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# Geographic Information — Gap-analysis: mapping and describing the differences between the current GDF and ISO/TC 211 conceptual models to suggest ways to harmonize and resolve conflicting issues



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# Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 211, *Geographic information/Geomatics*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.



# Introduction

## 0.1 Background

From the start, GDF (Geographic Data Files) was based on similar geospatial concepts as ISO/TC 211 standards (the ISO 19100 family of standards). Over the years, GDF has been specified to provide data structures to support a range of transport-related applications and in-car navigation systems. GDF forms the basis of today's solutions used by TomTom, HERE and other navigational systems. The ISO 19100 family of standards created by ISO/TC211 remain the conceptual basis for general geospatial purposes. The basic concepts standards of the ISO 19100 family do not support any specific application domains but have been widely adopted by the geospatial industry; ISO/TC211 standards also underpin key European legislation such as the INSPIRE Directive.

With the emergence of increasingly connected and automated road vehicles, there is a need to share geospatial information between the vehicle’s navigational and contextual awareness systems and the mapping and road authorities (the road-side actors). The exchange of map-data between these actors requires extensive interpretations and transformation rules to make sure that the map-data in the on-board car navigation systems is aligned with that of the road-side actors, and that exchanges of data robustly support safety and efficiency applications in an unambiguous, coherent way.

GDF continues to be developed to adapt to the requirements of road vehicle automation, as well as wider domains of application, such as public transport, geospatial and navigation data. A lack of alignment between GDF key concepts and those of ISO/TC211 standards reduces the collective efficacy of the combined standards, increases the complexity of utilizing standards-conformant data in an efficient manner and increases the risk and threats arising from ineffective conversions. This is not efficient, and is mostly due to the lack of harmonization between the conceptual models of GDF and ISO/TC 211 standards.

Both models are in extensive use: GDF in the vehicle in-car navigation industry and the ISO 19100 family of standards in the geospatial industry and with public authorities worldwide. Thus, it is not a non-disruptive option for one group of actors to switch to the other base of standards – nor indeed are these standards directly functionally equivalent. Therefore, the work underpinning this document aims to identify the gaps between the two concepts and suggest ways to bridge them.

First, there is a need to perform a gap analysis, and then after that, suggest means to bridge the gap and finally decide how to create standards or application schemas to accommodate the harmonization that is necessary. The identification of opportunities to adjust concepts to align GDF and ISO/TC 211 concepts supports the need to achieve an improved interoperability of road and vehicle data systems, and geospatial datasets in wider usage.

Within this document, comparative analysis and recommendations are provided. At a broad level, the analysis and recommendations suggest modifications to GDF to make an ISO 19100 family-based application schema in order to:

— make GDF ready to accommodate automated vehicles with support from ISO/TC 211;

— enable map data exchange between all actors (car makers, map makers, mapping authorities and road owners);

— align with ISO/TC 211-based standards and related technology used by European institutions, directives, CEN and in European-wide platforms like TN-ITS and DATEX II, and international stakeholder groups such as TISA.

During the development of this document, various iterations of the GDF have been used and reviewed. The current published version of GDF, known as GDF v5.1, Part 1, has been published as ISO 20524-1, published 2020-03-30, and ISO 20524-2, published 2020-11-30. These documents revise the previously used ISO 14825:2011, known as GDF v5.0. ISO 14825:2011 has been withdrawn. The analysis within this document uses GDF v5.1 (ISO 20524-1 and ISO 20524-2) as a reference baseline.

## 0.2 Overview of recommendations

### 0.2.1 General

This subclause brings together the recommendations that have been made throughout the body of this document. Each recommendation is summarized; in each case the reader is advised to review the relevant referenced clause for the full explanation. Also, in each case, the primary actor expected to address the recommendation is listed.

### 0.2.2 Model structure

See subclauses 7.1 and 7.2.1.

A more specific modularization of GDF according to the structure of the ISO 19100 family of standards is recommended to simplify maintenance, revision and reuse of the concepts in the document. Specified relations between the GDF Overall Conceptual Data Model and concepts from the ISO 19100 family of standards is recommended to improve interoperability and reduce the need for specific GDF concepts.

It is recommended that the generic feature model and the feature catalogue model in the GDF GDM be divided into specific models for a Generic Feature Exchange Model and a Feature Catalogue Model. The models are recommended to be defined as application schemas according to ISO 19109 and prepared for model-driven implementation.

There is a need for further studies on how to define the belt concept and the location referencing of GDF features in general in terms of ISO/TC 211 standards.

There is a need to achieve a greater clarity of linear referencing of belts.

To be addressed by ISO/TC 204 and ISO/TC 211.

### 0.2.3 General Conceptual Models

See subclause 7.2.

It is recommended that the internal GDF stereotypes “Feature”, “Attribute” and “Relationship” be replaced with the ISO 19109 stereotype “FeatureType”.

The core classes Feature and Attribute are recommended to be used only in the Generic Feature Exchange Model, while a specific superclass for feature classes is recommended to be used in the Feature, Attribute and Relationship Catalogues. The core Relationship class can be removed from the GDF GDM.

The conceptual models for attribute types and attribute values are recommended to be defined as metamodels to achieve an improved structure with a specified level of abstraction for concepts in the GDF model. The metamodels ought to extend the ISO 19109 GFM in order to achieve improved interoperability with models in, or based on, the ISO 19100 family.

It is recommended that the definition of a Feature in GDF be modified to include real-world phenomena that are not physical. Furthermore, it is recommended that classes for logical placement be evaluated and possibly changed to location referencing classes.

The album and dataset model are recommended to be defined in an application schema according to rules in ISO 19109. The model ought to include the data organization structure and the generic feature exchange model. To be addressed by ISO/TC 204.

### 0.2.4 The GDF Catalogues

See Clause 8.

It is recommended that the GDF Feature, Attribute and Relationship Catalogues be modelled as application schemas according to rules in ISO 19109. The GDF Metadata Catalogue is recommended to be modelled as a part of the model for album and dataset, with reuse of elements defined in ISO 19115-1.



It is recommended that a core superclass to replace the use of the classes Feature, Attribute and Relationship in the Feature, Attribute and Relationship Catalogues be defined.

The listing of unique IDs in ISO 20524-1:2020, A.1, A.2 and A.3 ought to be a report from the UML model, in order to maintain consistency. To be addressed by ISO/TC 204.

### 0.2.5 Encoding rules

It is recommended that GML implementation schemas for GDF be derived from the GDF application schemas. In order to enable handling of requirements for attribute content in GML, it is recommended that ISO/TC 211 seek to revise or amend ISO 19109 and ISO 19136-1 to facilitate such requirements.

If the two existing implementation encodings (MRS and GDF-XML) are to be maintained, specified conversion rules ought to be defined in order to enable conversions from the UML model. To be addressed by ISO/TC 204 and ISO/TC 211.

### 0.2.6 Aligning terminology

Annex A illustrates a continued difference between the definition of defined terms found in the GDF standards (ISO 20524-1 and ISO 20524-2) or ISO/TC 204 and definitions found in the ISO 19100 family of standards from ISO/TC 211. It is recommended that ISO/TC 211 lead activities to seek improved harmonization of defined terms and their definitions across the TCs. To be addressed by ISO/TC 204 and ISO/TC 211.

### 0.2.7 Aligning GDF time domain syntax with other ISO standards

It is recommended that a detailed analysis of the syntax characteristics supported by GDF and a comparison to the characteristics offered by the ISO 8601 series and ISO 19108 be undertaken in advance of preparation of future revisions of GDF (ISO 20524 series), with the aim of adopting ISO 8601 series and ISO 19108 conformant syntax mechanisms. To be addressed by ISO/TC 204 and ISO/TC 211.

### 0.2.8 Adding epoch value to dynamic coordinate reference system in GDF

Concern has been raised that GDF needs to differentiate between the use of 'static' and 'dynamic' coordinate reference systems, and add the epoch value in referencing to 'dynamic' CRS. To be addressed by ISO/TC 204.

# Geographic Information — Gap-analysis: mapping and describing the differences between the current GDF and ISO/TC 211 conceptual models to suggest ways to harmonize and resolve conflicting issues

## 1 Scope

This document maps and describes the differences between GDF (ISO 20524 series), from ISO/TC 204, and conceptual models from the ISO 19100 family, from ISO/TC 211, and suggests ways to harmonize and resolve issues of conflict.

Throughout this document, reference to GDF refers to GDF v5.1, ISO 20524-1 and ISO 20524-2, unless expressly identified otherwise. Where necessary, reference will be made to Part 1 or Part 2.

## 2 Normative references

There are no normative references in this document.

## 3 Terms and definitions

No terms and definitions are listed in this document.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

NOTE Geospatial terms occurring in ISO/TC 211 standards can also be found in https://isotc211.geolexica.org/[21].

## 4 Symbols and abbreviated terms

The following abbreviated terms apply:

ADAS advanced driver assistance systems

CRS coordinate reference system

GDF GDM geographic data files general data model

GDF geographic data files

GFM general feature model

GIS geographic information system

GML geography markup language

HD high definition

ITS intelligent transport systems

| | |
|---|---|
| MC&G | mapping, charting and geodesy |
| MDA | model driven architecture |
| MRS | media record structure |
| OEM(s) | original equipment manufacturer(s) |
| OWL | web ontology language |
| POI | point of interest |
| UML | unified modelling language |
| DIGEST | digital geographic information exchange standard |

## 5 Comparing terms and definitions

Throughout the later clauses of this document there is discussion concerning a comparison and recommendations for improved alignment of the defined terms and their definitions used in GDF and the ISO 19100 family.

In addition, Annex A provides a revised and updated version of a comparison of terms and definitions found in GDF and the ISO 19100 family presented in a tabular form. The basis for the content of Annex A is drawn from ISO 19132:2007, Annex E. This content has been updated to both reflect current terms and definitions found in the latest available editions of GDF and standards within the ISO 19100 family. Where the recommendations made in this document would result in modification of these defined terms and definitions, these are highlighted.



## 6 Business considerations

Geospatial datasets have hugely widescale application across every sector of commerce, industry and society. As such, the underpinning and interoperability provided by conformance to the geospatial standards defined by ISO/TC 204 and ISO/TC 211 in conjunction with OGC, the Open Geospatial Consortium, provide key tools for interoperability. These standards are widely adopted within the Intelligent Transport Systems (ITS) domains and within Geographic Information Systems (GIS) and geographic-enabled software and systems across many domains respectively.

Geospatial datasets relating to road networks are used for a very wide range of purposes, for example, navigation, asset management, network management, incident response, road design, drainage, acoustic propagation, land use planning and access planning, to name a few. Importantly, like other transport networks, road networks significantly interface and interact with other non-highway features, such as end-point destinations, POI gazetteers, footways, rights of way, soft estate, rail and water networks, points of access, public transport interfaces, etc. Coherence of the standards underpinning all of these geospatial data sets is important for interoperability and cross-domain interactions, analysis and applications and services.

Within road networks, and the domain of ITS, detailed geospatial information that represents road networks and the surrounding road environment is a critical component for route planning and navigation. Advanced Driver Assistance Systems (ADAS) and systems for automated driving depend on accurate and updated geospatial information from a variety of sources for the complete knowledge needed for legal and safe navigation. Modern road vehicles are increasingly equipped with sensor technologies. The outputs from these on-board sensors, and other sensors at the roadside, can be used to generate and create local contextual geospatial knowledge, and can share this information with map providers, Original Equipment Manufacturers (OEMs) and other road users. This sensor-derived data can be very transitory and dynamic in nature, or can indicate detection of permanent change. However, the local knowledge is neither sufficient for route planning nor for local navigation under challenging conditions, such as fog or snow-covered roads, or where road maintenance activities such as road closures are present; it needs to be combined with geospatial information from pre-processed databases covering larger areas.

Commercial map providers and OEMs create and deliver ITS databases and services for the users of ITS applications for route planning, navigation and other services. These products and services are being extended to support ADAS and automated driving with higher integrity map data, so-called High Definition (HD) maps. Map providers and OEMs need reliable and harmonized mechanisms that can provide them with information from authorities and other sources for further sharing with the road users, and for simulation and testing. Sharing information from authorities can improve the data quality of ITS databases for route planning and navigation and thereby improve public safety, reduce the risk of damage to infrastructure, improve strategic use of the road network and improve the quality of mobility services. To enable the flow of information, models that describe the real world and specifications for information exchange are needed; the harmonization and consistency of these models and specifications, ought to reduce translation losses and errors, and improve opportunities for service developments to reach the widest audiences possible.

# 7 Reference model

## 7.1 General structure

### 7.1.1 Analysis

A standardized methodology for information modelling is a core foundation for a digital representation of real-world features and events. The ISO 19100 family from ISO/TC 211, as well as GDF from ISO/TC 204, are based on the approach described in ISO 19103 and illustrated in Figure 1: a portion of the real world, referred to as the universe of discourse, is perceived in a specific context (e.g. geographic application in general, or navigation specifically) and defined in a conceptual model. The conceptual model is formally described and represented in a conceptual schema. The conceptual schema is described by use of a conceptual schema language. For this purpose, both GDF and the ISO 19100 family apply the Unified Modelling Language (UML)[10].



