

Road Transport and Traffic Telematics — Public Transport — Reference Data Model

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According to the replies received by the end of the review period, the responsible BSI Committee will decide whether to support the conversion into a European Standard, to extend the life of the prestandard or to withdraw it. Comments should be sent in writing to the Secretary of BSI Technical Committee EPL/278, Road transport informatics, at 389 Chiswick High Road, London W4 4AL, giving the document reference and clause number and proposing, where possible, an appropriate revision of the text.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled “International Standards Correspondence Index”, or by using the “Find” facility of the BSI Standards Electronic Catalogue.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the ENV title page, pages 2 to 414 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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English version

Road Transport and Traffic Telematics — Public Transport — Reference Data Model

Telematik für den Straßentransport und
Verkehr — Öffentlicher Verkehr —
Referenzdatenmodell

This European Prestandard (ENV) was approved by CEN on 8 October 1997 as a prospective standard for provisional application.

The period of validity of this ENV is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the ENV can be converted into a European Standard.

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

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1 Foreword

This European Prestandard has been prepared by Technical Committee CEN/TC 278 “*Road transport and traffic telematics*”, the secretariat of which is held by NNI.

This prestandard was prepared by the work area Transmodel of the EuroBus project and by the DRIVE II task force HARPIST. The EuroBus/Transmodel and HARPIST kernel team is considered as a subgroup of Working Group 3 of CEN TC278.

It has been approved by Topic Group 6 (TG6, entitled “Public Transport Data Models”) of the EC- Drive II programme and by two validation seminars open to participants in various DRIVE II projects, to European public transport operators and to other public transport experts.

It is based upon earlier results reached within the Drive I Cassiope project and the ÖPNV data model for public transport, a German national standard.

The different organisations that have technically contributed to the preparation of this prestandard are the partners of EuroBus/Transmodel and the HARPIST task force:

- Beachcroft Systems (UK),
- CETE-méditerranée (F),
- CTA Systems (NL),
- Ing. Conseil B. Bert (F),
- Koninklijk Nederlands Vervoer (NL),
- Leeds University (UK),
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- VSN Groep (NL).

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

This prestandard reflects 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.

Annex A of this document is normative, Annex B and Annex C are informative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this European Prestandard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

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2 Introduction

2.1 An efficient public transport operation and operations management, as well as attractive and accurate passenger information are the main objectives sought by public transport companies. The solution to reach this goal goes through the integrated approach, i.e. the possibility of integrating more easily application systems developed by different suppliers into one system (interoperability). The need for the integration of systems and the benefit that emanates from the interoperability of applications was the starting point of the research in the field of data modelling for public transport.

2.2 The integrated approach enables, for instance, a reliable exchange of information between different software products. This approach has at the same time to allow for the choice of the best adapted software for each company, without being bound to one single supplier. The experience shows, however, that software products of different suppliers are often incompatible or difficult to integrate. The operators are therefore either forced to run several products separately, or to rely on one specific supplier and its range of products, that may not be well adapted as a whole to a given company.

2.3 This document presents a data model for public transport, i.e. a description of the data structure, that has to be considered as the basis for an integrated system within a public transport company.

2.4 The prestandard presented here is dedicated to provide a solution to operators and software suppliers that now want to proceed towards an integrated system. Its aim is also to be a support for future developments.

2.5 An informative Annex C presents an executive summary of the model in order to allow to quickly understand the benefits of the model and its contents.

3 Scope

3.1 The prestandard proposed here has been developed independently from any specific application system. It takes into account expertise from the different existing practices of public transport operators throughout Europe.

3.2 It is designed to be a structure to enable interoperability between different commercial systems and thus to open the market.

3.3 The data model presented here has to be considered as a reference at the conceptual level. This means in particular, that no statement is being done about the logical level and thus about the way the model will be implemented.

3.4 This document presents the prestandard using the entity-relationship methodology, i.e. as a series of diagrams, composed of data (entities) and relationships between data (entity-relationship diagrams), and a data dictionary, i.e. a list of entity definitions together with main data attributes.

3.5 The methodology and the specific conventions used, should not be understood as a mandatory element of the standard, but as a tool for its representation.

3.6 The approach followed concentrated on the semantics of the Public Transport domain. It is not contradictory with the object — oriented approach that might be developed in future and represents a basis for the object — oriented developments. These object — oriented developments need a large amount of additional work and hence have not been taken into account in the present document.

3.7 The data model presented concerns the following domains:

- Scheduling
- Personnel disposition
- AVM
- Passenger information
- Fare collection
- MIS/Statistics.

An interface to the data model developed for the GDF standard is also described.

4 Normative references

This European prestandard takes into account the work undertaken in CEN TC278/WG7.2 concerning the GDF-norm (version 2.2).

5 Definitions

attribute

property of an entity

AVM

automated vehicle monitoring: computer-aided control of the transportation process, in this document corresponding to the functional area “perform and control the driving process”. Terms used as synonyms: VSCS (Vehicle Scheduling and Control System), AVL (Automated Vehicle Location and Control)

AVM data model

data domain, describing the data structures needed for the control of the actual public transport operation

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 the system can be based

conceptual level

in the context of data modelling, the conceptual data model

database

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

data domain

data structure (in this document, 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

data model

description of a real world domain in terms of data

entity

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

entity-relationship (E-R) methodology

methodology allowing for the representation of a data model in terms of entities and relationships

fare collection

all activities related to the collection of money from passengers, composed of the following functional areas: “define a fare policy”, “organise sales”, “operate sales”, “validate/check and charge”, “manage money transactions”

fare collection data model

data domain supporting a subset of fare collection functions

function

activity. In this document, a subactivity of a functional area

functional area

an arbitrarily defined set of activities, used, in this document, to define the objectives and limits of the data model. The definitions are given below

functional area “define a fare policy”

definition of a specific fare system to be used (distance, time or area related etc)

functional area “manage drivers”

optimisation of the use of the available drivers. “Personnel management” makes available the required number of drivers according to the rosters. “Transportation” is responsible for the optimal use of the drivers

functional area “manage money transactions”

activities related to the collecting of the money paid for the delivered service by passengers or organisations (clearing house, subsidizing authority) and distributing these revenues between the service suppliers

functional area “manage statistical results”

administration of the data collected during the operational process, management of the database(s) in order to provide relevant data for the company processes, and issuing of reports on the operations for various levels of the management

functional area “operate sales”

sale transactions of fare products and management of travel document issuing (retail shops, vending machines)

functional area “organise sales”

definition and management of the sales network including sales outlets and contracts with retailers (if any)

functional area “perform and control the driving process”

functions related to the driving and transportation of passengers according to given instructions (schedule), including all activities that support the driving process (traffic light priority, track switching, bay selection, advance/delay advice etc.). Monitoring of the driving process and its control in case of deviations

functional area “plan detailed timetables”

translation of the broad service requirements (derived, for instance from the functional area “plan the service to be offered”) into detailed timetables that give information on the exact timing of the service(s) on each type of day and for each time band

functional area “plan the service to be offered”

take all global decisions regarding the quality of the service that has to be offered, within the limits of budgets and other guidelines from management (define minimum and maximum travel times, interchange points etc.

functional area “prepare driver rosters”

composition of sequences of duty elements into duties (weeks, months) according to rules governing the number of hours worked in a period of several days, the allocation of rest days, the rotation of evening duties etc. and finally assignment of names of the drivers to the blocks

functional area “provide passenger information on actual service”

functions providing passive and on-request information on the actual service and on the actual (traffic) conditions

functional area “provide passenger information on planned service”

functions providing information on the planned service (i.e. information available before the 24 hours operational cycle) to passengers, either by display/video or audio (incl. phone desks). This information can be passive or delivered on request

functional area “(re)design the network”

take all global decisions regarding the network structure, taking into account the defined quality of service that has to be offered and the guidelines from management (budgets, policy)

functional area “schedule driver duties”

all activities necessary to define duty elements (parts of working days) that match the planned vehicle schedules, taking into account the general labour agreements

functional area “schedule vehicle blocks”

chaining and assigning of journeys to (logical) vehicles, allocation of the type(s) of vehicles to journeys, and optimising the use of the vehicles by switching them between lines

functional area “validate/check and charge”

activities related to the verification that the passenger is entitled to ride. Calculation of fare product prices, taking into account the given fare structure and the corresponding transport network and collection (and/or marking) of the travel document, or debiting of an amount of fare, corresponding to the planned trip and to the acquired passenger rights (e.g. user profile)

GDF

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

GDF database

a 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)

interoperability

the ability of (sub)systems to interact with another (sub)system according to a set of predefined rules (interface)

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

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

logical level

in the context of data modelling, the logical data model

management information system (MIS)

an application system providing the company management with 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

MIS data model

data domain supporting the use of management information systems and generation of company statistics. It is in principle related to all functional areas of a company, with particular reference to the functional area “manage statistical results”

oracle CASE-tool

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

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

passenger information

all activities related to informing the users of the transportation services, corresponding in this document to the functional areas “provide passenger information on planned service” and “provide passenger information on actual service”

passenger information data model

data domain supporting a subset of passenger information functions

personnel disposition

all activities related to the mid term and short term management of drivers, corresponding in this document to functional area “manage drivers”

personnel disposition data model

data domain supporting the functional area “manage drivers” (personnel disposition)

¹⁾ Richard Barker
CASE*METHOD — Entity Relationship Modelling
Addison-Wesley Publishing Company
Wokingham, England, 1989

relational data model

a 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

scheduling

all activities related to the tactical planning of transportation, corresponding in this document to the following functional areas: “plan detailed timetables”, “schedule vehicle blocks”, “schedule driver duties”, “prepare driver rosters”

scheduling data model

data domain built to support scheduling activities. This part of the model is also relevant for other functional areas

6 Requirements

6.1 General

6.1.1 According to the conventions of the chosen method for entity relationship modelling, the conceptual data model is described here by

- entity relationship diagrams in Oracle notation,
- textual explanations related to each of the diagrams,
- a report giving entities and their descriptions,
- a report giving entities, attributes and primary keys.

6.1.2 Textual explanations and diagrams are presented below in seven sections:

- Scheduling data model,
- Personnel Disposition data model,
- AVM data model,
- Passenger Information data model,
- Fare Collection data model,
- MIS data model,
- Interface to GDF.

6.1.3 Reports extracted from the data dictionary which holds the basic information for the diagrams are presented in Annex A (normative).

6.1.4 The methodology together with a list of constraints expressing consistency and integrity conditions, a detailed step-by-step presentation of the data model, and the functional model are presented in Annex B (informative).

6.2 Scheduling Data Model

6.2.1 General

6.2.1.1 The Scheduling domain covers the data needs of the functions that are related to the planning of the network and operations.

6.2.1.2 According to the functional breakdown, the Scheduling data model covers the following functional areas:

- plan detailed timetables,
- schedule vehicle blocks,
- schedule driver duties,
- prepare driver rosters.

6.2.1.3 The data needs of functions within the functional areas

- (re)design the network,
- plan the service to be offered

will also be partly described in the data model, without covering totally all the information needed by those functions.

6.2.1.4 A certain part of the Scheduling data model consists of information which is relevant not only for the Scheduling domain, but also for other domains, such as Automated Vehicle Monitoring or Passenger Information. The model parts describing the topology of the network, the lines and journeys, the run times and wait times etc. are used by functions in various domains, but are presented here in the Scheduling section, as they are needed at the beginning of any model presentation.

6.2.1.5 The following description of the Scheduling data model is subdivided by logical subjects with some textual explanations of each of the entities associated with these subjects, followed by one or two entity relationship diagrams illustrating the model parts in question providing a special view on these subjects.

6.2.2 Topology

6.2.2.1 Points

6.2.2.1.1 Points are the basic elements used to define the spatial structure of a public transport network. Thus, an entity POINT is defined as the most basic entity of the network model. A POINT is seen as the smallest identified location in space, and it marks the location of bus stops, garages or other types of POINTs.

6.2.2.1.2 A TYPE OF POINT is defined as an entity to describe common functionality for a number of POINTs. Each POINT is functionally classified as being of one or more types. To aid modelling, certain TYPEs of POINT are regarded as important enough to be additionally described by a separate entity. The most important of these are STOP POINT, TIMING POINT and MAPPING POINT.

6.2.2.1.3 A STOP POINT is the location of a bus stop where passengers can board or alight from vehicles. This may be restricted to boarding or alighting only.

6.2.2.1.4 A TIMING POINT is a location for which timing information necessary to build schedules may be recorded. Some companies may want to define run times (or wait times) not between (or for) all the STOP POINTs in the network, but only for a selection of these. The times related to the rest of the stops would then be derived by interpolation. It is also the case that timing information may be necessary for POINTs which are not STOP POINTs, but somewhere else on a route.

6.2.2.1.5 A MAPPING POINT is a POINT against which mapping information may be stored. This may be *topological information*, where there is no geographical reference, or *geographical information* to relate these points to a Geographic Data Format or other description of the road network or some other location referencing system such as co-ordinates.

6.2.2.1.6 Any one POINT may be viewed as of more than one type. For example, the same POINT may be a MAPPING POINT, a TIMING POINT and maybe a STOP POINT as well.

6.2.2.2 Stop Areas

6.2.2.2.1 Several STOP POINTs will sometimes be grouped together and referred to by a common name. This will often be at a cross-roads 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, which may be used not only for scheduling, but also for passenger information.

6.2.2.2.2 In the case of stops which are close together at opposite sides of a road, used by the two directions of one line, a STOP AREA need not be defined to express that these two STOP POINTs are related to each other, and known under the same name to the public. A reference between those two POINTs may be defined instead, which is represented as a circular relationship of the POINT entity in the model. One POINT may be referenced by more than one other POINT, so this is an alternative for modelling STOP AREAs also.

6.2.2.3 Links

6.2.2.3.1 Between two POINTs of any type a LINK may be defined to store spatial information (the distance a vehicle will cover crossing this link). A LINK is oriented from (and uniquely identified by) its start POINT and end POINT.

6.2.2.3.2 Timing information (run times) will be stored against TIMING LINKs which are defined between two TIMING POINTs.

6.2.2.3.3 ROUTE LINKs may be defined between two MAPPING POINTs. These are used to define physical paths through the network. They may be used on a very detailed level, in a way which allows data interchange with applications providing geographical information according to the GDF standard (see section 6.8 Interface to the GDF Data Model). Companies not wanting to relate the network to detailed road data can define their network model using fewer ROUTE LINKs.

6.2.2.3.4 Apart from its start and end POINTs, other POINTs may be defined to be located on a LINK as intermediate points. These may be for instance for AVM purposes, or for passenger or driver information. They are modelled by the POINT ON LINK entity. Each POINT ON LINK is identified by the LINK it is located on and 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.

6.2.2.3.5 Public transport LINKs may be classified by LINK TYPEs, which can be used to assign certain properties to particular LINKs, or to maintain a categorisation of LINKs under various different criteria. The PURPOSE OF LINK TYPING expresses a category of classifications for LINKs, e.g. referring to scheduling or AVM purposes, geography, or operational constraints.

6.2.2.3.6 The LINK TYPING entity shown on [Figure 1 — Topology](#) organises the assignment of one LINK TYPE (at most) to a LINK for each specified PURPOSE OF LINK TYPING. LINK TYPEs are associated with public transport LINKs only, and do not refer to TIMING LINKs or ROUTE LINKs, which represent separate concepts.

6.2.2.3.7 Examples of LINK TYPEs to be assigned to LINKs 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, and maybe other types which express the kind of journeys these LINKs have been defined for. For another purpose, it may be useful to distinguish between LINKs with separate bus lanes and without. For AVM purposes, LINK TYPEs may be used to express the specification of standard activations to control e.g. announcements, ticket validators, passenger information etc. which are identical for each LINK of a given LINK TYPE.

6.2.2.4 Garages

6.2.2.4.1 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.

6.2.2.4.2 One or more POINTs are used to define a GARAGE. These POINTs may be related to MAPPING POINTs which would give the location of the GARAGE.

6.2.2.5 Network Versions

6.2.2.5.1 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 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.

6.2.2.5.2 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 must be accessible in parallel for the network planning process.

6.2.2.5.3 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 which will be valid for the same period of time is kept separate by membership of the same NETWORK VERSION.

6.2.2.5.4 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, MAPPING POINT, ROUTE LINK, TIMING POINT and TIMING LINK. TYPE OF POINT and GARAGE are not related to a version, as there seems to be no need to record different definitions simultaneously, but the definition of a STOP AREA may have to be modified if a new NETWORK VERSION becomes valid.

6.2.2.5.5 The starting validity of a NETWORK VERSION is given by a specific date which is expressed by a relationship to the CALENDAR DAY entity. The end of the validity period can be derived as the latest date which is earlier than the start date of the next NETWORK VERSION recorded. This definition prevents any two NETWORK VERSIONs from overlapping in time, and for each date the NETWORK VERSION valid on that day is uniquely defined.

