



BSI Standards Publication

Public transport — Reference data model

Part 4: Operations monitoring and control

National foreword

This British Standard is the UK implementation of EN 12896-4:2019.

The UK participation in its preparation was entrusted to Technical Committee EPL/278, Intelligent transport systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2019
Published by BSI Standards Limited 2019

ISBN 978 0 539 02046 5

ICS 35.240.60

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 April 2020.

Amendments/corrigenda issued since publication

Date	Text affected
------	---------------

English Version

Public transport - Reference data model - Part 4: Operations monitoring and control

Transports publics - Modèle de données de référence -
Partie 4 : suivi et contrôle de l'exploitation

Öffentlicher Verkehr - Referenzdatenmodell Teil 4:
Betriebsüberwachung und Steuerung

This European Standard was approved by CEN on 19 April 2019.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.



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

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Contents

Page

European foreword.....	10
Introduction	11
1 Scope	12
1.1 General Scope of the Standard.....	12
1.2 Functional Domain Description	13
1.3 Particular Scope of this Document.....	13
2 Normative references	14
3 Terms and definitions	14
4 Symbols and Abbreviations.....	16
5 Operations monitoring and control	17
5.1 Introduction	17
5.2 Dated Operational Plans.....	18
5.2.1 Principles	18
5.2.2 Vehicle Work Production Components	19
5.2.3 Dated Vehicle Service	23
5.2.4 Dated Call	24
5.2.5 Implementation of Dated Plans	25
5.2.6 Production Plan	25
5.3 Resource Detection and Monitoring	27
5.3.1 Limits	27
5.3.2 Functions Related to the Monitoring Process	27
5.3.3 Resources to be monitored.....	28
5.3.4 Vehicle Detecting.....	29
5.3.5 Vehicle Monitoring	30
5.4 Vehicle Assignments	31
5.4.1 General	31
5.4.2 Assignments	32
5.4.3 Work Plan Assignment.....	32
5.4.4 Vehicle Assignment	33
5.5 Monitored Operations	33
5.5.1 Monitored Services.....	33
5.5.2 Monitored Passing Times.....	35
5.5.3 Other Monitored Situations.....	36
5.5.4 Expected and Registered Situation.....	37
5.6 Control Actions.....	37
5.6.1 General.....	37
5.6.2 Vehicle Control Actions.....	39
5.6.3 Elementary Journey Control Actions.....	40
5.6.4 Composite Journey Control Actions.....	43
5.6.5 Interchange Control Actions	44
5.7 Operational Events	46
5.8 Operational Messages.....	48
5.9 Situation Description.....	49
5.10 Monitored Facilities	52

Annex A (normative) Data Dictionary	55
A.1 Introduction	55
A.2 Data Dictionary — Operations Monitoring and Control	55
A.2.1 ALARM	55
A.2.2 ARRIVAL	55
A.2.3 CALL	56
A.2.4 CALL FOR MEANS	56
A.2.5 CALL FOR REPAIRS	56
A.2.6 CALL PART	56
A.2.7 CASUALTIES	57
A.2.8 CHANGE OF JOURNEY PATTERN	57
A.2.9 CHANGE OF JOURNEY TIMING	57
A.2.10 CHANGE OF VEHICLE	58
A.2.11 COMPOSITE JOURNEY CONTROL ACTION	58
A.2.12 CONTROL ACTION	58
A.2.13 DATED ARRIVAL	59
A.2.14 DATED CALL	59
A.2.15 DATED CALL PART	59
A.2.16 DATED DEPARTURE	59
A.2.17 DATED JOURNEY PART	60
A.2.18 DATED SPECIAL SERVICE	60
A.2.19 DATED VEHICLE JOURNEY INTERCHANGE	61
A.2.20 DATED VEHICLE SERVICE	61
A.2.21 DATED VEHICLE SERVICE PART	61
A.2.22 DELAY	62
A.2.23 DEPARTURE	62
A.2.24 DEPARTURE EXCHANGE	62
A.2.25 DEPARTURE LAG	63
A.2.26 DETECTED OPERATION	63
A.2.27 DRIVER INCIDENT	63
A.2.28 EASEMENT	64
A.2.29 ELEMENTARY JOURNEY CONTROL ACTION	64
A.2.30 ESTIMATED PASSING TIME	64
A.2.31 EXTRA DATED VEHICLE JOURNEY	65
A.2.32 FACILITY CONDITION	65
A.2.33 FACILITY MONITORING METHOD	66

A.2.34 FACILITY OPERATIONAL EVENT	66
A.2.35 FACILITY STATUS	66
A.2.36 FLEXIBLE JOURNEY ACTIVATION	67
A.2.37 IMPEDED TIME	67
A.2.38 INCIDENT	67
A.2.39 INTERCHANGE CANCELLATION	68
A.2.40 INTERCHANGE CONTROL ACTION	68
A.2.41 INTERCHANGE CREATION	69
A.2.42 INTERCHANGE MODIFICATION	69
A.2.43 JOURNEY CANCELLATION	70
A.2.44 JOURNEY CREATION	70
A.2.45 LOGICAL DRIVER	70
A.2.46 LOGICAL VEHICLE	70
A.2.47 LOGICAL VEHICLE CANCELLATION	71
A.2.48 LOGICAL VEHICLE CREATION	71
A.2.49 METHOD OF CAPTURE	71
A.2.50 MONITORED FACILITY	71
A.2.51 MONITORED JOURNEY PART FACILITY	72
A.2.52 MONITORED LOCAL SERVICE FACILITY	72
A.2.53 MONITORED OPERATION	72
A.2.54 MONITORED PLACE EQUIPMENT FACILITY	73
A.2.55 MONITORED SPECIAL SERVICE	73
A.2.56 MONITORED VEHICLE EQUIPMENT FACILITY	73
A.2.57 MONITORED VEHICLE JOURNEY	74
A.2.58 MONITORED VEHICLE JOURNEY FACILITY	74
A.2.59 OBSERVED PASSING TIME	74
A.2.60 OPERATIONAL EVENT	75
A.2.61 OPERATIONAL MESSAGE	75
A.2.62 PARTIAL JOURNEY CANCELLATION	75
A.2.63 PLANNED REMEDY	76
A.2.64 PRODUCTION PLAN	76
A.2.65 PT SITUATION	76
A.2.66 PT SITUATION AFFECTED SCOPE	76
A.2.67 PT SITUATION CONSEQUENCE	77
A.2.68 PT SITUATION CONSEQUENCE SCOPE	77
A.2.69 PT SITUATION GENERAL CONSEQUENCE	78

A.2.70 PT SITUATION MESSAGE	78
A.2.71 RELATED SITUATION	78
A.2.72 REMEDY	79
A.2.73 RESORPTION.....	79
A.2.74 RESPACING	79
A.2.75 SITE OPERATIONAL EVENT	80
A.2.76 SITUATION	80
A.2.77 SITUATION CAUSE	80
A.2.78 SITUATION REASON	81
A.2.79 SITUATION SOURCE	81
A.2.80 TYPE OF DELAY.....	81
A.2.81 TYPE OF SITUATION SOURCE	82
A.2.82 TYPE OF VEHICLE DETECTING	82
A.2.83 TYPE OF VEHICLE MONITORING.....	82
A.2.84 VEHICLE ASSIGNMENT	83
A.2.85 VEHICLE CONTROL ACTION.....	83
A.2.86 VEHICLE DETECTING	83
A.2.87 VEHICLE DETECTING LOG ENTRY	84
A.2.88 VEHICLE INCIDENT	84
A.2.89 VEHICLE MONITORING.....	84
A.2.90 VEHICLE MONITORING LOG ENTRY.....	85
A.2.91 VEHICLE WORK ASSIGNMENT	85
Annex B (normative) Additional Common Concepts — Extension to EN 12896-1:2016, <i>Public Transport – Reference Data Model – Part 1: Common Concepts</i>	86
B.1 Methodology and Conventions	86
B.1.1 Methodology for conceptual modelling.....	86
B.1.1.1 General	86
B.1.1.2 General	86
B.1.1.3 Packages.....	86
B.1.1.4 Package Prefixes and Package order.....	87
B.1.1.5 Part Prefixes and diagram names.....	88
B.1.1.6 Class diagrams	88
B.1.1.7 Class Diagram Presentations.....	89
B.1.1.8 Use of Colour.....	89
B.1.2 MODEL Class Diagrams.....	90
B.1.2.1 General	90
B.1.2.2 Classes and attributes	91

B.1.2.2.1	General	91
B.1.2.2.2	Attribute visibility	91
B.1.2.2.3	Attribute names.....	92
B.1.2.2.4	Attribute types.....	92
B.1.2.2.5	Multiplicity of Attributes.....	92
B.1.2.2.6	Common attributes	92
B.1.2.2.7	Simple Diagram Example	92
B.1.2.3	Relationships	94
B.1.2.3.1	General	94
B.1.2.3.2	Association relationships	94
B.1.2.3.3	Reflexive associations	94
B.1.2.3.4	Aggregation relationship	95
B.1.2.3.5	Generalization relationship	96
B.1.2.3.6	Multiplicity (Cardinality) of Relationships.....	97
B.1.2.3.7	Presence of Relationships on a given diagram.....	97
B.1.2.3.8	Relationships and navigability	98
B.1.2.3.9	Positional semantics for laying out classes and relationships.....	100
B.1.2.3.10	Explicit Frames	100
B.1.3	Summary of Rules for Transmodel Presentation	100
B.1.3.1	Presentation of Class Structure diagrams.....	100
B.1.3.2	Rules for naming and presenting classes	101
B.1.3.3	Rules for use of role names.....	101
B.1.3.4	Rules for use of multiplicity	102
B.1.3.5	Rules for relationship qualifiers.....	103
B.1.3.6	Rules for presenting relationships	104
B.1.3.7	Rules for Placing Role names.....	104
B.2	Extensions to the Common Concept MODEL.....	104
B.2.1	General.....	104
B.2.2	Additional Common Concepts — Additional Generalizations	104
B.2.2.1	Generic Type of Value – Conceptual MODEL.....	104
B.2.2.2	Generic Assignment – Conceptual MODEL	106
B.2.2.3	Generic Section – Conceptual MODEL	106
B.2.3	Extensions to the Generic Framework	107
B.2.3.1	General.....	107
B.2.3.2	Alternative Text – Conceptual MODEL.....	107
B.2.3.3	Generic View – Conceptual MODEL.....	108

B.2.3.4 Generic Loggable Object – Conceptual MODEL.....	109
B.2.3.5 Event Model – Conceptual MODEL.....	109
B.2.4 Extensions to the Reusable Components	110
B.2.4.1 Employee Model – Conceptual MODEL.....	110
B.2.4.2 Message Model – Conceptual MODEL.....	111
B.2.4.2.1 Messages.....	111
B.2.4.2.2 Publication Scope	112
B.2.4.3 Role Model – Conceptual MODEL	113
B.2.4.3.1 Generic Roles	113
B.2.4.3.2 Service Organization Roles	114
B.2.4.3.3 Employee Roles	114
B.2.4.3.4 Administrative Organization Roles	115
B.2.4.3.5 Technology Organization Roles	116
B.2.4.3.6 Messaging Roles.....	117
B.2.4.3.7 Transport Customer Roles.....	118
B.2.4.4 Security List – Conceptual MODEL.....	118
B.2.4.5 Transfer Time – Conceptual MODEL.....	119
B.2.5 Data Dictionary.....	119
B.2.5.1 General	119
B.2.5.2 ADMINISTRATIVE ORGANIZATION ROLE.....	120
B.2.5.3 ALTERNATIVE TEXT.....	120
B.2.5.4 ASSIGNMENT.....	120
B.2.5.5 BLACKLIST.....	120
B.2.5.6 CLASS ATTRIBUTE	121
B.2.5.7 CONDUCTOR ROLE.....	121
B.2.5.8 CUSTOMER SERVICE PROVIDER ROLE	121
B.2.5.9 CUSTOMER SERVICE ROLE.....	121
B.2.5.10 DATA COLLECTOR ROLE	122
B.2.5.11 DRIVER ROLE	122
B.2.5.12 EMPLOYEE.....	122
B.2.5.13 EMPLOYEE ROLE.....	122
B.2.5.14 EVENT	123
B.2.5.15 GENERAL EVENT	123
B.2.5.16 GENERAL OBSERVER ROLE	123
B.2.5.17 GENERAL SECTION	124
B.2.5.18 LOG.....	124

B.2.5.19	LOG ENTRY	124
B.2.5.20	LOGGABLE OBJECT	124
B.2.5.21	MESSAGE	125
B.2.5.22	MESSAGE PART	125
B.2.5.23	MESSAGE PRIORITY	125
B.2.5.24	ORGANIZATION ROLE.....	125
B.2.5.25	PT SCOPE.....	126
B.2.5.26	PUBLICATION APPROVER ROLE	126
B.2.5.27	PUBLICATION DECISION	126
B.2.5.28	PUBLICATION SCOPE	126
B.2.5.29	PUBLICATION WINDOW	127
B.2.5.30	PUBLISHING ACTION.....	127
B.2.5.31	PUBLISHING CHANNEL.....	127
B.2.5.32	QUALIFICATION.....	127
B.2.5.33	REGISTRAR ROLE	128
B.2.5.34	SECTION.....	128
B.2.5.35	SECTION IN LINK SEQUENCE	128
B.2.5.36	SECURITY LIST	128
B.2.5.37	SECURITY LISTABLE.....	129
B.2.5.38	SECURITY LISTING.....	129
B.2.5.39	SECURITY MANAGER ROLE.....	129
B.2.5.40	SERVICE OPERATOR ROLE.....	129
B.2.5.41	SITUATION AUTHOR ROLE	130
B.2.5.42	SPECIFIC OBSERVER ROLE.....	130
B.2.5.43	STATION EMPLOYEE ROLE	130
B.2.5.44	TECHNOLOGY ORGANIZATION ROLE.....	130
B.2.5.45	TRAFFIC INFORMATION OFFICER ROLE	131
B.2.5.46	TRANSFER TIME	131
B.2.5.47	TRANSPORT USER ROLE.....	131
B.2.5.48	TRAVEL DOCUMENT CONTROLLER ROLE	131
B.2.5.49	TRAVEL DOCUMENT CONTROLLING ORGANIZATION ROLE.....	132
B.2.5.50	TRAVEL ORGANIZATION ROLE.....	132
B.2.5.51	TYPE OF AUDIENCE	132
B.2.5.52	TYPE OF EVENT.....	132
B.2.5.53	TYPE OF MESSAGE	133
B.2.5.54	TYPE OF MESSAGE PART CONTENT	133

B.2.5.55	TYPE OF QUALIFICATION	133
B.2.5.56	TYPE OF SECURITY LIST	133
B.2.5.57	TYPE OF VALUE	134
B.2.5.58	View	134
B.2.5.59	WHITELIST	134
Annex C (informative) Data Model Evolution		135
C.1	Change Requests	135
C.2	Source of Text	163
C.3	Diagram Status	163
Annex D (informative) Mapping to DATEX II and SIRI (SX and FM)		165
D.1	Related standards	165
D.2	Mapping with DATEX II	165
D.2.1	DATEX II	165
D.2.2	DATEX II and Transmodel	166
D.2.3	Overview of correspondence of Situation elements	166
D.2.4	Outline Mapping between DATEX II and Transmodel	169
D.3	Mapping with SIRI SX and SIRI FM	170
D.3.1	SIRI — Service Interface for Real-time Information	170
D.3.2	Outline Mapping between SIRI— SX — and Transmodel	171
D.3.3	Outline Mapping between SIRI— FM— and Transmodel	172
Bibliography		174

European foreword

This document (EN 12896-4:2019) has been prepared by Technical Committee CEN/TC 278 “Intelligent transport systems”, the secretariat of which is held by NEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2020, and conflicting national standards shall be withdrawn at the latest by March 2020.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

The series is composed of the following documents:

- *Public transport – Reference data model – Part 1: Common concepts;*
- *Public transport – Reference data model – Part 2: Public transport network;*
- *Public transport – Reference data model – Part 3: Timing information and vehicle scheduling;*
- *Public transport – Reference data model – Part 4: Operations monitoring and control;*
- *Public transport – Reference data model – Part 5: Fare management;*
- *Public transport – Reference data model – Part 6: Passenger information;*
- *Public transport – Reference data model – Part 7: Driver management;*
- *Public transport – Reference data model – Part 8: Management information & statistics; and*
- *Public transport – Reference data model – Part 9: Informative documentation [CEN/TR].*

Together these create version 6 of the European Standard EN 12896, known as “Transmodel”, and thus replace EN 12896:2006, known as “Transmodel v5.1”.

In comparison with EN 12896:2006, the technical modifications made are presented in CEN/TR 12896-9, *Public transport – Reference data model – Part 9: Informative documentation*.

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

Introduction

Part 1 of this European Standard presents the following items:

- Rationale for the Transmodel Standard;
- Use of the Transmodel Standard;
- Applicability of the Transmodel Standard;
- Conformance Statement;
- Transmodel Origins;
- Reference to the Previous Version and Other Documents.

The data structures represented in Part 1 are generic patterns that are referenced by different other parts.

Part 2 of this European Standard presents space-related data structures.

Part 3 presents time-related data structures and replaces the sections of EN 12896:2006 referring to the time-related Tactical Planning Components and to Vehicle Scheduling.

Part 4 (this part) presents data referring to daily operations (i.e. to operational days), different from those planned for day types (space-related data structures and tactical planning components) and including operational raw data referring to operations follow-up.

Part 5 presents fares structures including sales, validation and control.

Part 6 presents Passenger Information (planned and real-time).

Part 7 presents Driver Management including Driver Scheduling (day-type related driver schedules), Rostering (ordering of driver duties into sequences according to some chosen methods) and Driving Personnel Disposition (assignment of logical drivers to physical drivers and recording of driver performance).