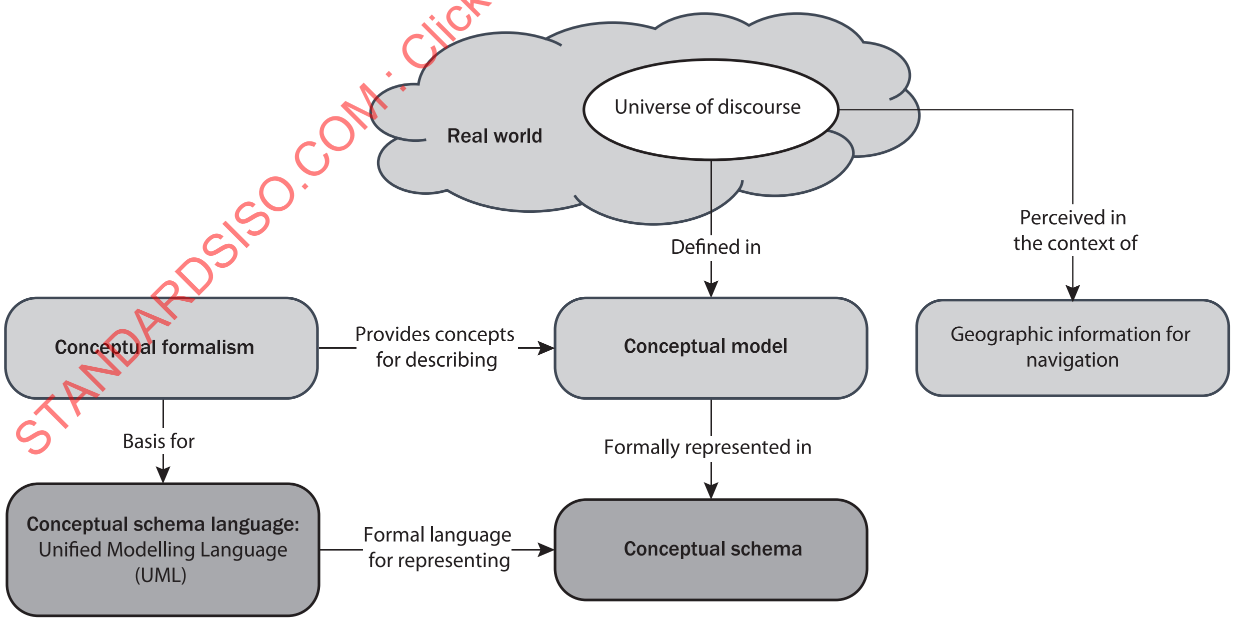



**Figure 1 — Information modelling (adapted from ISO 19103)**

The standards in the ISO 19100 family are based on the concepts of a Model-Driven Architecture (MDA) [11] and a specific use of UML defined in the UML profile in ISO 19103 and the General Feature Model (GFM) defined in ISO 19109. The founding principle in MDA is that models (represented in schemas) are defined for different levels of abstraction. Furthermore, the conceptual schemas are independent of specific implementation technologies. This brings benefits of being able to create multiple technology-dependent implementations from common abstract models.

ISO 19103 defines four levels of abstraction for the use of MDA for geographic information, as illustrated in Figure 2.

Within Figure 2:

— The top level contains the metamodels that define how information models is to be specified, e.g. the UML Metamodel.

— The second level contains abstract schemas with basic concepts for representing e.g. geometry, time and coordinate reference systems.

— The third level describes application schemas for specific applications such as 3D City Models or road networks. The application schemas reuse concepts from the abstract schemas.

— Finally, the fourth level contains implementation schemas for specific implementation technologies. Specific rules for conversion from UML to individual implementation technologies (such as XML, GML, JSON, etc.) are applied to derive implementation schemas from the application schemas.

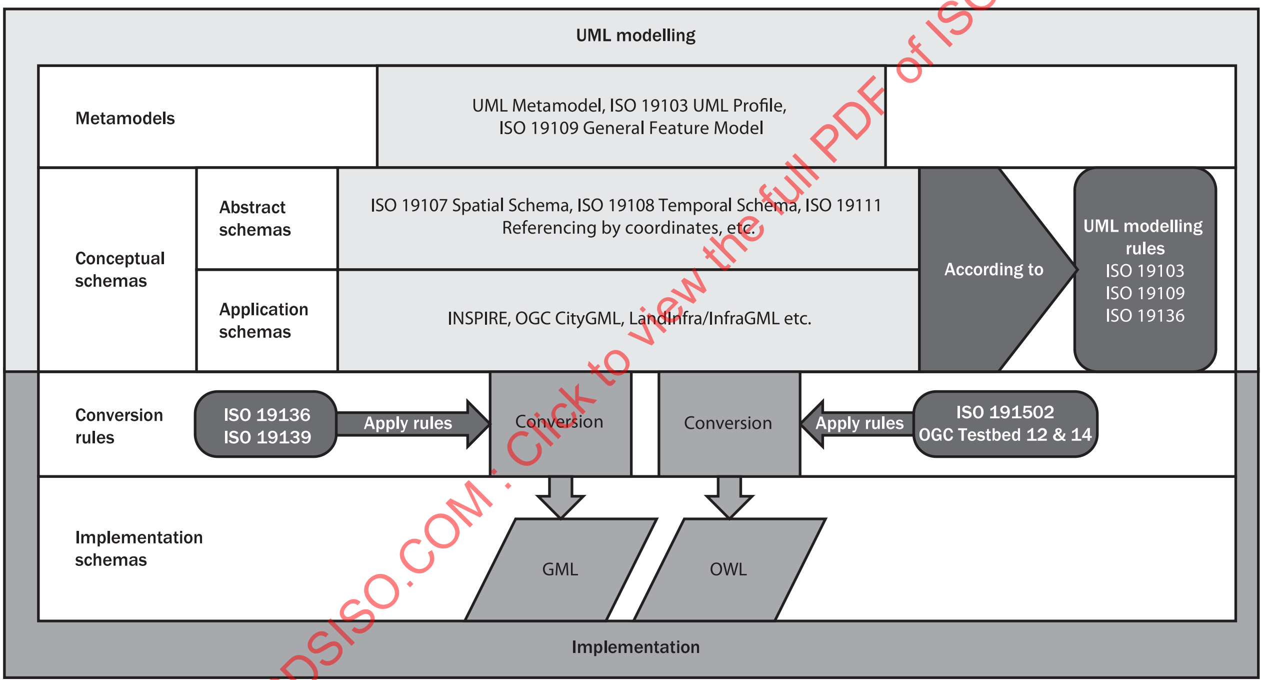



**Figure 2 — Model Driven Architecture (MDA) as defined in ISO 19103 (adapted from Reference [12])**



The scope of ISO/TC 211 has mainly been to develop conceptual schemas in the two top levels of abstraction as defined in ISO 19103. The core standards ISO 19103 and 19109 define metamodels and modelling rules at the top level, while the majority of standards in the ISO 19100 family are defined as abstract conceptual schemas. Application specific schemas for geospatial purposes are, in general, not developed by ISO/TC 211, but rather by national or regional authorities, agencies or organizations.

Information modelling based on MDA has been applied for standards in the ITS domain as well, e.g. in the ISO 21219 TPEG2 series for traffic and travel information services and the European public transport standards such as CEN 12896 Transmodel and the CEN 16157 DATEX II series for traffic information exchange. These standards are based on modelling and conversion rules that are similar but not identical to rules in the ISO 19100 family.

The GDF standard (both the withdrawn ISO 14825:2011 [GDF v5] and the current revisions of GDF, ISO 20524-1 and ISO 20524-2 [GDF v5.1]) contains a complete specification of concepts from several levels of abstraction according to the structure in Figure 2, ranging from a metamodel to implementation schemas. The GDF standard does not have a clear separation of the different levels of abstraction. In order to perform a comparison between concepts defined in GDF and the ISO 19100 family, a mapping from the structure of GDF to the MDA structure in ISO 19103 is suggested in Figure 3. Further details are discussed in subsequent clauses of this document.

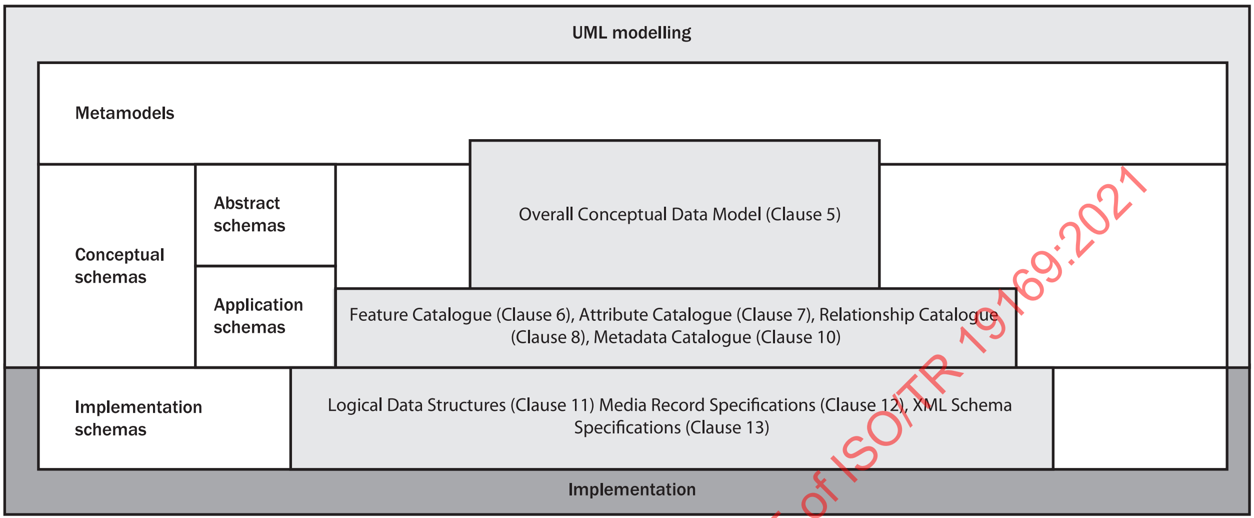



**Figure 3 — Suggested mapping of GDF clauses to ISO 19103 MDA structure**

Explanation of Figure 3:

— Clause 5 in GDF defines the Overall Conceptual Data Model which forms the fundamentals for the catalogues that are defined in GDF Clauses 6, 7, 8 and 10. The Overall Conceptual Data Model is partly a metamodel that defines specific UML concepts, and partly an abstract conceptual schema for reuse in the catalogues.

— The Feature model in GDF subclause 5.2 is implemented as a generic model for feature exchange and can be considered an application schema.

— The Structure model in GDF subclause 5.8 can also be considered an application schema, implemented in GDF Clause 11.

— The GDF catalogues in GDF Clauses 6, 7, 8 and 10 are directly comparable to the application schema level.

— The implementation specifications described in Clauses 11, 12, and 13 can be defined as implementation schemas in the MDA levels of abstraction. Clause 11 realizes the structure defined in GDF subclause 5.8 and describes the logical structure independent of file or database format. Clauses 12 and 13 describe implementation in specific technologies.

— Clause 9 in GDF describes feature representation rules which can be considered more a cartographic issue that is independent of the modelling structure.

### 7.1.2 Consideration of options

The MDA approach has clear advantages for interoperability, reuse and revision of schemas and has been successful for the development of interoperable standards in the GIS domain. This is also true for several domain application areas within the ITS domain, as described in subclause 7.1.1 of this document. The metamodels and the abstract conceptual schemas from the ISO 19100 family are reused in application schemas world-wide, defined by national and regional authorities, agencies and organizations representing a wide range of geospatial information. Implementation schemas for database and exchange formats are derived from the application schemas, and large amounts of structured geospatial information is maintained according to the application schemas[13].



Furthermore, the core concepts from the ISO 19100 family have been implemented in the majority of GIS software. This enables the exchange of information according to the ISO 19100 family between stakeholders and software. Developers of application schemas can select to reuse specific parts and versions of abstract schemas, and schemas in separate standards can be revised individually. As different application schemas are founded on the same abstract concepts, conversions between different application schemas are possible. Examples of such conversions are mapping from national application schemas in European states to the common INSPIRE application schemas for the European Union.

The GDF standard reuses some concepts from the metamodels and abstract schemas defined in the ISO 19100 family of standards. Additionally, some specific concepts are defined in the Overall Conceptual Data Model in GDF. The previous structure of GDF with the whole range of concepts defined in one standard has the advantage that implementers need to consider only one standard, in isolation, based on current editions. However, a module-based approach would be preferred to simplify maintenance of individual parts of the standard suite. Furthermore, the lack of precise reuse of concepts from the ISO 19100 family is a challenge for interoperability, exchange and reuse of information between the GIS and ITS domains.