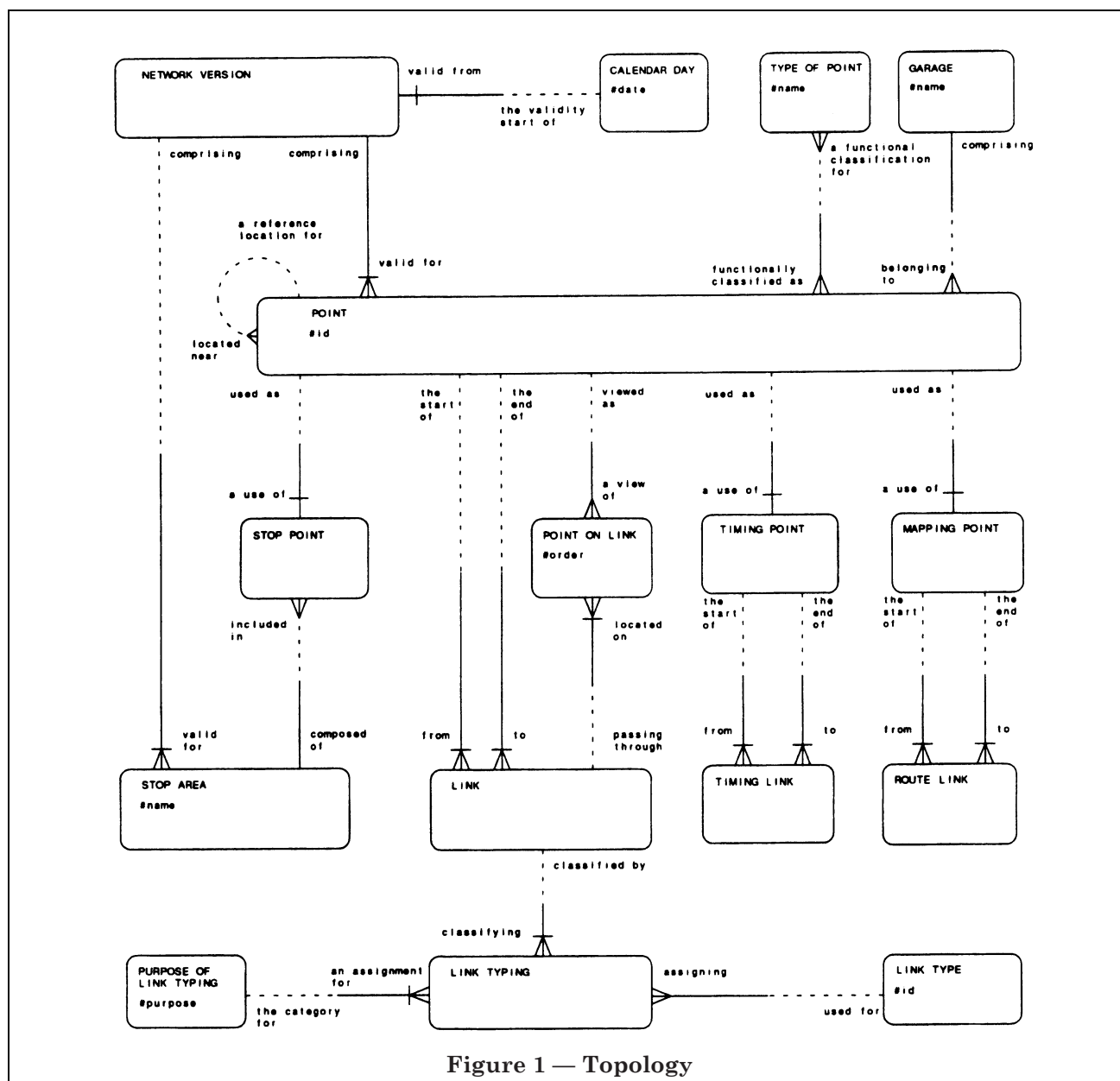


Figure 1 — Topology

6.2.3 Lines

6.2.3.1 Routes

6.2.3.1.1 A ROUTE is a physical path through the road network which vehicles may take for their operation. It is independent of the stops on the route and is defined by a sequence of MAPPING POINTs, which must include enough MAPPING POINTs to identify the physical path uniquely, but may include many more MAPPING POINTs and may relate the ROUTE to a geographical database or road map.

6.2.3.1.2 There must be ROUTE LINKs available to proceed from one MAPPING POINT of this sequence to the next.

6.2.3.1.3 Users may describe the public transport network with reference to the road network and geography, but they do not need to. If no geographical mapping is applied, it is the responsibility of users to define the itinerary unambiguously. If GDF-based applications are used, users should ensure that ROUTE LINKs accessible by these applications do not overlap on the same physical path.

6.2.3.1.4 There may be more than one chain of public transport LINKs covering the same physical path.

6.2.3.1.5 A ROUTE may pass through the same MAPPING POINT more than once, in the case of a loop. Therefore, the POINT ON ROUTE entity (which forms an ordered list to define the itinerary of the ROUTE) has an order as its unique identifier and a relationship to MAPPING POINT and thus to POINT, to refer to the location which the ROUTE passes through.

6.2.3.1.6 The general orientation of a ROUTE may be described by an expression like “outwards”, “backwards” etc., often referring approximately to the city centre. These classifications may lead to the definition of arbitrarily chosen DIRECTIONS, which may be used for passenger information, but are also relevant for scheduling. Two DIRECTIONS may be defined as being opposite to each other.

6.2.3.1.7 ROUTE LINKs used as building elements for the ROUTE network may also be classified by their DIRECTION. Two ROUTE LINKs defined between the same MAPPING POINTs, but in the reverse order, must have opposite DIRECTIONS (if any).

6.2.3.1.8 The definition of a ROUTE may vary between different validity periods of network data. Therefore, the ROUTE entity is dependent on the NETWORK VERSION. Each POINT ON a particular ROUTE consequently must be a view of a (MAPPING) POINT which belongs to the same NETWORK VERSION as that ROUTE itself.

6.2.3.2 *Journey Patterns*

6.2.3.2.1 There may be different patterns of working on the same ROUTE. Vehicles may stop at different STOP POINTs during different journeys on that ROUTE, and a different selection of TIMING POINTs may be used to schedule these different journeys. These distinct patterns of working are expressed by the JOURNEY PATTERN entity. Being dependent on the ROUTE it is on, a JOURNEY Pattern is implicitly associated with a particular NETWORK VERSION.

6.2.3.2.2 The working of a JOURNEY PATTERN is defined by an ordered list of POINTs, which must be STOP POINTs or TIMING POINTs. As the same POINT may occur more than once in the same JOURNEY PATTERN, a POINT IN JOURNEY PATTERN (similar to a POINT ON ROUTE) is identified by that JOURNEY PATTERN together with an order. A relationship to POINT determines the STOP POINT or TIMING POINT which is related to that order.

6.2.3.2.3 There must be a LINK between each pair of consecutive POINTs IN JOURNEY PATTERN. There may be more than one chain of LINKs overlapping or covering the same physical path. Distances may be given for the LINKs; and must be given if not all the POINTs IN JOURNEY PATTERN are defined as TIMING POINTs, in order to allow for interpolation of passing times. Distances may also be needed for other purposes under certain circumstances (e.g. for GDF-based applications).

6.2.3.2.4 Sometimes operators may wish to define run times at a very detailed level. To be able to do this, under certain circumstances (if a journey passes through the same TIMING LINK more than once) an ordered list of TIMING LINKs must be associated with this specific JOURNEY PATTERN. The TIMING LINK IN JOURNEY PATTERN is introduced only to cater for the needs of these rare cases (see the Journey Times section **6.2.6**).

6.2.3.2.5 Usually journeys are scheduled using the first POINT IN JOURNEY PATTERN as a timing reference (which will then have to be a TIMING POINT). Operators are given the opportunity to choose another timing reference by a particular relationship which specifies the TIMING POINT IN JOURNEY PATTERN from which the journeys on this particular JOURNEY PATTERN will be timed.

6.2.3.3 *Lines*

6.2.3.3.1 A LINE is a grouping of ROUTEs which is generally known to the public by a similar name or number. These ROUTEs are usually very similar to each other from the topological point of view, being variants of a core route with some deviations on certain parts only. Often the vehicle journeys on these ROUTEs are scheduled jointly with tight synchronisation in order to provide a regular service on this specific LINE. They are often grouped together for presentation of the timetable to the public.

6.2.3.3.2 Two ROUTEs defined by the same MAPPING POINTs (and thus using the same physical path), but with opposite DIRECTIONS, will generally belong to the same LINE.

6.2.3.4 *Groups of Lines*

6.2.3.4.1 LINES may be grouped into GROUPs OF LINES for particular purposes, such as fare collection, day type assignment, merged timetables or vehicle or driver scheduling. Each GROUP OF LINES must be defined for only one purpose, which is expressed by a TYPE OF LINE GROUPING.

6.2.3.4.2 A LINE may be in different groups for different purposes, and may also belong to more than one GROUP OF LINES for one single purpose. It is the responsibility of users to assure consistent groupings, suitable for the specific purpose in question.

6.2.3.5 *Common Sections*

6.2.3.5.1 In many public transport networks, particularly in big cities, there will be parts of the network where ROUTEs (and JOURNEY PATTERNS) overlap. In other words, line bundling will occur where passengers have the choice among several LINES to reach their destination.

6.2.3.5.2 The topological aspect of line bundling is not taken into account in the conceptual model, as this is derived information. On the other hand, a synchronised schedule will probably be offered for the most relevant parts of network sections with bundled LINES. These relevant parts may be chosen arbitrarily by the schedulers, and they need not cover the whole length of the common itinerary of the ROUTEs and JOURNEY PATTERNS in question. Some common itineraries may not be chosen for schedule synchronisation at all.

6.2.3.5.3 Therefore, an entity COMMON SECTION is introduced in order to define those network sections where bundled LINES have to be considered jointly in the scheduling process. A COMMON SECTION is determined by a set of JOURNEY PATTERNS (which give details on the stops on the ROUTEs on these LINES), together with a set of POINTs, each of which has to be a view of a POINT IN one of those JOURNEY PATTERNS.

6.2.3.5.4 The purpose of defining a COMMON SECTION is to inform the scheduling system of the STOP POINTs and TIMING POINTs commonly used by different JOURNEY PATTERNS which are worth taking into account for service optimisation. Apart from that, the definition of COMMON SECTIONS may be needed to specify the parts of the network where an AVM system has to take care of the common service with respect to the control of vehicle headways.

6.2.3.6 *Companies, Departments and Organisational Units*

6.2.3.6.1 The COMPANY entity is used to store information concerning the public transport companies which are themselves involved in the service area covered by a particular model application.

6.2.3.6.2 A COMPANY will consist of several departments. Those departments which operate specific branches of the public transport system are modelled in the OPERATING DEPARTMENT entity.

6.2.3.6.3 An OPERATING DEPARTMENT will consist of one or more ORGANISATIONAL UNITs which are responsible for the scheduling process, restricted to a defined number of LINES. The use of ORGANISATIONAL UNITs for other purposes is described in section 6.2.8.5.

6.2.3.6.4 The OPERATING DEPARTMENT usually comprises all the ORGANISATIONAL UNITs responsible for those LINES in the network which are served by the same means of transport (e.g. bus, tram, metro), or using the same type of operation (e.g. regular service, express service, night service).

6.2.3.6.5 If several public transport companies are operating in the same service area, one LINE may be operated by two or more ORGANISATIONAL UNITs of OPERATING DEPARTMENTS which belong to different COMPANYS.

6.2.3.6.6 In some cases, the organisational aspect of responsibilities for planning and operation need not necessarily be present in the model for a public transport company. Therefore, the relationships to (and the existence of) these organisational entities are optional.

6.2.3.6.7 This model is intended primarily for use within one operating company. However, other organisations, such as those providing passenger information about a number of different operating companies, will need an amendment to the usual model. In these cases, vehicle journeys should be identified by a relationship to an ORGANISATIONAL UNIT, which is not present in the current model (see the Journeys section 6.2.4).

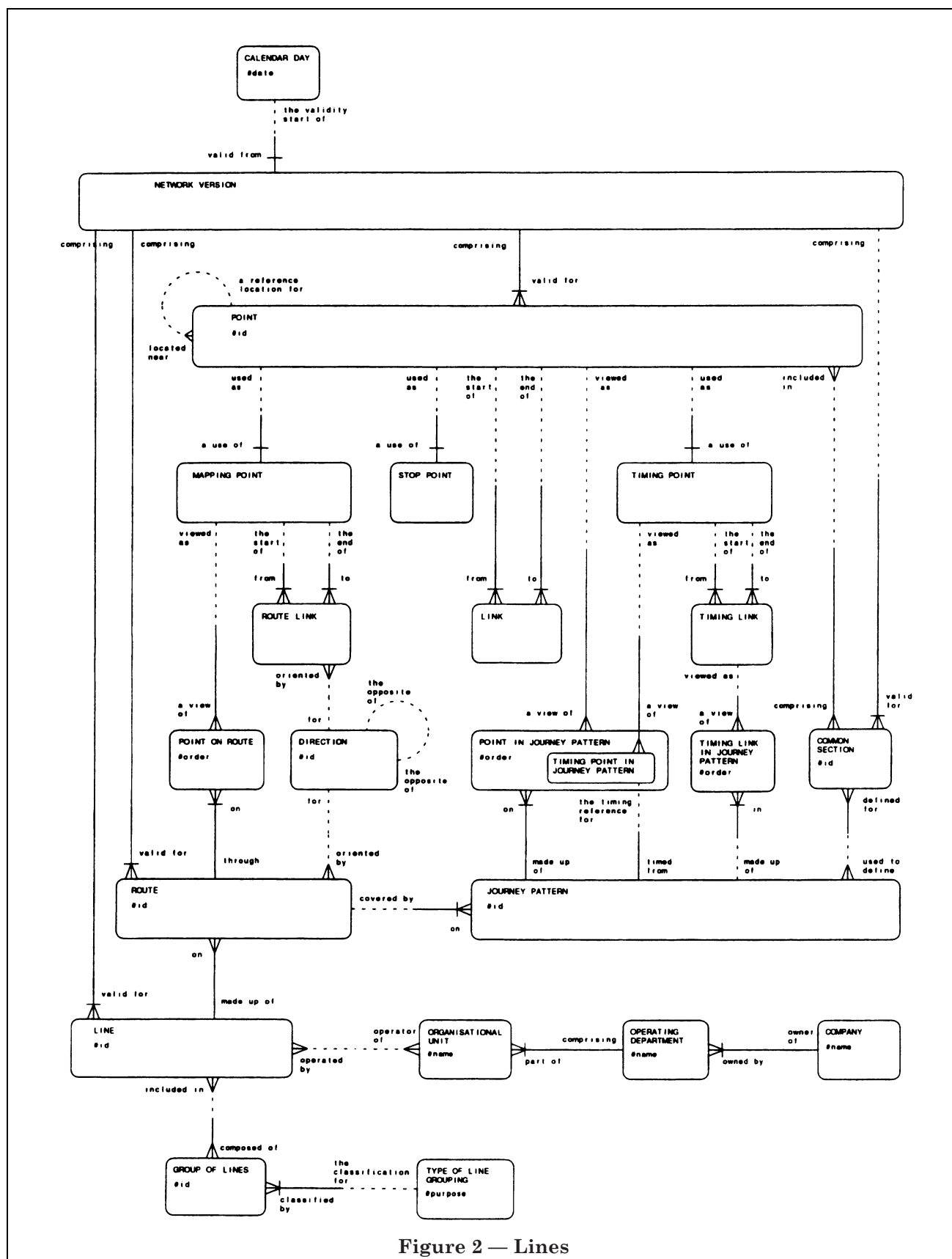


Figure 2 — Lines

6.2.4 Journeys

6.2.4.1 Day Types

6.2.4.1.1 The transport offer of a public transport company is provided according to different levels of demand. The most crucial parameter which determines the demand is the type of day, which means primarily whether it is workday or weekend, but also e.g. school holiday, market day etc.

6.2.4.1.2 A DAY TYPE is defined as a combination of various different properties a day may have, and which will influence the transport demand. Any single condition which is relevant to the demand will be recorded as a particular PROPERTY OF DAY.

6.2.4.1.3 For example, workday, Sunday, school holiday, market day etc. would each be a PROPERTY OF DAY. A workday during school holidays which is a market day would be a DAY TYPE. This particular DAY TYPE would be a combination of those three PROPERTYs OF DAY.

6.2.4.2 Vehicle Journeys

6.2.4.2.1 The daily operation of a vehicle is described by VEHICLE JOURNEYS. A VEHICLE JOURNEY is the defined movement of a vehicle using a specified JOURNEY PATTERN on a particular ROUTE. More precisely, it is a class of journeys which would take place at the same time on each day of a specific DAY TYPE.

6.2.4.2.2 While the spatial information for a VEHICLE JOURNEY can be completely derived from its ROUTE and JOURNEY PATTERN, the temporal information will be derived from run times stored against the TIMING LINKs and wait times stored against the TIMING POINTs which the journey will pass through. The start time will mandatorily have to be stored for each VEHICLE JOURNEY in order to calculate the absolute passing times from the relative run and wait times, which are expressed as durations.