Part 8 presents Management Information and Statistics.

1 Scope

1.1 General Scope of the Standard

The main objective of the present standard is to present the Reference Data Model for Public Transport, based on:

- the Reference Data Model, EN 12896, known as Transmodel V5.1;
- EN 28701:2012, *Intelligent transport systems – Public transport – Identification of Fixed Objects in Public Transport (IFOPT)*, although note that this particular standard has been withdrawn as it is now included within Parts 1 and 2 of this standard (EN 12896-1:2016 and EN 12896-2:2016) following their successful publication;

incorporating the requirements of:

- EN 15531-1 to -3 and CEN/TS 15531-4 and -5: *Public transport – Service interface for real-time information relating to public transport operations (SIRI)*;
- CEN/TS 16614-1 and -2: *Public transport – Network and Timetable Exchange (NeTEx)*, in particular the specific needs for long distance train operation.

Particular attention is drawn to the data model structure and methodology:

- the data model is described in a modular form in order to facilitate the understanding and the use of the model;
- the data model is entirely described in UML.

The following functional domains are considered:

- Network Description: routes, lines, journey patterns, timing patterns, service patterns, scheduled stop points and stop places;
- Timing Information and Vehicle Scheduling (runtimes, vehicle journeys, day type-related vehicle schedules);
- Passenger Information (planned and real-time);
- Fare Management (fare structure, sales, validation, control);
- Operations Monitoring and Control: operating day-related data, vehicle follow-up, control actions;
- Driver Management:
 - Driver Scheduling (day-type related driver schedules),
 - Rostering (ordering of driver duties into sequences according to some chosen methods),
 - Driving Personnel Disposition (assignment of logical drivers to physical drivers and recording of driver performance);
- Management Information and Statistics (including data dedicated to service performance indicators).

The data modules dedicated to cover most functions of the above domains will be specified.

Several concepts are shared by the different functional domains. This data domain is called “Common Concepts”.

1.2 Functional Domain Description

The different functional domains (enumerated above) taken into account in the present document, and of which the data have been represented as the reference model, are described in EN 12896-1:2016, *Public transport – Reference data model – Part 1: Common concepts*.

1.3 Particular Scope of this Document

The present document entitled *Public transport – Reference data model – Part 4: Operations monitoring and control* incorporates the following data packages:

- Dated Production Components MODEL;
- Call MODEL;
- Production Plan MODEL;
- Detecting and Monitoring MODEL;
- Control Action MODEL;
- Event and Incident MODEL;
- Messaging MODEL;
- Situation MODEL; and
- Facility Monitoring and Availability MODEL.

The data structures represented in this part form descriptions of data that are specific to operations for an operational day (as opposed to those planned for day types). They reference to structures as described in EN 12896-1:2016, such as version frames or generic grouping mechanisms, but also to EN 12896-2:2016 and EN 12896-3:2016.

This document itself is composed of the following parts:

- Main document (normative) presenting the data model for the domain Operations Monitoring and Control;
- Annex A (normative), containing the data dictionary, i.e. the list of all the concepts and attribute tables present in the main document together with the definitions;
- Annex B (normative), providing a complement to EN 12896-1:2016, particularly useful for parts 4 to 8 of the Public Transport Reference Data Model;
- Annex C (informative), indicating the data model evolutions; and
- Annex D (informative), providing a mapping between the Situation Publication model of DATEX II (EN 16157 and CEN/TS 16157 (all parts), *Situation Publication Data Model 2.2, 2013*), SIRI Situation Exchange (CEN/TS 15531-5:2016) and SIRI Facility Monitoring (CEN/TS 15531-4:2011).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 12896-1:2016, *Public transport – Reference data model – Part 1: Common concepts*

EN 12896-2:2016, *Public transport – Reference data model – Part 2: Public transport network*

EN 12896-3:2016, *Public transport – Reference data model – Part 3: Timing information and vehicle scheduling*

CEN/TS 15531-5:2016, *Public transport – Service interface for real-time information relating to public transport operations – Part 5: Functional service interfaces situation exchange: Situation Exchange*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 General Terms and Definitions:

3.1.1

attribute

property of an entity

3.1.2

conceptual data model

description of a real-world domain in terms of entities, relationships and attributes in an implementation independent manner in order to provide a structure on which the rest of the development of an application system can be based

3.1.3

conceptual level

conceptual data model in the context of data modelling

3.1.4

database

collection of data

Note 1 to entry: Often used in the sense of the physical implementation of a data model.

3.1.5

data domain

data structure 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

Note 1 to entry: In this document, a part of the Reference Data Model for Public Transport.

3.1.6

data model

description of a real-world domain in terms of data and relationships

3.1.7

entity

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

3.1.8

fare management

all activities related to the collection of money from passengers

3.1.9

function

activity, or a sub-activity of a functional area

3.1.10

functional area

arbitrarily defined set of activities used to define the objectives and limits of the data model

3.1.11

interoperability

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

3.1.12

logical data model

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

3.1.13

logical denormalized model

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

3.1.14

logical level

logical data model in the context of data modelling

3.1.15

management information

activities allowing the company management to collect the information necessary to meet problem-solving needs

3.1.16

object-oriented data model

data structure expressed according to principles that allow for a direct implementation as an object-oriented database, where information is represented in form of objects, i.e. respecting the principle of encapsulation meaning in particular that each data is accessed or modified through operations (methods) belonging to it

3.1.17

operations monitoring and control

activities related to the transportation process, i.e. real-time functions related to the driving and transportation of passengers according to given instructions, including the monitoring of the driving process and its control in case of deviations, as well as all activities that support the driving process such as traffic light priority, track switching, bay selection, advance/delay advice, etc.

3.1.18

passenger information

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

3.1.19

personnel disposition

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

3.1.20

Real-time control

see Operations monitoring and control

3.1.21

relational data model

type of logical data model giving the information as series of tables (relations) and attributes, and possessing the following characteristics:

- a) all attribute values are atomic;
- b) all “tuples” (rows/occurrences) are distinct;
- c) no part of the primary key may be null; and
- d) foreign key values correspond to an existing primary key in another relation or be null

3.1.22

scheduling

see Tactical Planning

3.1.23

tactical planning

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

3.2 Domain Specific Terms and Definitions:

For the operations monitoring and control domain, there are no additional terms that are not included in Annex A.

4 Symbols and Abbreviations

AVM	Automated Vehicle Monitoring
AVMS	Automated Vehicle Management System
IFOPT	Identification of Fixed Objects in Public Transport (EN 28701:2012)
ISO	International Organization for Standardization

IT	Information Technology
NeTEx	Network and Timetable Exchange (CEN/TS 16614 series)
PT	Public Transport
PTO	Public Transport Operator
SIRI	Service Interface for Real-time Information (EN 15531 (all parts) and CEN/TS 15531 (all parts))
SIRI— FM	Service Interface for Real-time Information Facility Monitoring (CEN/TS 15531-4)
SIRI— SX	Service Interface for Real-time Information Situation Exchange (CEN/TS 15531-5)
UML	Unified Modelling Language
URI	Uniform Resource Identifier
URL	Universal Resource Locator.

5 Operations monitoring and control

5.1 Introduction

The operational management of public transport is classically divided into two distinct phases:

- a “tactical planning” phase, consisting of designing and building a reference schedule (described in EN 12896-2:2016 and EN 12896-3:2016); and
- a further phase of adapting the reference schedule to the real operating conditions, in a plan that is constantly updated during the operating day. This phase is known as “real-time control”.

Note that in the first phase, the “tactical planning” phase, data are typically handled on a macroscopic level describing significant parts of the intended operation as complete sets of coherent data. It is possible to prepare multiple complete sets of coherent data in parallel, reflecting different planning strategies on a higher level, with one such set selected to be the base for the operation on a certain day for a certain scope. In this case the concept of organizing data into VERSION FRAMEs (as described in EN 12896-1:2016) is useful as it provides a mechanism to work with, and choose between, coherent sets of data at a higher level for pre-selected scopes.

In the second phase, the “real-time control” phase, the higher-level plan is already partly in operation; the movement of real world passengers, vehicles and personnel has already started, and the current plan cannot easily be replaced in its entirety with a different pre-prepared plan. Instead, changes to compensate for disturbances of different kinds need to be applied gradually and individually, taking the current position of personnel and vehicles into consideration. In this case the VERSION FRAME concept is of less relevance.

The data collected during real time operations is a constant source of information related to the theoretical reference schedules and is thus likely to be used as feedback in order to adapt them. The boundary between these two phases (tactical planning and real-time control) is, in most cases, fixed arbitrarily. It may take place at the beginning of the operating day, two days in advance, when the drivers are rostered, etc. Such a limit is often marked by the freezing of a “production plan”, which will be the reference for real-time control on a whole operating day.

The reference schedule is optimized to fit specified service quality objectives (e.g. frequency, punctuality, crowding or interchange management) while respecting operational constraints (e.g. constraints due to driver or vehicle management). However, it can only define an optimal plan in average operating conditions. When these average conditions are no longer present (e.g. because of

disturbances such as change in traffic conditions, failures, incidents, etc.), it becomes necessary to carry out “control actions”, in order to compensate for the service deterioration.

It is commonly accepted that real-time control aims to relate operations to the reference schedule. However, if the situation is far from the average conditions, then the reference schedule is no longer a standard to be respected; in this case only the service quality objectives remain, guiding the control actions, modifying the reference schedule, and possibly resulting in a complete rescheduling.

Modern public transport networks are equipped with automated tools able to facilitate real-time control, usually named Automatic Vehicle Monitoring (AVM) systems. The main functions of an AVM system (AVMS) in the control process are:

- locating vehicles, with regard to the PT network and possibly to the infrastructure;
- controlling tolerance thresholds with respect to the service objectives, in order to help the controller in the detection of disturbances and to help the driver maintain the timetable or headway;
- controlling data and voice exchanges, for information of controllers, drivers and passengers;
- handling of (technical or operational) alarms;
- providing assistance for the design of control actions;
- computing data for traveller information (e.g. estimated passing times);
- various activation functions (e.g. traffic light priority); and
- collecting data for statistical purposes (e.g. observed run times).

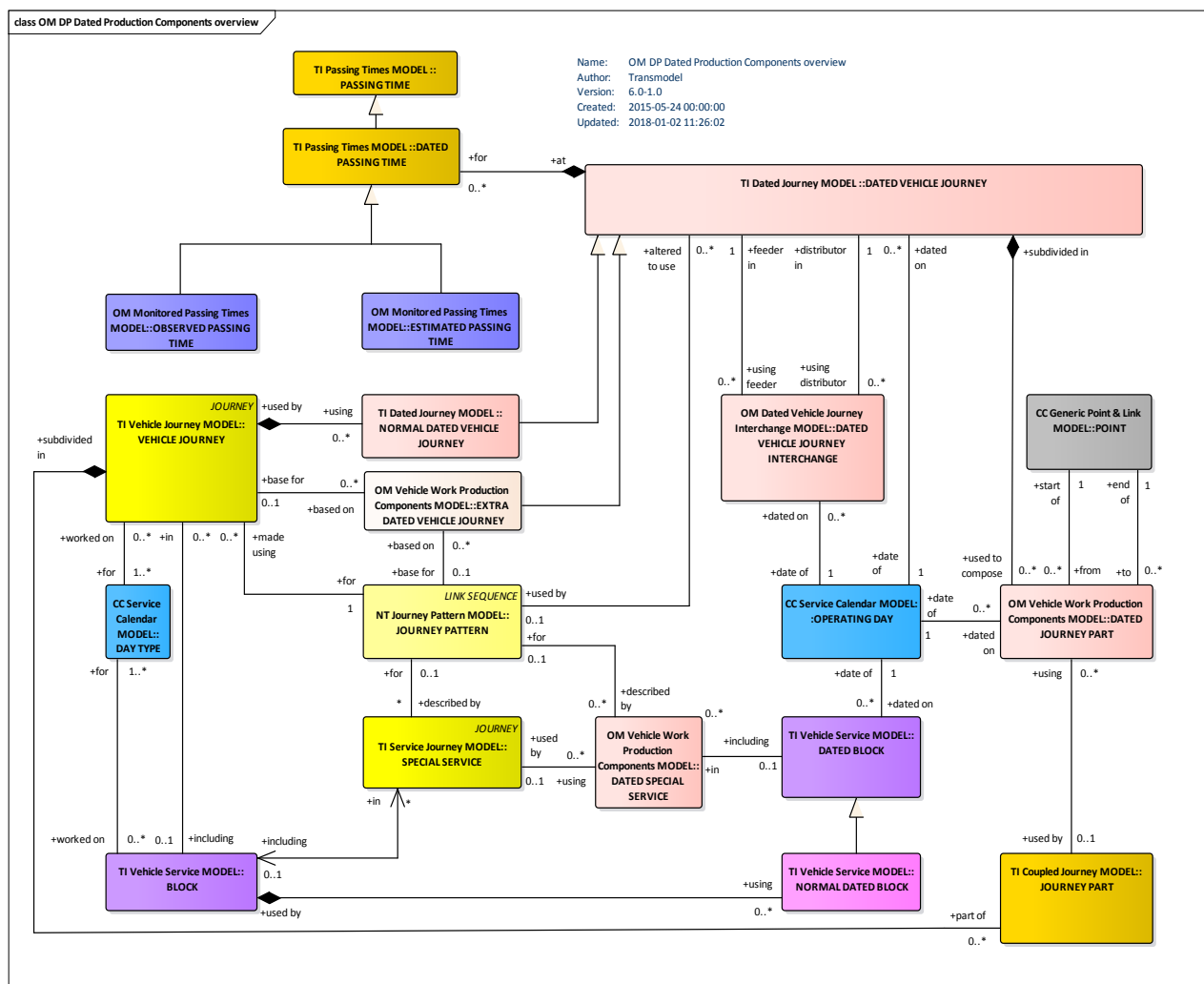
The modelling requirements imply distinguishing some important abstract concepts, in particular:

- physical resources (e.g. a particular driver) and logical resources (e.g. a theoretical anonymous vehicle); and
- various states of the work plan, in particular the latest valid work plan (e.g. as ordered by the controller), the monitored situation (e.g. as monitored by the AVMS) and the expected situation (as forecasted, from the monitored situation and the plans).

5.2 Dated Operational Plans

5.2.1 Principles

Operations require an operational plan for each OPERATING DAY. Such dated plans are elaborated in anticipated time, on a short-term horizon (a few days or possibly a few weeks before the day of operations) and frequently updated. They are usually derived from tactical plans for DAY TYPES. The latter are assigned to OPERATING DAYS, according to rules taking into account the characteristics of the considered calendar (see SERVICE CALENDAR described in EN 12896-1:2016) and the PROPERTIES OF DAY assigned to each OPERATING DAY. The composition of dated plans is rather similar to the composition of plans for day types (see in particular Dated Journey Model in EN 12896-2:2016 and EN 12896-3:2016). However, they include a lot of information that cannot be planned easily on a regular basis: occasional special services, results of the personnel disposition process (in particular planned rest days or other absences), etc.



be added, etc. If these changes are only valid for one or a few days, the reference schedule for a DAY TYPE is not modified, but the changes are only stored for the appropriate OPERATING DAYS.

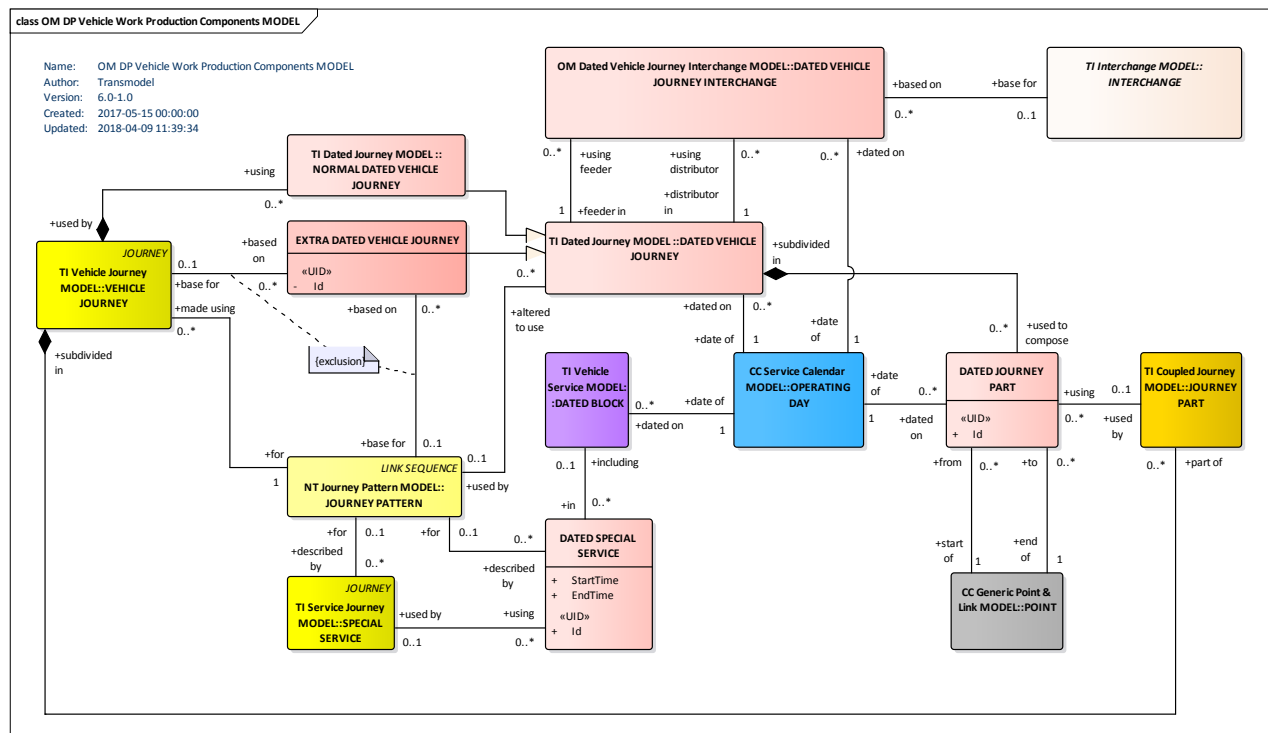


Figure 2 — Vehicle Work Production Components MODEL

The entity DATED VEHICLE JOURNEY describes a vehicle journey planned for one specific OPERATING DAY.