Finally, implementation schemas for GDF are not derived directly from application schemas but have been created manually. This approach is time-consuming, error prone and can lead to differences between conceptual schemas and implementation schemas.

### 7.1.3 Recommendation and expected impact

A more specific modularization of GDF according to the structure of the ISO 19100 family of standards is recommended to simplify maintenance, revision and reuse of the concepts in the standard. A modularization can be performed within the main GDF standards, or through Parts or a series of standards as in the ISO 19100 family and the various Parts of the ISO 21219 series. The latter is a preferable solution for maintenance and revision. Furthermore, specified relations between the GDF Overall Conceptual Data Model and concepts from the ISO 19100 family is recommended to improve interoperability and reduce the need for specific GDF concepts. Finally, implementation schemas can be derived from application schemas, following conversion rules as defined in the ISO 19100 family.

Note As mentioned in subclause 7.1.1 of this document, the MDA approach and the derivation of implementation schema direct from application schema successfully underpins a number of series of standards in the ITS domain. The conversion rules adopted for this purpose do differ between each series of standards. For the purpose of alignment of GDF with the ISO 19100 family, use of the conversion rules defined in ISO 19100 family standards is recommended (ISO 19118, ISO 19136 series, ISO/TS 19139-1). Specific conversion rules for other implementation technologies as defined in GDF Clauses 11, 12 and 13 can need some modifications to be applied in an MDA-based derivation of implementation schemas. It is recommended to define conversion rules following the MDA approach according to requirements in ISO 19118.

A prototype model that can be a foundation for a modularized GDF, based on ISO 19100 family standards, is suggested in Reference [14] and illustrated in Figure 4. The model is based on the General Feature Model from ISO 19109 and the Feature Catalogue model from ISO 19110. Three main application schemas are suggested in Reference [14]: the Feature Catalogue, the Feature Catalogue Exchange Model and the Feature Exchange Model. Further details are to be found in Reference [14]. Figure 5 presents the proposed configuration of the suggested model in an MDA structure.

Compared to the existing GDF standard, the Overall Conceptual Model in Figure 5 corresponds to the basic concepts in Clause 5 of GDF (ISO 20524-1). The Feature, Attribute, Relationship and Metadata Catalogue Application Schemas correspond to the existing Clauses 6, 7 and 8 of GDF. The Catalogue Exchange Model and the Feature Exchange Model are Application Schemas based on the Overall Conceptual Model and correspond to parts of Clause 5 of GDF.



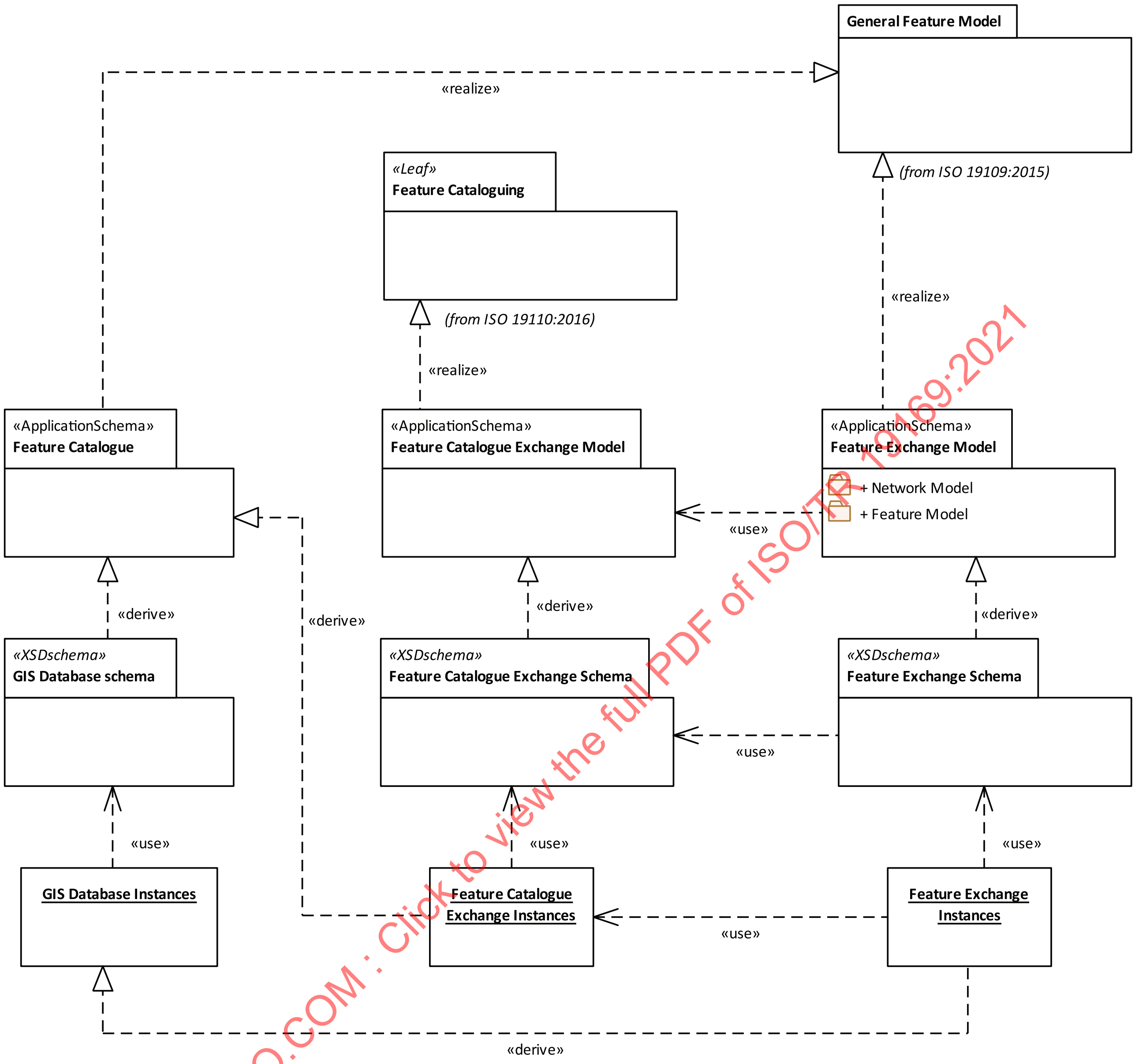



**Figure 4 — Suggested modularization of GDF (adapted from Reference [14])**

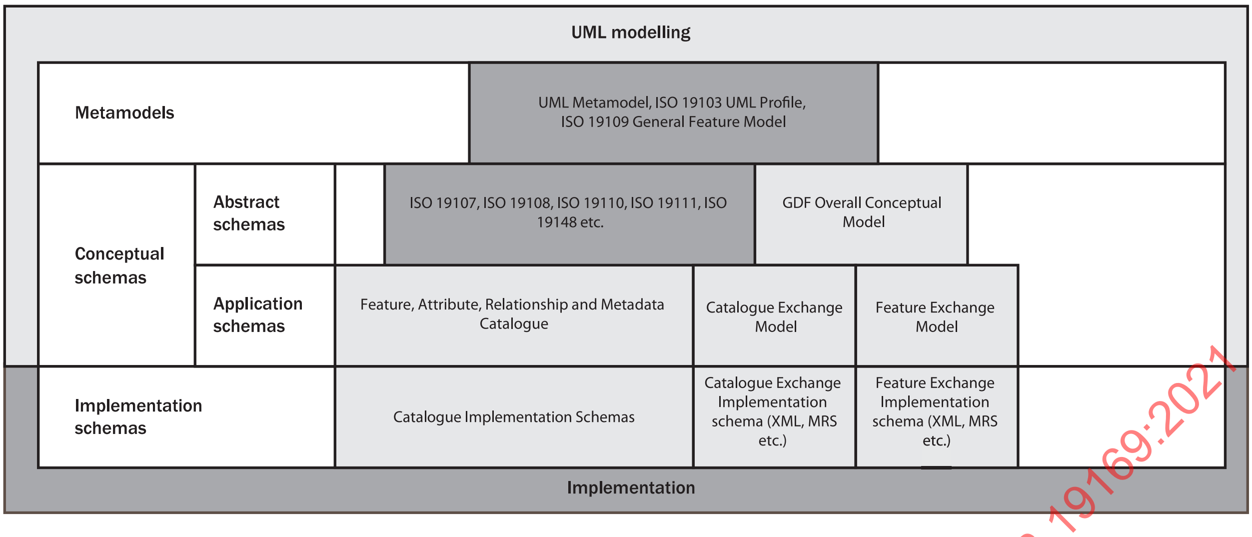



**Figure 5 — Suggested modularization of GDF in an MDA structure**



## 7.2 General Conceptual Models

### 7.2.1 General feature models

#### 7.2.1.1 Analysis

ISO 19109 describes a General Feature Model (GFM) for geographic information. The model is defined as a metamodel according to the MDA structure in ISO 19103 (see Figure 2) and specifies the use of UML concepts for development of application schemas of geographic information. The ISO 19109 GFM is shown in Figure 6.

The core concepts of the ISO 19109 GFM are the metaclasses for FeatureType, PropertyType with specializations AttributeType, Operation and FeatureAssociationRole, and FeatureAssociationType. The metaclasses are instantiated in conceptual models through core UML concepts:

— FeatureType is instantiated as UML Classes.

— AttributeType is instantiated as attributes of UML Classes.

— Operation is instantiated as operations on UML Classes.

— FeatureAssociationRole is instantiated in UML Classes through the roles on the connecting ends of associations to other UML Classes.

— FeatureAssociationType is instantiated as associations between UML Classes, and can be further refined to compositions or aggregations. FeatureAssociations can also be instantiated as UML Association Classes with attributes.

The use of the core ISO 19109 GFM concepts in other models are further discussed in subsequent clauses.

NOTE 1 An Association Class is a complex UML concept that is subtyped from both the Association and Class concepts in the UML Metamodel. Association Classes have rarely been used in models in, or based on, the ISO 19100 family. Classes (feature types) associated with other classes through FeatureAssociationRoles have been used for this purpose.

NOTE 2 FeatureAssociationType was a subtype of FeatureType in the first edition of ISO 19109 (2005). The subtyping was removed in the current edition (2015), as it was not used in models and could lead to unexpected abnormalities such as abstract associations and associations with associations. FeatureType classes with FeatureAssociationRoles are recommended for representing a phenomenon with associations to another phenomenon.

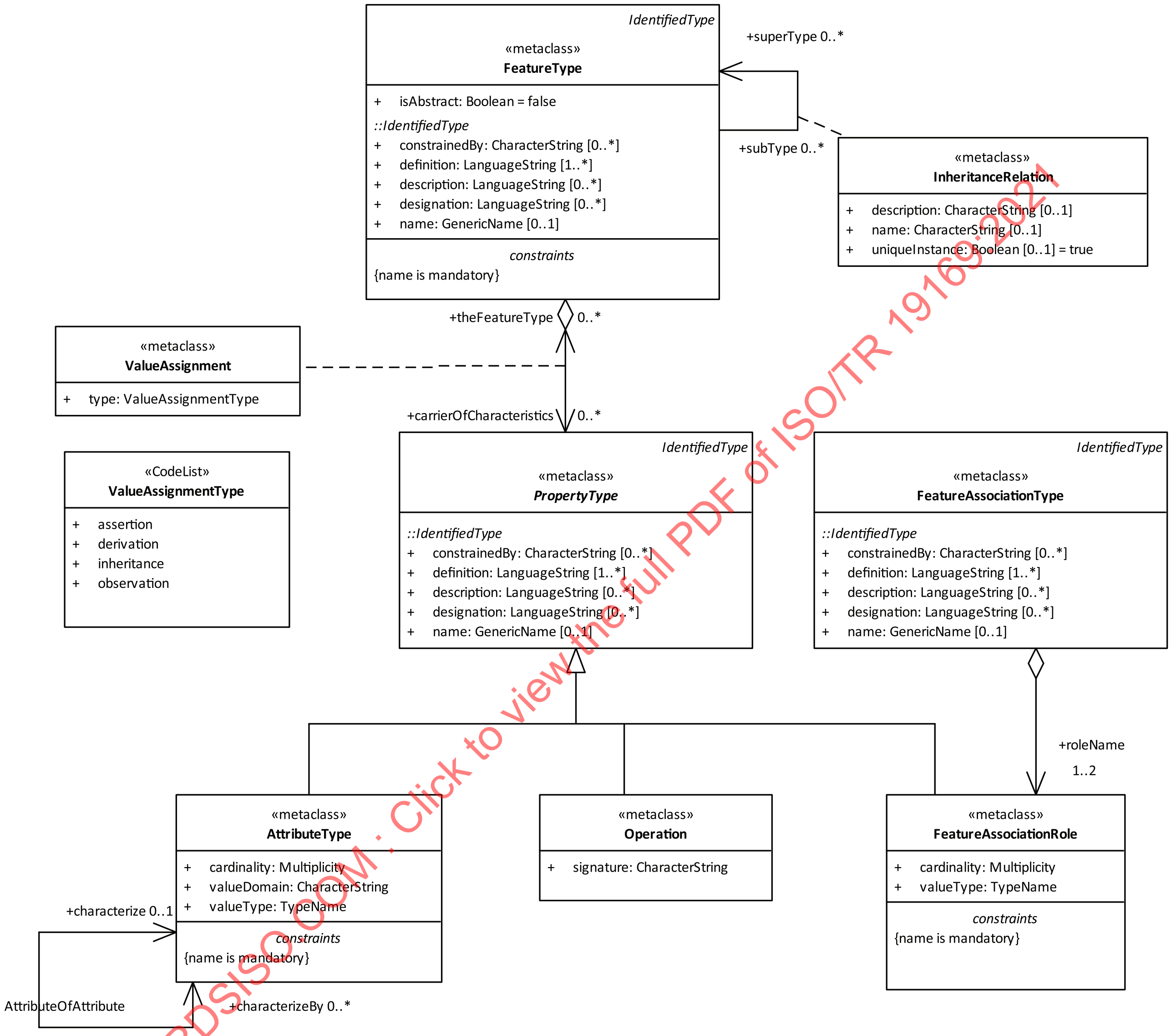





**Figure 6 — The General Feature Model (GFM) from ISO 19109**

ISO 19110 describes a conceptual model for Feature Catalogues, defined as a realization of the GFM. The feature catalogue model defines the core concepts for catalogues of feature types, property types and feature association types from the ISO 19109 GFM, as illustrated in Figure 7.