6.2.4.2.3 There may be LINEs, ROUTEs and JOURNEY PATTERNs which are not used by any VEHICLE JOURNEY at all on certain DAY TYPEs. 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 which 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.

6.2.4.2.4 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. Any company-specific rules limiting the services on particular LINEs, ROUTEs or JOURNEY PATTERNs to some selected DAY TYPEs could be added at the implementation level.

6.2.4.3 Service Journeys, Dead Runs and other Journey Types

6.2.4.3.1 There are two different main types of VEHICLE JOURNEYS: passenger-carrying SERVICE JOURNEYS and non-service DEAD RUNs.

6.2.4.3.2 A SERVICE JOURNEY is the movement of a vehicle between the first and the last POINT IN a JOURNEY PATTERN where passengers will regularly be allowed to board or alight from vehicles at stops. These journeys are usually published and known by passengers.

6.2.4.3.3 A DEAD RUN may be necessary for the vehicle to proceed from the GARAGE it was parked at to the first STOP POINT of the JOURNEY PATTERN where it will start its service operation, or from the last STOP POINT it has stopped at (finishing its service) back to the GARAGE where it will be parked. A DEAD RUN may also occur when a vehicle changes from one ROUTE to another one in order to continue its service there.

6.2.4.3.4 Those JOURNEY PATTERNs which will be served by SERVICE JOURNEYS are related to a specific sub-type SERVICE JOURNEY PATTERN. JOURNEY PATTERNs which may be used by DEAD RUNs are allocated to the DEAD RUN PATTERN sub-type. The distinction between these two sub-types of JOURNEY PATTERN may be needed by scheduling algorithms in order to determine which spatial connections are available for DEAD RUNs that will be automatically created during block optimisation. The distinction may also be needed to choose among different types of run times possibly defined for LINKs the different types of JOURNEY PATTERN are composed of.

6.2.4.3.5 In addition to the distinction between SERVICE JOURNEYS and DEAD RUNS, operators may wish to classify VEHICLE JOURNEYS by further criteria than is possible with the sub-types explicitly defined. For these purposes a JOURNEY TYPE may be assigned which would express other common properties of VEHICLE JOURNEYS apart from the classification as DEAD RUN or SERVICE JOURNEY (e.g. “journey at the maximum load period”). However, in case these sub-types are not implemented at the physical level in a particular application, the JOURNEY TYPE entity can be used in a generic way to express any categorisation.

6.2.4.3.6 In practice there may be generally reasons not to implement all the sub-types as defined at the conceptual level of the data model. This may particularly occur in the case of JOURNEY PATTERNS and VEHICLE JOURNEYS, where other sub-types may be chosen in practical implementations, or no distinct sub-types are necessary at all. In these cases, the relationships between the sub-types of JOURNEY PATTERN and VEHICLE JOURNEY need to be adapted accordingly.

6.2.4.4 *Time Demand Types*

6.2.4.4.1 Run times and wait times vary during the day, depending on traffic conditions on the roads and on the number of passengers boarding or alighting from vehicles at stops. An artificial parameter to indicate particular levels of these conditions is defined by the TIME DEMAND TYPE entity.

6.2.4.4.2 The TIME DEMAND TYPEs mainly indicate situations like peak hour traffic conditions, off-peak traffic, night-owl traffic etc. Run time durations usually differ between these situations. Wait times at stops rather depend on the passenger load which also varies with the time of day, but in a very similar pattern to the traffic conditions on the roads. Therefore, the TIME DEMAND TYPE serves as an indicator for specific conditions influencing run times as well as wait times.

6.2.4.4.3 Each VEHICLE JOURNEY takes place at a defined time which can be characterised by specific traffic conditions and a certain passenger load level. To express these characteristics, a TIME DEMAND TYPE will be assigned to the journey which in turn will be used to choose the appropriate run and wait times from the defined set of times (see section 6.2.5 General Times).

6.2.4.5 *Vehicle Types*

6.2.4.5.1 A VEHICLE TYPE characterises the common properties of a defined class of public transport vehicles. The properties most relevant for scheduling are the seating and standing capacities.

6.2.4.5.2 Depending on the time of day when a SERVICE JOURNEY takes place, and on the ROUTE and JOURNEY PATTERN which it is made on, a default VEHICLE TYPE may be proposed for this journey. This proposal will preferably be taken into account by the scheduling algorithm applied to compile blocks of vehicle operation.

6.2.4.5.3 For each VEHICLE TYPE a next preference may be expressed to determine which other VEHICLE TYPE should be chosen instead if the default proposal cannot be met by the block compilation procedure.

6.2.4.5.4 More information on VEHICLE TYPEs and their use in the model is given in section 6.2.9.

6.2.4.6 *Timetable Versions*

6.2.4.6.1 Public transport companies usually adjust their service offer to changes in demand. The transport demand may vary seasonally (summer/winter) or for other reasons (e.g. school holidays), and the company may want to define different schedules for time periods with substantially different levels of demand. The main activity to define a new schedule is to determine the SERVICE JOURNEYS which would serve the SERVICE JOURNEY PATTERNS, according to the changes of the service to be offered.

6.2.4.6.2 New timetables are often defined periodically. A new timetable has to be prepared and recorded in advance before it finally becomes valid. Thus, the data associated with a new timetable have to be kept in parallel with another set of existing timetable data which are still the basis of actual operation at the time when the future service is planned.

6.2.4.6.3 Therefore, a TIMETABLE VERSION is necessary to embrace a full set of timetable data which are valid for the same period of time, and to separate these data from other sets of timetable data which were valid or will be valid during other periods.

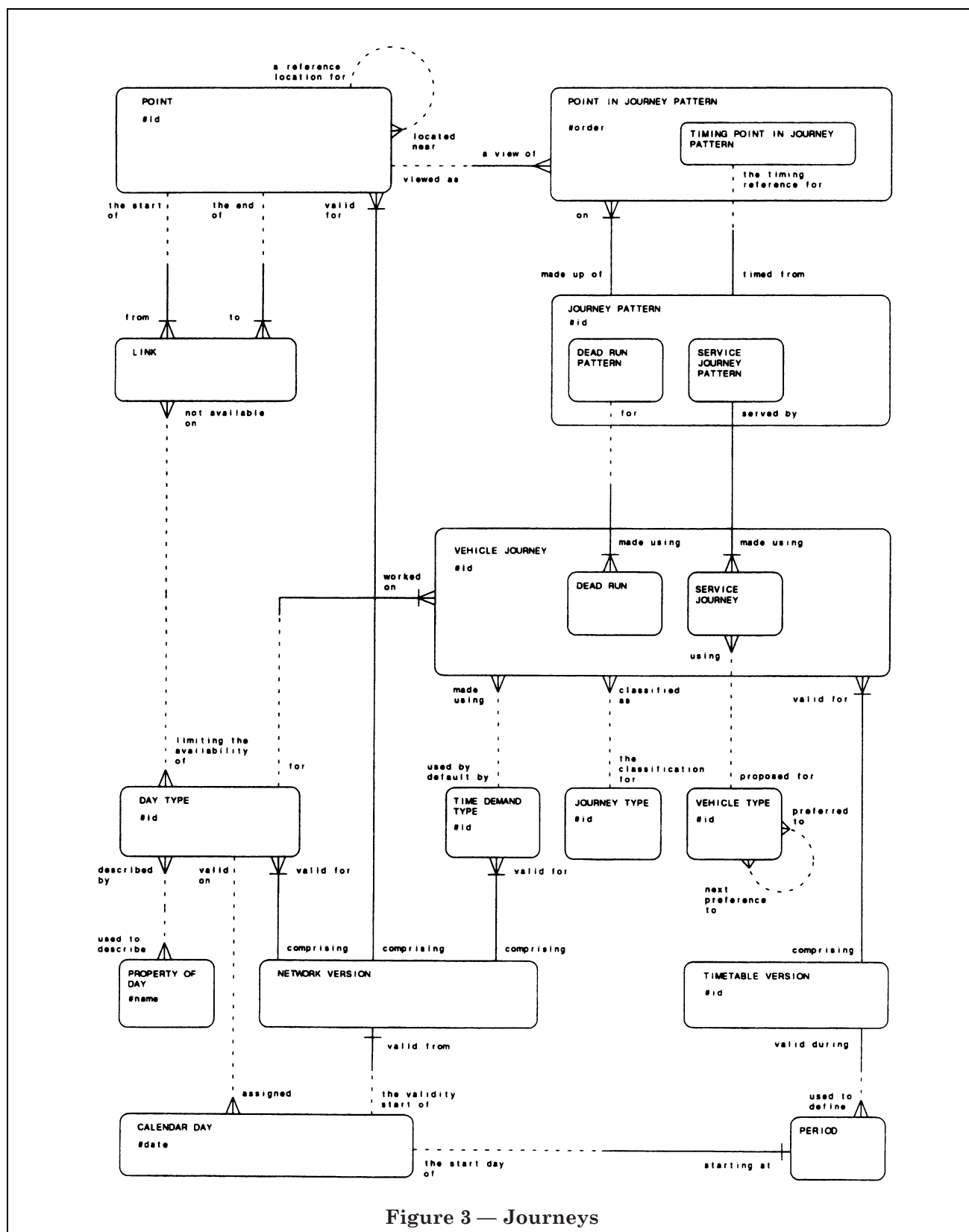


Figure 3 — Journeys

6.2.4.6.4 A PERIOD is a continuous interval between two CALENDAR DAYs. The validity of a TIMETABLE VERSION is given by one or more PERIODs. This means there may be gaps in the validity time of a TIMETABLE VERSION, as there may be another version valid during a particular PERIOD within the interval between the first and the last validity day of that TIMETABLE VERSION (e.g. a particular timetable for school holidays may be embedded in a general summer schedule).

6.2.4.6.5 As changes in transport demand occur more frequently (and at other points of time) than modifications to the network, the validity periods of TIMETABLE VERSIONs are different (often shorter) than those of NETWORK VERSIONs.

6.2.4.6.6 Each VEHICLE JOURNEY is defined for a specific TIMETABLE VERSION. This VEHICLE JOURNEY will then be operated every day (of a specified DAY TYPE) during the validity PERIOD(s) associated with that TIMETABLE VERSION.

6.2.5 General Times

6.2.5.1 Run Times and Wait Times

6.2.5.1.1 There are two main types of times necessary for producing a timetable: run times and wait times. A run time is the time taken to cross a TIMING LINK. A wait time is the time spent at a TIMING POINT. These times may vary for different TIME DEMAND TYPEs.

6.2.5.1.2 Estimated wait times of vehicles at STOP POINTs during SERVICE JOURNEYs which are due to the time needed by passengers for boarding or alighting will often be incorporated in the run times defined for the TIMING LINKs on the ROUTEs concerned. In these cases, the default wait times at the STOP POINTs will implicitly be zero, but not be explicitly recorded. Extra wait times may be recorded for interchanges on particular JOURNEY PATTERNs and LINEs, see section **6.2.5.3**.

6.2.5.2 Default Times

6.2.5.2.1 A set of default run times will be recorded for each TIMING LINK, one for each TIME DEMAND TYPE. The run times will probably be different if a vehicle crosses a TIMING LINK during a DEAD RUN or a SERVICE JOURNEY. In the case of a SERVICE JOURNEY, there may be additional STOP POINTs in the JOURNEY PATTERN where passengers can board or alight from the vehicle.

6.2.5.2.2 Therefore, default run times will be recorded in two different entities: DEFAULT SERVICE JOURNEY RUN TIME and DEFAULT DEAD RUN RUN TIME.

6.2.5.2.3 Using these default run times, the timing information for each VEHICLE JOURNEY can be derived by looking for the TIMING POINTs in the associated JOURNEY PATTERN, accessing the TIMING LINKs between these TIMING POINTs and choosing the appropriate run time recorded for those TIMING LINKs in the DEFAULT SERVICE JOURNEY RUN TIME or DEFAULT DEAD RUN RUN TIME entity, respectively.

6.2.5.2.4 The choice among the run times recorded for one TIMING LINK (which are valid for different TIME DEMAND TYPEs) is determined by the TIME DEMAND TYPE which has been assigned to the VEHICLE JOURNEY.

6.2.5.3 Journey Pattern Times

6.2.5.3.1 A more precise control of run times than is possible by using defaults at TIMING LINK level is given if JOURNEY PATTERN RUN TIMEs are defined. A JOURNEY PATTERN RUN TIME is a run time for a TIMING LINK which will be valid only for VEHICLE JOURNEYs made on the specified JOURNEY PATTERN. It will override the default run times for this TIMING LINK.

6.2.5.3.2 Again, JOURNEY PATTERN RUN TIMEs are sets of times for different TIME DEMAND TYPEs. The TIME DEMAND TYPE for a particular VEHICLE JOURNEY is used to select the appropriate time from the set recorded for a particular TIMING LINK.

6.2.5.3.3 A JOURNEY PATTERN WAIT TIME may be recorded to define the time a vehicle will have to wait at a specified TIMING POINT, e.g. to allow a large number of passengers to board or alight, or to wait for a connecting vehicle on another LINE. These wait times depend on the JOURNEY PATTERN which the VEHICLE JOURNEY is made on, and on the TIME DEMAND TYPE.

6.2.5.3.4 JOURNEY PATTERN WAIT TIMEs may occur on DEAD RUNs also, e.g. at a certain TIMING POINT in a DEAD RUN PATTERN where the driver will be relieved.

6.2.5.4 *Turnaround Times*

6.2.5.4.1 Actual turnaround times are not considered as part of the data model for scheduling. But there are some limitations for turnaround times which are sometimes used as parameters by scheduling systems for the vehicle scheduling procedure.

6.2.5.4.2 The maximum length of time which a vehicle may be scheduled to wait at a particular terminus is recorded in the TURNAROUND TIME LIMIT entity. If, as a result of block compilation, the time a vehicle will have to stay at the terminus exceeds this maximum value, the scheduler will be warned by the system, and he will be recommended to call back the vehicle to a GARAGE, or to try a further step of block optimisation.

6.2.5.4.3 The TURNAROUND TIME LIMIT is dependent on the TIME DEMAND TYPE, and it is stored against a pair of TIMING POINTs which represent the POINT where a vehicle may end a SERVICE JOURNEY and the POINT where it would start from for the subsequent SERVICE JOURNEY (these POINTs are usually STOP POINTs).

6.2.5.4.4 A minimum duration, which is the time physically needed by a vehicle to change its direction, is also stored in the TURNAROUND TIME LIMIT. This may include a short movement which is not worth modelling explicitly as a DEAD RUN, and for which no specific DEAD RUN PATTERN has been defined. But this minimum duration will be superseded by the run times (plus wait times, if any) associated with an explicitly modelled DEAD RUN between the two TIMING POINTs concerned.

6.2.5.5 *Journey Pattern Layover*

6.2.5.5.1 A certain time allowance may be given at the end of each VEHICLE JOURNEY on a specified JOURNEY PATTERN, to allow for delays or for other purposes. This can be regarded as a buffer time which may or may not be actually consumed in real time operation.

6.2.5.5.2 This time allowance ("layover") can be defined separately for each JOURNEY PATTERN and TIME DEMAND TYPE, and it will be stored in the JOURNEY PATTERN LAYOVER entity.

6.2.5.6 *Time Bands*

6.2.5.6.1 Some companies may want to choose automatically the TIME DEMAND TYPEs for the VEHICLE JOURNEYs, by the use of TIME BANDs.

6.2.5.6.2 A TIME BAND is a continuous period of time of day, defined by its start and end time. For each VEHICLE JOURNEY and each TIMING POINT in the associated JOURNEY PATTERN the TIME BAND can be calculated during which the vehicle passes the TIMING POINTs and crosses the TIMING LINKs in question. Assigning a TIME DEMAND TYPE to each TIME BAND would then allow automatic selection of the TIME DEMAND TYPE that applies for the VEHICLE JOURNEY, and the TIME DEMAND TYPE need not explicitly be defined for VEHICLE JOURNEYs at all.

6.2.5.6.3 But a great deal of information is needed to define an appropriate set of TIME BANDs for this purpose. Traffic conditions vary from street to street, from crossroad to crossroad, are dependent on the driving direction, and may be different from day to day. To allow for this complexity, the TIME DEMAND TYPE ASSIGNMENT which assigns TIME DEMAND TYPEs to TIME BANDs takes into account the DAY TYPE as well as a certain geographical subdivision of the network. TIMING LINK GROUPs may be defined where TIMING LINKs which have similar temporal patterns will be grouped together depending on traffic conditions.

6.2.5.6.4 These TIMING LINK GROUPs may be used to differentiate geographically which TIME DEMAND TYPEs would be applied during the TIME BANDs. Probably different TIME BANDs will have to be defined for the different TIMING LINK GROUPs, as, for example, peak hour conditions will exist at different times in different parts of the town, or at different times depending on the direction.