NORMAL DATED VEHICLE JOURNEYS are based upon a VEHICLE JOURNEY, as produced for a DAY TYPE by the scheduling process. If there is no disturbance in the service, these normal journeys will be an exact image of the theoretical plan, applied to the specific OPERATING DAY. However, short-term modifications may be applied to these journeys, for instance when the controller decides to let a vehicle turn before the terminus. This means that the last part of the vehicle's current journey is cancelled as well as the first part of the vehicle's next journey in the other direction. One way of doing this is by applying two PARTIAL JOURNEY CANCELLATION control actions (see subclause 5.6.3.4). Such CONTROL ACTIONS update the latest valid plan and produce modified versions of the relevant DATED VEHICLE JOURNEYS.

Additional DATED VEHICLE JOURNEYS may be included in the PRODUCTION PLAN for an OPERATING DAY by applying the JOURNEY CREATION control action (see subclause 5.6.3.1). Such EXTRA DATED VEHICLE JOURNEYS could be created from scratch, or by duplication of an existing journey with modification of the departure time, for instance. Sometimes EXTRA DATED VEHICLE JOURNEYS are based on existing JOURNEY PATTERNS. An EXTRA DATED VEHICLE JOURNEY may, for instance, correspond to a reinforcement of the service, or result from a complete rescheduling.

There are also situations when EXTRA DATED VEHICLE JOURNEYS are created to complement a DATED VEHICLE JOURNEY that is already running, but that will not be completed due to mechanical failures or large delays of the originally assigned vehicle. Sometimes such a replacement EXTRA DATED VEHICLE JOURNEY that is working the latter JOURNEY PARTs of the planned VEHICLE JOURNEY can be run at the same time as the original vehicle is still working to complete the first JOURNEY PARTs of the same planned VEHICLE JOURNEY.

A DATED VEHICLE JOURNEY serves one JOURNEY PATTERN. Any NORMAL DATED VEHICLE JOURNEY for which the working pattern has not been modified by a CONTROL ACTION will serve the JOURNEY PATTERN of its parent VEHICLE JOURNEY. In case of modification, the new JOURNEY PATTERN of the DATED VEHICLE JOURNEY is specified either by a reference to an existing JOURNEY PATTERN exactly matching the modification, or by a description of the relative modifications in relation to the original JOURNEY PATTERN. The same applies to EXTRA DATED VEHICLE JOURNEYS; they can be described with a reference to an existing JOURNEY PATTERN that matches the intended JOURNEY PATTERN exactly, or by a reference to an existing JOURNEY PATTERN in combination with a description of relative modifications in relation to this JOURNEY PATTERN.

The classification of JOURNEY PATTERNS through TYPE OF JOURNEY PATTERN may include some categories of occasional JOURNEY PATTERNS, to be used only by extra or modified DATED VEHICLE JOURNEYS (e.g. for occasionally shortened or deviated routes).

The entity DATED VEHICLE JOURNEY has an attribute 'departure time'. In case of a NORMAL DATED VEHICLE JOURNEY, this time will be the same as for the parent VEHICLE JOURNEY, unless modifications of this departure time have been ordered.

DATED SPECIAL SERVICES are created following the same principles. Regular services will be derived from a SPECIAL SERVICE planned for a DAY TYPE. In most cases, DATED SPECIAL SERVICES will be extra (occasional) special services, valid only for the considered OPERATING DAY.

5.2.2.2 Dated Blocks

The changes made in the DATED VEHICLE JOURNEYS often generate changes in the BLOCKs planned for a DAY TYPE. Therefore, it is necessary to define DATED BLOCKs, which will be valid only on a specific OPERATING DAY (see EN 12896-3, *Public transport – Reference data model — Part 3: Timing information and vehicle scheduling*).

Most of the DATED BLOCKs will be identical to an existing BLOCK, possibly with some modifications. These DATED BLOCKs are called NORMAL DATED BLOCKs, with a relationship with the parent BLOCK.

If an extra journey is planned, this may invoke the need for a new vehicle to come from a garage, in which case a complete new (extra) DATED BLOCK is created from scratch.

A DATED BLOCK shall in principle include DATED VEHICLE JOURNEYS or DATED SPECIAL SERVICES. When a NORMAL DATED BLOCK is generated, it includes the journeys and services present in the planned (reference) BLOCK.

However, there may be changes during the OPERATING DAY and the complete set of DATED VEHICLE JOURNEYS, normal and extra, presently or historically, included in certain DATED BLOCKs. It may be possible to deduce, by checking the VEHICLE WORK ASSIGNMENT CONTROL ACTIONS, which LOGICAL VEHICLES are related to which DATED BLOCKs and DATED VEHICLE JOURNEYS.

In common with the DATED VEHICLE JOURNEY, a DATED BLOCK has a specific identifier (ID), in addition to the OPERATING DAY foreign key.

5.2.2.3 Dated Journey Parts

A DATED VEHICLE JOURNEY may be subdivided into DATED JOURNEY PARTs. DATED JOURNEY PARTs may be using planned JOURNEY PARTs (see EN 12896-3:2016, 5.3.9.2) or may be created ad-hoc. One situation when this is of interest is when coupling or un-coupling trains.

The train-coupling model (see EN 12896-3:2016, 5.3.9.1) is affected by operational restrictions such as different days of operation or if one of the involved VEHICLE JOURNEYS are partially cancelled.

An example of such situation is as follows:

- There is a VEHICLE JOURNEYS (train 101) serving the stations A – B – C in sequence;

- There is a VEHICLE JOURNEYS (train 202) serving stations A – B – D and that is coupled with train 101 between A and B and then uncoupled in B.

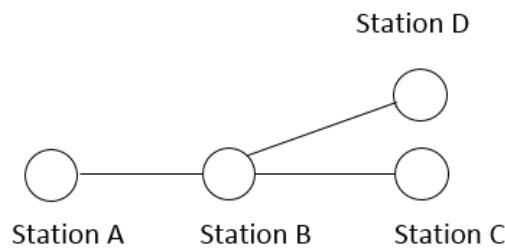


Figure 3 — Uncoupling at station B

The following situations may occur:

- a) Train 202 is operating the same OPERATING DAYS as train 101. In this case uncoupling in B takes place every common day of operation;
- b) Train 101 is operating every day but train 202 is only operating some days. In this case uncoupling in B takes place only on the days of operation of train 202;
- c) Train 101 is only operating some days, and train 202 is also operating on these days but only between B and D. In this case there is no uncoupling as the trains were never coupled in the first place;
- d) Train 202 is operating some days serving the stations A – B – D, but it is not coupled to another train.

Note also that sometimes VEHICLE JOURNEYS that are operating on different OPERATING DAYS may be coupled. This may be the case when one of the involved trains is running for more than the duration of one OPERATING DAY (e.g. a train between Paris-Moscow).

5.2.2.4 Dated Vehicle Journey Interchange

The entity DATED VEHICLE JOURNEY INTERCHANGE describes an INTERCHANGE between two DATED VEHICLE JOURNEYS.

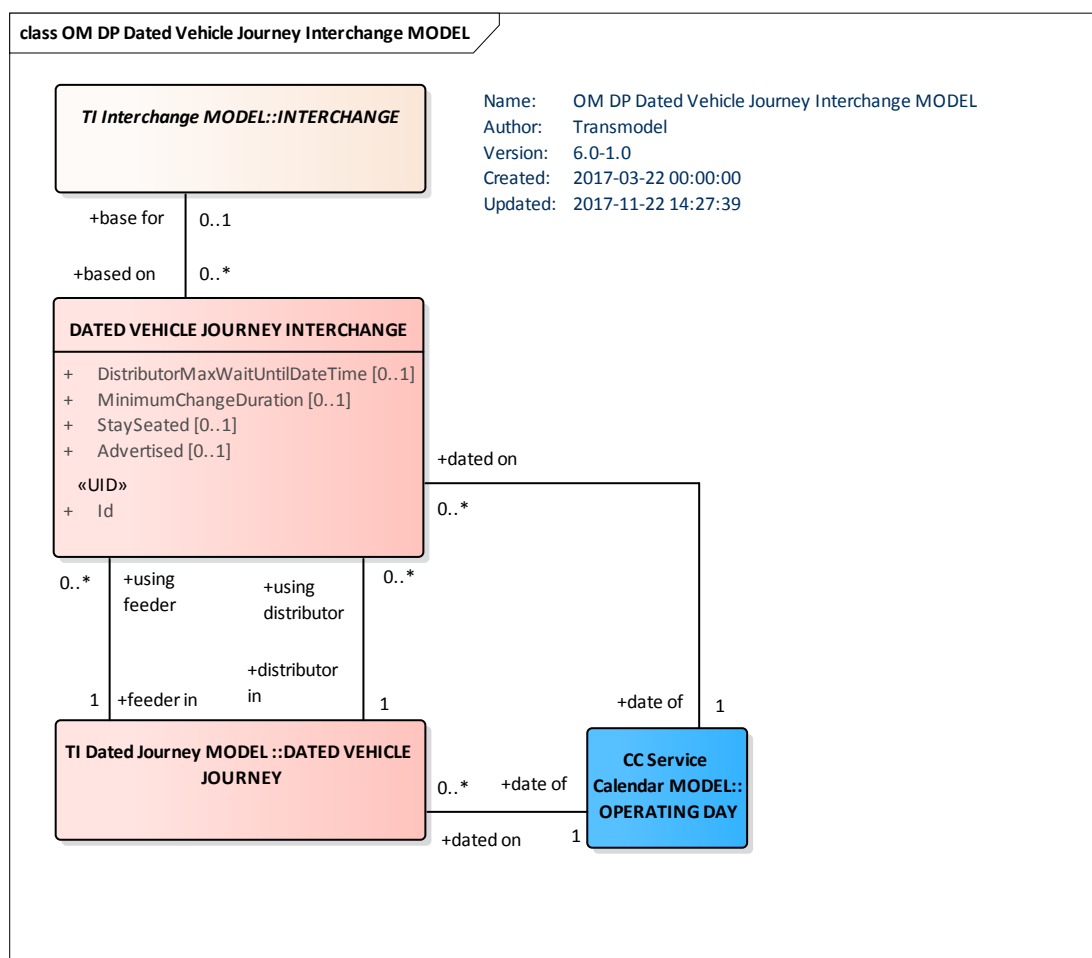


Figure 4 — Dated Vehicle Journey Interchange MODEL

It can be the result of a planned SERVICE JOURNEY INTERCHANGE, the application of an INTERCHANGE RULE or the result of a CONTROL ACTION.

Short-term modifications may be applied to these DATED VEHICLE JOURNEY INTERCHANGES, for instance when the controller decides to extend the time span that the distributor VEHICLE should wait for the feeder VEHICLE, cancels a DATED VEHICLE JOURNEY INTERCHANGE or adds a new DATED VEHICLE JOURNEY INTERCHANGE to the PRODUCTION PLAN for an OPERATING DAY.

5.2.3 Dated Vehicle Service

In addition to the DATED BLOCK that represents the work of a logical vehicle on a particular OPERATING DAY from the time it leaves a PARKING POINT after parking until its next return to park at a PARKING POINT there is also a concept that allows the operators to distinguish additional sequences of DATED BLOCKs starting and ending in a garage (i.e. the end points shall be GARAGE POINTs). Such a DATED VEHICLE SERVICE PART may be composed, for instance, of two DATED BLOCKs, separated by a parking period spent, without any driver, at a PARKING POINT which is not a GARAGE POINT (e.g. parking periods at off-peak hours for buses, at a parking point in the city).

The whole work of a LOGICAL VEHICLE for an OPERATING DAY is described by a DATED VEHICLE SERVICE, composed of one or several DATED VEHICLE SERVICE PARTs.

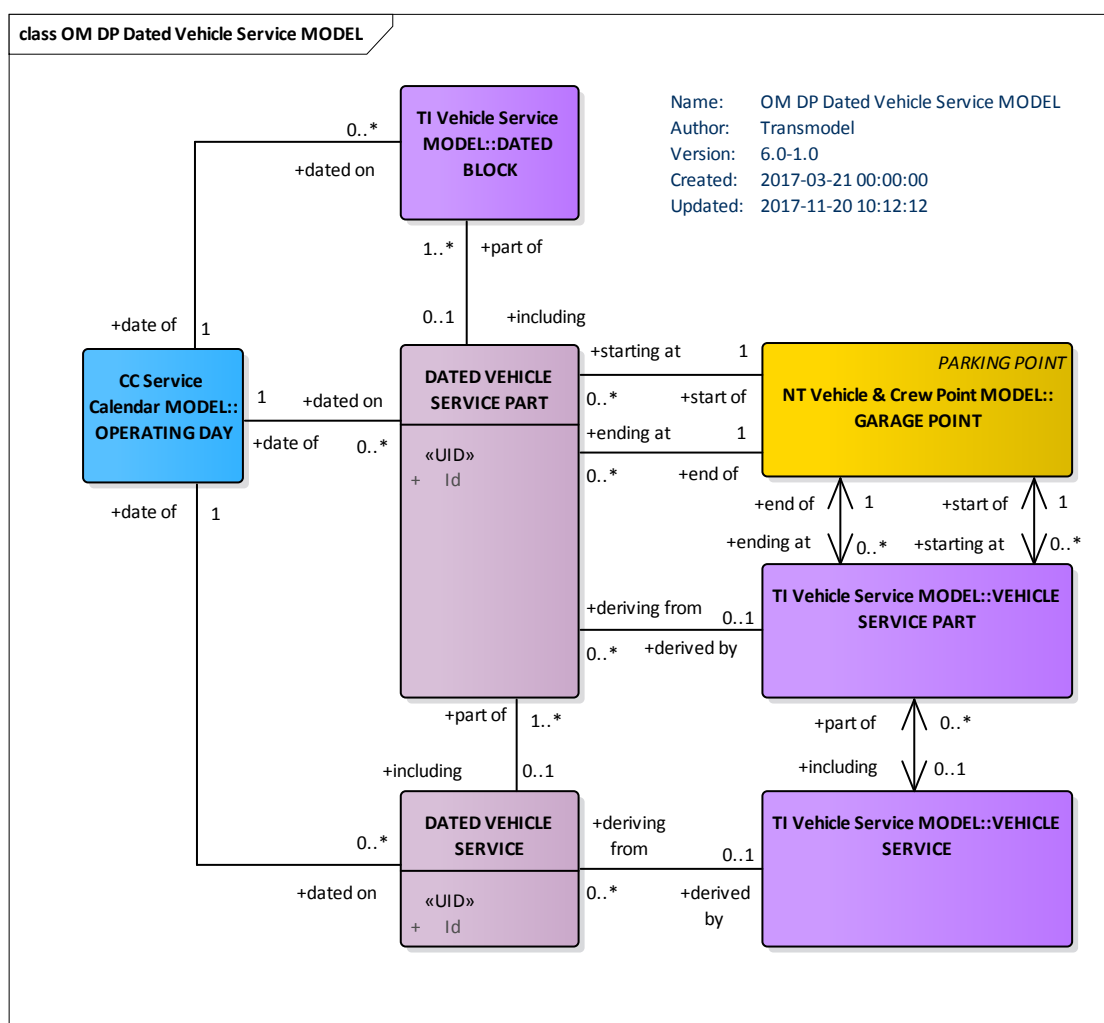


Figure 5 — Dated Vehicle Service MODEL

However, many users of the reference model will not implement these three levels (DATED BLOCK, DATED VEHICLE SERVICE PART and DATED VEHICLE SERVICE) of activities. The concept of DATED VEHICLE SERVICE is not strictly necessary, once the number of required vehicles has been optimized and, in many situations, the distinction between DATED BLOCK and DATED VEHICLE SERVICE PART is not useful. Therefore, in a company data model, two or all three concepts may be merged in a single concept (e.g. DATED BLOCK).

5.2.4 Dated Call

Transmodel is in principle built out of elementary entities, not ones that are derived or aggregated. One of the few exceptions to this rule is the DATED CALL concept which provides a general view that simplifies the grouping of some types of commonly used data.