— The class FC_FeatureType is a realization of the ISO 19109 GFM metaclass FeatureType.

— The classes FC_PropertyType, FC_FeatureAttribute, FC_FeatureOperation and FC_AssociationRole are realizations of the ISO 19109 GFM metaclasses PropertyType, AttributeType, Operation, and AssociationRole respectively.

— The class FC_FeatureAssociation is a realization of the GFM metaclass FeatureAssociationType.

NOTE 3 The class FC_FeatureAssociation is subtyped from FC_FeatureType, like in the GFM in the first edition of ISO 19109 (2005). It is not clear why this subtyping is still present in the revised version of ISO 19110, but it makes it possible to describe associations between two FeatureTypes in the feature catalogue as an Association Class with attributes.

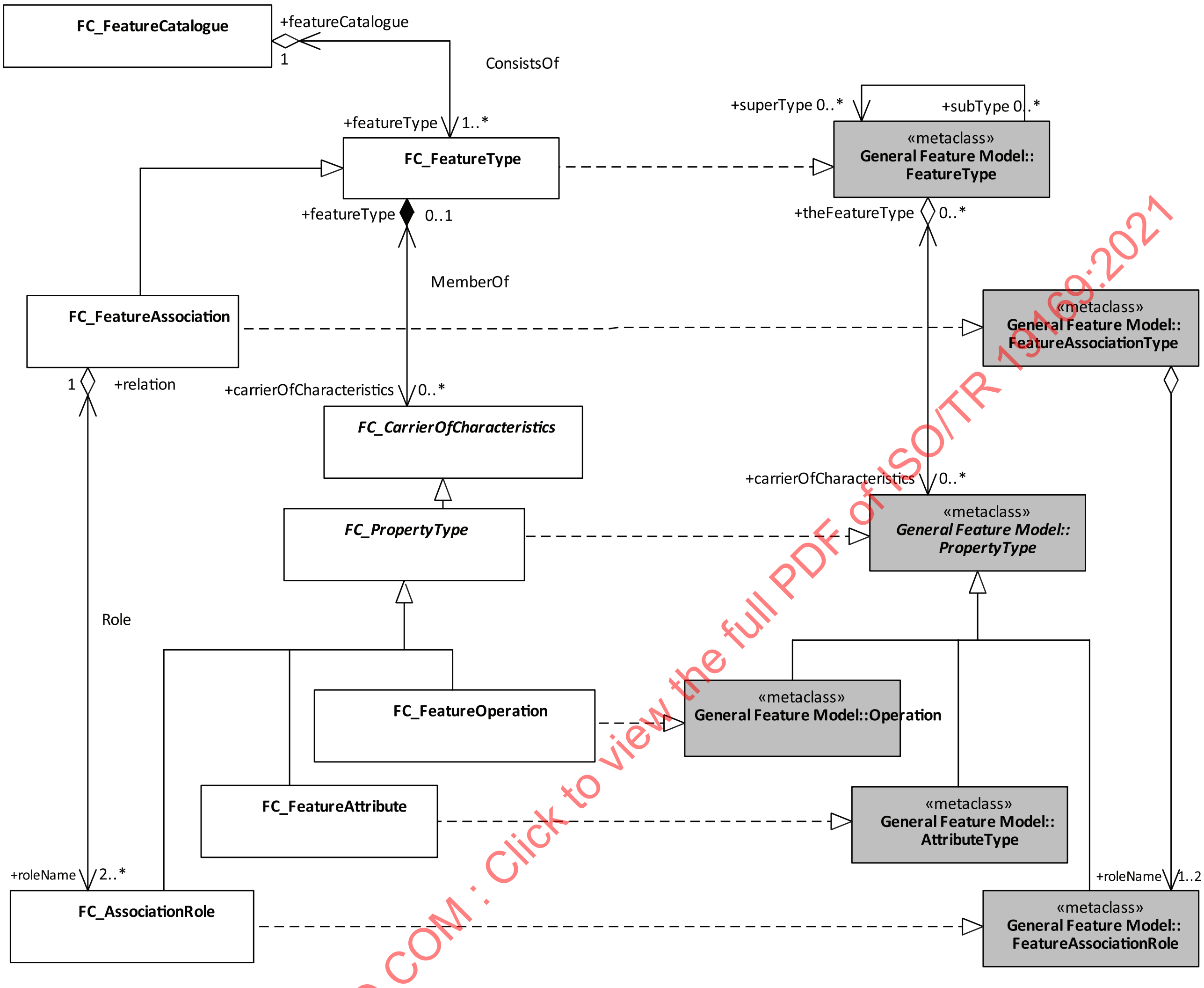



**Figure 7 — Conceptual model of a feature catalogue with realization from the ISO 19109 GFM, from ISO 19110**



The core model of GDF (ISO 20524-1) is the General Data Model (GDM), defined in Clause 5 of GDF and illustrated in Figure 8 (from ISO 20524-1:2020, Figure 8). The GDF GDM serves several purposes in the standard:

— It is defined in GDF subclause 5.1 (ISO 20524-1) to be a metamodel, though the concepts are not modelled as metaclasses. The core concepts for Features, Attributes and Relationships are modelled as regular UML classes and reused as supertypes in the Feature, Attribute and Relationship Catalogues respectively.

— It defines the generic model of a feature catalogue with FeatureClasses, FeatureThemes and FeatureCategories. The feature catalogue model is implemented as tables in Annex A of GDF (ISO 20524-1).

— It is used in the implementation specifications for GDF, with classification of feature types based on geometry and topology type. All features, relationships and attributes are instantiated as generic types with relations to identifiers in the catalogues. This implementation is an essential feature in GDF that reduces data set redundancy in a data file.

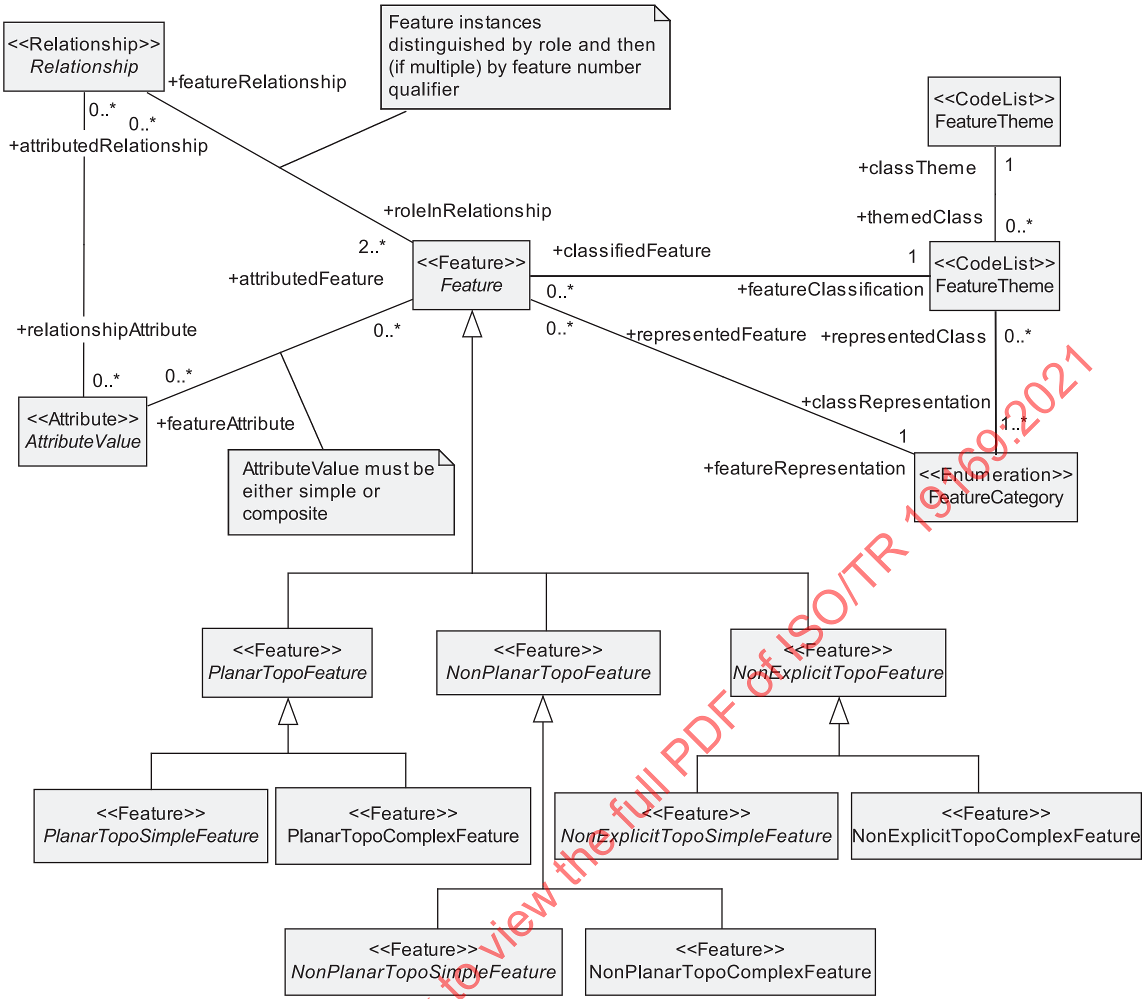



**Figure 8 — The General Data Model of GDF**

The GDF GDM also includes the concept of complex features as implementable subtypes of Feature. A complex feature consists of other features as feature parts, as shown for planar topology features in Figure 9.

Finally, GDF part 2 describes a specific type of area features, named a belt. A belt is a feature with a defined set of surrounding lines: side lines that represent the sides (e.g. road markings or road edges) and terminal lines that represent the ends. The belt feature has at least one direction that represents an orientation of the feature as a property. A belt feature is discriminated from an area feature by having the property of directions enabling ITS applications to represent properly a specific area with directional phenomena, e.g. specifying the direction of traffic flow. Figure 10 shows examples of belt features applied in the field of ITS application.

Note An area feature specified in ISO 19107 can be degenerated to a simpler representation but this is not specified (e.g. could be degenerated to a point or a line). The belt feature of ISO 20524-2 does have a specified mechanism of degeneration (i.e. a line).