6.2.5.6.5 A company which does not want this level of complexity for the TIME DEMAND TYPE ASSIGNMENT may define the whole network as only one TIMING LINK GROUP. But probably the run and wait times for VEHICLE JOURNEYs derived by this method would sometimes not then be realistic.



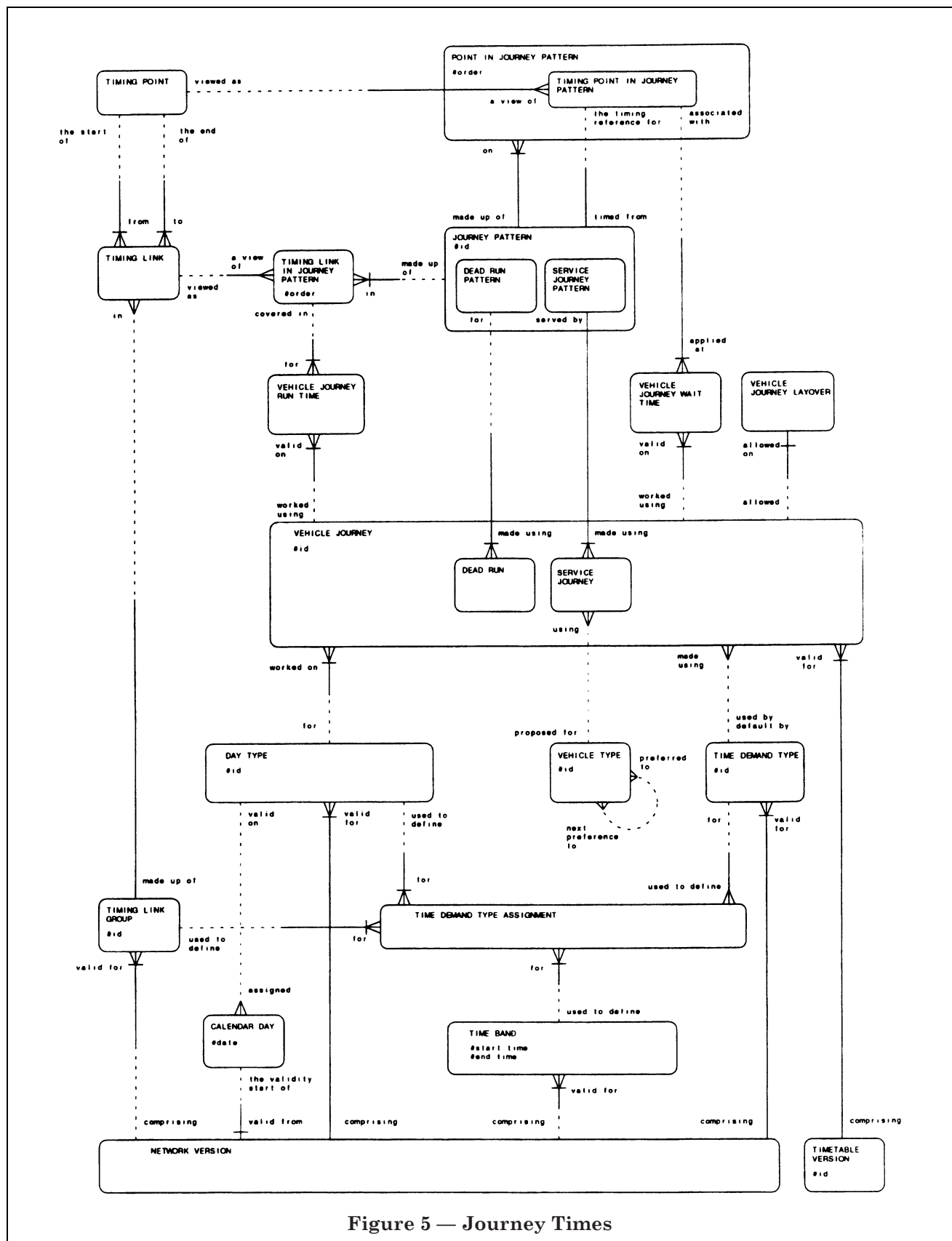


Figure 5 — Journey Times

6.2.6 *Journey Times*

6.2.6.1 *Vehicle Journey Run Times*

6.2.6.1.1 Sometimes there may be reasons why a more precise control of run and wait times is needed than is possible using the defined times at JOURNEY PATTERN level. In the case of a very long VEHICLE JOURNEY, e.g. in a rural area, a single TIME DEMAND TYPE may not apply to the whole journey, because traffic conditions change substantially between its start and end. Alternatively, a vehicle might be slowed intentionally on a particular VEHICLE JOURNEY to meet a scheduled interchange.

6.2.6.1.2 A VEHICLE JOURNEY RUN TIME is specific to one VEHICLE JOURNEY and may be used to override other run times for a particular TIMING LINK. The actual start time is known for the VEHICLE JOURNEY RUN TIME to cover this TIMING LINK, so it is not a set of times depending on traffic conditions, but an individual time.

6.2.6.1.3 A particular TIMING LINK may be crossed more than once in a JOURNEY PATTERN, so it may take a vehicle different times to cover the same TIMING LINK at different points of time during one VEHICLE JOURNEY. For example, the same TIMING LINK may be crossed once in off-peak conditions, then again in peak conditions. For this reason VEHICLE JOURNEY RUN TIMES must be stored for TIMING LINKs IN JOURNEY PATTERN (which are identified by their order within the JOURNEY PATTERN) rather than just TIMING LINKs.

6.2.6.1.4 It is assumed that many operators will not wish to use this level of detail for specifying run times.

6.2.6.2 *Vehicle Journey Wait Times*

6.2.6.2.1 A VEHICLE JOURNEY WAIT TIME may be stored for each individual VEHICLE JOURNEY at arbitrary TIMING POINTs IN JOURNEY PATTERN which the journey is made on. Like the run times at VEHICLE JOURNEY level, these are not sets of time to be chosen for different TIME DEMAND TYPEs, but rather individual durations applying to specific points of time which can be calculated from the start time of the journey.

6.2.6.2.2 A VEHICLE JOURNEY WAIT TIME, if it exists, overrides any JOURNEY PATTERN WAIT TIMES which may have been stored for the TIMING POINT in question.

6.2.6.3 *Vehicle Journey Layover*

6.2.6.3.1 A time allowance for delays or for other purposes can be given jointly for all the VEHICLE JOURNEYs on a specified JOURNEY PATTERN, but it may also be defined separately for individual VEHICLE JOURNEYs as a VEHICLE JOURNEY LAYOVER.

6.2.6.3.2 This would override the JOURNEY PATTERN LAYOVER for the specified VEHICLE JOURNEY. It is not dependent on the TIME DEMAND TYPE, as it is applied at a defined point of time which is determined by the timing information related to the VEHICLE JOURNEY.

6.2.7 *Interchanges*

6.2.7.1 *Connection Links*

6.2.7.1.1 In order to reach the destination of the trip, a passenger will have to change between vehicles on different LINES, if there is no direct service between the source and the destination STOP POINTs. A transfer will be necessary, where the passenger will leave the vehicle at a particular STOP POINT and enter another vehicle (which serves another JOURNEY PATTERN, usually on a different LINE) at the same, or another, STOP POINT.

6.2.7.1.2 If these STOP POINTs are different, they will often (but need not necessarily) belong to the same STOP AREA. Passengers will then have to walk a certain distance to reach the stop positions of connecting vehicles for the subsequent rides in their trips.

6.2.7.1.3 A CONNECTION LINK expresses the physical (spatial) possibility for a passenger to change from one public transport vehicle to another to continue the trip. It is described by various times taken by different types of passenger to traverse the link between two specified STOP POINTs (which may be identical in case the connecting vehicles stop close to each other). The connection is flagged as suitable or not for mobility-impaired passengers.

6.2.7.1.4 The time information given for CONNECTION LINKs will be used by the timetable planning and scheduling software to synchronise SERVICE JOURNEYs for possible interchanges between different LINES. It will also be used for passenger information.

6.2.7.2 *Default Interchanges*

6.2.7.2.1 When optimising the start times of the SERVICE JOURNEYS, the scheduler has to take into account certain parameters affecting service quality, for example the influence of passenger waiting times at interchanges on their total travel times. Therefore, the waiting times at interchanges resulting from the journey schedule should be as short as possible. But on the other hand, the public transport company has to provide its service efficiently, according to a limited number of vehicles available.

6.2.7.2.2 Thus the waiting times of passengers at interchanges, resulting from the schedule, will be a compromise of what is desirable and what is possible. To ascertain the best compromise, certain quality parameters are defined which have to be taken into account by the VEHICLE JOURNEY optimisation and synchronisation process.

6.2.7.2.3 One of these parameters is the maximum waiting duration which would be allowed for an interchange between vehicles on different LINES, using a pair of STOP POINTs (which may be identical) to leave the first and enter the second vehicle. If this maximum duration is exceeded for a pair of SERVICE JOURNEYS, this will no longer be regarded as a possible interchange between these journeys at these STOP POINTs at all. In this situation, the scheduler will perhaps be warned by the system and be asked to retime these journeys; otherwise these journeys may not be advertised as connected at the specified STOP POINTs.

6.2.7.2.4 Another parameter is the standard duration which should be aimed at for the passenger waiting time at an interchange. This should be taken into account as a reference value when timing the SERVICE JOURNEYS. Like the maximum duration, it will also apply to all LINES and JOURNEY PATTERNS which allow for an interchange using two specified STOP POINTs.

6.2.7.2.5 Maximum duration and standard duration of the passenger waiting times at interchanges are recorded in the DEFAULT INTERCHANGE entity, which is related to the two STOP POINTs where passengers would leave the arriving and enter the departing vehicles.

6.2.7.3 *Service Journey Pattern Interchanges*

6.2.7.3.1 Sometimes the maximum and standard durations defined as planning parameters for scheduled passenger waiting times at interchanges need to be differentiated depending on the SERVICE JOURNEY PATTERNS involved.

6.2.7.3.2 The quality level to be aimed at will certainly depend on the service frequency on the SERVICE JOURNEY PATTERNS. If these frequencies are more or less similar, the same default values can be used as maximum and standard durations of interchange waiting times. But if the frequency is very low on one SERVICE JOURNEY PATTERN and considerably higher on another, the situation is different. An interchange waiting time of 13 minutes may be acceptable for passengers if the buses only run every two hours on a particular SERVICE JOURNEY PATTERN, but would not be a good solution if the buses run every 15 minutes.

6.2.7.3.3 In order to allow for a more differentiated definition of quality standards for interchanges, the maximum and standard waiting durations may be given separately for a particular pair of SERVICE JOURNEY PATTERNS and a corresponding pair of STOP POINTs which must be on the respective JOURNEY PATTERNS. This information is owned by an entity called SERVICE JOURNEY PATTERN INTERCHANGE.

6.2.7.4 *Service Journey Interchanges*

6.2.7.4.1 In real-time operation, vehicles may sometimes have to wait at STOP POINTs where there are important interchanges even if the arriving vehicles are delayed. If certain interchanges are advertised to the public and controlled during operation, the company will probably define certain rules and instructions for drivers on how to react in case of deviations from the planned schedule.

6.2.7.4.2 The SERVICE JOURNEY INTERCHANGE entity is used to record a quality parameter for ensuring connections, providing the maximum time a vehicle may wait for connecting vehicles. This information is related to two SERVICE JOURNEYS with a planned interchange using two STOP POINTs. These two STOP POINTs will usually belong to the same STOP AREA, or may even be identical, if both SERVICE JOURNEYS are using the same STOP POINT as a POINT IN their JOURNEY PATTERNS.

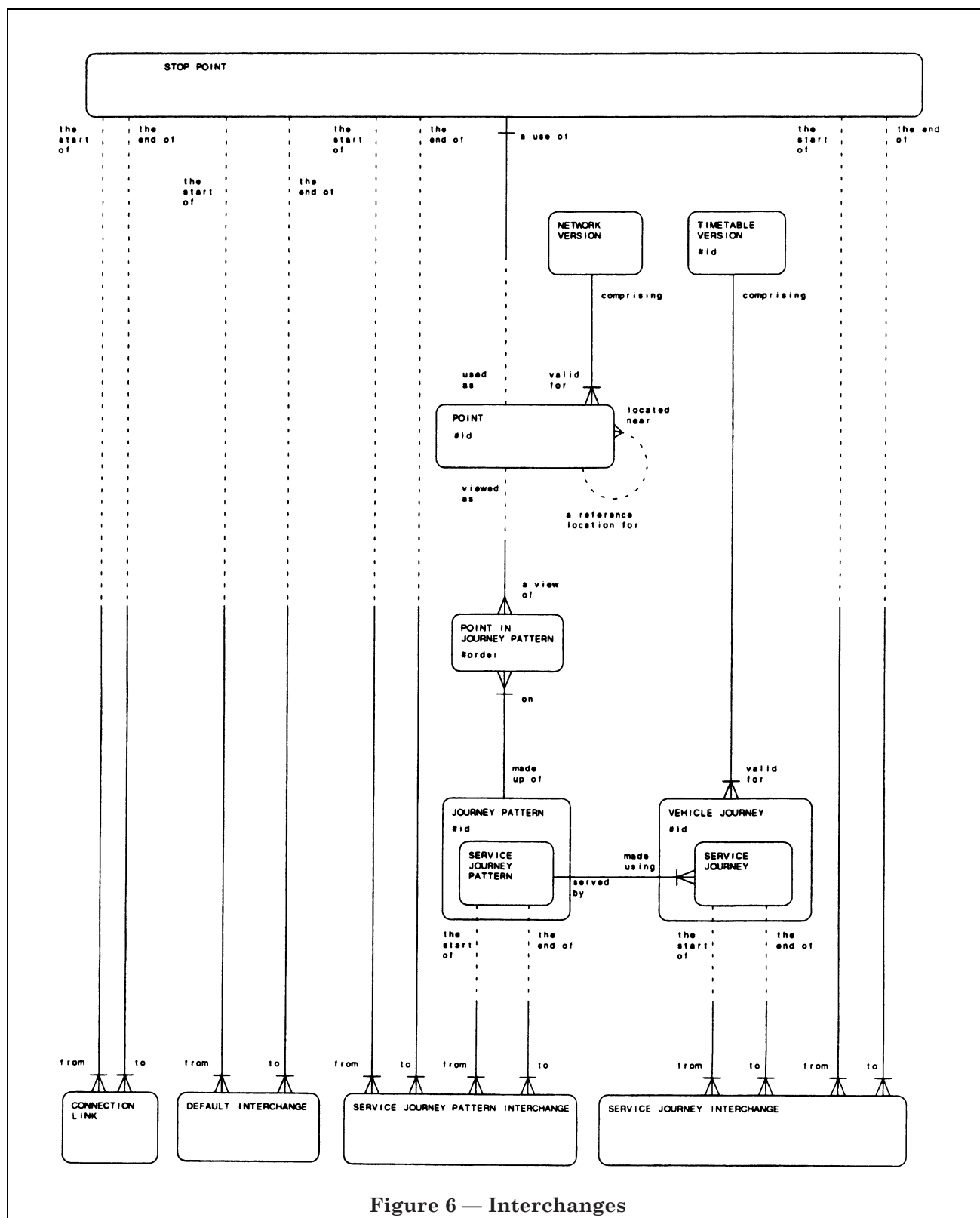


Figure 6 — Interchanges

6.2.7.4.3 If an AVM system is used to monitor and control operations, the SERVICE JOURNEY INTERCHANGE provides input data necessary to evaluate deviations from the schedule with respect to interchanges. If the first vehicle is delayed less than the maximum wait time defined for the SERVICE JOURNEYS and STOP POINTS in question, the driver of the second vehicle will be advised to wait for the first. If the delay exceeds this value, the driver of the second vehicle will receive the instruction to continue the SERVICE JOURNEY without waiting. Therefore, the SERVICE JOURNEY INTERCHANGE entity and its relationships could be regarded as an important part of an AVM data model.

6.2.8 Vehicle Scheduling

6.2.8.1 Extra Types of Point for Scheduling

6.2.8.1.1 Some TIMING POINTS may be predefined as RELIEF POINTS, at which drivers may start or stop driving and spend their breaks. These are often at or near a GARAGE.

6.2.8.1.2 Some RELIEF POINTS are specified as PARKING POINTS where a vehicle may be parked for some time during the day or overnight.

6.2.8.2 Blocks

6.2.8.2.1 A BLOCK includes all the SERVICE JOURNEYS and DEAD RUNS for one vehicle, from the time it leaves its original PARKING POINT, to the time it returns to park at this or another PARKING POINT. Between two BLOCKS the vehicle is available for the vehicle manager to be possibly assigned to other work.

6.2.8.2.2 The parts of the model described in previous sections provide the data needed as input to the vehicle scheduling process. In this process, VEHICLE JOURNEYS of the same DAY TYPE are compiled into BLOCKS, which will be the work of one (logical) vehicle. The DAY TYPE of a BLOCK may be ascertained from the DAY TYPE of the VEHICLE JOURNEYS it includes.