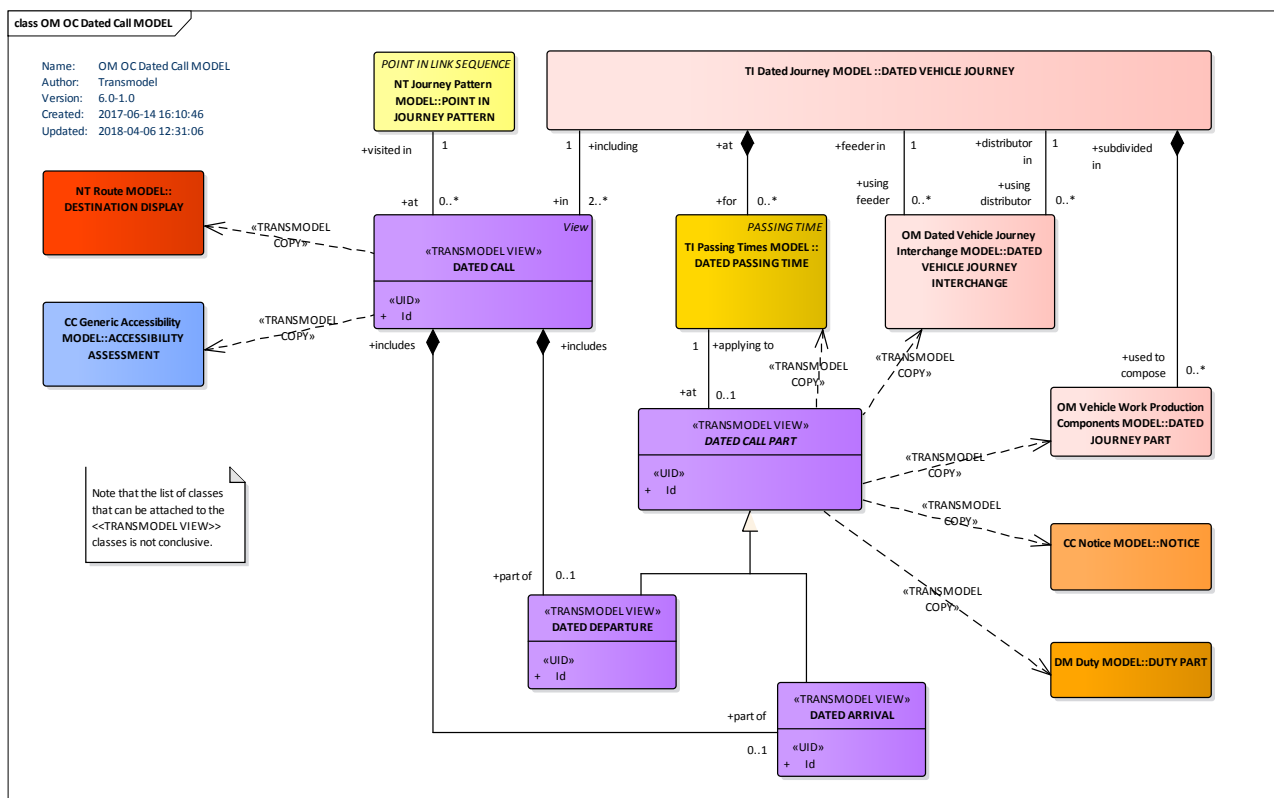


Figure 6 — Dated Call MODEL

A DATED CALL is a Transmodel view that represents the aggregation of information referring to a DATED VEHICLE JOURNEY at a POINT IN JOURNEY PATTERN. This construction, used in implementations such as SIRI (see EN 15531 (all parts) and CEN/TS 15531 (all parts)), is introduced to provide a single object to relate to, instead of having to use the double references to a DATED VEHICLE JOURNEY and a POINT IN JOURNEY PATTERN when conveying information that is specific for that combination. The aggregation concerns, for instance, DATED PASSING TIMES, NOTICES, etc.

The concept can be further refined by separating data that is specific to the arrival or departure only by using the Transmodel views DATED ARRIVAL and DATED DEPARTURE.

5.2.5 Implementation of Dated Plans

The reference model provides only a limited number of “dated” entities, mainly referring to vehicle scheduling. The principles described above may be applied to numerous other concepts. In particular, most operators will implement dated duties for personnel disposition. It is, for instance, a usual practice to implement dated duties some days in advance, in order to facilitate the driver assignment work. The generic scheme described for the management of versions (see EN 12896-1:2016) is useful to guide this implementation. The conceptual “dated” entities may be implemented in various ways, for instance in replicating all VEHICLE JOURNEYS for each OPERATING DAY, or only in recording exceptions and changes, etc.

5.2.6 Production Plan

The PRODUCTION PLAN is a specific VERSION of the resource planning for a specific OPERATING DAY. It represents a conventional image of one version of the latest valid plan, frozen at a point in time defined by the user, according to local requirements (e.g. 2 days before the start of each OPERATING DAY, at 18:00 hrs.).

The following may be attached to a PRODUCTION PLAN:

- the logical resources assigned to work this plan (see subclause 5.3.3);
- the dated components of the production: DATED VEHICLE JOURNEYS, DATED SPECIAL SERVICES;
- the dated sets of activities assigned to the resources: DATED BLOCKS, dated driver duties, etc.;
- the various elementary plans and versions possibly associated to the dated PRODUCTION PLAN: VEHICLE SCHEDULE VERSION, DRIVER SCHEDULE VERSION, TIMETABLE VERSION, etc.

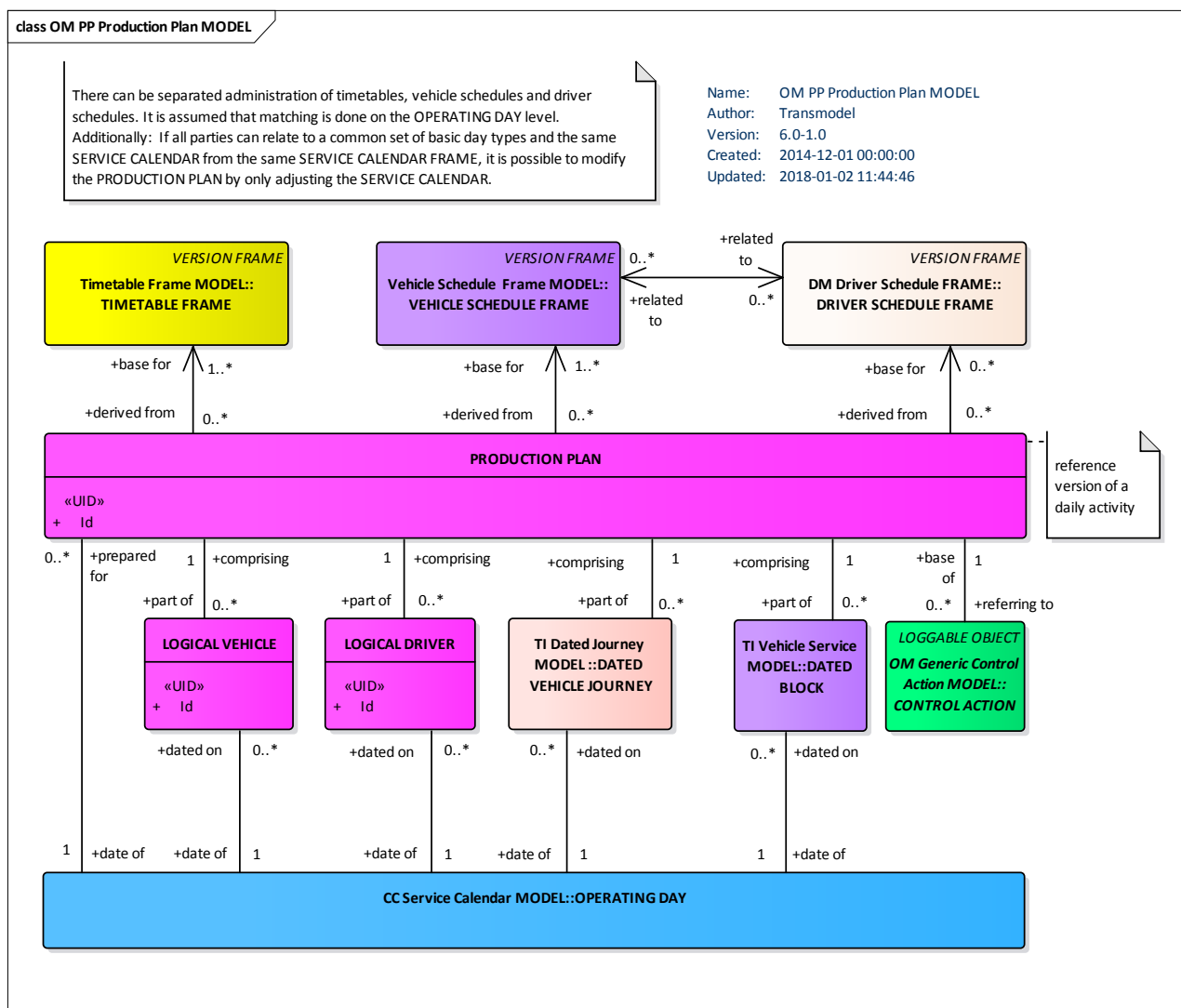


Figure 7 — Production Plan MODEL

In some cases, all elements composing a PRODUCTION PLAN (e.g. VEHICLE JOURNEYS, driver duties, BLOCKS, etc.) for a certain OPERATING DAY refer to the same DAY TYPE, but this is not a strict requirement. E.g. a VEHICLE JOURNEY worked on a “Friday” DAY TYPE may on certain OPERATING DAYS be operated in parallel with a VEHICLE JOURNEY worked on a “Weekdays” DAY TYPE.

Several VERSION FRAMEs may be combined in a PRODUCTION PLAN (e.g. three VEHICLE SCHEDULE FRAMEs covered by one DRIVER SCHEDULE FRAME).

The responsibility for operating and planning the operation may be divided among multiple parties, each party providing different aspects and parts of the PRODUCTION PLAN. Different parts of the operation are covered in different multiple parallel TIMETABLE FRAMES, VEHICLE SCHEDULE FRAMES and DRIVER SCHEDULE FRAMES that may be more or less independently maintained in different systems.

The scope of the respective VERSION FRAMES from which the PRODUCTION PLAN is derived are to be specified by the responsible parties in an unambiguous fashion. The scope for a TIMETABLE FRAME is often a LINE, but could also be a GROUP OF LINES, a GARAGE (interpreted as all VEHICLE JOURNEYS operated from that GARAGE), etc. The scope for a VEHICLE SCHEDULE FRAME is often the GARAGE (interpreted as all BLOCKS for all VEHICLE JOURNEYS operated from that GARAGE) but could also be an OPERATOR (interpreted as all BLOCKS for all VEHICLE JOURNEYS operated by that OPERATOR) etc.

The building rules of a PRODUCTION PLAN may include some VALIDITY CONDITIONS that are used to select the correct VERSION of data for the respective VERSION FRAMES.

It is not necessary that a certain VEHICLE SCHEDULE FRAME is restricted to refer only to VEHICLE JOURNEYS from a single TIMETABLE FRAME, neither is it necessary that all VEHICLE JOURNEYS in a certain TIMETABLE FRAME must be included in BLOCKS from a single VEHICLE SCHEDULE FRAME.

Different parties may have different views on what they consider to be the scope of the PRODUCTION PLAN, in essence the “VERSION FRAME” of the PRODUCTION PLAN.

For example, a regional PT authority might have a view that the complete tendered public transport operation in the region is covered by a single PRODUCTION PLAN, thus involving a large number of TIMETABLE VERSION FRAMES, VEHICLE SCHEDULE FRAMES and possibly also DRIVER SCHEDULE FRAMES.

At the same time an OPERATOR responsible for running part of that operation might focus only on the subset of VEHICLE JOURNEYS, BLOCKS and driver duties worked by that same OPERATOR and consider that as the scope for the PRODUCTION PLAN. Such a limitation can be useful to reduce the workload for the OPERATORS AVMS.

5.3 Resource Detection and Monitoring

5.3.1 Limits

The on-line control of public transport operations involves collecting and computing data about the resources used for these operations (mainly vehicles and crew).

In the present version of the reference model, the problem of vehicle monitoring is fully addressed, whereas crew monitoring concerns are only treated to a limited extent.

5.3.2 Functions Related to the Monitoring Process

Several main functions can be distinguished in the on-line vehicle control process:

- detection of a vehicle, which means collecting raw data about a vehicle (e.g. its current location or its current speed);
- monitoring a vehicle, which means to ascertain relationships between a vehicle and data describing (possibly partly) a planned transportation service (e.g. to monitor that a vehicle is operating a certain SERVICE JOURNEY and is behind its schedule);
- computing forecasts on the service to come (e.g. to calculate estimated passing times);
- recording consolidated data about the service actually operated by each vehicle.

It is important to distinguish between detection and monitoring, because a detected vehicle is not necessarily monitored if the available information is not sufficient to describe a monitored situation.

However, the basic objective of on-line control and of the systems aimed at assisting this function (AVM) is to monitor vehicles in order to implement various actions (follow-up of the service, corrective control actions, activation of passenger information devices or traffic light priorities, etc.). The detection in itself is not really a concern for the reference data model but is a tool to allow the monitoring to be done.

AVM systems are able to represent the monitored situation, which reflects in principle the actual situation at any time. One of the main interests for operators is to relate this situation (journey under way) to the latest valid plan (journey supposed to be under way). However, some uncertainty may occur in this relationship, due to technical failures or deviations from the normal route, for instance. Moreover, some monitoring systems dedicated to passenger information may even ignore the theoretical plans.

Forecasting passing times is an essential function, in particular for passenger information. From the information provided by the latest valid plan (or simply the PRODUCTION PLAN) and the monitored situation, AVM and passenger information systems compute an estimated plan, providing for instance the estimated passing times for the rest of the journey under way and possibly the following journey.

After completion of the operating day, the production follow-up process consists of consolidating a realized production report. This is based on the data provided by the monitoring and by the recorded control actions, completed or corrected by other information (such as reason for changing or comments), in order to provide a report reflecting as precisely as possible the realized production.

The distinction between detection, monitoring, forecasts and recording is convenient for classical operations and systems, for which the technical capabilities or the human behaviour may introduce some uncertainty. In some public transport systems (notably automatic metro systems), these functions may be merged in a single function, which represents a fully automated control of operations.

More generally, the above principles should be interpreted as examples of usual practices which will have to be adapted to any particular situation.

5.3.3 Resources to be monitored

As described in EN 12896-3:2016, it is often convenient for many functions to manage logical resources, instead of physical resources. This is in particular the case for most monitoring functions, because they require to distinguish:

- a logical (theoretical and anonymous) resource (e.g. a logical vehicle or a logical driver);
- a physical resource (e.g. a particular VEHICLE), to be assigned to a logical resource;
- a work plan (e.g. a DATED BLOCK composed of DATED VEHICLE JOURNEYS, or a “dated duty”).

In stable situations, the concept of logical resource does not have any concrete meaning. When a PRODUCTION PLAN is validated and frozen, for instance, it is possible to assign physical VEHICLES to pieces of work plan (e.g. BLOCKS) directly. However, many modifications to the initial plan arise during the day of operations, which are likely to complicate this simple assignment.

For instance, the physical VEHICLE to be monitored is not always known by the system. Some passenger information systems monitor anonymous vehicles, collecting only data about the line and the covered JOURNEY PATTERN, at a point where a vehicle is detected. A logical resource may be created and used in the monitoring system before any assignment to a physical resource or a work plan. During the design of a control action, a logical resource may have, provisionally, two contradictory work plans attached.

For these reasons, the concept of logical resource may be used at any stage of planning or operating the services, with the meaning of an available anonymous resource. The reference model does not make explicit such a concept for all stages. At the tactical planning stage (scheduling for DAY TYPES), for example, it remains implicit in the model, although it may be used by scheduling algorithms: the objectives of the reference model deal only with scheduling results. In contrast, such a concept is needed for exchange of information at the operations monitoring stage. Therefore, any vehicle involved in a monitoring process is identified by the concept of LOGICAL VEHICLE, which can be understood as an available vehicle resource, to be monitored.

Each LOGICAL VEHICLE shall be created by a specific LOGICAL VEHICLE CREATION, which is classified as a CONTROL ACTION (see subclause 5.6.2.3). In practice, such an action is explicit only when it corresponds to the creation of an extra resource, to be added to the available fleet. In many other cases, the creation of a LOGICAL VEHICLE is performed automatically. In classical AVM systems, the monitoring process starts at the beginning of the OPERATING DAY (or at least before the start of the first BLOCK of each vehicle) by creating as many LOGICAL VEHICLES as resources are available, including the reserve, for this OPERATING DAY. In other systems, a LOGICAL VEHICLE is created when it is detected for the first time (e.g. when the on-board system is switched on). In such cases, the corresponding LOGICAL VEHICLE CREATIONS represent simple LOG ENTRIES (see B.2.3.3), which can be omitted in a real implementation.

A LOGICAL VEHICLE is identified by an ID and an OPERATING DAY. To a LOGICAL VEHICLE may be assigned a VEHICLE (see subclause 5.4.4) and a work plan (see subclause 5.4.3).

Similarly, a LOGICAL DRIVER represents an available driving resource, to be assigned to a physical driver and a work plan (e.g. a dated duty).

5.3.4 Vehicle Detecting

The process of detection consists of recognizing a vehicle and assigning some data collected by the detection devices to it. The entity VEHICLE DETECTING represents the LOG ENTRIES (see B.2.3.3) of all detection events occurring during a day. It is identified by an ID and characterized by an attribute 'timestamp'. This timestamp describes the time, as precisely as possible, at which the data has been collected (there may be a certain delay between the detection time and the data recording in a central system).

The detected data may be variable, according to the system capabilities, and multiple data of different types such as physical location, speed, direction, doors opened, occupancy etc. can be included in a VEHICLE DETECTING. Each kind of data can be separately registered as a VEHICLE DETECTING LOG ENTRY and marked with the appropriate TYPE OF VEHICLE DETECTING. The data may be raw data, derived or calculated.

A VEHICLE DETECTING may be related to a LOGICAL VEHICLE. The systems often detect the ID of the physical VEHICLE, which may allow the recognition of the LOGICAL VEHICLE, thanks to a recorded VEHICLE ASSIGNMENT CONTROL ACTION. Sometimes, the assignment information may be missing, at least provisionally.

The most classical detected information is the vehicle location, which may consist of a POINT (e.g. the vehicle passes an ACTIVATION POINT, such as a beacon), a LINK (rail systems often detect the presence of a train on an INFRASTRUCTURE LINK), or another PLACE. Such PLACES may be various locations (see EN 12896-1:2016), which may include volatile places which are not recorded in the data system, such as those described by coordinates, or defined as a provisional POINT ON LINK with the distance from the start of the link.