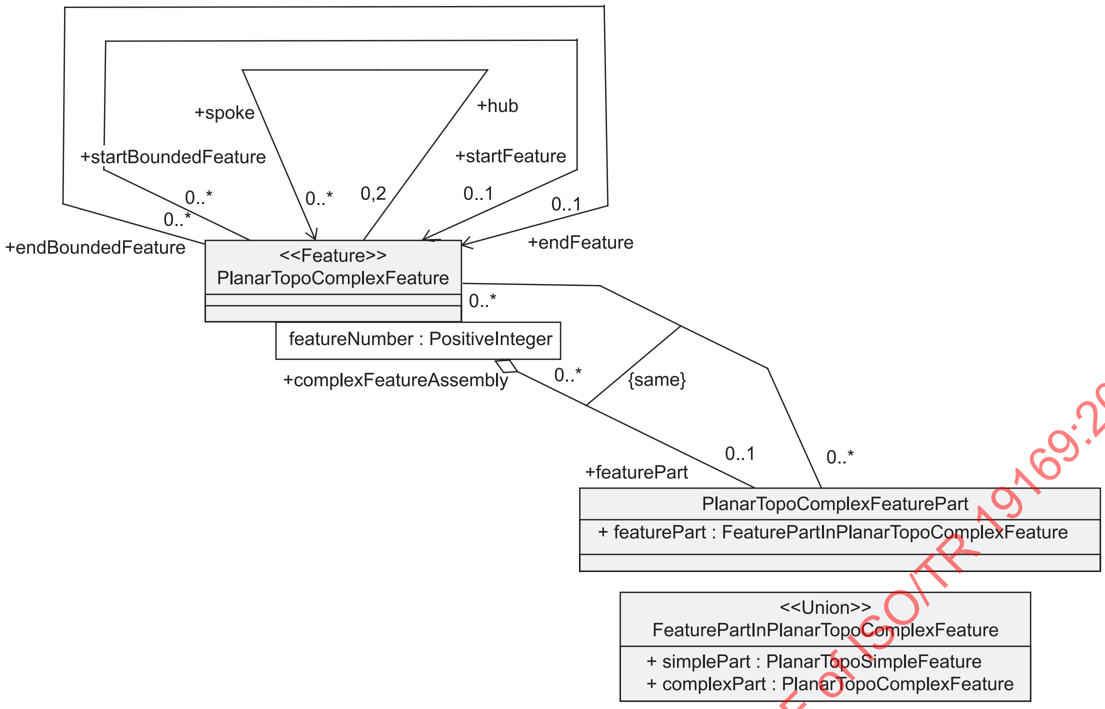
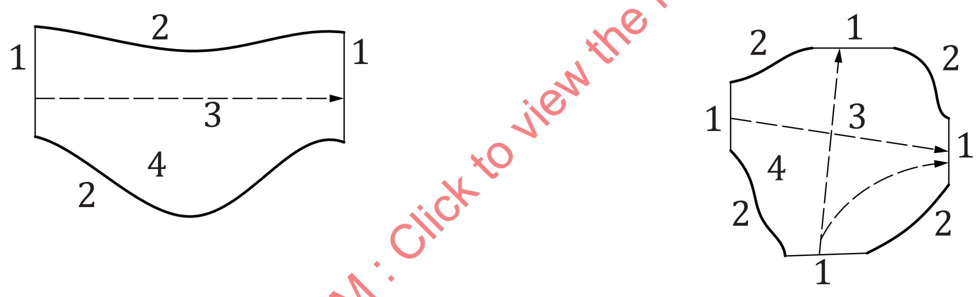



**Figure 9 — The conceptual model of Planar Topology Complex Features (from ISO 20524-1)**




**a) Road** **b) Intersection**

**Key**

1 terminal line
2 side line
3 direction
4 belt

**Figure 10 — Example of Belt structure (from ISO 20524-2)**



### 7.2.1.2 Consideration of options

The GDF GDM mixes several levels of abstraction from the MDA approach defined in ISO 19103. Besides being a metamodel, it is an abstract conceptual model and an application schema for a generic feature model and a feature catalogue. The mixed purpose ought to be avoided in order to create models and concepts with a clear purpose.

Furthermore, the relations to core concepts from standards in the ISO 19100 family are not specified, specifically concepts for location referencing through geometry or linear referencing. The concepts of complex features and belt features are not defined in ISO/TC 211 standards and need to be defined for use in ISO 19109-conformant application schemas.

### 7.2.1.3 Recommendation and expected impact

An improved structure of GDF with closer relations to the ISO 19100 family of standards is recommended. It is recommended that the GDF GDM be split into several parts, according to the scope and level of abstraction it is meant to serve. The structure described in Reference [14] and illustrated in Figure 4 and Figure 5 can be a basis for further development.

— Metaclasses are recommended to be specified in a separate metamodel based on the ISO 19109 GFM. Whether a specific metamodel for GDF is needed will be discussed in subsequent clauses.

— It is recommended that the generic feature model and the feature catalogue model in the GDF GDM be divided into specific models for a Generic Feature Exchange Model and a Feature Catalogue Model. The models are recommended to be defined as application schemas according to ISO 19109 and prepared for model-driven implementation. A further development of the prototype suggested in Reference [14] as presented in Figure 11 can be a basis for the improved models.

The improved structure would make the different core parts of the GDF standard more explicit, and the standard would become interoperable with the ISO 19100 family of standards.

The model presented in Figure 11 is centred around the class "Feature", like in the GDF GDM. Just as a GDF GDM Feature can have attributes, a Feature in Figure 11 can have properties. A Feature can also be complex and have feature parts through a self-association. However, the model does support not the function of the complex feature, which implies so-called "map generalization". In addition, the model does not yet cover the concept of belts. There needs to be further studies to define how to use ISO 19100 family concepts to model complex features, belts and a greater clarity of linear referencing of belts.

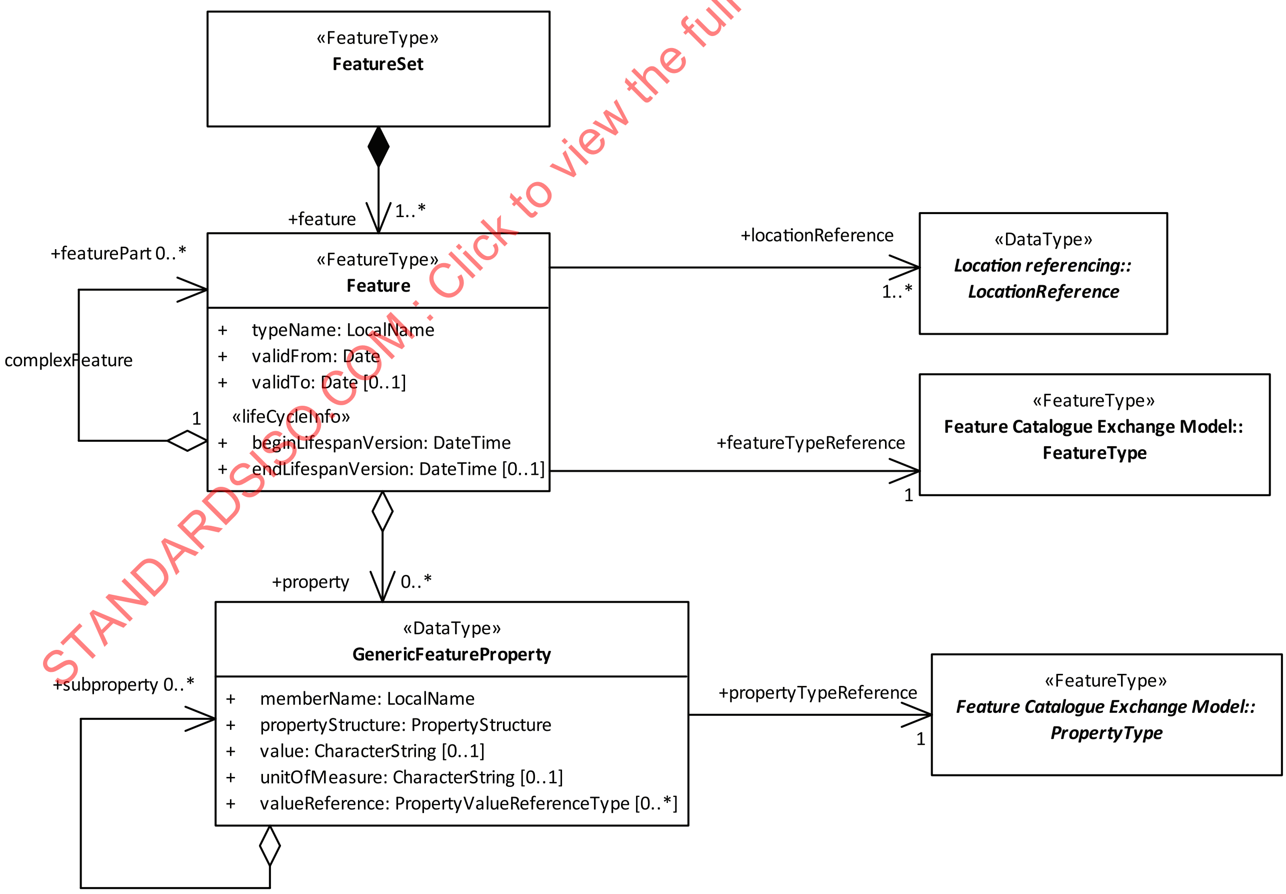



**Figure 11 — Suggested Generic Feature Exchange Model (adapted from Reference [14])**

### 7.2.2 Feature models

#### 7.2.2.1 Analysis

ISO 19101-1 defines features as abstraction of real-world phenomena, and ISO 19109 requires that features be modelled as instances of the ISO 19109 GFM Metaclass FeatureType. This requirement is implemented in UML models by modelling features as UML Classes with stereotype “FeatureType” as illustrated in Figure 12.

The term phenomena in the definition from ISO 19101-1 includes both physical objects such as railings and more abstract objects such as a manoeuvre.

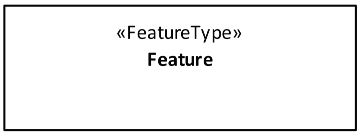



**Figure 12 — Generic feature type class according to ISO 19109**

GDF defines a feature as a database representation of a real-world object. The term “object” can be interpreted in various ways but is more related to physical objects than the term phenomena from ISO 19101-1. Abstract objects such as manoeuvre are modelled in GDF using the Relationship concept.

Features in GDF are modelled as subtypes of the core abstract class Feature with stereotype “Feature” in two parts of the standard:

1) The GDF GDM (Figure 8) defines abstract subtypes of Feature for different types of graph topologies, and implementable subclasses underneath these for point, line and area features. The GDF GDM is the generic model that is used in implementation specifications. The associations between Feature and other concepts in the GDF GDM (attribute values, relationships, feature classes and feature categories) are the basis for linking features in implementations to attribute values and relationships on one side and to feature classes on the other side. Figure 13 shows the conceptual model of implementable subtypes of the abstract class PlanarTopoSimpleFeature. As illustrated in Figure 8, the class PlanarTopoSimpleFeature is a subtype of PlanarTopoFeature which is a subclass of Feature.

2) The GDF Feature Catalogue defines feature themes and feature classes. The core class Feature is subtyped into abstract classes for feature themes. These feature theme classes are further specialized into feature classes for specific abstractions of real-world objects. Each feature theme class can have attributes that are common for all feature classes within the theme. Figure 14 shows feature classes for the road furniture feature theme. The Feature Catalogue is implemented as tables in Annex A of GDF and referred to with identifiers in the implementation schemas. The associations in the GDF GDM are not implemented in the Feature Catalogue, only the inherited ID attribute from the core class Feature is implemented. The ID attribute is not shown in Figure 14.