6.2.8.2.3 A vehicle may have to perform a DEAD RUN between the PARKING POINT where it has been parked and the start point of its first SERVICE JOURNEY of the day. It may need another DEAD RUN to return from the last point of its last SERVICE JOURNEY to the PARKING POINT. If there are SERVICE JOURNEYS on different ROUTES in one BLOCK, further DEAD RUNS may be necessary for the vehicle to move from one ROUTE to the next.

6.2.8.3 Relief Opportunities

6.2.8.3.1 One BLOCK for a VEHICLE may last for many hours or even the whole day. Drivers cannot work as long and so arrangements must be made to relieve drivers during the BLOCKS. RELIEF POINTS are predefined for this purpose.

6.2.8.3.2 Every point of time within a BLOCK when the vehicle passes a RELIEF POINT is known as a RELIEF OPPORTUNITY. RELIEF OPPORTUNITIES may or may not be taken for actually relieving the driver.

6.2.8.3.3 Each RELIEF OPPORTUNITY will occur at a RELIEF POINT which is viewed as a TIMING POINT IN JOURNEY PATTERN. If a JOURNEY PATTERN WAIT TIME or a VEHICLE JOURNEY WAIT TIME is recorded for this TIMING POINT IN JOURNEY PATTERN, the precise point in time of the RELIEF OPPORTUNITY cannot be derived from the times scheduled for the VEHICLE JOURNEY in question. In this case, the RELIEF OPPORTUNITY time may be chosen explicitly within the specified wait time, or may be determined implicitly as the (calculated) point in time when the VEHICLE JOURNEY first arrives at this RELIEF POINT.

6.2.8.3.4 A similar situation appears for RELIEF OPPORTUNITIES at the last TIMING POINT IN a JOURNEY PATTERN (i.e. its destination), for which a JOURNEY PATTERN LAYOVER or a VEHICLE JOURNEY LAYOVER has been specified. The exact time of these RELIEF OPPORTUNITIES should then allow for the scheduled layover durations after the planned arrival at the RELIEF POINT.

6.2.8.4 Vehicle Types for Blocks

6.2.8.4.1 As described in section 6.2.4.5 a particular VEHICLE TYPE, maybe with a next preference, may have been proposed for a particular SERVICE JOURNEY.

6.2.8.4.2 At the stage of BLOCK compilation, different SERVICE JOURNEYS must be combined into a BLOCK and a particular VEHICLE TYPE must be assigned to the whole BLOCK. It may not be possible to ensure that SERVICE JOURNEYS for a BLOCK all have the same proposed VEHICLE TYPE. However, any previous proposals or next preferences recorded for VEHICLE TYPEs should be taken into account at this stage to ensure that the VEHICLE TYPE meets the requirements of all the SERVICE JOURNEYS in the BLOCK.

6.2.8.4.3 More information about VEHICLE TYPEs relevant to the assignment to a BLOCK is described in section 6.2.9 which is devoted to Vehicle Types.

6.2.8.5 *Organisational Units*

6.2.8.5.1 Many companies will wish to break down their operations in some way so that they do not schedule all operations together as one task. They may do this by having separate database systems for each subdivision of their services and running the scheduling programs using all the data in each database. It is more likely that they will wish to have a single database, but undertake the scheduling separately on different sections of the data. The data may be subdivided in many different ways to suit the practices of the company concerned.

6.2.8.5.2 The entity ORGANISATIONAL UNIT is included in the model to allow these subdivisions. Section 6.2.3.6 introduced this entity and its relationship to LINEs. Thus, LINEs could be grouped for input to a scheduling program. Other entities which may be related to ORGANISATIONAL UNIT in order to group and restrict the input to the scheduling programs are GARAGE, RELIEF POINT and VEHICLE. One ORGANISATIONAL UNIT may be the manager for one or more GARAGEs and responsible for certain RELIEF POINTs and VEHICLEs.

6.2.8.5.3 BLOCKs compiled by the vehicle scheduling program may also be related to a particular ORGANISATIONAL UNIT. This allows the BLOCKs input to a driver scheduling program to be restricted by ORGANISATIONAL UNIT.

6.2.8.5.4 The modelling of organisation of this sort is difficult to specify, since organisational structure and practice may well vary considerably across companies and time. For this reason, all the relationships between this and other entities are optional, thus the entity ORGANISATIONAL UNIT can be omitted completely or used to group the company data in a variety of ways.

6.2.8.5.5 Given this flexible model, a number of constraints will be needed to ensure that the ORGANISATIONAL UNIT is sensibly used. For example, most companies will wish to specify that the SERVICE JOURNEYs compiled into a single BLOCK should be related to SERVICE JOURNEY PATTERNs on ROUTEs which are related to LINEs belonging to the same ORGANISATIONAL UNIT; and that the BLOCK concerned must be related to the same ORGANISATIONAL UNIT. Some users may wish to specify that a BLOCK may only start and end at a PARKING POINT which is a RELIEF POINT used by the ORGANISATIONAL UNIT to which that BLOCK is related. Other companies may allow RELIEF POINTs to be used by any ORGANISATIONAL UNIT.

6.2.8.5.6 The annex B.1 of this document includes a list of constraints to maintain the integrity of the model. However, many constraints, which would be useful to particular companies to support their own organisational practice, will not be included. It will be the responsibility of each user company to include the constraints it needs in its own system.

6.2.8.6 *Vehicles*

6.2.8.6.1 The VEHICLE entity is used to describe the *physical* public transport vehicles available for planning of operations and daily disposition (in contrast to *logical* vehicles considered for BLOCK compilation). Each VEHICLE must be classified as of a particular VEHICLE TYPE.

6.2.8.6.2 A VEHICLE may normally be parked at a particular GARAGE. This is expressed by a relationship to the GARAGE entity, giving the default GARAGE for this VEHICLE. The VEHICLE may be assigned to an ORGANISATIONAL UNIT which is responsible for it, if this entity is present in the specific model application for the company in question.

6.2.8.6.3 Given this information, it is possible to calculate the numbers of VEHICLEs of each VEHICLE TYPE available for the scheduling process per ORGANISATIONAL UNIT and per GARAGE.

6.2.8.7 *Course of Journeys and Vehicle Schedule*

6.2.8.7.1 There are two main methods applied to schedule vehicles in European public transport companies. The first one starts with the definition of VEHICLE JOURNEYs for all the LINEs of an ORGANISATIONAL UNIT, and then chains all these VEHICLE JOURNEYs into suitable BLOCKs of vehicle operation. As a result of this method, one BLOCK may be operated on several (or even many) different LINEs.

6.2.8.7.2 The second method defines GROUPs OF LINEs (usually composed of only one or two LINEs) first, and then schedules the VEHICLE JOURNEYs separately for each of these groups, with possible exceptions. This method generates BLOCKs usually operated only on the LINEs of the GROUP.

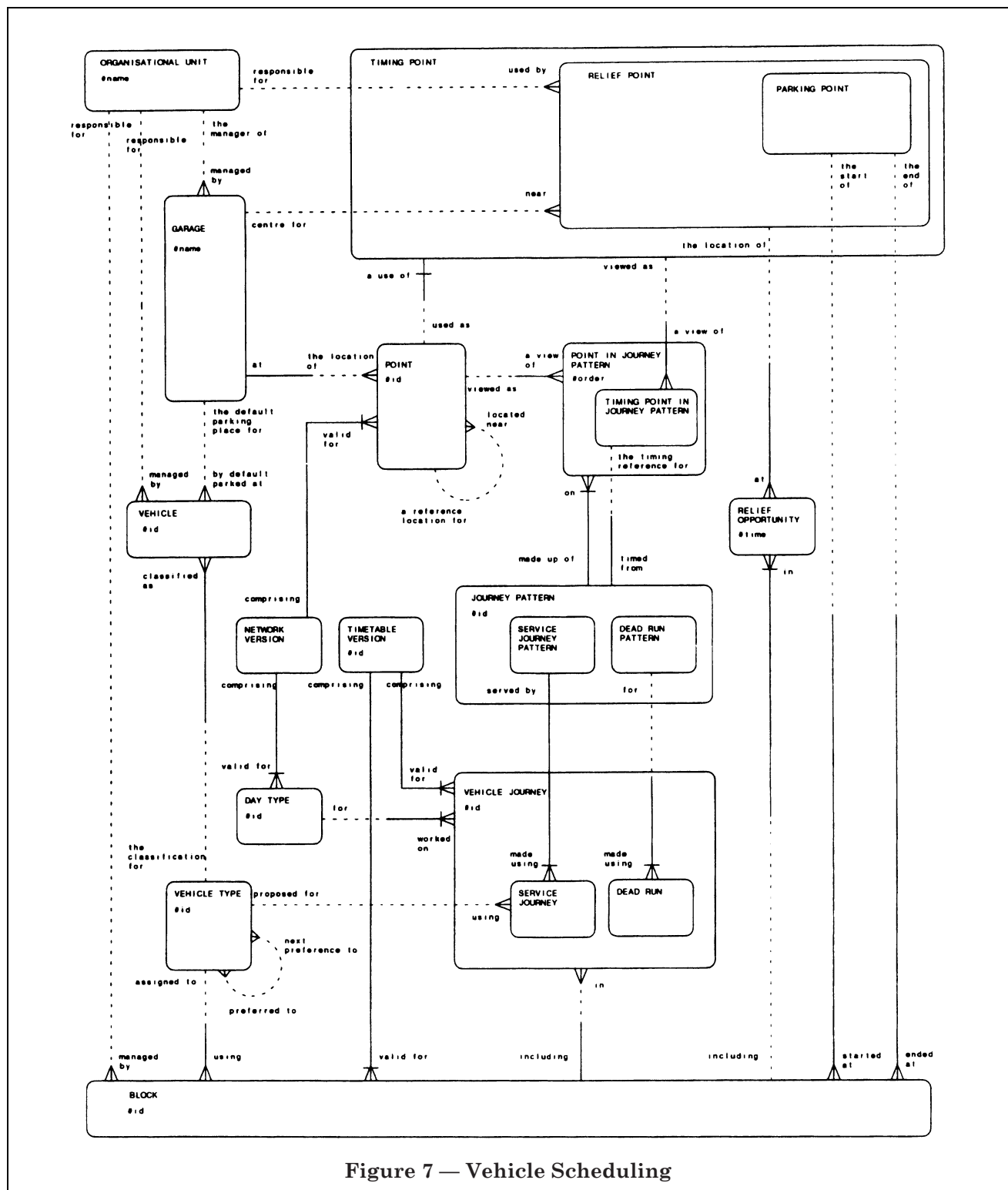


Figure 7 — Vehicle Scheduling

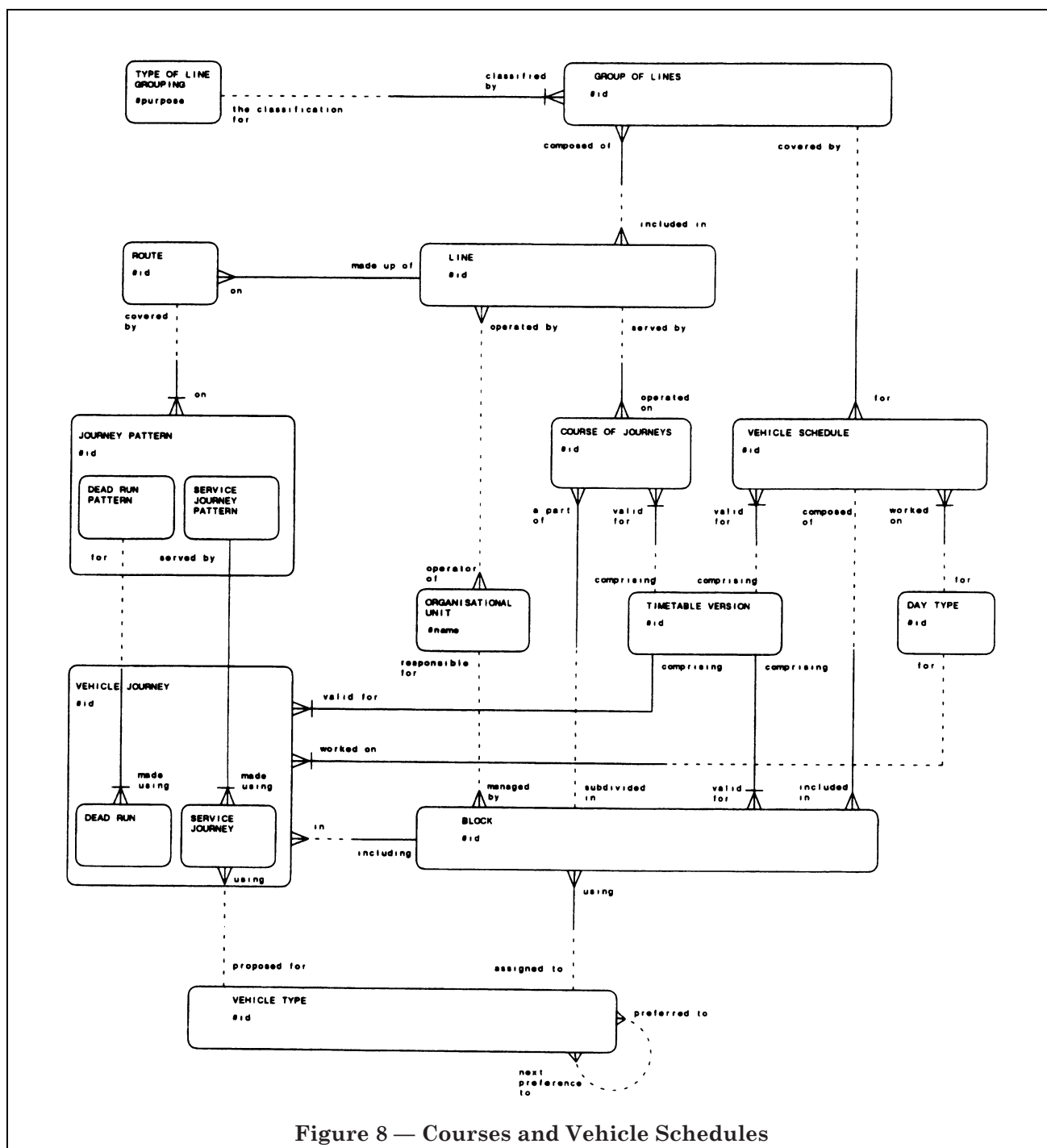


Figure 8 — Courses and Vehicle Schedules

6.2.8.7.3 The first method allows a better optimisation of the planned services and a more efficient compilation of BLOCKS. The second allows more easily to carry out on-line modifications to the service.

6.2.8.7.4 Two additional entities are often used to organise and represent the results of the vehicle scheduling process, depending on the method applied: COURSE OF JOURNEYS and VEHICLE SCHEDULE.

6.2.8.7.5 A COURSE OF JOURNEYS is a part of a BLOCK continuously operated on one single LINE, without interruption. Thus a BLOCK will include several COURSES OF JOURNEYS if it consists of VEHICLE JOURNEYS serving more than one LINE. Each change of the vehicle from one LINE to another marks the start of another COURSE OF JOURNEYS.

6.2.8.7.6 Many companies will define COURSEs OF JOURNEYS consisting of all the VEHICLE JOURNEYS in a BLOCK operated subsequently on the same LINE. A new COURSE OF JOURNEYS will then start only if the vehicle changes the LINE within the BLOCK. In this case, the VEHICLE JOURNEYS included in each COURSE OF JOURNEYS can be derived from other information in the model.

6.2.8.7.7 However, in some cases BLOCKs are subdivided into COURSEs OF JOURNEYS using additional criteria, e.g. change of the driver or other (arbitrarily chosen) events or situations. An (optional) attribute giving the *start time* of a COURSE OF JOURNEYS in the BLOCK will then determine which journeys are included in that course.

6.2.8.7.8 A VEHICLE SCHEDULE groups together all the BLOCKs operated on a specific GROUP OF LINES for one DAY TYPE. VEHICLE SCHEDULEs may be set up for GROUPs OF LINES and DAY TYPEs before VEHICLE JOURNEYS are compiled into BLOCKs and then assigned to the corresponding VEHICLE SCHEDULEs. This reflects a way of working corresponding to the second scheduling method mentioned above.

6.2.8.7.9 Operators using the first method for scheduling, building BLOCKs possibly operated on any LINE of an ORGANISATIONAL UNIT, will often use COURSE OF JOURNEYS to organise a subdivision of BLOCKs for various planning purposes, or to identify (logically) the different vehicles circulating simultaneously on one and the same LINE. They will probably not always need the VEHICLE SCHEDULE entity in their model.

6.2.8.7.10 For operators building BLOCKs separately for rather limited GROUPs OF LINES, and grouping them into VEHICLE SCHEDULEs, according to the second method, a COURSE OF JOURNEYS will generally be identical with a BLOCK. The COURSE OF JOURNEYS entity will not be needed then in many cases, but can be used for exceptions.

6.2.8.7.11 Each COURSE OF JOURNEYS and each VEHICLE SCHEDULE must include, like a BLOCK, only VEHICLE JOURNEYS defined for the same DAY TYPE. This means, these entities are valid for one DAY TYPE only.