Some information linked to the monitoring process may be directly collected during the detection, such as the JOURNEY PATTERN currently used, the DATED BLOCK in progress, etc. Such information is sometimes keyed in from within the vehicle by the driver.

Some other raw information may be detected, such as the DIRECTION used (e.g. compared to the DIRECTION of a ROUTE), the current speed, the fact that the doors are open, the fact that the vehicle is currently coupled to other vehicles, the vehicle occupancy, alarms, etc. These other types of detection may be recorded as a DETECTED OPERATION, characterized by a “type of operation”.

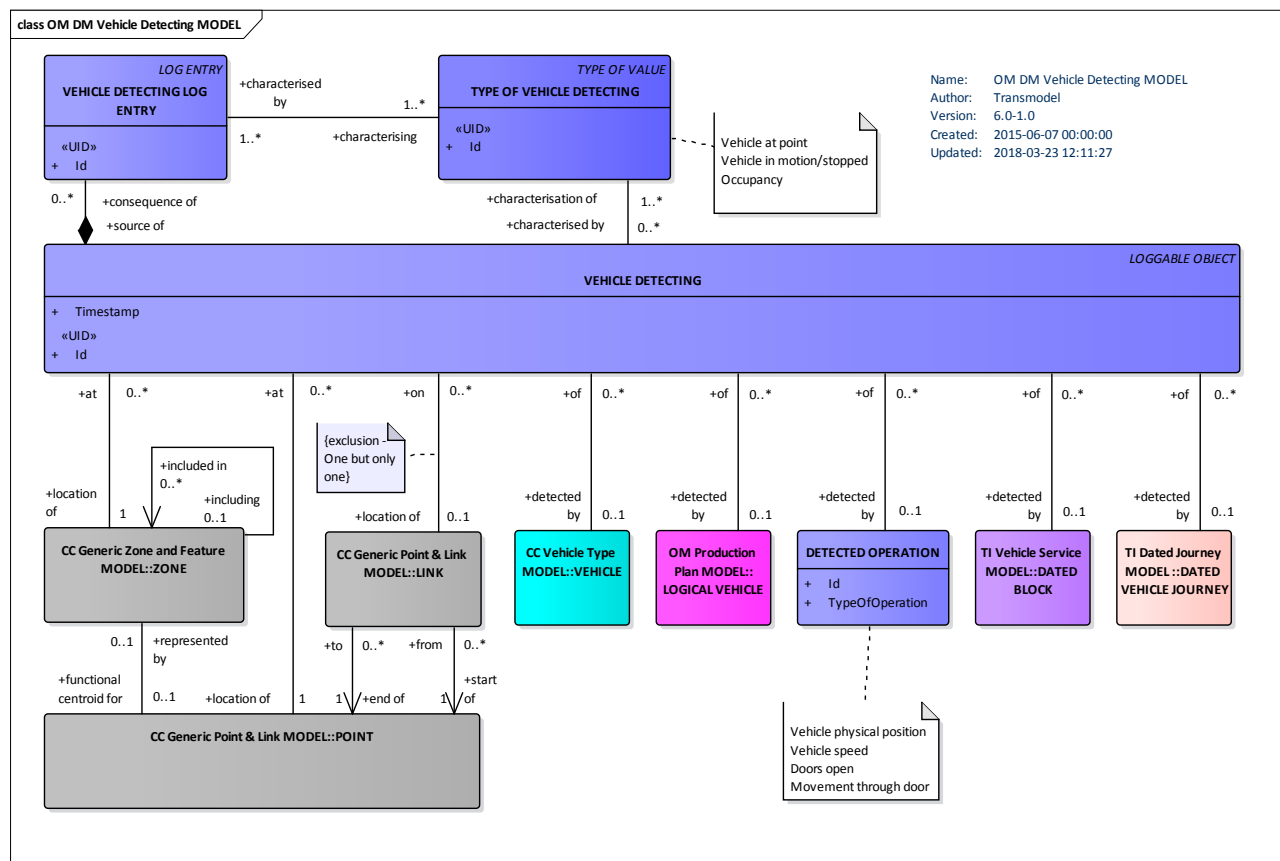


Figure 8 — Vehicle Detecting MODEL

5.3.5 Vehicle Monitoring

The process of vehicle monitoring consists of computing all available data, in particular the latest valid plan and the data collected through the detection process, in order to ascertain the position of a vehicle on the network and to compare it to its plan. For instance, the raw location data are used from the detection is transformed in a position along a certain JOURNEY PATTERN, and a possible advance or delay computed with regard to the schedule of a DATED VEHICLE JOURNEY serving that JOURNEY PATTERN.

Any monitored data are recorded through a VEHICLE MONITORING. Instances of this entity are log entries of all monitoring actions performed during a day.

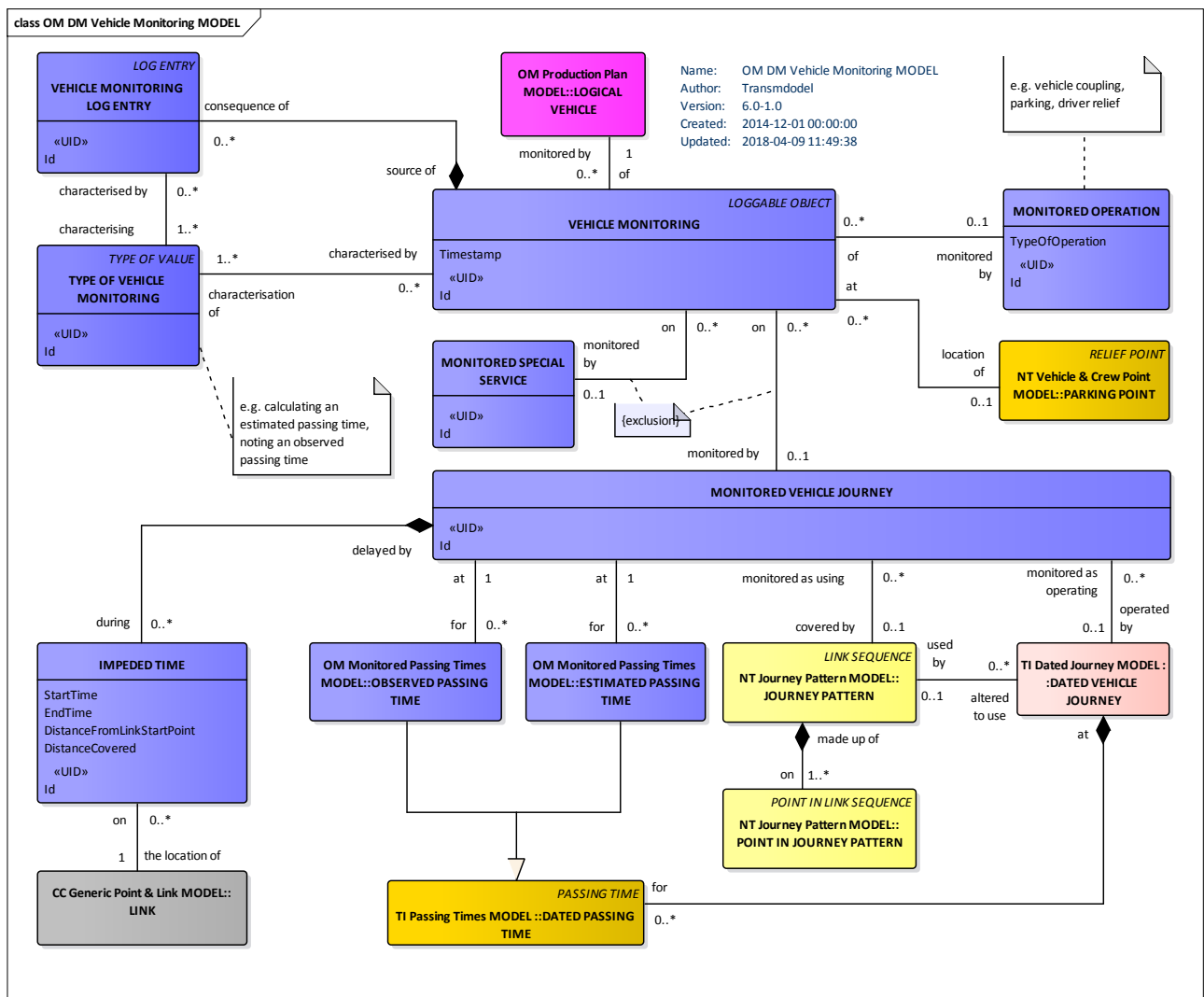


Figure 9 — Vehicle Monitoring MODEL

A VEHICLE MONITORING shall be related to one LOGICAL VEHICLE. It is identified by this LOGICAL VEHICLE, and a 'timestamp'. As with VEHICLE DETECTING, this timestamp describes the time of the monitored situation (at this point in time, the vehicle is recognized as operating this vehicle journey), rather than the time at which it is recorded.

Various types of situations may be monitored as indicated by the TYPE OF VEHICLE MONITORING. Sometimes a single VEHICLE MONITORING may also result in multiple, related VEHICLE MONITORING LOG ENTRIES noting the observed passing time of a point and the calculation of estimated passing times at a number of later points for the same vehicle.

5.4 Vehicle Assignments

5.4.1 General

The vehicle detection, as described in subclause 5.3.4, may relate the detected information either to a VEHICLE number, to a LOGICAL VEHICLE, to a DATED VEHICLE JOURNEY, or to a DATED BLOCK, depending on the system capabilities. The various assignment processes described below allow the checking of the detected information and the transformation of the detected data into monitored data in

a consistent way, and also serve as the basis for the VEHICLE ASSIGNMENT CONTROL ACTION (see subclause 5.6.2).

5.4.2 Assignments

In many situations, the aim of the vehicle assignment process is to relate a physical VEHICLE to a work plan (e.g. one or several DATED BLOCKS). However, there are situations where such a simple assignment is not sufficient (e.g. during the design of a control action or the replacement of a failing vehicle, etc.) and the use of the LOGICAL VEHICLE concept is required to cope with a possible temporary inconsistency. Moreover, there are operational situations where no work plan is known (e.g. for certain passenger information systems, or for reserve vehicle, some cases of demand-responsive systems, etc.), and others where the physical vehicle identification is not known or uncertain.

To cope with such a variety of situations, the modelling is based on different types of assignments. Such an assignment occurs for instance when a work plan is assigned to a logical vehicle, when a physical vehicle no longer corresponds to a logical vehicle, etc. The current assignments of each LOGICAL VEHICLE are the result of all the assignment events that have taken place (on the OPERATING DAY of this LOGICAL VEHICLE). Such assignments concern:

- the assignment of a work plan to a logical vehicle;
- the assignment of a physical vehicle to a logical vehicle.

5.4.3 Work Plan Assignment

One of the most important monitoring events is the assignment of a work plan to a LOGICAL VEHICLE. In many systems, it is the first monitored event on each day, because it may be carried out as soon as the DATED BLOCKS for that day are generated.

In principle, the assignment of a work plan to a LOGICAL VEHICLE shall be the result of a specific VEHICLE WORK ASSIGNMENT. This entity is classified as a CONTROL ACTION (see subclause 5.6.2.2). In practice, such an action is explicit only when it corresponds to a modification of a previous assignment, or to a work plan assignment to a new resource, during the day of operations. At the beginning of this day, in most systems where dated plans are used, an initial assignment is carried out automatically as soon as the LOGICAL VEHICLES are created. This assignment is often implicit: by default, for instance, all DATED BLOCKS belonging to a dated VEHICLE SERVICE bearing the same code as the LOGICAL VEHICLE are assigned to this LOGICAL VEHICLE. In other cases, the work plan assignment may be the result of a DATED BLOCK detection (e.g. block number keyed by the driver). In such cases, the corresponding VEHICLE WORK ASSIGNMENTS are trivial and represent simple log entries. On the contrary, further assignments, for instance the assignment of a reinforcement DATED VEHICLE JOURNEY to a reserve LOGICAL VEHICLE, will be recorded as VEHICLE WORK ASSIGNMENTS that are, strictly speaking, CONTROL ACTIONS.

Any VEHICLE WORK ASSIGNMENT assigns to a LOGICAL VEHICLE either:

- one or several DATED BLOCKS;
- one or several DATED VEHICLE JOURNEYS.

As with any CONTROL ACTION, a VEHICLE WORK ASSIGNMENT is timed by a 'validation time'. A LOGICAL VEHICLE may be subject to several VEHICLE WORK ASSIGNMENTS. An assignment may be broken using the same entity (thanks to a flag "assign or cancel"). An assigned DATED BLOCK or DATED VEHICLE JOURNEY may be amended during the day by modifications due to further CONTROL ACTIONS (e.g. timing modification of a journey). The result of the active assignments and control actions represents the latest valid plan for each resource.

In many situations, the work plan assigned to a LOGICAL VEHICLE consists of one or several DATED BLOCKs. Each DATED BLOCK is composed of all activities included in that block, i.e. DATED VEHICLE JOURNEYS (including SERVICE JOURNEYS and DEAD RUNs), DATED SPECIAL SERVICES, and possible other activities (e.g. preparation time or vehicle cleaning, described as TIME ALLOWANCES, or vehicle PAUSE).

In other situations, the data referring to the BLOCKs as planned by the operator are not known (e.g. in a multi-operator environment), or some activity components are not known or are neglected (e.g. DEAD RUNs or time allowances). In such situations, users may describe the work plan as composed only of DATED VEHICLE JOURNEYS. This solution is relevant whenever the whole information describing activities included in a block is not available. It may be used, too, by users willing to monitor elementary activities (e.g. journeys) instead of sets of activities (e.g. BLOCKs). In this case, however, the solution shall be equivalent to the previous one (work plan described by DATED BLOCKs) only if all elementary activities composing a BLOCK are assigned to the resource; the corresponding modelling (which would involve dated time allowances or pauses) is not documented in the reference model.

The assignment of a work plan is not mandatory, as a plan is not necessarily applied to any vehicle (e.g. for reserve vehicles, or for demand-responsive systems), or the plan may not be known by the system (e.g. in some passenger information systems).

Numerous assignment events will be the corollary of a structured CONTROL ACTION (see for instance CHANGE OF VEHICLE in subclause 5.6.2.5. In some cases, a LOGICAL VEHICLE may be assigned to two (or more) incompatible work plans, or the same plan assigned to several LOGICAL VEHICLEs. This is in particular the case during the building of a CONTROL ACTION consisting of exchanging VEHICLEs. It is the responsibility of the application in charge of monitoring to manage this inconsistency through the timed VEHICLE WORK ASSIGNMENT. For example, most of the current systems prevent such an inconsistency by obliging the user to cancel the former assignment completely before entering the new one.

5.4.4 Vehicle Assignment

At the beginning of the OPERATING DAY (or before the start of each DATED BLOCK), available VEHICLEs may be assigned to LOGICAL VEHICLEs. In addition, further modifications in the vehicle assignment are likely to occur during the OPERATING DAY, due to failures, changes in the plan, maintenance actions, etc.

The assignment of a physical VEHICLE to a LOGICAL VEHICLE shall be the result of a specific VEHICLE ASSIGNMENT. This entity is classified as a CONTROL ACTION (see subclause 5.6.2.1). It takes place, in principle, in a GARAGE, before the start of the work plan assigned to the LOGICAL VEHICLE. As with any CONTROL ACTION, a VEHICLE ASSIGNMENT is timed by a 'validation time'. A LOGICAL VEHICLE may be subject to several VEHICLE ASSIGNMENTs. An assignment may be broken using the same entity (thanks to a flag "assign or cancel"). A provisional inconsistency may occur in some situations (e.g. during the design of a control action). The result of the various assignments represents the current assignment of each resource.

5.5 Monitored Operations

5.5.1 Monitored Services

Most VEHICLE MONITORING events will relate a LOGICAL VEHICLE to its current position on the network. When such events concern the monitoring of vehicle location, VEHICLE MONITORING shall be associated to either:

- a MONITORED VEHICLE JOURNEY;
- a MONITORED SPECIAL SERVICE; or

— a PARKING POINT.

A MONITORED VEHICLE JOURNEY describes a journey recognized as being in progress, at the time of the VEHICLE MONITORING. There are two possibilities to describe a MONITORED VEHICLE JOURNEY.

Whenever possible, a MONITORED VEHICLE JOURNEY will be related to a DATED VEHICLE JOURNEY. This means that the system states that the journey underway is a DATED VEHICLE JOURNEY present in the latest valid plan. A vehicle waiting at a terminus may be monitored as spending a layover time (therefore not spending a parking period between two BLOCKS or a vehicle pause); conventionally, this layover time belongs to the journey to come afterwards (see EN 12896-3:2016).

In normal situations, this DATED VEHICLE JOURNEY is the expected journey, i.e. the DATED VEHICLE JOURNEY planned at that time in the DATED BLOCK assigned as the work plan to the monitored LOGICAL VEHICLE. However, there may be some inconsistency with the work plan. This is particularly true when the service has a major delay and when the LOGICAL VEHICLE is supposed to run a further DATED VEHICLE JOURNEY after the monitored journey. In some rare cases, the system may even monitor a DATED VEHICLE JOURNEY belonging to another DATED BLOCK than that assigned to that LOGICAL VEHICLE.

In other situations, the system is unable to identify any DATED VEHICLE JOURNEY but recognizes a particular JOURNEY PATTERN as being served by the MONITORED VEHICLE JOURNEY. Some passenger information systems, which do not use any reference to a work plan, are built according to this scheme. In classical AVM systems, this may happen if the vehicle follows an unexpected JOURNEY PATTERN, possibly because a CONTROL ACTION has been ordered verbally but not yet entered by the controller. Some modern systems, coupled to a geographical system, allow the building of an unknown ROUTE and a JOURNEY PATTERN when a vehicle serves them. Such new ROUTEs and JOURNEY PATTERNS may be proposed, during the operations follow-up phase (see subclause 5.5.4), to be stored as occasional patterns.