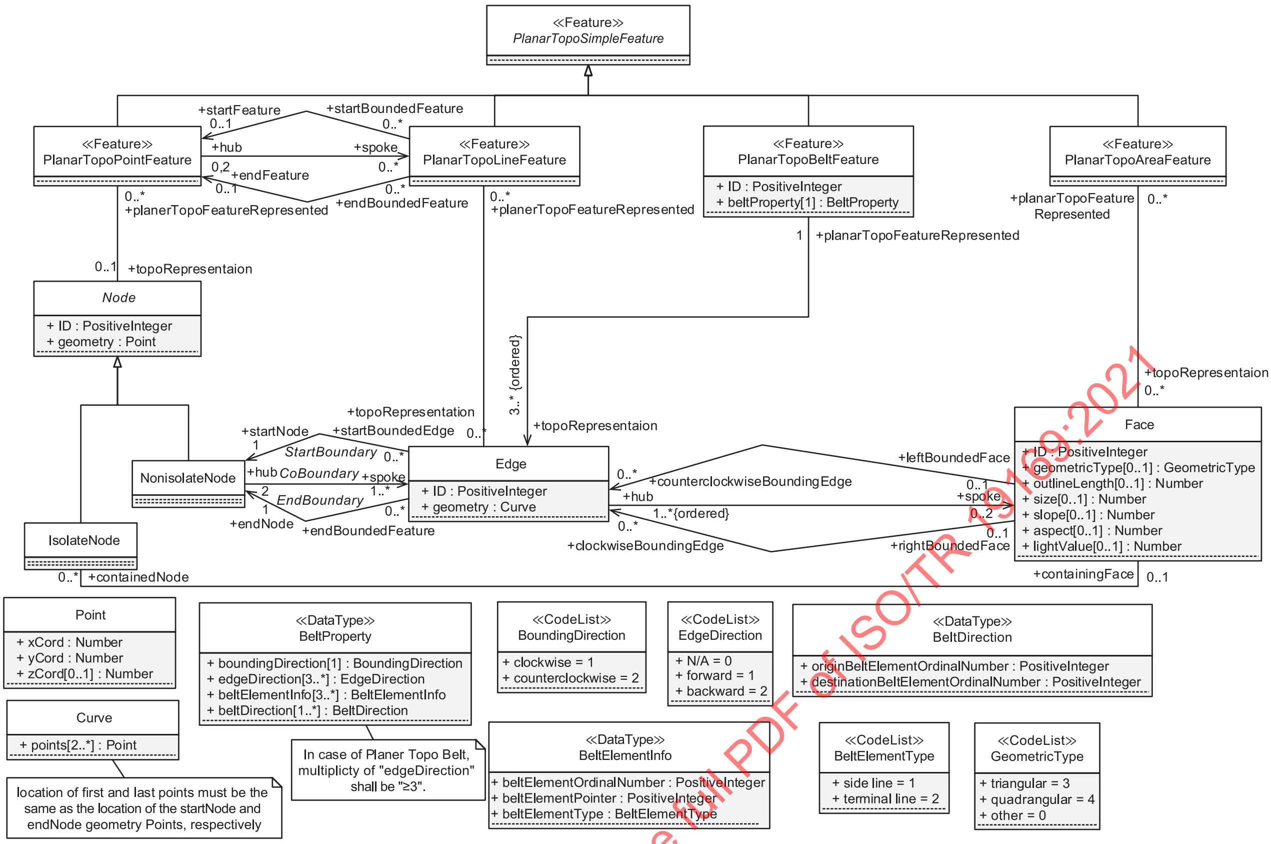



**Figure 13 — The GDF conceptual data model of Planar Topological Simple Features**

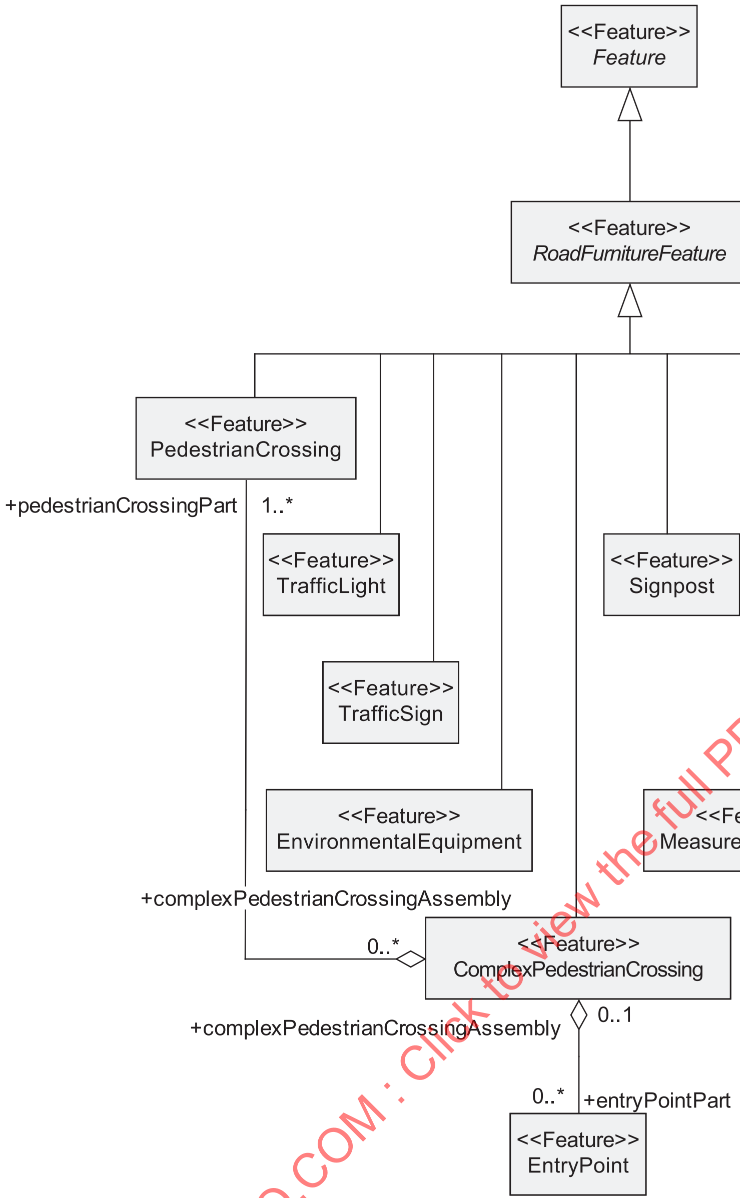



**Figure 14 — The GDF Conceptual Data Model for Feature Classes in the Feature Theme Road Furniture**



#### 7.2.2.2 Consideration of options

The use of the stereotype “Feature” in GDF is identical to the use of classes with the stereotype “FeatureType” as specified in ISO 19109. In order to improve interoperability, it is recommended that only one of the stereotypes be used in both GDF and standards in, or based on, the ISO 19100 family. The ISO 19109 stereotype “FeatureType” has been implemented in a wide range of specifications in, or based on, the ISO 19100 family. It is a fundamental concept for MDA according to ISO 19103, ISO 19109 and ISO 19136-1. Some examples of implementations are the European INSPIRE Specifications and OGC specifications such as LandInfra/InfraGML and CityGML, which are widely used world-wide.

The core abstract class Feature in GDF can be considered as a generic realization of the GFM Metaclass FeatureType, as illustrated in Figure 12. However, the use of the class as a core concept for two different model branches with different purposes have some implications. The core class represents a generic feature for exchange in the GDF GDM, while it represents a core Feature Class in the GDF Feature Catalogue. All characteristics from the core class are inherited for all implementable classes, including associations from the GDF GDM.

#### 7.2.2.3 Recommendation and expected impact

As the use of the stereotype "Feature" in GDF is identical to the use of the stereotype "FeatureType" as described in ISO 19109, there does not seem to be any need for a specific Feature metaclass and stereotype in GDF. It is therefore recommended that the internal GDF "Feature" stereotype be replaced with the ISO 19109 stereotype "FeatureType".

Furthermore, in order to describe concepts with a clear purpose, the different model branches ought to have specifically scoped top classes. The core class Feature ought only to be used in the Generic Feature Exchange Model, while a specific superclass for feature classes ought to be used in the Feature Catalogue.

### 7.2.3 Attribute models

#### 7.2.3.1 Analysis

ISO 19109 describes the concepts AttributeType and FeatureAssociationRole in the ISO 19109 GFM. The AttributeType concept is to be modelled as an attribute of a UML class or as an UML association from the representing class to a class representing the value domain of the AttributeType. The AttributeType metaclass is further subtyped into different thematic types of attributes, as shown in Figure 15. Specific rules are defined for some of the subtypes of AttributeType, but the specific metaclasses are not used for practical modelling purposes.

The UML Profile in ISO 19103 defines metaclasses for modelling the value domain of attribute types. The value domain of an attribute can be one of (see Figure 16):

— a data type (implemented from the UML metaclass DataType). A data type can be simple or composite. An instance of a data type has no identity and cannot exist on its own;

— an enumeration with a fixed list of values (implemented from the UML metaclass Enumeration, which is a subtype of DataType);

— a code list with an extendable list of values (implemented from the ISO 19103 metaclass CodeList, subtyped from the UML metaclass DataType);

— a union of possible data types (implemented from the ISO 19103 metaclass CodeList, subtyped from the UML metaclass Classifier); or

— a class (implemented from the ISO 19109 metaclass FeatureType, subtyped from the UML metaclass Class).

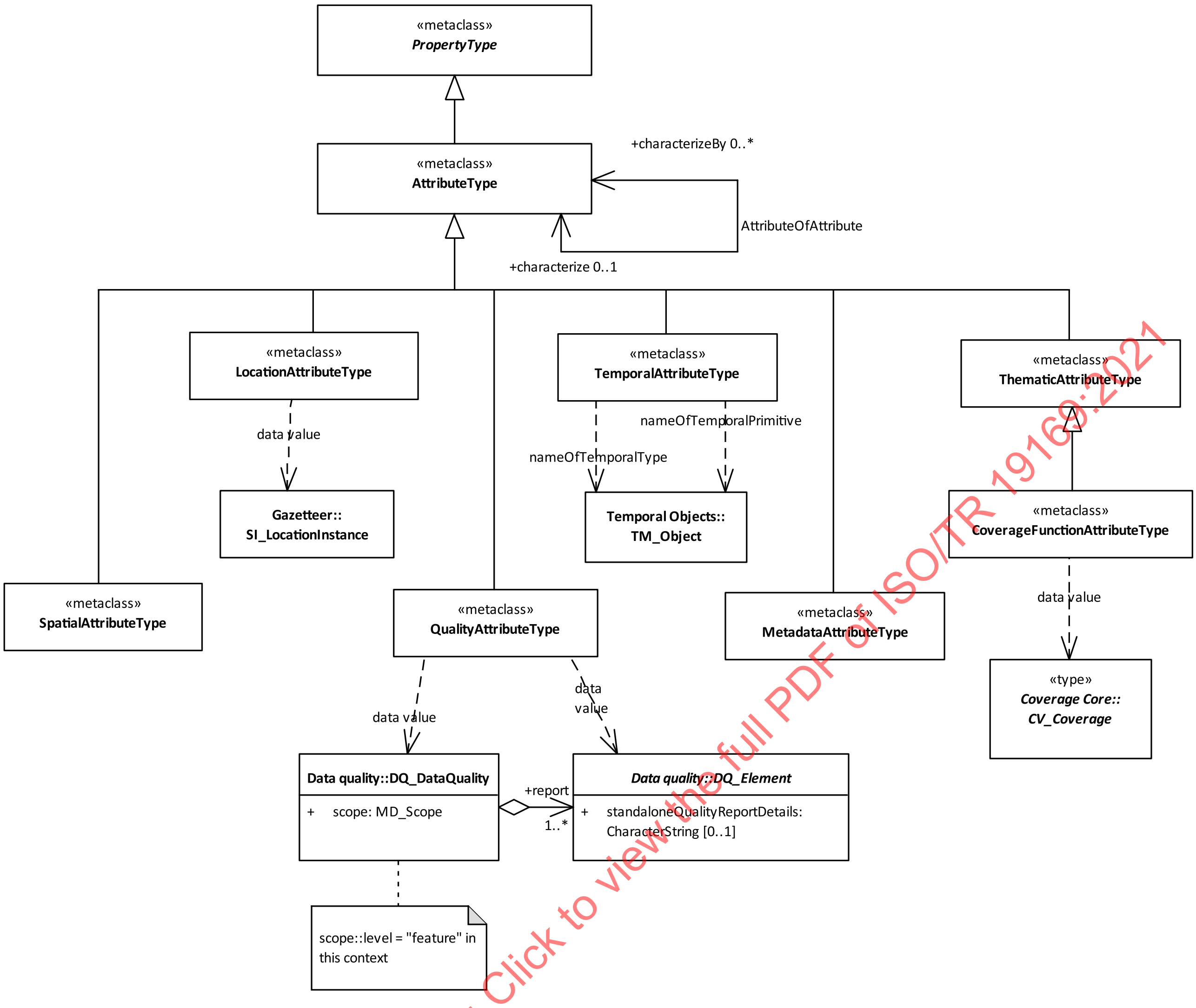



Figure 15 — Attributes of Feature Types (from ISO 19109)

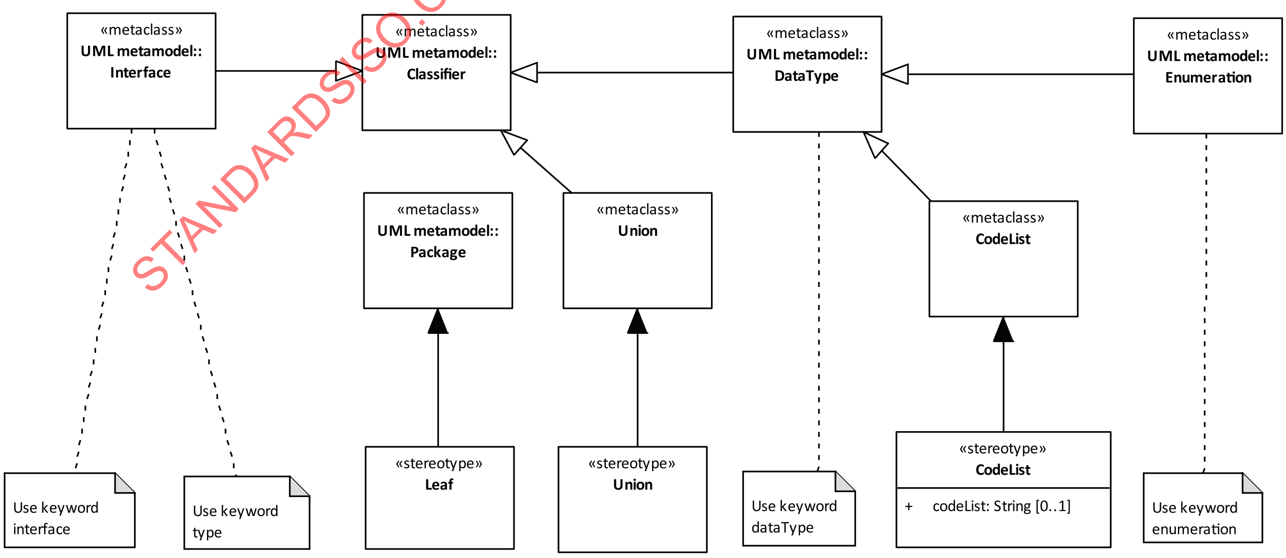



Figure 16 — The ISO 19103 Formal UML Profile

GDF defines the stereotype “Attribute” for composite attributes in addition to the possible value domain types defined in ISO 19103. The stereotype “Attribute” is used for attributes where a single instance can be identified and applied to several features. This approach reduces the need for duplication of information in a data set, as identical attribute values can be assigned to several features instead of being duplicated. Attribute types in the GDF Attribute Catalogue are defined with one of the stereotypes “Attribute”, “DataType”, “Enumeration”, “CodeList” or “Union”.