6.2.9 Vehicle Types

6.2.9.1 General Remark

6.2.9.1.1 Some explanation of VEHICLE TYPEs was given in section 6.2.4.5. Section 6.2.8.4 refers to considerations about VEHICLE TYPEs, which must be taken into account in the assignment of VEHICLE TYPEs to BLOCKs. This long-term assignment determines which individual VEHICLES may be chosen by the vehicle manager to perform this BLOCK during short-term vehicle disposition.

6.2.9.1.2 As already explained in section 6.2.8.4, the VEHICLE TYPE assigned to a BLOCK must meet the requirements of all the SERVICE JOURNEYS in that BLOCK. This is achieved if all the SERVICE JOURNEYS in that BLOCK are proposed to be performed by the same VEHICLE TYPE. If VEHICLE JOURNEYS proposed to be performed by different VEHICLE TYPEs are combined in one BLOCK, the next preferences of VEHICLE TYPEs can be checked in order to decide whether this combination is suitable, with respect to the VEHICLE TYPE (capacity) requirements.

6.2.9.1.3 If there are not enough vehicles of a required type available on the actual day, the vehicle manager may also have to fall back on next preferences of VEHICLE TYPEs to choose a vehicle for a particular BLOCK.

6.2.9.2 Safety Considerations

6.2.9.2.1 VEHICLES of a certain VEHICLE TYPE may not be able, allowed or safe to cross particular ROUTE LINKs 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, that a VEHICLE TYPE is safe to traverse a particular ROUTE LINK.

6.2.9.2.2 ROUTEs are defined by an ordered list of MAPPING POINTs, where consecutive POINTs on a ROUTE are connected by ROUTE LINKs. Preferences for SERVICE JOURNEY PATTERNs, proposals for SERVICE JOURNEYS and assignment of VEHICLE TYPEs to BLOCKs must check that all the ROUTE LINKs in associated ROUTEs are safe for the chosen VEHICLE TYPE.

6.2.9.3 Vehicle Type Preferences

6.2.9.3.1 A ranked list of VEHICLE TYPEs may be recorded for each SERVICE JOURNEY PATTERN for each DAY TYPE and TIME DEMAND TYPE. This may be taken into account in proposing a VEHICLE TYPE for a SERVICE JOURNEY.

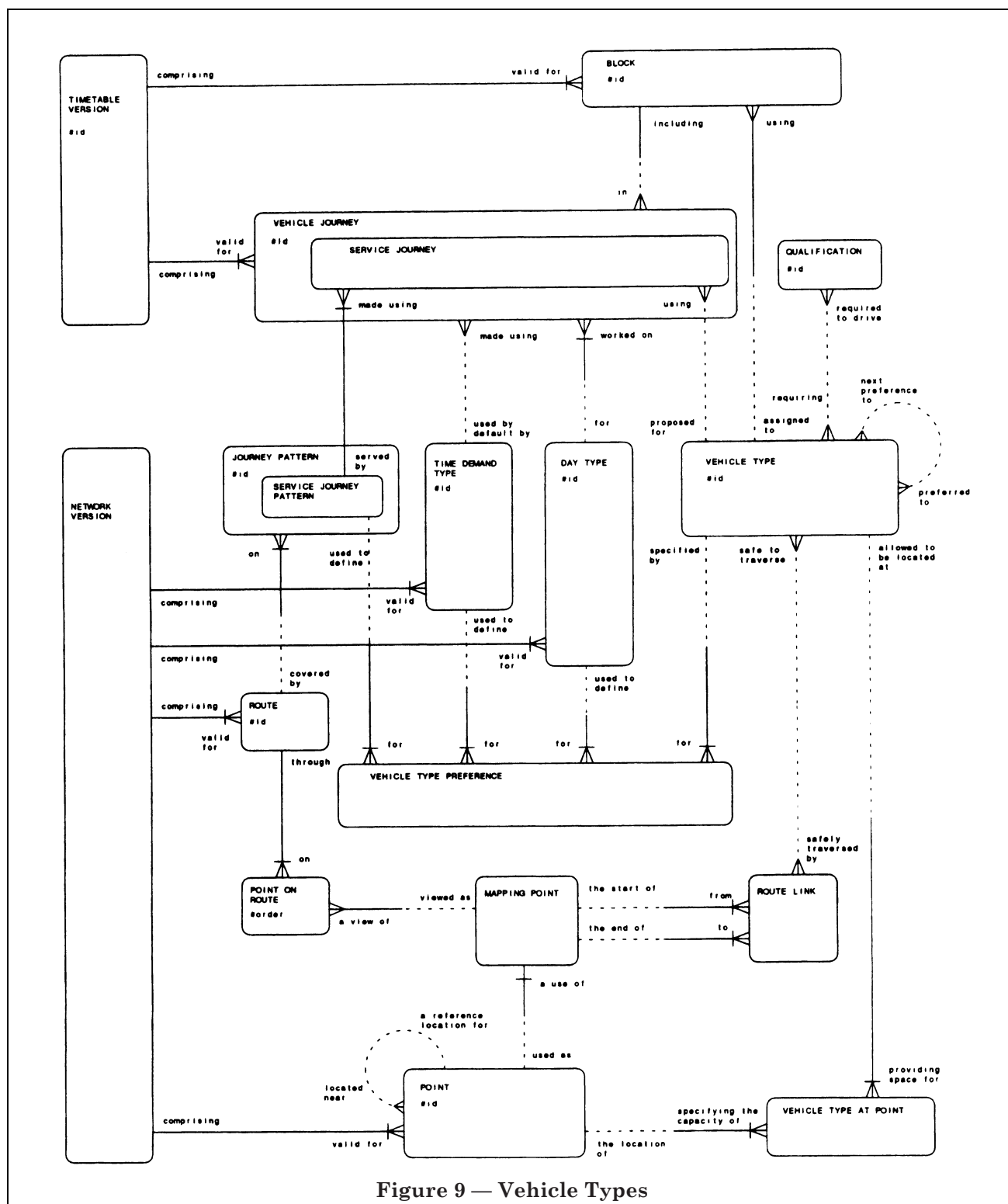


Figure 9 — Vehicle Types

6.2.9.4 Vehicle Types at Points

6.2.9.4.1 VEHICLES of a certain VEHICLE TYPE may not be allowed, or physically not able, to stop for any length of time at particular 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 POINT concerned. This will usually be a STOP POINT. If the number is 0, then VEHICLES of that VEHICLE TYPE cannot stop at this POINT at all. This restriction must be taken into account when a VEHICLE TYPE is proposed for a VEHICLE JOURNEY and when it is assigned to a BLOCK.

6.2.9.5 Driver Qualifications

6.2.9.5.1 For each VEHICLE TYPE there may be one or more specific QUALIFICATIONs a driver must have in order to be able or allowed to drive a vehicle of this particular type. This may for instance be a certain kind of driver's license. The required QUALIFICATIONs will be checked in the Personnel Disposition process, when an individual driver is assigned to a duty which covers VEHICLE JOURNEYs in a BLOCK worked by this particular VEHICLE TYPE.

6.2.10 Driver Scheduling

6.2.10.1 General Remarks

6.2.10.1.1 Driver scheduling involves the construction of driver DUTYs to cover the timetabled SERVICE JOURNEYs at minimum cost. This process must also give drivers fair workloads which comply with the law and with the agreements made between the company and driver unions. There are a number of parameters, such as maximum length of driving time allowed without a break, which will be essential input for the driver scheduling algorithm. These are not included in the data model presented here, because they do not have a complex structure or relationships with each other or any of the entities within the data model, but are simple values.

6.2.10.1.2 In many cases BLOCKs of SERVICE JOURNEYs and DEAD RUNs will have already been compiled and will be used as input for the driver scheduling process. However, schedulers do not always want to work in that order, so the model allows DUTYs to be entered into the system, before pieces of vehicle work have been assigned to them.

6.2.10.2 Duties and Their Component Parts

6.2.10.2.1 A DUTY describes a day's work for a logical driver on one DAY TYPE. It may be under the charge of a particular ORGANISATIONAL UNIT. A DUTY may be a SPARE DUTY, in which case no specific work has yet been assigned to it, or an ASSIGNED DUTY, which is composed of a hierarchy of components of various levels.

6.2.10.2.2 Different existing models use different component levels and the model presented in this document includes more levels than any one company is likely to want, in order to support these existing ways of structuring the data. Some of these entities may only be used within the driver scheduling package and will not be needed in a common database. They are included in the model because they explain the relationships between entities which will be in a common database.

6.2.10.2.3 An ASSIGNED DUTY may be divided into one or two (or sometimes even more) DUTY PARTs, which are bounded by sign on and sign off. A DUTY consisting of two DUTY PARTs is commonly known as a "split" duty. Each DUTY PART may be divided into STRETCHes which are periods of work separated by BREAKs.

6.2.10.2.4 Each STRETCH may be divided into SPELLs. DRIVING SPELLs are those parts of the driver's work which is performed continuously on one vehicle and bounded by a relief taken at a RELIEF OPPORTUNITY. NON-DRIVING SPELLs are either STAND-BYs or TASKs, classified as of a certain TASK TYPE. This covers TASKs such as taking buses through a wash, which are performed by drivers in some companies.

6.2.10.2.5 The start and end times of NON-DRIVING SPELLs are stored in the "start time" and "end time" attributes for this entity. The start and end times of a DRIVING SPELL can be derived from the times of the RELIEF OPPORTUNITYs at the start and end of that DRIVING SPELL.

6.2.10.2.6 The VEHICLE JOURNEYS to be covered by each DRIVING SPELL can be derived from the model as shown in the diagrams on [Figure 7 — Vehicle Scheduling](#) and [Figure 10 — Driver Duties](#). A DRIVING SPELL is bounded by two RELIEF OPPORTUNITIES. These RELIEF OPPORTUNITIES are points in time in a particular BLOCK. This BLOCK consists of VEHICLE JOURNEYS, and all the VEHICLE JOURNEYS in that BLOCK between the start and the end RELIEF OPPORTUNITY will be driven by the driver who has to work that DRIVING SPELL.

6.2.10.2.7 When the Driver Scheduling is complete, relationships between all the layers of DUTY hierarchy must have been recorded.

6.2.10.2.8 Start and end times of DUTY PARTs and STRETCHes may be stored as attributes of these entities or they may be derived from the SPELLs if the component SPELLs have been specified. Checks must be included to ensure that the different ways of finding this information give consistent results.

6.2.10.2.9 The interval between the start and end time of a DUTY PART must include the time necessary for a driver to proceed from the start TIMING POINT specified for this DUTY PART to the TIMING POINT where the first STRETCH has to be started, and the time needed to proceed from the TIMING POINT where the last STRETCH will be finished to the end TIMING POINT of that DUTY PART. If start and end times are explicitly specified for a STRETCH, these must similarly embrace any necessary trips of the driver to proceed to the TIMING POINTs where the different SPELLs in that STRETCH will have to be started, or where a BREAK may be spent (see section [6.2.10.7](#) on Driver Trips).

6.2.10.2.10 DUTYs may be related to ORGANISATIONAL UNITs. The BLOCKs to be covered by these DUTYs may also be related to an ORGANISATIONAL UNIT. Constraints may well be needed, for example, to check that BLOCKs covered by a DUTY are managed by the ORGANISATIONAL UNIT which is in charge of that DUTY. However, as discussed in section [6.2.8.5](#), this sort of constraint will be the responsibility of users.

6.2.10.3 *Duty Types*

6.2.10.3.1 DUTYs must be classified as of a particular DUTY TYPE which indicates their time profile for the purposes of rostering. Rostering algorithms usually make an initial assignment of DUTYs to logical drivers according to the DUTY TYPE, to give a spread of DUTYs which is fair or agreed for each driver.

6.2.10.3.2 DUTY TYPEs may be either SPLIT DUTYs or CONTINUOUS (“straight”) DUTYs, or may be individually defined by a company to meet its own particular needs (e.g. to allow for DUTYs made up of three or more DUTY PARTs). They may be further classified by descriptions such as “early” or “late”. The ranges of start and end times of each DUTY TYPE can be described by relationships to the TIME BAND entity. The time range of the unpaid part of a SPLIT DUTY is described in the same way.

6.2.10.3.3 If a DUTY is made up of two DUTY PARTs it must be classified as of DUTY TYPE: SPLIT DUTY. If it is made up of only one DUTY PART it must be classified as DUTY TYPE: CONTINUOUS DUTY.

6.2.10.4 *Breaks and Pauses and Fill In Times*

6.2.10.4.1 Drivers cannot work continuously for long periods of time and must be given BREAKs. The length of work periods between BREAKs and the length of the BREAKs is a matter of legal requirement and company and union agreement. In this model, BREAKs are identified by the STRETCH of work that they follow. BREAKs must be arranged at a TIMING POINT where there is a BREAK FACILITY including toilets and meals and other refreshments. This is usually at a RELIEF POINT where the driver is relieved by another driver, but in some cases the driver may have to walk to another TIMING POINT which is near to the RELIEF POINT and is a more suitable place to stay during a BREAK (for example a service centre in a pedestrian zone).

6.2.10.4.2 The start time of a BREAK can be derived from the end time of the corresponding STRETCH. The attribute “duration” may be used to give the planned length of the BREAK. When the Driver Scheduling is complete, the order of the STRETCHes within a DUTY PART may be derived from their start times. Thus, the end time of a BREAK may be derived from the start time of the next STRETCH in the DUTY PART.

6.2.10.4.3 BREAKs are deliberately built in to the DUTYs. PAUSEs, on the other hand, are spare times at the end of VEHICLE JOURNEYS which usually arise as a result of the Vehicle Scheduling process, and may be used as rest or refreshment times for drivers. They may be taken in a BREAK FACILITY, but the driver remains responsible for the VEHICLE during the PAUSE. In some cases, PAUSEs may also be planned deliberately. (The PAUSE entity, with its relationship to VEHICLE JOURNEY, is shown in [Figure 11 — Driver Trips](#)).

6.2.10.4.4 FILL IN TIMEs are the times when a driver may be waiting at a TIMING POINT for some reason. In some cases extra time has to be added to a SPELL for it to come up to an agreed minimum. Or the Driver Scheduling process may result in spare time before or after DRIVING SPELLs.

6.2.10.5 *Preparation and Finishing Activities*

6.2.10.5.1 At the begin or the end (or both) of a DUTY or of one of its component parts, a driver may have to perform certain activities to prepare for, or to finish, the work regularly assigned to the DUTY. These activities may include signing on or off, controlling the amount of money and taking over or giving back the purse (if the driver has to collect fares from the passengers), controlling the condition of the vehicle, or other activities related to the DUTY components in question.

6.2.10.5.2 The durations scheduled for these preparation and finishing activities may be recorded in the corresponding attributes for a DUTY, a DUTY PART, a STRETCH, a SPELL and also for a single BLOCK (or even separately for each COURSE OF JOURNEYS) in a DRIVING SPELL. Each company may choose the levels it wants to use for the specification of these durations.

6.2.10.5.3 The start and end times which have been specified for DUTY PARTs and for STRETCHes should embrace any preparation and finishing durations. If preparation and finishing durations are recorded for a SPELL, these should be included in the interval between the start and end time if it is a NON-DRIVING SPELL. These durations must however be added to the time between the start and end RELIEF OPPORTUNITYs of a DRIVING SPELL.

6.2.10.6 *Qualifications*

6.2.10.6.1 A DUTY may require personal QUALIFICATIONs of the driver who will be assigned to it by the personnel disposition manager. These may be a certain number of years of driving experience, special knowledge of a particular part of the network, particular social or demographic characteristics, or other properties which may affect the suitability of a driver for a particular kind of DUTY.

6.2.10.6.2 The necessary QUALIFICATIONs may be specified for each SPELL of driver work, taking into account the individual activities included in the SPELL in question, or may be related to the whole DUTY. The first case requires the management of QUALIFICATIONs on a rather detailed level. In the second case, the duty manager will often have the choice among a limited number of defined QUALIFICATIONs to be entered at DUTY level, reflecting the global needs for all activities in the lower level component parts of the DUTY.

6.2.10.6.3 The QUALIFICATIONs specified for DUTYs or SPELLs will have to be checked by the personnel disposition manager when individual drivers are chosen to actually work the scheduled DUTYs. If QUALIFICATIONs are recorded both for a DUTY and for certain SPELLs in that DUTY, the driver assigned to it is assumed to possess the entirety of all these QUALIFICATIONs. Additional QUALIFICATIONs required for driving a particular VEHICLE TYPE used for the VEHICLE JOURNEYS covered by this DUTY may have to be taken into account additionally (see section 6.2.9.5).

6.2.10.7 *Driver Trips*

6.2.10.7.1 Driver Scheduling must allow for the time it takes a driver to get to the starting point and to return from the finishing point of her SPELL of work. This DRIVER TRIP will often be on foot, but may be on a SERVICE JOURNEY driven by another driver. The time for these trips may depend on the time of day. The entity DRIVER TRIP TIME allows for a set of times for each DRIVER TRIP depending on the TIME BAND, but many companies will just store one time per DRIVER TRIP.