As long as the MONITORED VEHICLE JOURNEY is not completed, there is some uncertainty as regards the monitoring data. For instance, the vehicle may be monitored as serving a particular JOURNEY PATTERN, but then operates an unexpected short turn at an intermediate TURN STATION. The system should in principle be able to declare a further VEHICLE MONITORING, modifying the previous one by indication of the JOURNEY PATTERN actually served (which has its end at the TURN STATION). A later entry of the corresponding CONTROL ACTION by the controller may facilitate this process (if the system accepts such a delayed entry).

If all these monitoring processes fail, the system will declare the vehicle as “not monitored”. This will happen for instance if a bus is located at a place not known by the system as belonging to any ROUTE (unexpected deviation). This is not to be confused with the worse situation where the system is even unable to detect any location (“vehicle lost” statement).

Similar to a MONITORED VEHICLE JOURNEY, a VEHICLE MONITORING may state that the LOGICAL VEHICLE is serving a MONITORED SPECIAL SERVICE. In such a case, the monitored service will be associated to either a DATED SPECIAL SERVICE or a JOURNEY PATTERN devoted to special services. This monitoring supposes that the ROUTEs and JOURNEY PATTERNS used by SPECIAL SERVICES are described with a sufficient precision. However, the corresponding relationships (between MONITORED SPECIAL SERVICE and DATED SPECIAL SERVICE or JOURNEY PATTERN) are not shown in the diagram.

The third monitoring possibility occurs when a VEHICLE MONITORING states that the LOGICAL VEHICLE is currently parked at a particular PARKING POINT. This will happen in particular when the vehicle is at the GARAGE or when a parking period is planned at this point during a DATED BLOCK.

It is of importance to distinguish the latest valid plan from the monitored situation on the network. The monitored situation may sometimes not be precise enough (failure, gap in the location process, etc.) or not detailed enough to be related to a work plan. The latest valid plan is not always up to date, for instance when a CONTROL ACTION is ordered verbally before having been entered in the monitoring

system by the controller. In some systems, the work plan is even not registered in the system (e.g. when the system is only oriented towards passenger information).

5.5.2 Monitored Passing Times

Theoretical PASSING TIMES at SCHEDULED STOP POINTS may be computed from the basic timing information (see EN 12896-3:2016). In the design of the operational plan for a specific OPERATING DAY, such planned PASSING TIMES may be amended by changes made on the schedule. This will produce “target passing times” for this day, supporting the monitoring of operations. In addition, forecasts may be made on “estimated passing times”, mainly for passenger information, and actually “observed passing times” may be recorded by a monitoring system. All these concepts are described by the generic entity PASSING TIME, which has several sub-types.

Modifications of the plan for a specific OPERATING DAY, in particular changes in journeys, are likely to generate the need to recalculate the passing times. These modified passing times are defined as DATED PASSING TIMES. Several sub-types of DATED PASSING TIME reflect the different status and use of passing times at different moments in time.

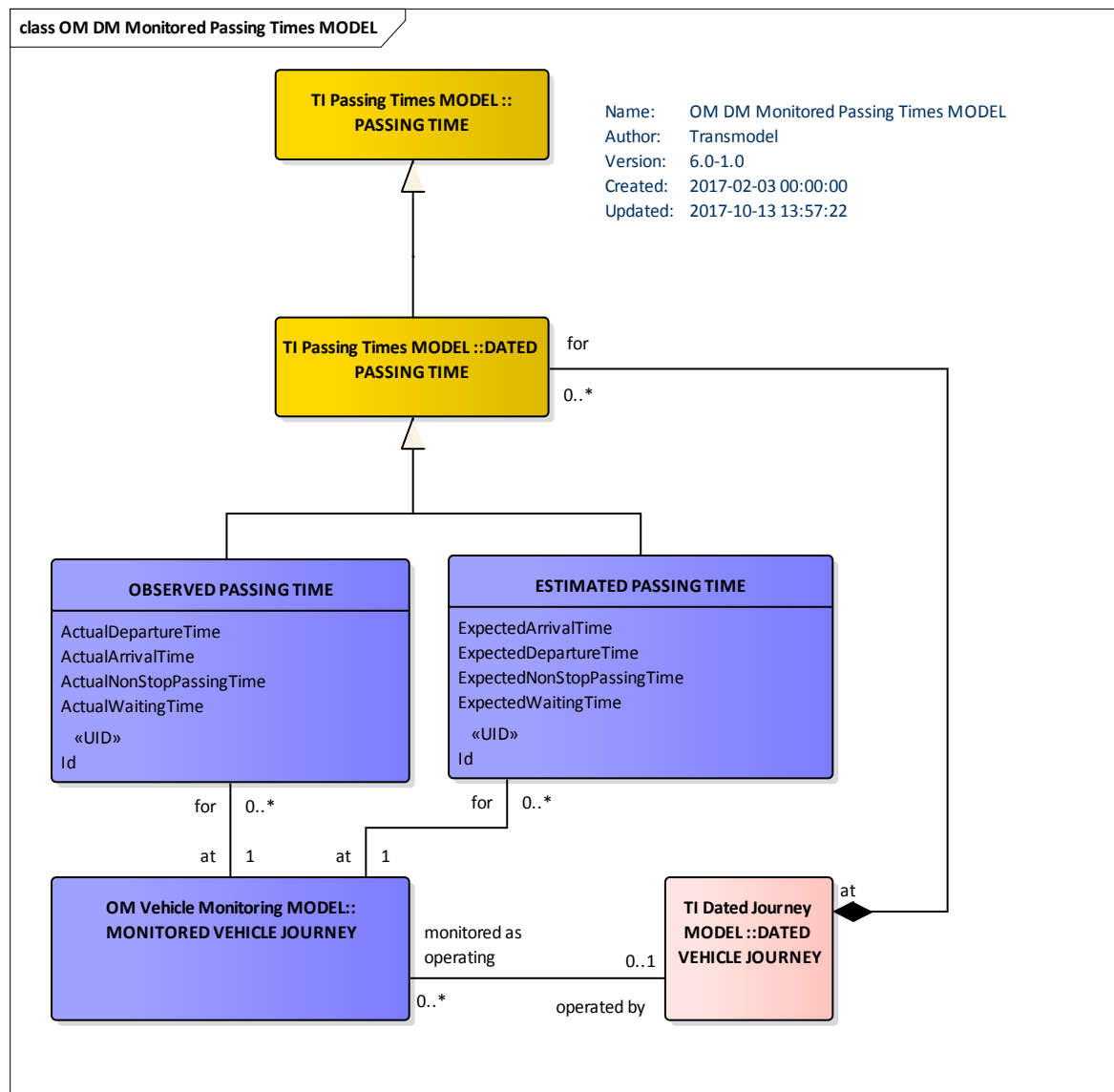


Figure 10 — Monitored Passing Times MODEL

A first calculation of DATED PASSING TIMES may be carried out as soon as the DATED VEHICLE JOURNEYS for a particular OPERATING DAY are defined. Such passing times are called TARGET PASSING TIMES. They are calculated for all points that are defined as TIMING POINTs IN JOURNEY PATTERN for the corresponding DATED VEHICLE JOURNEYS.

The TARGET PASSING TIMES are normally generated for the first time a few days before the OPERATING DAY, and are constantly updated from that moment on, according to the modifications applied to the schedule. The TARGET PASSING TIME can be seen as the latest official plan for vehicle operation.

The drivers will certainly try to meet the TARGET PASSING TIMES, but in practice the vehicle may deviate from this plan due to the traffic circumstances. Various systems (such as AVM) can monitor these deviations and provide an estimation of PASSING TIMES at the next stop points, for passenger information or for service control. This estimation may be based on planned run times or on mean run times (the latter being often calculated for passenger information functions). Such ESTIMATED PASSING TIMES will be displayed at stops and will be used for trip planning queries. They may be used as well by the AVM system, in order for instance to alert the controller on a forecasted delay for a relief.

An ESTIMATED PASSING TIME is computed for a particular MONITORED VEHICLE JOURNEY, at a specified POINT IN JOURNEY PATTERN. The ESTIMATED PASSING TIMES are constantly changing with every new piece of information received about the progress of the vehicle on its route. It can be useful to store some ESTIMATED PASSING TIMES for statistical reasons.

The entity OBSERVED PASSING TIME describes the actual PASSING TIMES that have been recorded at a specific POINT. This information is used to compute further ESTIMATED PASSING TIMES and, of course, for statistical purposes. OBSERVED PASSING TIMES result from the monitoring process and are therefore related to a MONITORED VEHICLE JOURNEY. This entity may also be used for manual collection (surveys) of passing times. Any collected passing time that cannot be related to a MONITORED VEHICLE JOURNEY should be described, on the contrary, only as a VEHICLE DETECTING at the measurement POINT.

5.5.3 Other Monitored Situations

Some other events may be monitored, according to the detection capabilities of the system. They may be recorded as MONITORED OPERATION, characterized by a 'type of operation', and related to a VEHICLE MONITORING event. Among those in relation with the reference model, the most important are:

- the actual coupling or separating of vehicles (see EN 12896-3:2016); and
- the INTERCHANGE STATUS (see EN 12896-3:2016) recording.

Such MONITORED OPERATIONS would require some complementary information to be attached to VEHICLE MONITORING events, such as, in the case of vehicle coupling, the place of this event (e.g. a PARKING POINT).

Some systems allow the monitoring of events related to driver management. Drivers are identified by the keying of an ID number or possibly by using a badge. With such systems, signing-on and -off events will be monitored as "driver monitoring events", when they occur at a CREW BASE or at other places. An actual relief, occurring on a vehicle, may be additionally classified as MONITORED OPERATION, as it may be related to a monitored LOGICAL VEHICLE. This information would allow the monitoring of a LOGICAL DRIVER as driving a particular LOGICAL VEHICLE.

Users of systems not having this capability may however follow-up the drivers by trusting the work plan assigned to LOGICAL DRIVERS. The "dated duties" will be related to the DATED BLOCKs using "dated relieves" (and to DATED VEHICLE JOURNEYS using DATED JOURNEY PARTs), allowing such a

control. In such a case however, some uncertainty remains because the latest valid plan for drivers may not be up to date.

5.5.4 Expected and Registered Situation

The production follow-up requires a subset of all information collected by the monitoring process to be recorded. A critical data to record is the OBSERVED PASSING TIME, for instance at all TIMING POINTs or even at all SCHEDULED STOP POINTs. Such a recording may be used, for instance, for quality indicators (e.g. mean delays) or statistical purposes (e.g. study of run times).

The production follow-up is based on the monitored situation (e.g. OBSERVED PASSING TIMES), with reference to the latest valid plan (e.g. TARGET PASSING TIMES). However, this information should be, in frequent cases, complemented by other data which is not collected during the monitoring process. For instance:

- updating the latest valid plan, when some CONTROL ACTIONs have not been entered or need to be completed;
- correcting the monitored situation as necessary when some uncertainty remains (e.g. vehicle temporarily lost by the location system). This is particularly crucial for the follow-up of drivers' work (basis for pay-roll), which is often not precisely monitored by the system;
- validating, or not, some information, such as new ROUTEs and JOURNEY PATTERNs monitored by the system (see 5.5.1);
- adding appropriate information: this is also relevant for driver work, as some wage increases or change of time allowance may occur, depending on the actual duration of spells; a period monitored as a waiting time for a vehicle may be corrected as being the result of a failure, etc.;
- completing the records by adding management information, such as reasons for having changed the plan, comments, etc.

5.6 Control Actions

5.6.1 General

The transportation supply is defined in a PRODUCTION PLAN with some tolerance margins (the most typical being the layover time) in order to adapt the production to minor events without disruption of the service (schedule adherence). The drivers in particular are often invited to adapt their driving, whenever possible, in order to keep the vehicle within these margins.

However, when these margins are exceeded (major incident, important delay, etc.), the latest valid plan is too far from the actual situation and it becomes necessary to amend this plan. These amendments are achieved through the use of CONTROL ACTIONs. Such CONTROL ACTIONs, affecting the PRODUCTION PLAN, are the most critical decisions to make for the personnel in charge of operations.

Real-time operations control is usually under the responsibility of an operations controller, who should have an overall view of the situation. Other actors are involved, mainly the drivers but also inspectors or maintenance staff. Their primary role in this process is to inform the controller, or in some cases to make decisions. An essential characteristic of the controller's work is the need to predict the evolution of disturbances, their repercussions on operations, and the effects of envisaged CONTROL ACTIONs. In some cases, there are also technical systems that can initiate and apply CONTROL ACTIONs automatically based on previously defined rules, knowledge about the current situation or other grounds.

Once the PRODUCTION PLAN has been frozen, further modifications, in particular during the OPERATING DAY, are recorded as CONTROL ACTIONs. A CONTROL ACTION corresponds to the

description of a deliberate modification of the PRODUCTION PLAN. At any time during an OPERATING DAY, the initial PRODUCTION PLAN, amended by all operated CONTROL ACTIONs, forms the latest valid plan for production. CONTROL ACTION is hence a use of DELTA (see EN 12896-1:2016).

Due to the independence of the schedules composing an operational plan, a certain inconsistency may remain at some stages. A part of a BLOCK may, for instance, not be covered by any driver work between reliefs, or may be covered by several at the same time. During the design of a CONTROL ACTION in real time, a LOGICAL VEHICLE may be assigned to two incompatible journeys, or to two BLOCKs at the same time. An efficient control system should include mechanisms dealing with such inconsistencies.

CONTROL ACTIONs may produce changes in the structure of the activities performed by the resources. This is particularly true when modifications made on journeys cause the duration of a driver's continuous work in the same vehicle to be extended. This may have consequences on that driver's paid time. One of the important functions of an AVM system is to alert the control staff in such cases of inconsistency or induced changes.

A range of CONTROL ACTIONs may be used to reorganize the PRODUCTION PLAN. Another important function of an AVM system is to facilitate the design and the follow-up of such CONTROL ACTIONs. The most useful are described below. The CONTROL ACTIONs are sub-divided in five groups in the following way: ELEMENTARY and COMPOSITE JOURNEY CONTROL ACTIONs, DRIVER CONTROL ACTIONs, INTERCHANGE CONTROL ACTIONs and VEHICLE CONTROL ACTIONs.

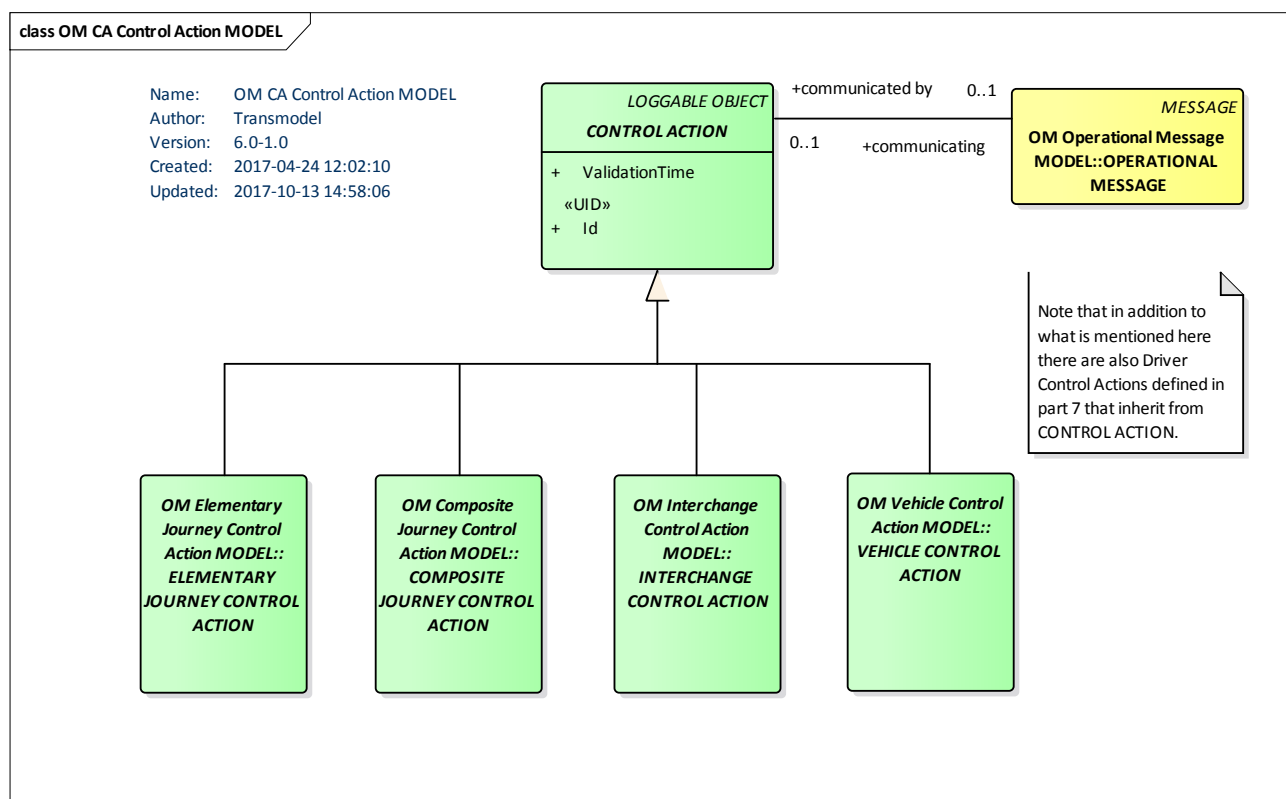


Figure 11 — Control Actions MODEL

5.6.2 Vehicle Control Actions

5.6.2.1 General

VEHICLE CONTROL ACTIONS are CONTROL ACTIONS that affect a LOGICAL VEHICLE. It should be noted that in certain situations one VEHICLE CONTROL ACTION is sometimes mandatorily followed by another one.