Furthermore, GDF specifies conceptual models for attribute types and attribute values. The conceptual model for attribute types (Figure 17) lays the foundation for how attribute types are to be modelled in the GDF Attribute Catalogue. The conceptual model of attribute types is modelled as a hierarchy of attribute type classes and is a classification in the same manner as in ISO 19109 (Figure 15) but following a different classification approach. The conceptual model for attribute values (Figure 18) is the basis for assigning attribute values to features according to the GDF GDM.

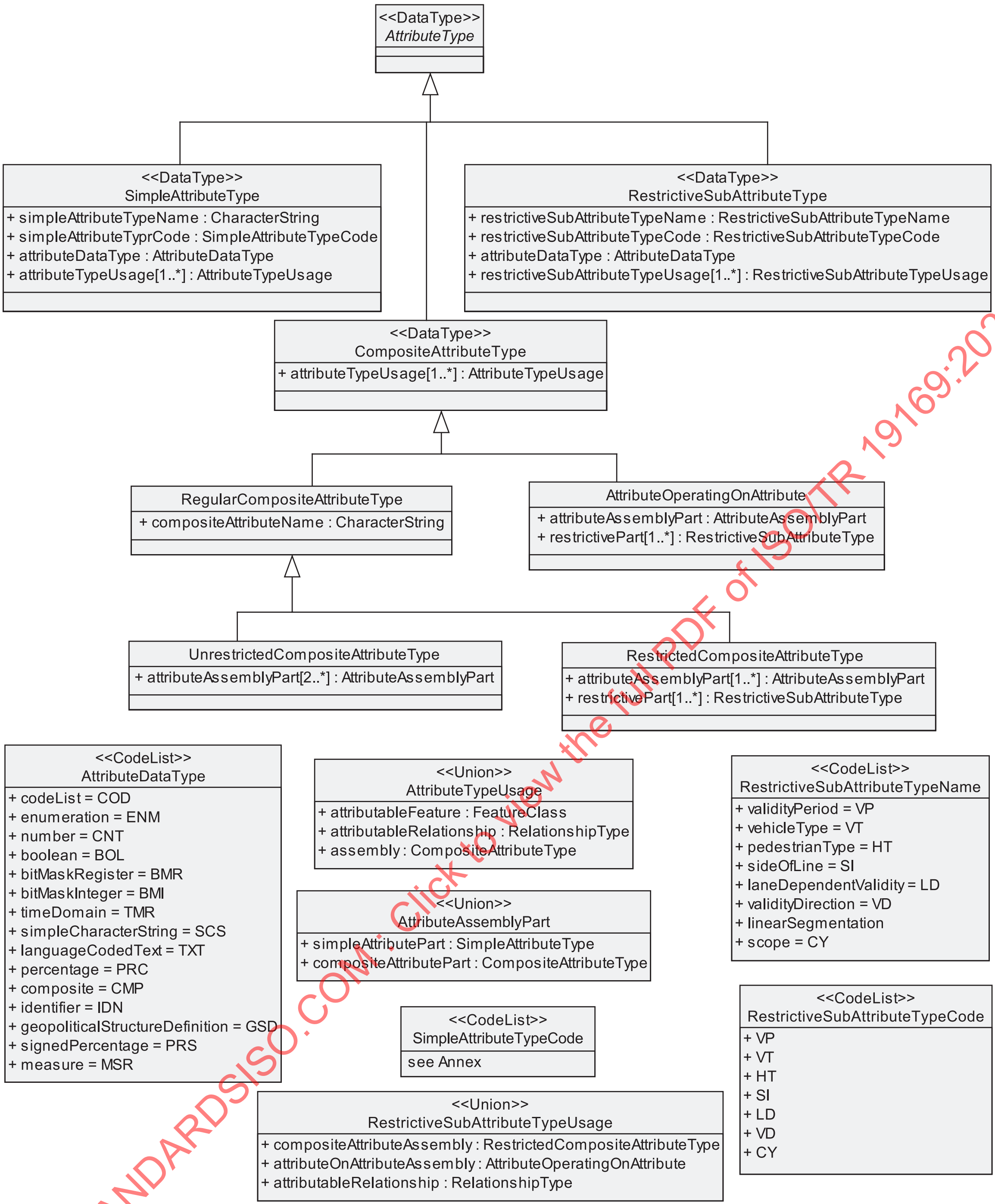





**Figure 17 — The GDF conceptual data model for Attribute Types**

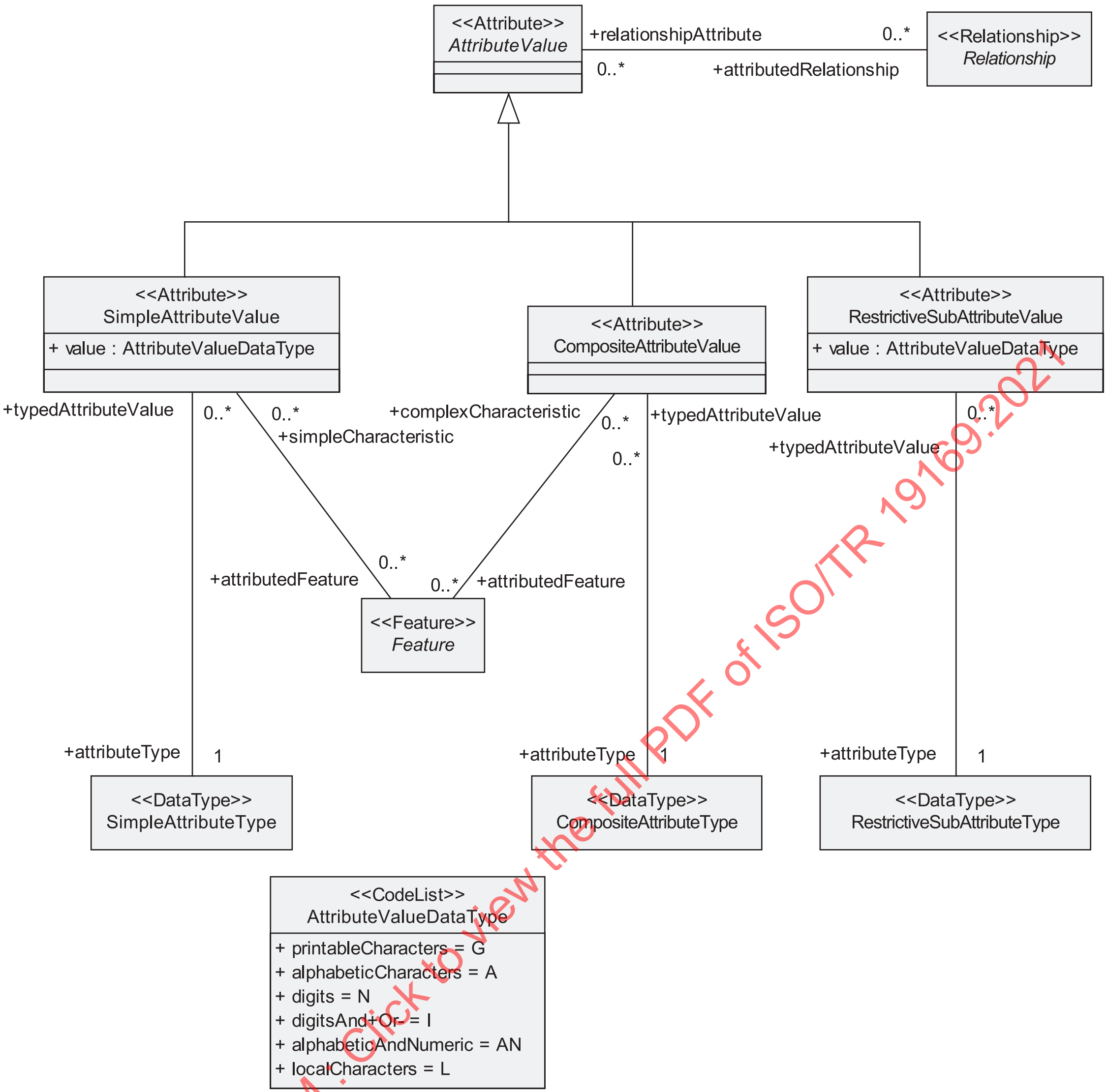



**Figure 18 — The GDF conceptual data model for Attribute Values**



The GDF Attribute Catalogue defines classes that are to be implemented as value domains for attributes of features. Global attributes are defined in tables and assigned to feature or relationship classes from several specified feature themes. Other attributes are defined for specific feature themes or for specific feature classes.

#### 7.2.3.2 Consideration of options

The two ISO 19109 GFM metaclasses AttributeType and FeatureAssocationRole can be considered equivalent for most implementations. For example, attributes and association roles for a feature type are implemented identically in XML schemas, as child elements of the element implementing the feature type. This is probably also the background for the rule req/uml/attribute in ISO 19109, which states that an AttributeType from the GFM is to be modelled as either an attribute or an association role. However, this rule is rather confusing as the two concepts are described with different metaclasses in the ISO 19109 GFM.

A good practice for modelling attributes or associations is to use attributes for data types and associations for classes. In standards modelled according to ISO 19103 and ISO 19109 this would mean that attributes with domain value defined as a DataType, CodeList, Enumeration or Union ought to be modelled as attributes, while attributes with domain value from a FeatureType can be modelled as associations. The modelling of attributes and relations in GDF is good according to this practice.

The GDF models for attribute types (Figure 17) and attribute values (Figure 18) describes a hierarchical classification of attribute types and attribute values at a meta-level. The classification is like the classification in the ISO 19109 GFM but with a different approach. However, the classes in Figure 17 and Figure 18 are defined as implementable classes with stereotypes “Attribute” or “DataType”, they are not modelled as metaclasses as has been done in ISO 19109. Furthermore, there is a duplication of the associations between AttributeValue and Feature in the model: the conceptual model of attribute values (Figure 18) defines associations between subclasses of AttributeValue and the core class Feature. This association is defined between the superclasses AttributeValue and Feature in the core GDF GDM. The redefined associations can lead to a possible duplication of associations between features and attribute values, or a mix of associations at different levels in the model.

The use of the term “Attribute” as a stereotype is confusing and in conflict with the term “attribute” as a classifier in a UML class. It is recommended to use a different term to identify the concept of attribute values (instances of attribute classes) that can exist individually. Technically, as “Attribute” classes represent abstractions of real-world phenomena that can exist individually, the classes are more comparable to feature types from ISO 19109 than to UML data types. According to the ISO/TC 211 definition and use of the term “feature”, they can be defined as feature types. One possible solution is therefore to use the ISO 19109 stereotype “FeatureType” for classes that are now stereotyped “Attribute”. This is equivalent to classes defined as feature types in models based on the ISO 19100 family of standards, such as address components and postal descriptors in the INSPIRE Data Specification on Addresses[15], as illustrated in Figure 19.