6.2.10.7.2 It is possible that a DRIVER TRIP might be complex and might involve waiting for infrequent SERVICE JOURNEYS. In this case, companies might prefer to assess the time it will take by methods normally used for passenger information queries. For this reason, DRIVER TRIP may be associated with a TRIP defined by two PLACEs which are its origin and destination.

6.2.10.7.3 DRIVER TRIPs may be necessary for various reasons, and may be between TIMING POINTs with different roles in the scheduling process. These may be TIMING POINTs

- where a DUTY PART starts or ends, and sign on and sign off may take place,
- where drivers may be relieved and which therefore are RELIEF POINTs,
- where a BREAK FACILITY is available and therefore drivers may spend their BREAK time,
- where a VEHICLE JOURNEY ends, and a PAUSE is given to the driver which he will spend using a BREAK FACILITY nearby,
- where a NON-DRIVING SPELL will take place,

- where the VEHICLE to be taken over by the driver is parked and which therefore is a PARKING POINT,
- where a particular FILL IN TIME is spent that has been scheduled for the driver.

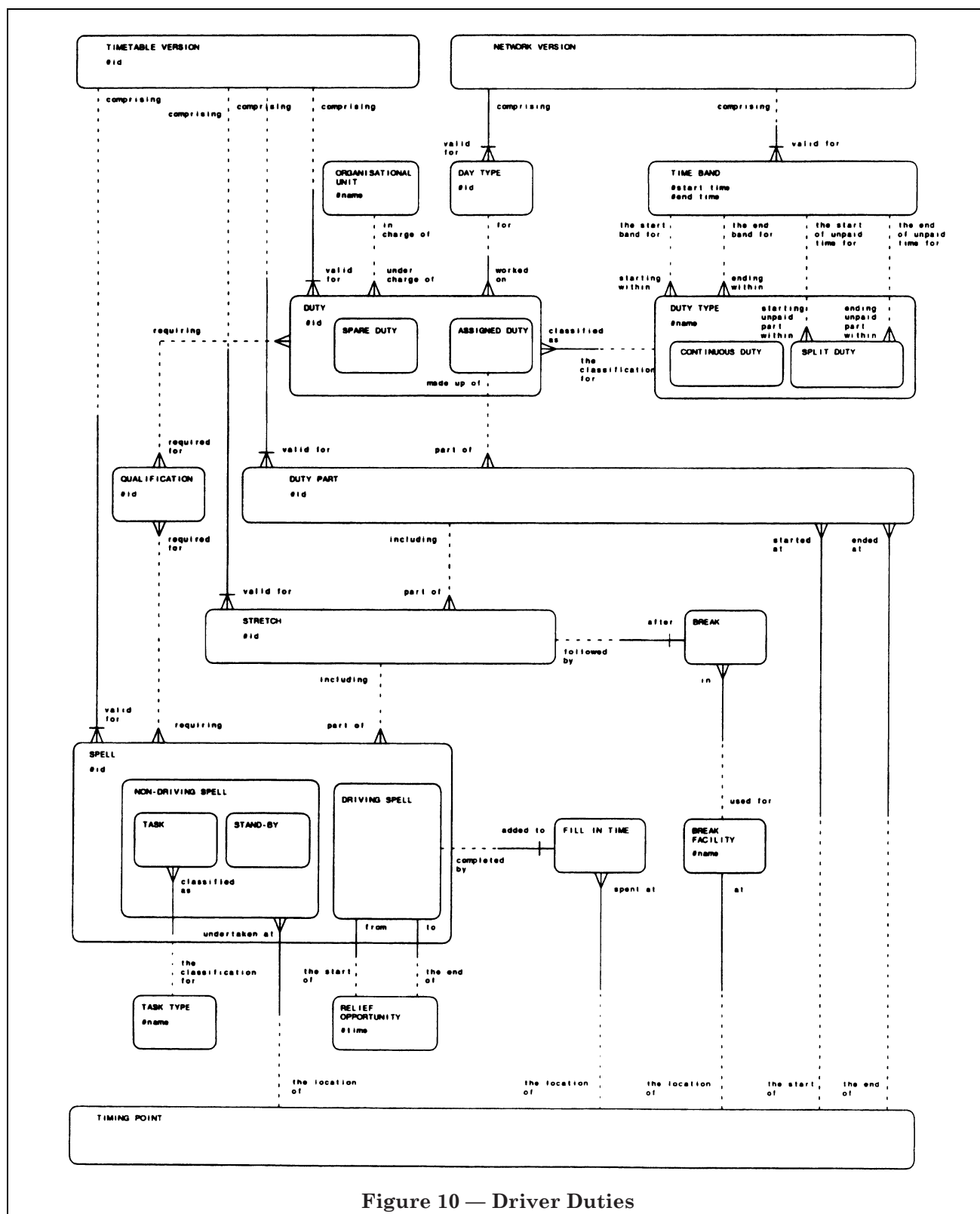


Figure 10 — Driver Duties

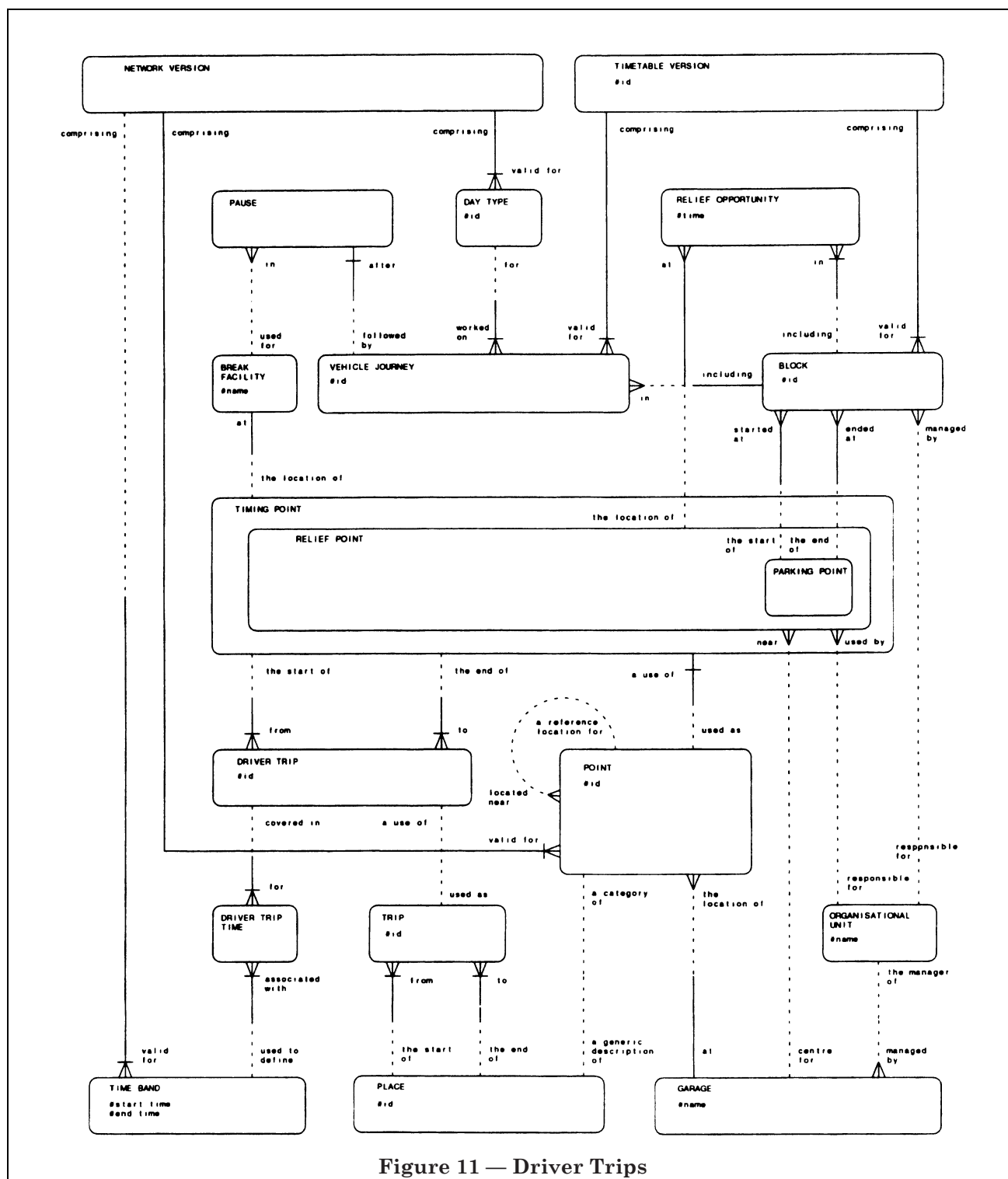


Figure 11 — Driver Trips

6.2.10.7.4 DRIVER TRIPS may be necessary between any of these kinds of **TIMING POINTS** as a result of the scheduling process. The **DRIVER TRIP TIME** entity shown in the diagram on [Figure 11 — Driver Trips](#) would then hold the time demands for all of these **DRIVER TRIPS** needed to define the connection between the different component parts of a **DUTY**.

6.2.10.7.5 Some operators may not want to specify explicitly any origin or destination of the trip a driver has to perform before the start or after the end of a DUTY PART, respectively. To allow for this practice, optional attributes “driver access duration” and “driver return duration” of the DUTY PART entity may be used to define a lump sum for wage accounting to cover these access or return trips. This may include the time drivers spend for their way from home to work and vice versa.

6.2.10.8 Accounting Factor

6.2.10.8.1 The work time of drivers may not always be paid evenly at the same rates. If this is the case, input information needs to be recorded for particular component parts of DUTYs, which will be needed for wage accounting after the DUTYs have actually been worked.

6.2.10.8.2 An accounting factor may be defined using a corresponding attribute of DUTY PART, STRETCH or SPELL. This factor gives the percentage of paid time in the STRETCHes or SPELLs in question. It will usually range from 0 to 1, and will actually be 1 in most cases. (Alternatively, an accounting duration may be specified instead of a factor, if the company wants to express the modified amount of time to be paid in terms of a lump sum).

6.2.10.8.3 The accounting factor is more relevant for BREAKs, PAUSEs and FILL IN TIMEs. These parts of a driver’s work time are sometimes paid by a percentage less than 100. A DRIVER TRIP may also be not fully paid in some cases. An accounting factor may therefore also be stored for a DRIVER TRIP.

6.2.10.8.4 If accounting factors are specified at different levels of the DUTY components hierarchy, the factor stored against a DUTY PART or STRETCH will override all specifications given at lower levels, but will not override the accounting factor for a BREAK.

6.2.10.8.5 Accounting factors are not used to specify an increase of the wages as a result of particular aggravation circumstances during work, or to give an additional bonus for overtime worked by the driver. Entities to describe these factors will be introduced in the Personnel Disposition data model.

6.2.11 Rostering

6.2.11.1 General Remarks

6.2.11.1.1 After driver DUTYs have been scheduled, all the DUTYs have to be assigned to all the drivers in a way that meets the legal restrictions and the agreements made between the company and the driver unions. Furthermore, preferences expressed by the drivers themselves may be taken into account to a certain extent.

6.2.11.1.2 To do this, it is necessary to define subsets of DUTYs which will be worked through in order by one driver during a particular planning period. Within this period, the DUTYs to be worked by a driver must have been set in a specific sequence with respect to their DUTY TYPEs. This is necessary to ensure that the workload is distributed equally among all drivers, and no driver has an unacceptable pattern of DUTY TYPEs assigned to him/her (e.g. only SPLIT DUTYs for many subsequent days).

6.2.11.1.3 There are different rostering methods applied in companies within one country, and even more in the whole of Europe. This document aims to provide a generic data structure which could be used as a basis for different methods of building a driver roster. Therefore, there are more entities in the rostering model than would ever be needed by any one single company, but each company may choose those parts of the rostering model that would satisfy the needs of the particular rostering method they want to apply.

6.2.11.1.4 Methods of driver management are likely to evolve, including the development of new concepts fundamentally different from any classical rostering schema. New approaches better adaptable to modern management principles and differentiated driver preferences will probably be tried and used by public transport companies in the future.

6.2.11.1.5 This prestandard has not been designed to hinder any innovative developments particularly to be expected in the field of driver management. The rostering part of the conceptual data model therefore has to be considered as a reference basis for companies working with one of the conventional rostering methods covered by the model, but is not obligatory for applications having implemented other advanced planning methods.

6.2.11.2 Roster Matrices

6.2.11.2.1 A ROSTER MATRIX is a duty plan for a certain period of time and for a number of drivers, into which the relevant DUTYs to be worked will be entered.

6.2.11.2.2 The rows of the matrix are associated with the drivers and the columns with the days of the chosen planning period. Some companies may use this schema vice versa, but according to the most common practice, this prestandard has defined the rows and columns of a ROSTER MATRIX as the ROW/DRIVER and the COLUMN/DAY entity, which may be reversed in a particular application.

6.2.11.2.3 A ROSTER ELEMENT, defined by one ROW/DRIVER and one COLUMN/DAY, is the place where an individual DUTY will be entered which will have to be worked by that particular driver on the CALENDAR DAY associated with the column of the matrix.

6.2.11.2.4 Drivers are not always treated together in one big ROSTER MATRIX. Groups of drivers will be defined, and for each group a separate ROSTER MATRIX will be used to assign sequences of DUTYs to the drivers in this specific group. Thus, there may be more than one ROSTER MATRIX in one COMPANY or ORGANISATIONAL UNIT. These may have different structures or include different types of DUTY.

6.2.11.2.5 The grouping of drivers and their assignment to different ROSTER MATRIXes may take into account different contractual regulations of work time, or individual preferences for certain DUTY TYPEs or patterns of duty sequences (e.g. part time work). Individual preferences and contractual agreements may be expressed by a relationship between the DRIVER entity and the ROSTER MATRIX, expressing that this particular matrix is constructed in a way that meets the individual constraints of the specified DRIVERS (and vice versa).

6.2.11.2.6 The DRIVER entity describes a *physical* driver who is an EMPLOYEE of the public transport company, in contrast to the ROW/DRIVER entity which means a *logical* driver in the planning process, without having an individual person attached to it.

6.2.11.2.7 The responsibility for the rostering process may be subdivided among several ORGANISATIONAL UNITs of the company. Each ROSTER MATRIX may therefore be owned by a particular ORGANISATIONAL UNIT. An ORGANISATIONAL UNIT may have DRIVERS (and other EMPLOYEEs) at its disposal who may be allocated to the ROSTER MATRIXes set up by this ORGANISATIONAL UNIT.

6.2.11.3 Roster Cycles

6.2.11.3.1 Using ROSTER CYCLEs is one of the possible methods of setting up sequences of DUTY TYPEs which will be assigned to the ROWs/DRIVERS in a ROSTER MATRIX. DUTYs of these specified types will then be entered into the ROSTER ELEMENTs to provide a suitable order of working times for each driver.

6.2.11.3.2 A ROSTER CYCLE is a period of time, generally defined as a number of days, to which a sequence of work and rest days will be assigned. The work days will be further specified by DUTY TYPEs to be worked subsequently in the order given by the cycle days.

6.2.11.3.3 This ROSTER CYCLE will be used to define a recurring pattern of WORK and REST days (or DUTY TYPEs and REST days) which serves as a basis when DUTYs are entered into a ROSTER MATRIX. In a first step of the rostering process, the DUTY TYPE/REST pattern of the ROSTER CYCLE is assigned repeatedly to a ROW/DRIVER of the ROSTER MATRIX. The same assignment is made for the adjacent rows, but with a lag in the COLUMN/DAY which is usually between 1 day and the total length of the ROSTER CYCLE minus 1.

6.2.11.3.4 This assignment is done without respect to the fact that in most cases there are fewer DUTYs to be worked on weekends than during the week. Additional free days (REST days) will have to be assigned to replace existing assignments in order to balance the number of DUTYs depending on the variations of the service. This procedure is carried out by the software packages in question, and need not be reflected in the data model.

6.2.11.4 Roster Designs

6.2.11.4.1 The concept of ROSTER DESIGN is based on another method for setting up sequences of DUTY TYPEs and REST days which will be used to enter DUTYs into the ROSTER MATRIX. This method defines sequences of DUTY TYPEs and REST days for a certain number of calendar weeks, taking into account the different numbers of DUTYs of each type to be worked on the different week days.

6.2.11.4.2 A ROSTER DESIGN is a building unit for a ROSTER MATRIX which is made up of a specified number of DESIGN WEEKs, e.g. 1 week, 4 weeks or 5 weeks. Each DESIGN WEEK consists of seven DESIGN WEEK ELEMENTs, which represent the seven DAYS OF WEEK. A relationship between ROSTER DESIGN and DAY OF WEEK determines which DAY OF WEEK will be first in the order of DESIGN WEEK ELEMENTs of the DESIGN WEEKs in that ROSTER DESIGN (for example: each DESIGN WEEK will start on a Saturday).

