2.6.4 Places

In passenger information systems, the origin or destination of a passenger trip may be formulated in various ways, often rather vague. It may be for instance:

- a public site, known by the user by a name;
- a stop point or a stop area;
- a urban environment: neighbourhood, housing estates, administrative entity;
- a street;
- an address;
- a precise point, e.g. plotted on a digital map or selected by an operator.

The entity PLACE is a generic description of all geographical elements that may be used to define the origin and the destination of a passenger trip. In particular, a PLACE may be identical to an instance of POINT, STOP AREA or ZONE.

3.2.6.5 Complex Features

It is often necessary to define a group of objects of different types in a simpler representation, omitting the details. For instance, a train station composed of tracks, platforms, vending machines etc., or a depot composed of halls, parking areas, lanes, maintenance facilities etc., are viewed in some layers as single POINTs. This is described by the entity COMPLEX FEATURE (named by analogy with the GDF standard).

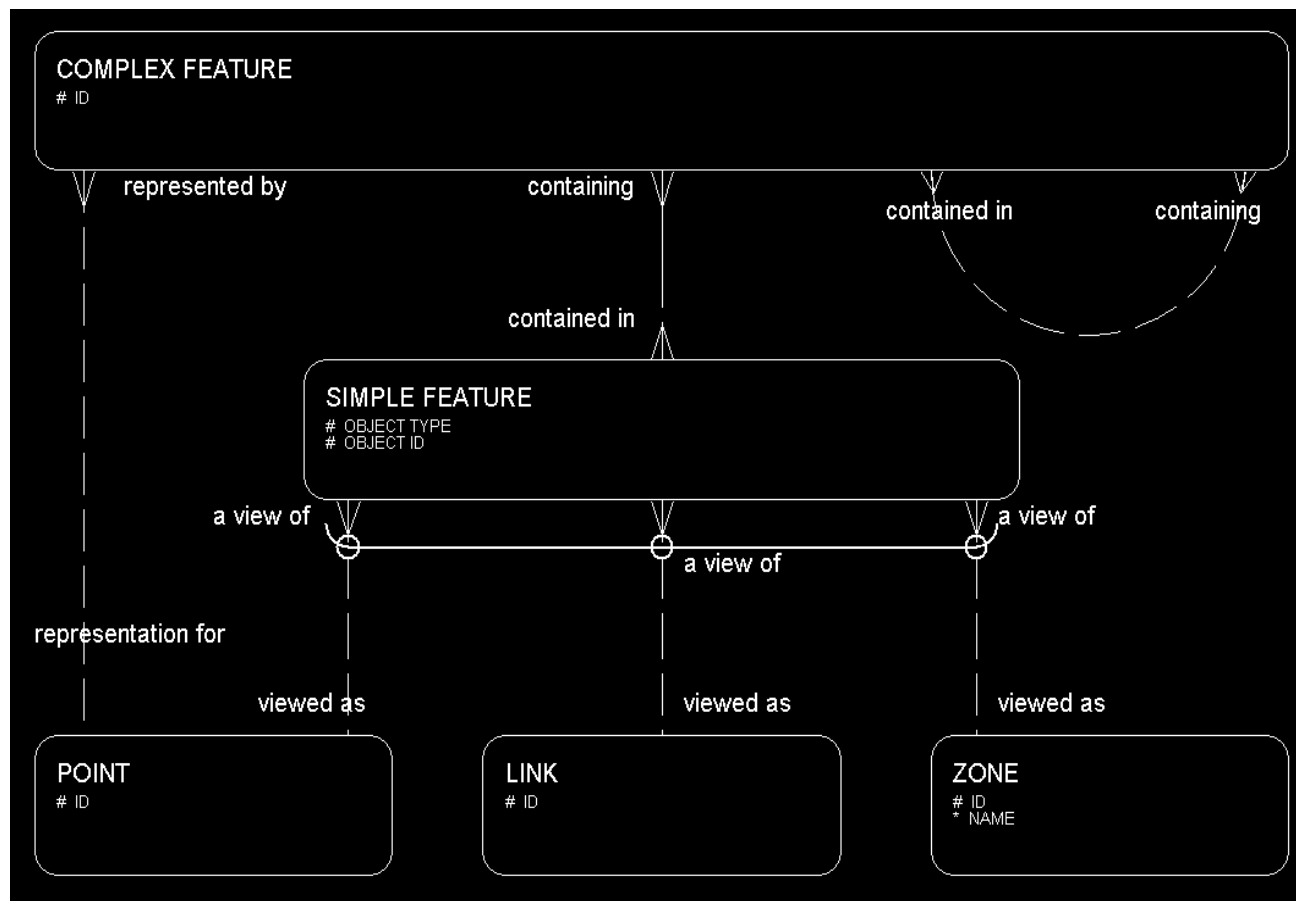


Figure 16 — Complex Features

A **COMPLEX FEATURE** is composed of one or more **SIMPLE FEATURES**. A **SIMPLE FEATURE** is identical to an instance of either a **POINT**, a **LINK**, or a **ZONE**. As the entity **SIMPLE FEATURE** is introduced only for modelling the complexity of the **COMPLEX FEATURE**, it may be left out in real implementations.

A **COMPLEX FEATURE** usually combines elements of different kinds as **POINTS**, **LINKS**, **ZONEs** (each of them not necessarily of the same type), and even other **COMPLEX FEATURES**. It should not be mixed up with a group of elements (e.g. **GROUP OF POINTS**), combining elements of one single type only (e.g. one **GROUP OF LINKS** may be all **LINKS** in a tunnel, which is not a **COMPLEX FEATURE**).

As a **ZONE**, a **COMPLEX FEATURE** may be represented by a single **POINT**.