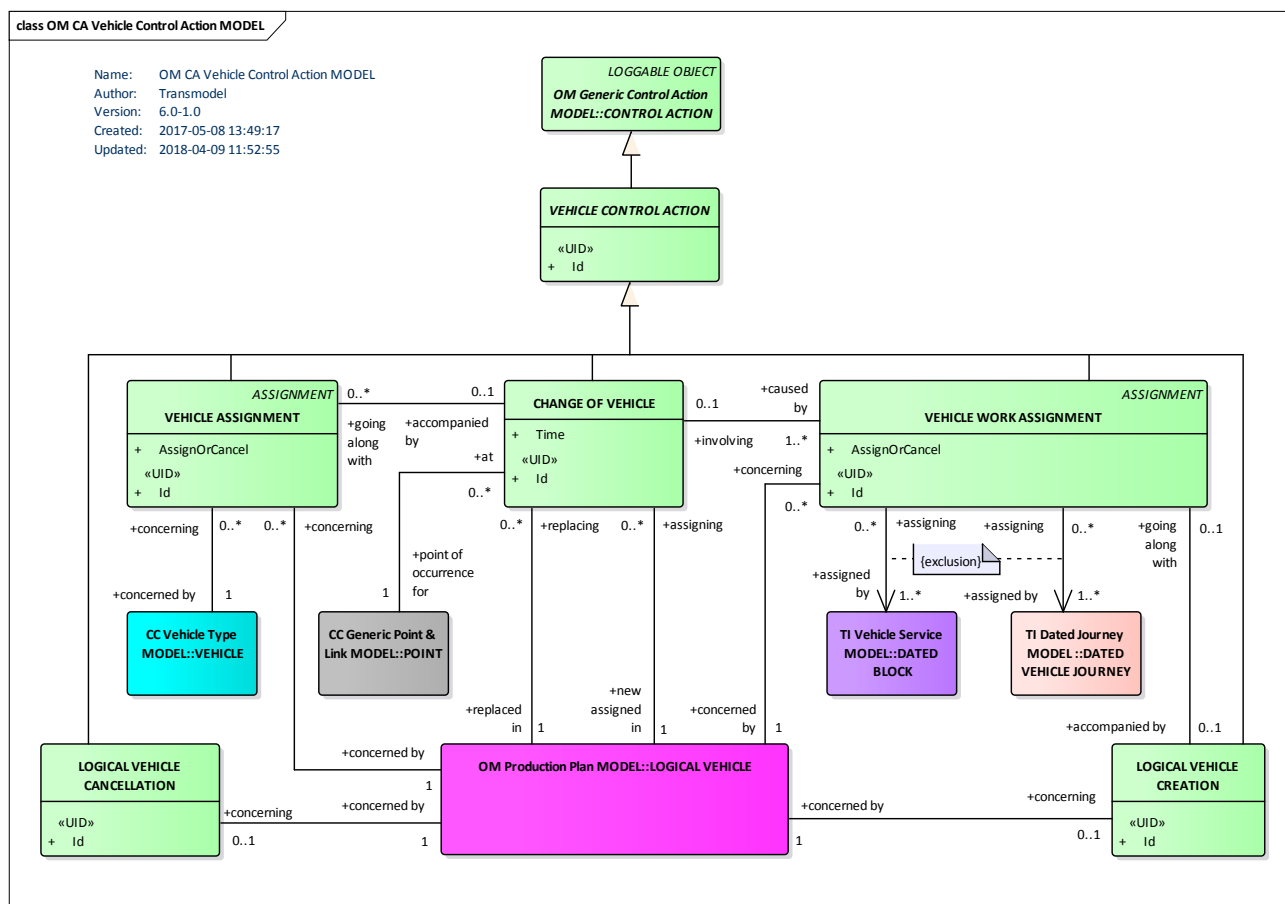


Figure 12 — Vehicle Control Actions MODEL

5.6.2.2 Vehicle Assignment

A VEHICLE ASSIGNMENT action consists of the assignment, or the cancellation of an assignment, of a physical VEHICLE to a LOGICAL VEHICLE. This assignment may be overridden by a further assignment.

5.6.2.3 Vehicle Work Assignment

A VEHICLE WORK ASSIGNMENT action consists of the assignment, or the cancellation of an assignment, of a LOGICAL VEHICLE to a planned work, represented as DATED BLOCKs or as DATED VEHICLE JOURNEYS. This assignment may be overridden by a further assignment.

5.6.2.4 Logical Vehicle Creation

A LOGICAL VEHICLE CREATION action consists of creating a completely new LOGICAL VEHICLE (e.g. reinforcement or replacement resource). It is often accompanied by a VEHICLE WORK ASSIGNMENT, in order to assign a work plan to the new resource.

5.6.2.5 Logical Vehicle Cancellation

A LOGICAL VEHICLE CANCELLATION action consists of removing a LOGICAL VEHICLE from the PRODUCTION PLAN. The work assigned to it (DATED BLOCKs and DATED VEHICLE JOURNEYS) may remain unassigned for a while.

5.6.2.6 Change of Vehicle

A CHANGE OF VEHICLE action consists of removing, at a certain point in time and space, all work assigned to a LOGICAL VEHICLE and assigning it to another LOGICAL VEHICLE. The exchanged work comprises all DATED BLOCKs and their contents (DATED VEHICLE JOURNEYS and possible DATED SPECIAL SERVICES) included in the work plan of the replaced vehicle. Any CHANGE OF VEHICLE is completed by the appropriate VEHICLE WORK ASSIGNMENT. A CHANGE OF VEHICLE is often accompanied by one or two VEHICLE ASSIGNMENTs, replacing also the physical vehicles.

Such an exchange is likely to occur while the replaced vehicle is already working a block (e.g. because of a mechanical failure). In such a case, only the remaining work is transferred, which implies the creation of an extra DATED BLOCK, comprising all remaining elements (e.g. DATED VEHICLE JOURNEYS) included in the exchanged DATED BLOCK.

The exchange may even occur during a DATED VEHICLE JOURNEY, i.e. at other points than termini. In such a case, DATED JOURNEY PARTs may be created to describe the parts respectively assigned to the replaced and the replacing vehicle.

In addition, some powerful systems will assist the controller in the design of the necessary DEAD RUNs to operate the exchange (e.g. if the replacing vehicle comes from a GARAGE). Such DEAD RUNs will be added to work plan of the corresponding vehicles.

5.6.3 Elementary Journey Control Actions

5.6.3.1 General

ELEMENTARY JOURNEY CONTROL ACTIONs are a specific subset of ELEMENTARY CONTROL ACTIONs which affect a single DATED VEHICLE JOURNEY or, in some instances, multiple DATED VEHICLE JOURNEYS in parallel.

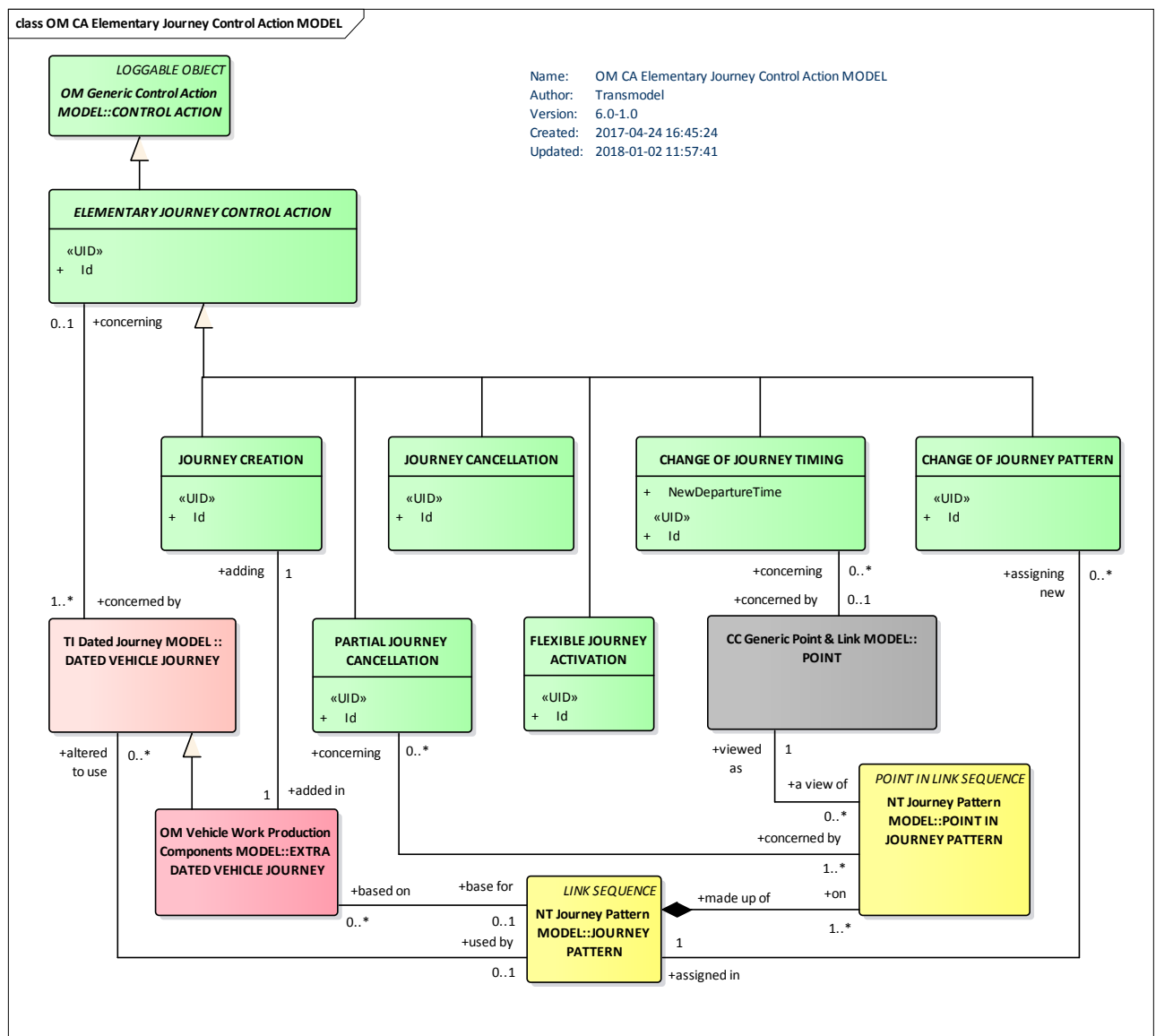


Figure 13 — Elementary Journey Control Actions MODEL

5.6.3.2 Journey Creation

A JOURNEY CREATION action is an elementary action in which a completely new DATED VEHICLE JOURNEY is added to the latest valid plan. This action is often complemented by other actions (e.g. RESPACING).

5.6.3.3 Flexible Journey Activation

Some planned journeys have a booking pre-condition meaning that they will only be run if there is a known demand. This could be related to different types of demand responsive transport in sparsely-populated area where the passengers need to book their journey in advance.

Another scenario is to pre-plan additional journeys that can be put into operation so as to quickly increase capacity in addition to the normal operation. This may be relevant on certain lines where large variations in passenger demand can be expected for external reasons.

The FLEXIBLE JOURNEY ACTIVATION control action is thus used to activate DATED VEHICLE JOURNEYS with booking pre-conditions.

5.6.3.4 Journey Cancellation

A JOURNEY CANCELLATION action is an elementary action consisting of deleting a DATED VEHICLE JOURNEY from the latest valid plan. It is often complemented by other actions (e.g. RESPACING).

5.6.3.5 Partial Journey Cancellation

PARTIAL JOURNEY CANCELLATION is similar to JOURNEY CANCELLATION, with the difference that the complete DATED VEHICLE JOURNEY is not cancelled, only part of it. It can be seen as deleting part of a DATED VEHICLE JOURNEY from the last ordered plan.

A PARTIAL JOURNEY CANCELLATION can also be viewed as assigning a JOURNEY PATTERN that is a subset of the original JOURNEY PATTERN to a DATED VEHICLE JOURNEY, and thus being a special case of CHANGE OF JOURNEY PATTERN highlighting the reduction of service aspect.

A PARTIAL JOURNEY CANCELLATION can also be expressed as referring to the original JOURNEY PATTERN shortened from a certain POINT IN JOURNEY PATTERN or cancelled between POINTs IN JOURNEY PATTERN.

5.6.3.6 Change of Journey Pattern

A CHANGE OF JOURNEY PATTERN action consists of assigning a different JOURNEY PATTERN (and the ROUTE supporting it) to a DATED VEHICLE JOURNEY from that which was originally planned. The modification may for instance consist of using an alternate ROUTE when some part of the normal ROUTE is blocked.

In some cases, a corresponding ROUTE and JOURNEY PATTERN may be created on this occasion.

A special usage of this CONTROL ACTION is related to a change of platform, such as when a train is to arrive at and/or depart from a station at a different track than what was originally planned. In this case the new JOURNEY PATTERN will be identical to the original JOURNEY PATTERN except that one of the POINT IN JOURNEY PATTERNS will refer to a different SCHEDULED STOP POINT from that which was stated in the original JOURNEY PATTERN.

5.6.3.7 Change of Journey Timing

A CHANGE OF JOURNEY TIMING action consists of changing one or several characteristics of a DATED VEHICLE JOURNEY related to timing:

- Departure time of the journey (from the first POINT IN JOURNEY PATTERN);
- Departure time of the journey from an intermediate POINT IN JOURNEY PATTERN;
- TIME DEMAND TYPE assigned to the journey;
- TIMING POINT acting as timing reference for the journey;
- Assignment of a specific VEHICLE JOURNEY RUN TIME.

In reality, changing the departure time from the first POINT IN JOURNEY PATTERN is probably the most frequent practice, hence the only one detailed in the model.

5.6.4 Composite Journey Control Actions

5.6.4.1 General

A COMPOSITE JOURNEY CONTROL ACTION affects a set of DATED VEHICLE JOURNEYS with a correlated set of adjustments. In some systems, the COMPOSITE JOURNEY CONTROL ACTIONS are not implemented explicitly but instead the same effect is accomplished through a set of coordinated ELEMENTARY JOURNEY CONTROL ACTIONS.

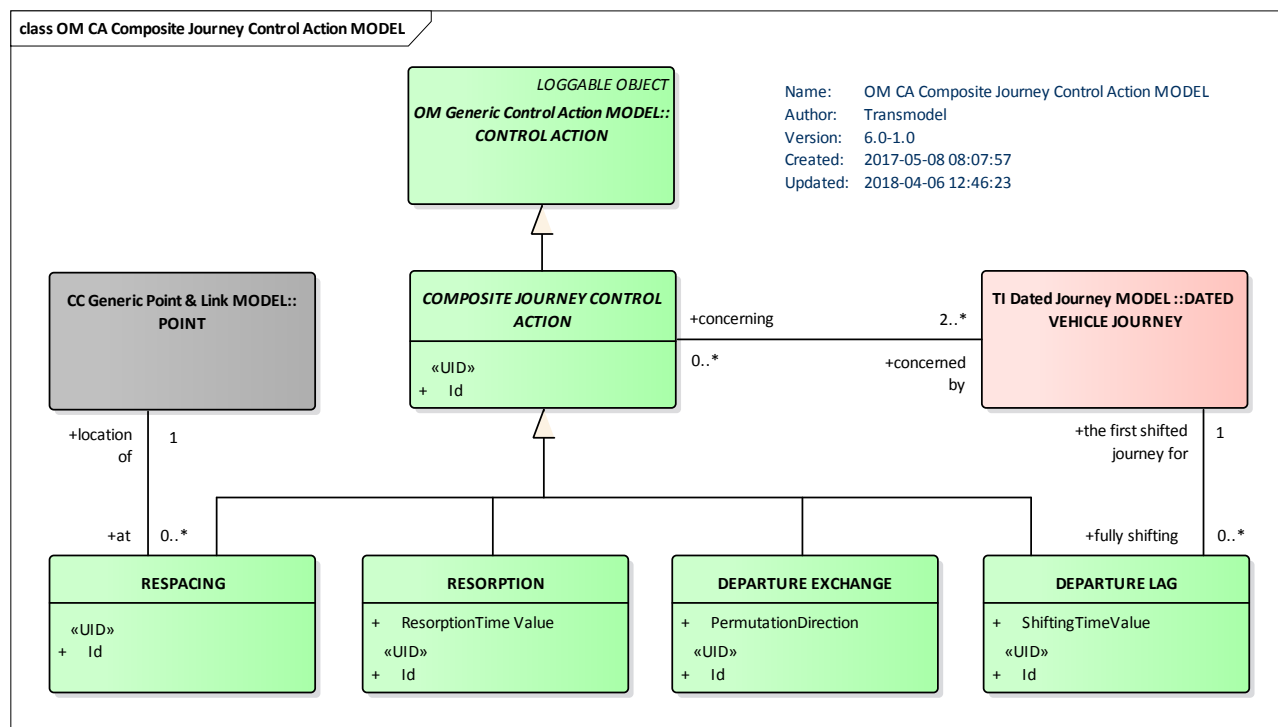


Figure 14 — Composite Journey Control Actions MODEL

5.6.4.2 Departure Lag

A DEPARTURE LAG action consists of gradually shifting a set of departures at one POINT. It allows a change of the timetable without abrupt variations in the intervals.

It concerns a certain number of DATED VEHICLE JOURNEYS (e.g. 6), which in principle follow the same JOURNEY PATTERN. The departure time of one of these journeys (e.g. the 4th) is shifted with the full “shifting time value” (positive or negative, e.g. + 9 min). The following journeys (e.g. the 5th and the 6th) are shifted with the same value. The previous journeys except the first are shifted with interpolated values (e.g. 3 min for the 2nd, 6 min for the 3rd).