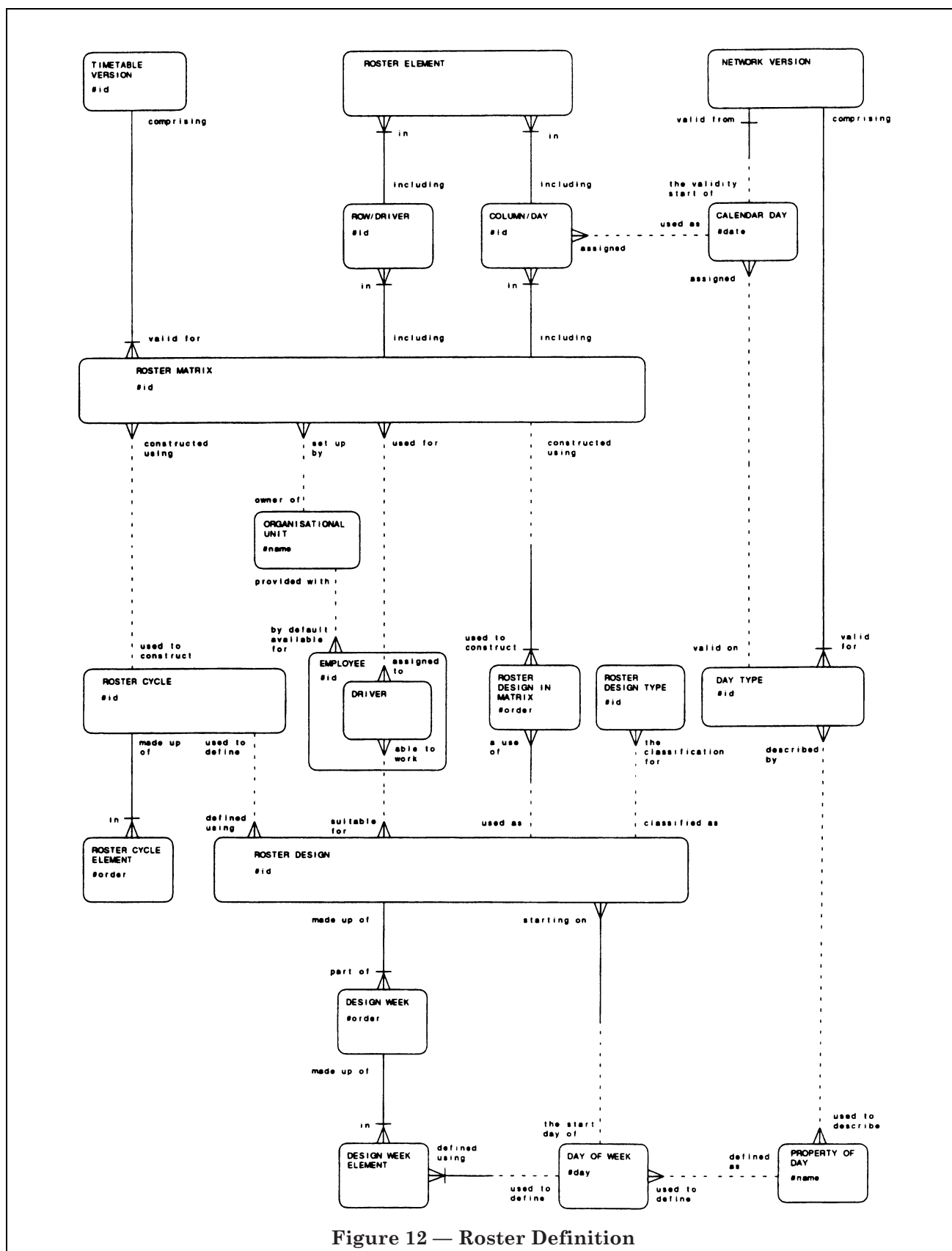
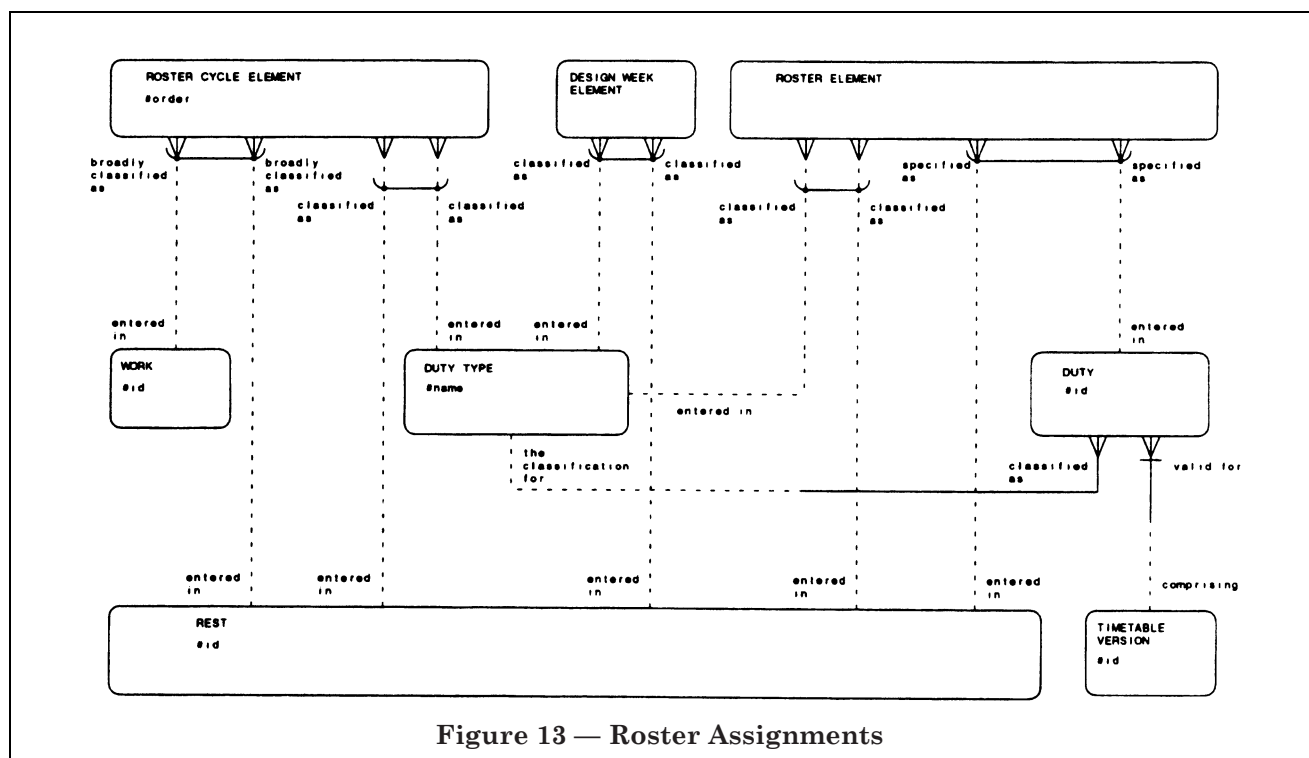


Figure 12 — Roster Definition



6.2.11.4.3 A DAY OF WEEK (or a combination of these) may sometimes be chosen to define a particular **PROPERTY OF DAY**, a combination of which is used to describe a **DAY TYPE**.

6.2.11.4.4 DUTY TYPES or REST days will be assigned to each DESIGN WEEK ELEMENT, giving a specified pattern of DUTY TYPEs and REST days to each of the DESIGN WEEKs of the ROSTER DESIGN. The DUTY TYPEs within one DESIGN WEEK may sometimes be chosen as being of the same broad type (e.g. “early working”).

6.2.11.4.5 The whole ROSTER DESIGN may be classified by a ROSTER DESIGN TYPE, which may describe the ROSTER DESIGN in terms of the number of weeks it covers, the proportion of work to free days, the broad type of DUTYs assigned to certain positions in the ROSTER DESIGN, and/or other defining factors.

6.2.11.4.6 Special ROSTER DESIGNS may particularly suit individual work time regulations or personal preferences for a certain group of drivers, while other designs are less favourable for them. According to the individual constraints and preferences, those DRIVERS may be specified which are able to work a ROSTER DESIGN, and which ROSTER DESIGNS are suitable for a given DRIVER.

6.2.11.5 Roster Assignments

6.2.11.5.1 After a ROSTER MATRIX (or several) has been defined and the decision has been made on how to structure the input for the rostering process (i.e. the DUTYs differentiated by their type), either by means of a ROSTER CYCLE or by ROSTER DESIGNs, assignments will be made to obtain a satisfying pattern of DUTYs for each driver for the planning period in question.

6.2.11.5.2 If ROSTER CYCLES are used to define sequences of DUTYs to be entered into the ROSTER MATRIX, there are usually three stages of assignments. In a first stage, only a pattern of WORK and REST days is assigned to the ROSTER CYCLE, specifying a WORK or REST for each ROSTER CYCLE ELEMENT. In a second stage, those ROSTER CYCLE ELEMENTS to which WORK has been assigned are given a DUTY TYPE. This assignment takes into account the agreements made between the company and the driver unions. The last stage of the rostering process will result in a final assignment of DUTYs to the ROSTER ELEMENTs of the ROSTER MATRIX. The rostering software will use the structure of DUTY TYPEs and REST days in the ROSTER CYCLE to determine the sequence of DUTYs for each ROW/DRIVER in the ROSTER MATRIX. It will have to balance and optimise the final assignment of DUTYs according to the number of DUTYs to be worked on each DAY TYPE, and taking into account driver preferences.

6.2.11.5.3 If the DESIGN WEEK method is used, a pattern of DUTY TYPEs and RESTs is assigned to each DESIGN WEEK in a ROSTER DESIGN. This pattern can be defined by a suitable ROSTER CYCLE with a given assignment of DUTY TYPEs and RESTs, or it can be defined by individual assignments of a DUTY TYPE or REST to each DESIGN WEEK ELEMENT. The rostering software will use this information to enter DUTYs into ROSTER ELEMENTs, using sophisticated algorithms which optimise the sequence of DUTYs for the DRIVERS/ROWs according to a variety of rules which are not modelled, as this prestandard does not attempt to reflect the functionality of software products at all. ²⁾ provides an introduction to crew rostering using design weeks.

6.3 Personnel Disposition Data Model

6.3.1 Introduction

6.3.1.1 The Personnel Disposition data model covers the data needs of the functional area *manage driving personnel* of the functional model. This includes the following functions:

- plan mid term assignment of drivers to duties,
- plan short term assignment of drivers to duties,
- control drivers,
- collect and process the driver data.

6.3.1.2 A part of the data needed by the personnel disposition functions is already included in the Scheduling data model, and this is not repeated here. Among these, most relevant for the personnel disposition process, is the information on driver scheduling and particularly on duty rostering, which is the starting point for the management of drivers and has to provide the necessary input of information for the personnel disposition functions.

6.3.1.3 In the future, information output from AVM systems will perhaps also be used as input data for personnel disposition and wage accounting systems. In this case, the software for personnel disposition will have to become even more complex than it sometimes is today. The personnel disposition data model, however, is rather simple, being limited to the main data structures needed as input for managing the drivers and calculating their wages.

6.3.1.4 The methods applied for driver management, and especially wage calculation, vary between countries and operators. Legal requirements, company rules and agreements, and constraints inherent in the different national conditions differ substantially. It is therefore difficult to develop data structures covering all the needs which may arise from the various different practices in one single model.

6.3.1.5 An attempt was made to define some basic structures generic enough to cover the information needs which have been expressed explicitly and given as input to the harmonisation process. However, the basis of input was limited to contributions from only few countries, so the level of obligation of the personnel disposition model cannot be seen as strict as for other parts of the reference model.

6.3.2 Driver Assignments

6.3.2.1 Assignment of Drivers to Rows in a Roster Matrix

6.3.2.1.1 The process of rostering defines a pattern of DUTY TYPEs and REST days and at the next stage specifies individual DUTYs for the DUTY TYPEs. These assignments are planned long-term, whereas the DUTYs entered into the ROSTER ELEMENTs may be subject to optimisations or re-planning in the medium-term.

6.3.2.1.2 As the result of this process, DUTYs have been assigned to (logical) drivers which are represented as rows in a ROSTER MATRIX. These logical drivers are modelled by an entity ROW/DRIVER. The total number of logical drivers is determined by the maximum number of DUTYs to be worked on a DAY TYPE.

6.3.2.1.3 The number of physical drivers required to cover all the ROWs/DRIVERs of the ROSTER MATRIXes set up by the public transport company is of course higher, because reserves are necessary to balance driver absences in case of holidays, illness etc. Physical drivers are represented in the model by the entity DRIVER, but EMPLOYEEs other than DRIVERs may sometimes also be needed to cover all the DUTYs to be worked on a particular CALENDAR DAY.

²⁾ An Approach to Bus-Crew Roster Design in London Regional Transport
W.Townsend, Leeds Polytechnic
Journal of the Operations Research Society, Vol. 39, No. 6, 1988

6.3.2.1.4 The first goal (and one of the main tasks) of personnel disposition is to define relationships between the logical drivers, as present in the ROSTER MATRIXes, and physical drivers, who are employed by the company to drive buses or other public transport vehicles. In other words, driver management has to assure that for each day of operation there are enough (physical) drivers available for the DUTYs which have to be worked on that day, and which have already been assigned to logical drivers taking into account criteria of suitable duty sequences to meet work agreements and driver preferences.

6.3.2.1.5 The assignment of physical to logical drivers can be carried out practically based on different time horizons. Some companies may want a long-term driver assignment and establish a fixed relationship between EMPLOYEEs and ROWs/DRIVERs in a ROSTER MATRIX for a time in advance, maybe as long as the validity period of a TIMETABLE VERSION, or even longer.

6.3.2.1.6 Some other companies will start their driver assignments only on a medium-term basis, specifying the EMPLOYEEs to be associated with the ROWs/DRIVERs of a ROSTER MATRIX for a number of days in advance, but not fixing them for e.g. a whole TIMETABLE VERSION. Companies which have already defined their assignments in the long term will probably have to override some of these assignments, because unforeseeable events will certainly necessitate modifications to the planning.

6.3.2.1.7 The main task of driver management is, however, to ensure the availability of enough EMPLOYEEs with the appropriate qualifications to work all the DUTYs which have been scheduled for each individual day of operation. In this sense, driver management is rather short-term oriented, defining which physical driver has to take over the place of which logical driver for the actual day. In the data model, the DRIVER ASSIGNMENT entity is used to specify for each CALENDAR DAY and each ROW/DRIVER of a ROSTER MATRIX which EMPLOYEE will have to work the DUTY which has been entered into the ROSTER ELEMENT defined by this ROW/DRIVER and the COLUMN/DAY associated with that CALENDAR DAY.

6.3.2.1.8 The EMPLOYEE specified by this assignment will be a DRIVER in most cases. But sometimes a company may want to fall back upon other EMPLOYEEs also, such as older persons who were DRIVERs for many years but have taken over other jobs in the company since then, or maintenance staff with a driver's license etc.

6.3.2.1.9 In practice, the assignment of physical to logical drivers is of course not done separately for each CALENDAR DAY, but for a number of days in advance. One physical driver will probably be assigned to one and the same ROW/DRIVER in a ROSTER MATRIX for a number of consecutive CALENDAR DAYs, in order to follow the duty sequence which has been defined for this logical driver. Any medium-term assignment may of course be overridden in the short-term, either due to unexpected absences of drivers from work, or as a result of further optimisations or duty exchanges requested by drivers themselves.

6.3.2.2 Qualifications

6.3.2.2.1 A number of particular QUALIFICATIONs may be assigned to each EMPLOYEE, especially DRIVER, in order to record a specific knowledge, capability, experience, or formally certified education etc. All the QUALIFICATIONs recorded for an EMPLOYEE define the profile of his/her operational availability.

6.3.2.2.2 On the other hand, DUTYs may require special QUALIFICATIONs from drivers in order to ensure that all the tasks covered by this DUTY can be carried out correctly. The ownership of a bus driver's license will certainly be a QUALIFICATION necessary for each DUTY which covers at least one DRIVING SPELL on a bus, or STAND-BY. Some companies may, for example, want to record a special suitability for DUTYs with school bus operation. Experience in a particular service area or even on a particular route may be recorded in the description of the QUALIFICATION.

6.3.2.2.3 The QUALIFICATIONs a driver must have to work a DUTY may also be derived from special QUALIFICATIONs required for particular SPELLs, or for VEHICLE TYPEs used for VEHICLE JOURNEYs in the corresponding DRIVING SPELLs of the DUTY.

6.3.2.2.4 As soon as an EMPLOYEE is specified by a DRIVER ASSIGNMENT for a ROW/DRIVER and a CALENDAR DAY, it has to be checked that this EMPLOYEE possesses all the QUALIFICATIONs needed for the DUTY which has to be worked by this ROW/DRIVER on the COLUMN/DAY associated with that CALENDAR DAY.