This action takes often place at the starting terminus of journeys. However, it may be planned at any POINT served by the concerned ROUTE. In such a case, the timing of the journeys will be adapted accordingly (possibly with run time interpolation, if that POINT is not a TIMING POINT).

5.6.4.3 Departure Exchange

A DEPARTURE EXCHANGE action consists of altering, at one POINT, the departure times of two or several DATED VEHICLE JOURNEYS which follow the same JOURNEY PATTERN. It is a convenient way of treating, for instance, a delay of only one journey. The permutation may occur in descending or ascending order.

As with a DEPARTURE LAG, a DEPARTURE EXCHANGE may occur in theory at any POINT served by the concerned ROUTE. In practice, this action will often only be implemented at the starting terminus.

5.6.4.4 Resorption

A RESORPTION action consists of progressively resorbing a delay on one DATED VEHICLE JOURNEY by rescheduling the departure times of the following journeys serving the same JOURNEY PATTERN. It is a way of maintaining regular intervals after a disturbance on a particular journey.

For instance, if the first concerned DATED VEHICLE JOURNEY is delayed 9 min, the second is delayed 6 min, the third by 3 min and the fourth keeps the planned time.

As with a DEPARTURE LAG, a RESORPTION may occur at any POINT served by the concerned ROUTE.

5.6.4.5 Respacing

A RESPACING action is complementary to a JOURNEY CREATION or CANCELLATION, or a LOGICAL VEHICLE CREATION or CANCELLATION. It consists of respacing departure times, after a journey or a vehicle has been added or cancelled, in order to preserve the regularity of intervals. The new intervals of the remaining journeys are calculated by interpolation.

As a DEPARTURE LAG, a RESPACING may occur at any POINT served by the concerned ROUTE.

5.6.5 Interchange Control Actions

5.6.5.1 General

Interchange control actions are CONTROL ACTIONs that affect DATED VEHICLE JOURNEY INTERCHANGEs.

A DATED VEHICLE JOURNEY INTERCHANGE specifies that a certain DATED VEHICLE JOURNEY (the distributor) should wait for another specified DATED VEHICLE JOURNEY (the feeder) to arrive before departing from a shared stop even if the feeder is somewhat delayed. There will be a specified limit for how long the distributor shall wait at the most.

INTERCHANGE CONTROL ACTIONs are used when there is a need to make short-term changes to the current set of DATED VEHICLE JOURNEY INTERCHANGEs.

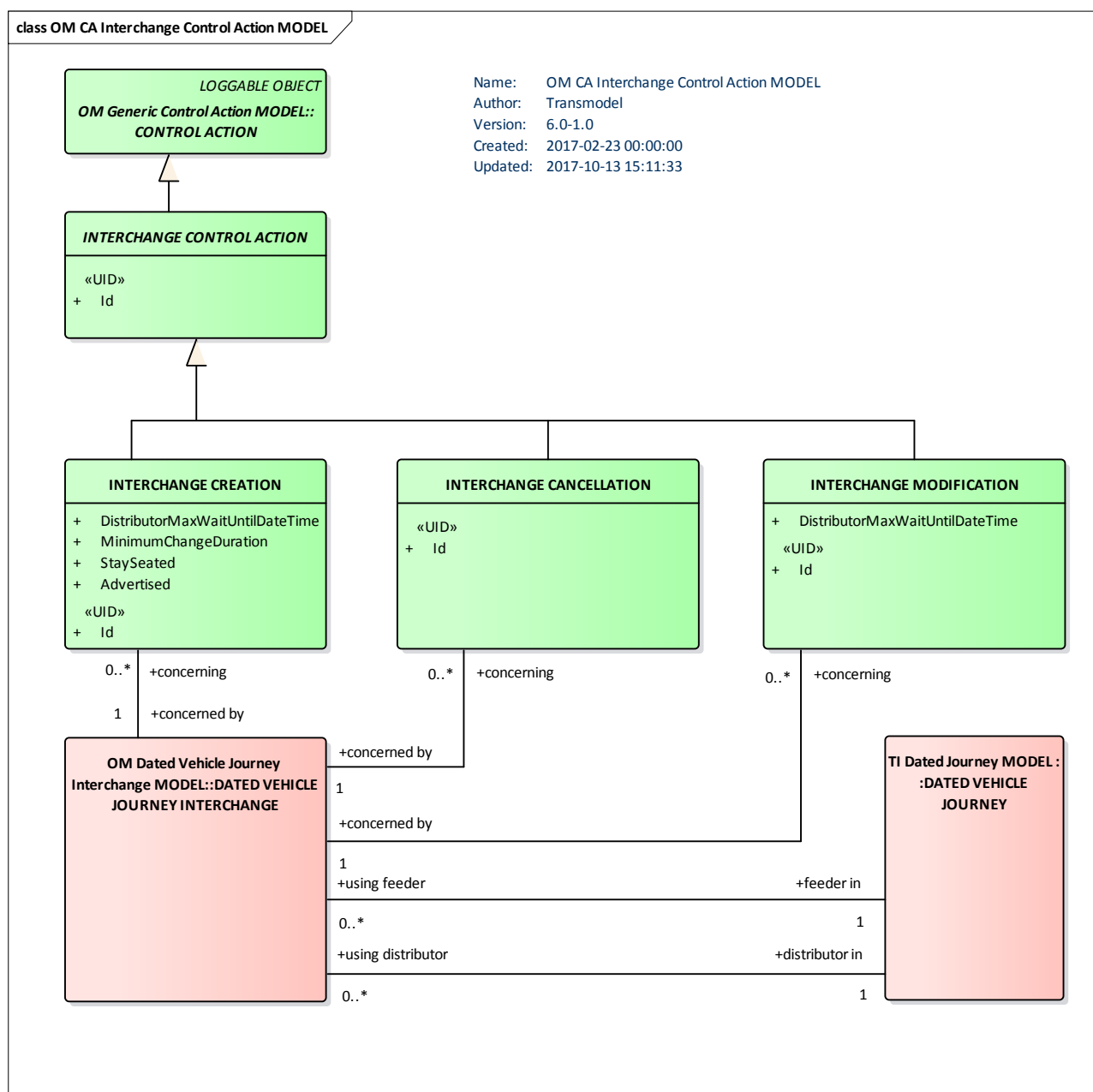


Figure 15 — Interchange Control Actions MODEL

5.6.5.2 Interchange Cancellation

An INTERCHANGE CANCELLATION action is a CONTROL ACTION consisting of deleting a DATED VEHICLE JOURNEY INTERCHANGE from the latest valid plan so that a distributor DATED VEHICLE JOURNEY no longer needs to wait for a feeder DATED VEHICLE JOURNEY.

5.6.5.3 Interchange Creation

An INTERCHANGE CREATION action is a CONTROL ACTION consisting of adding a completely new DATED VEHICLE JOURNEY INTERCHANGE between a feeder DATED VEHICLE JOURNEY and a distributor DATED VEHICLE JOURNEY to the latest valid plan.

5.6.5.4 Interchange Modification

An INTERCHANGE MODIFICATION action is a CONTROL ACTION expressing that the *DistributorWaitUntilDateTime* parameter for an existing DATED VEHICLE JOURNEY INTERCHANGE in the latest valid plan is modified so that the duration a distributor DATED VEHICLE JOURNEY needs to wait for a feeder DATED VEHICLE JOURNEY is changed.

5.7 Operational Events

Various types of events may affect the functioning of the public transport network: incidents, alarms, failures, etc. Many of them are recorded in the data system when they are of interest for the production follow-up, the management information, or the technical functioning follow-up.

The generic entity EVENT describes all events recorded in the data system. An EVENT is characterized by a “time” (timestamp). Whenever possible, this time would be the time of the event (from the functional point of view), more than the time of recording. The latter will be, however, the only accessible data in many cases. EVENTS are classified through a TYPE OF EVENT. This classification often distinguishes internal EVENTS, due to the functioning of the network, from external EVENTS, due to another cause.

An example of a general EVENT might be extreme weather conditions.

The OPERATIONAL EVENT is a specialization of EVENT affecting the public transport operation (production follow-up, management of information or the technical functioning), occurring on an OPERATING DAY. An EVENT generally results in the implementation of a CONTROL ACTION.

The main subtypes of OPERATIONAL EVENTS are ALARMS, INCIDENTs, FACILITY OPERATIONAL EVENTS and SITE OPERATIONAL EVENTS.

An ALARM may be the result of a vehicle detection failure or a system failure, for instance. It may also arise from the monitoring process: for instance, when a threshold is exceeded with regard to the latest valid plan; an advance or delay compared to the plan which is longer than a certain value; location detection out of the normal route, etc.

INCIDENTs are of various types, such as accident on the road, traffic jam, vehicle breakdown, incident caused by the behaviour of a passenger, illness of a driver, etc. An INCIDENT may be classified either as a VEHICLE INCIDENT, related to a LOGICAL VEHICLE, or as a DRIVER INCIDENT, related to a LOGICAL DRIVER

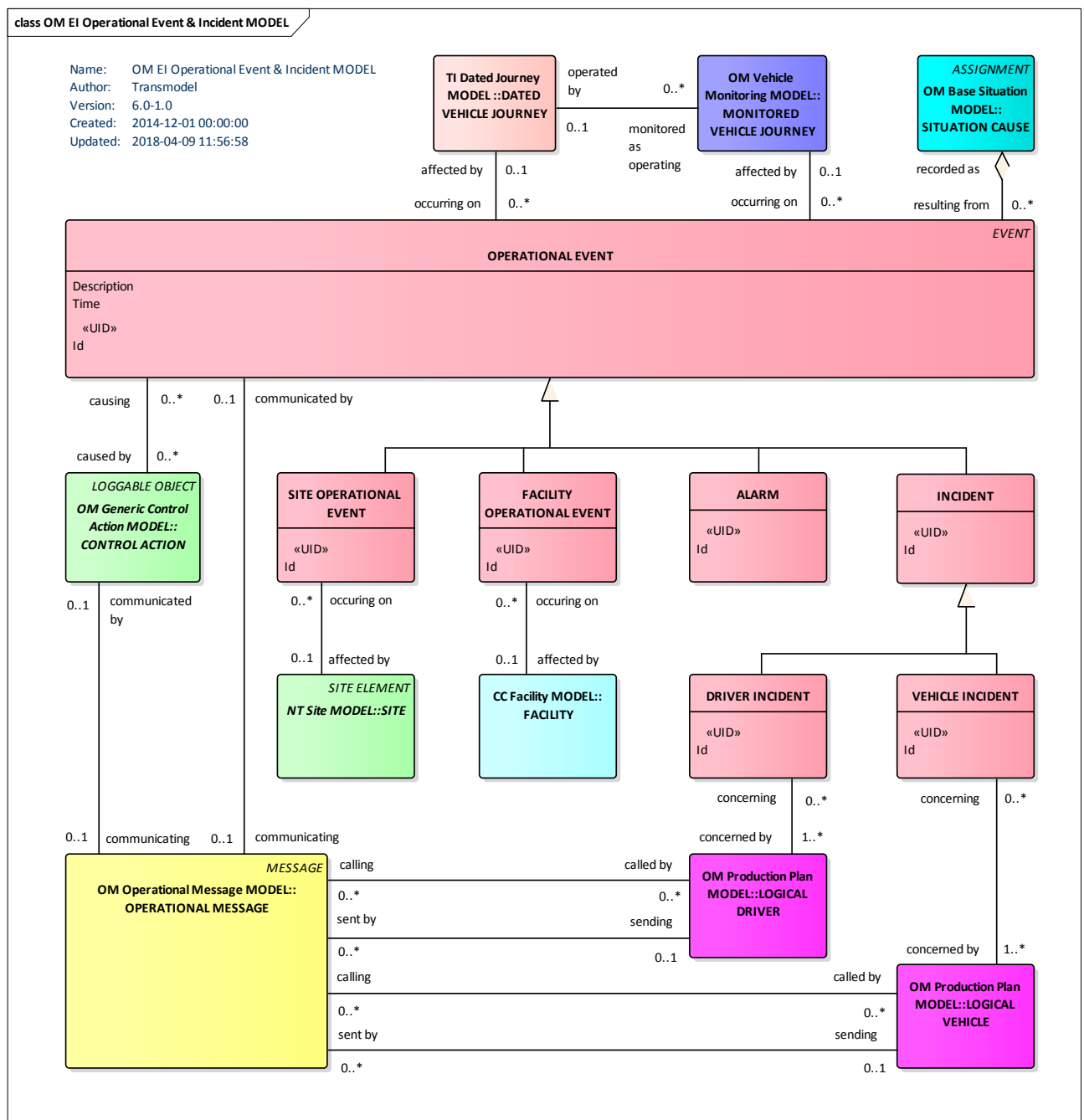


Figure 16 — Operational Event and Incident MODEL

A vehicle journey related OPERATIONAL EVENT is, whenever possible, referring to a DATED VEHICLE JOURNEY from the latest valid plan. If the planned journey is not identified, an OPERATIONAL EVENT may be related to a MONITORED VEHICLE JOURNEY.

One or several OPERATIONAL EVENTS may be recorded as being the cause of one or several CONTROL ACTIONS. This is often recorded for production follow-up, possibly with regard to the contract with the AUTHORITY (e.g. if service disturbances due to internal EVENTS are penalized).

An OPERATIONAL EVENT may be the subject of an OPERATIONAL MESSAGE.

5.8 Operational Messages

The exchange of information between actors involved in the real-time control process is often made up of messages (e.g. radio call). Such messages and their characteristics can be recorded in the control system. In most classical systems, only distress calls and automatic messages are recorded.

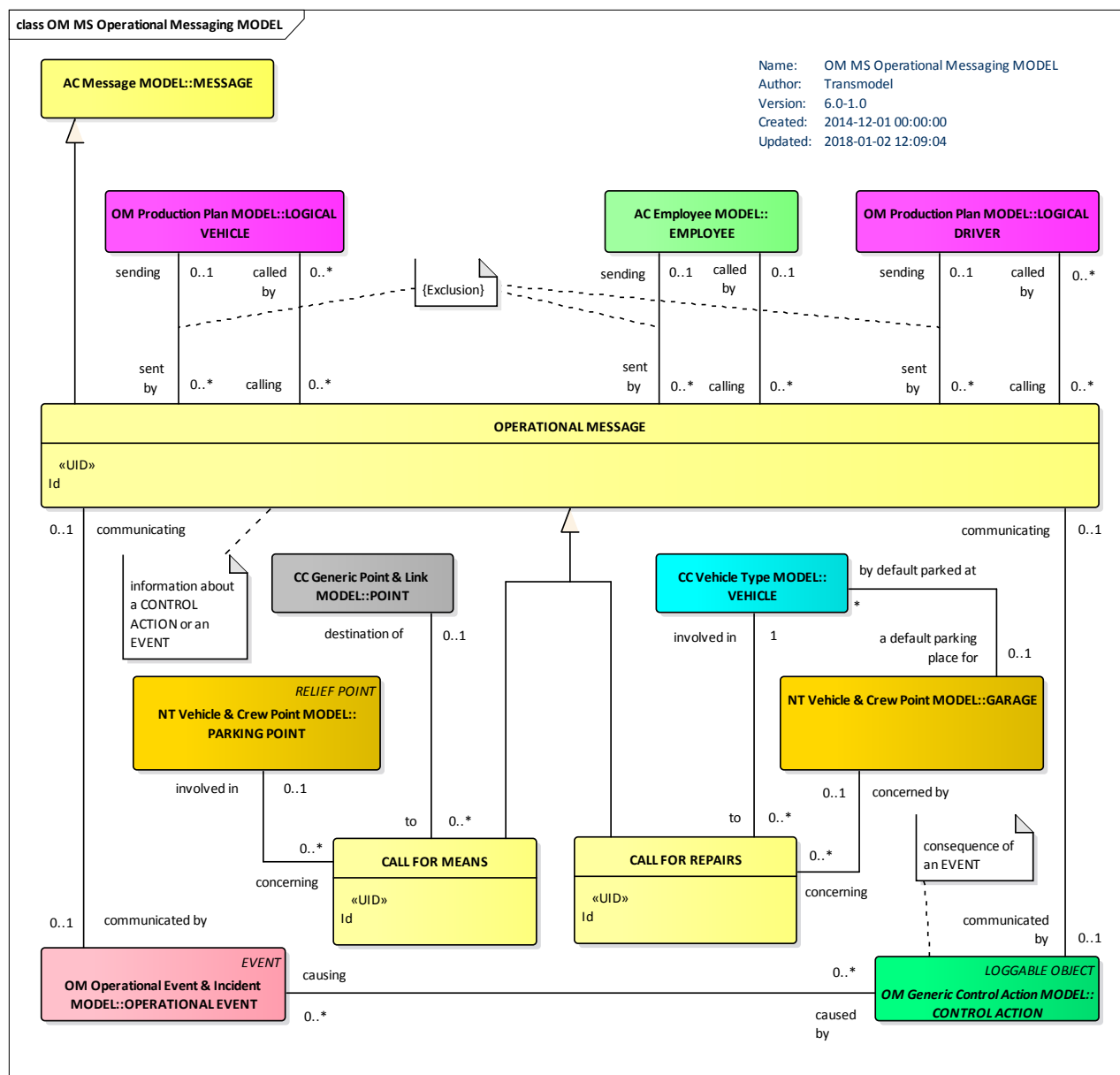


Figure 17 — Operational Messaging MODEL

The entity OPERATIONAL MESSAGE represents an exchange of information between two (or more) actors, about the functioning of operations. An OPERATIONAL MESSAGE may be sent, and received by:

- a LOGICAL DRIVER;
- a LOGICAL VEHICLE;
- an EMPLOYEE (e.g. the controller in charge of the line).