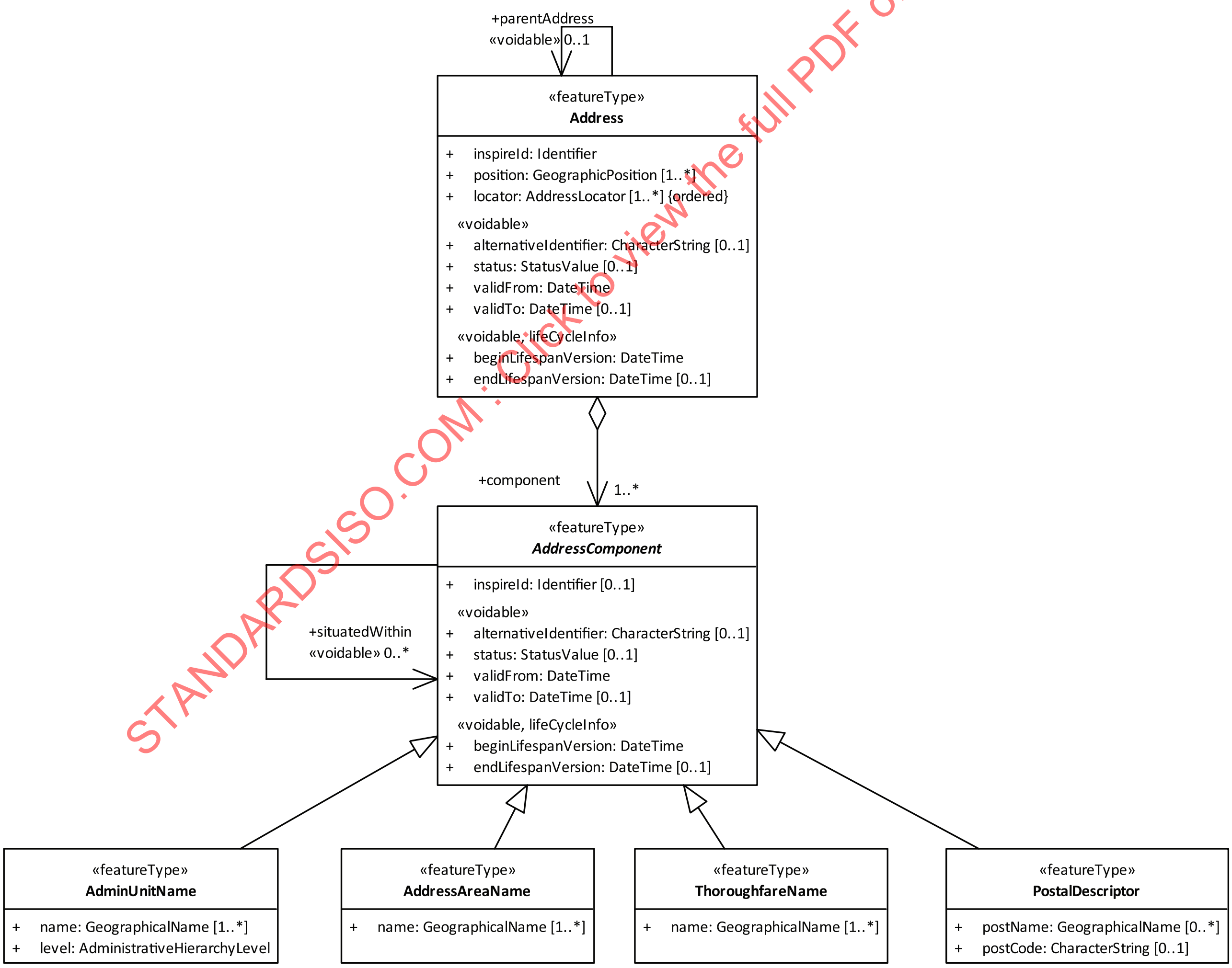



**Figure 19 — INSPIRE Addresses Spatial Object Types (from Reference [15])**

Optionally, if a clear distinction is needed for classes that are only to be used for attribute value domains, a specific metaclass with an accompanying stereotype can be defined in a UML Profile for GDF. A different name than “Attribute” would then be preferred, to avoid confusion.

#### 7.2.3.3 Recommendation and expected impact

It is recommended that the conceptual models for attribute types and attribute values be defined as metamodels to achieve an improved structure with a specified level of abstraction for concepts in the GDF model. The metamodels ought to extend the ISO 19109 GFM, in order to achieve improved interoperability with models in, or based on, the ISO 19100 family. The extended General Feature Model can be of interest for other domains as well and could be developed as an addition to ISO 19109.

Attribute classes represent abstractions of real-world phenomena and can be modelled as feature types with the ISO 19109 stereotype “FeatureType” instead of the GDF stereotype “Attribute”. A specific concept for attribute classes is probably not needed. If a specific concept for attributes is needed in GDF, a different term from “Attribute” ought to be used, to avoid confusion.

In addition, the same approach as recommended for features ought to be followed (see subclause 7.2.2.3 in this document): one core class for attributes in the Generic Feature Exchange Model, and one specific superclass for attribute classes in the Attribute Catalogue.

### 7.2.4 Relationship models

#### 7.2.4.1 Analysis

GDF defines the Relationship concept for identifiable spatial relations between two or more features that are not necessarily of different classes, and with attributes on the relation. The stereotype “Relationship” is used for defining classes as Relationships. The conceptual model for Relationships (Figure 20) is a part of the GDF GDM and specifies that an instance of a Relationship is to be of a Relationship Type and be associated with at least two instances of Feature.

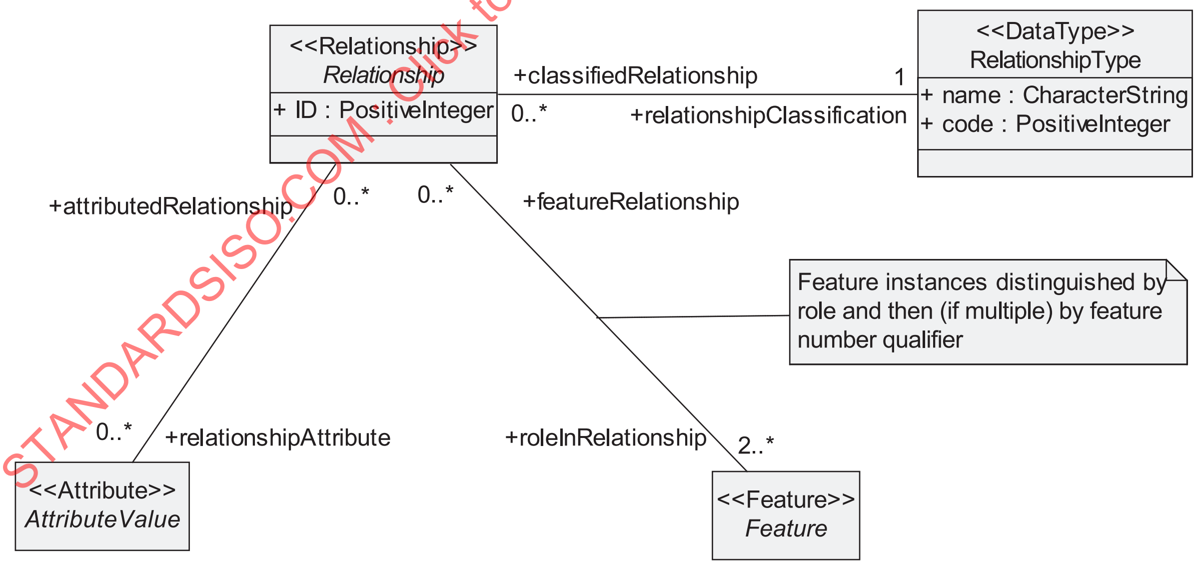



**Figure 20 — The GDF conceptual data model for Relationships**

Like the core class Feature, the core class Relationship is used in two parts of the standard.

1) The GDF GDM defines the generic class Relationship. The class is set as abstract in the model, but it is implemented as an instantiable class in the implementation specifications.

2) In the Relationship Catalogue, where the class Relationship is subtyped into instantiable Relationship Types representing specific abstractions of real-world relationships. Figure 21 shows

an example from the Relationship Catalogue, with Manoeuvre Relationships modelled as a subtype of the core abstract class Relationship. The Relationship Catalogue is implemented as tables in Annex A of GDF and referred to with identifiers in the implementation schemas.

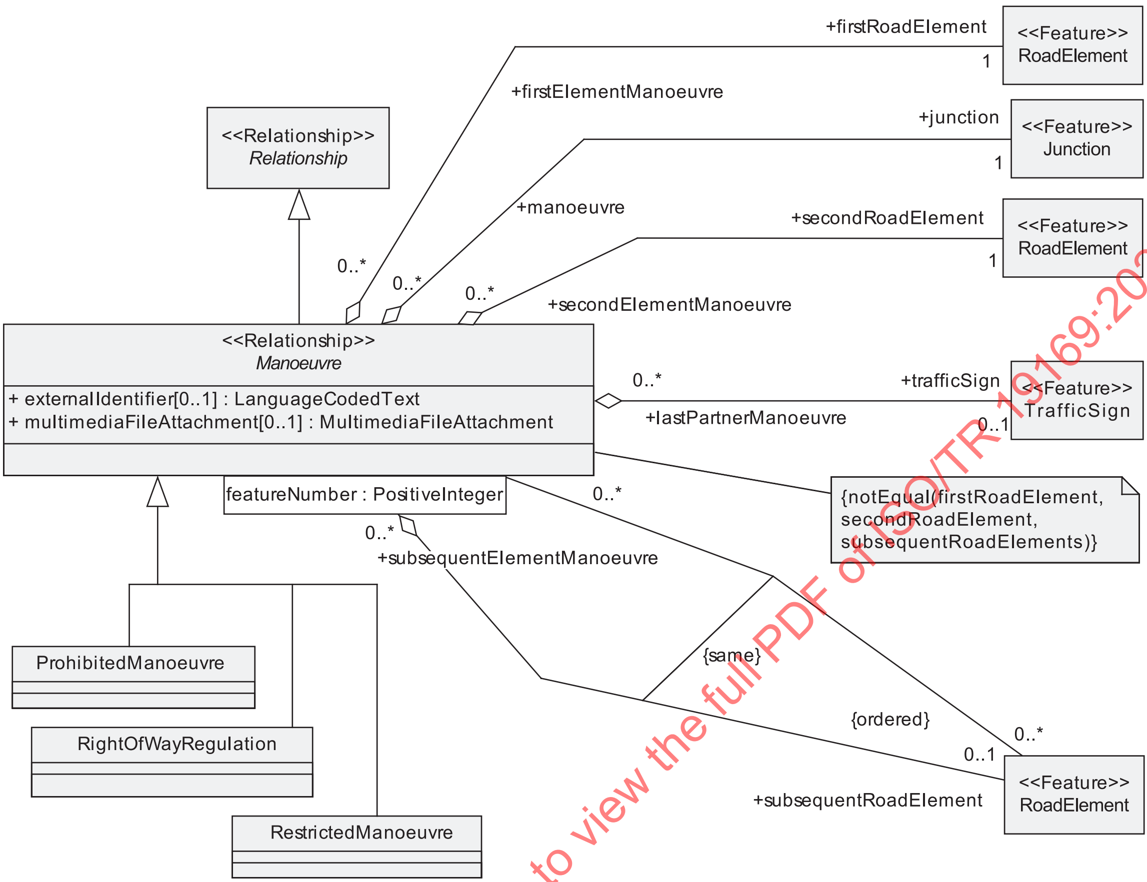



**Figure 21 — The GDF Conceptual Data Model for Manoeuvre Relationships**



The ISO 19109 GFM defines the FeatureAssociationType concept for associations between two feature types (or self-associations for one feature type), modelled as UML Associations or UML Association Classes. As noted in subclause 7.2.1, Association Classes can be used for associations with their own attributes, but this concept has rarely been used in models in, or based on, the ISO 19100 family.

### 7.2.4.2 Consideration of options

The ISO 19109 GFM does not have a specified equivalent concept to the Relationship concept in GDF. Therefore, in order to improve the harmonization between GDF and models in, or based on, the ISO 19100 family, the role of the Relationship concept needs to be defined according to the GFM. The ISO 19109 GFM metaclass FeatureAssociationType describes a relation between two classes and can be attributed by using an UML Attribute Class. However, a FeatureAssociation is only concerning one specific relation which is connecting two classes, while the Relationship concept in GDF can connect many classes. Therefore, FeatureAssociationType is not a possible equivalent for the Relationship concept.

The only technical difference between the Relationship concept and the Feature concept in the GDF GDM is the mandatory associations from the Relationship class to the Feature class. Except for this difference, the concepts are equivalent. A Relationship can therefore be considered a special kind of Feature, with at least two associations being mandatory. Application schemas based on ISO 19109 (e.g. the European INSPIRE Specification of Transport Networks[16]) have used the FeatureType concept for classes that are defined as Relationships in GDF. The basis for this use of the FeatureType concept lies in the definition of a feature as an abstraction of a real-world phenomenon. A phenomenon does not need to be a physical object, it can be a more abstract thing such as a manoeuvre. On the other hand, GDF defines a feature as a representation of a real-world object. The difference between the terms (phenomenon and object) is a matter of interpretation, but an object can be considered to be more physical.

Two possible solutions can be considered for defining the Relationship concept according to the GFM:

1) Define a Relationship metaclass with an accompanying stereotype specifically for GDF, as a subtype of FeatureType. Specify that it is to have at least two association roles. With this solution, the Relationship concept can still be used in GDF.

2) Use the "FeatureType" stereotype for relationships as well as for features in GDF. This solution will be closer to the approach in ISO/TC 211 based application schemas for transport network such as INSPIRE.

Figure 22, adapted from Reference [14], shows how parts of the relationship class Manoeuvre from Figure 21 can be modelled as classes based on the FeatureType concept.

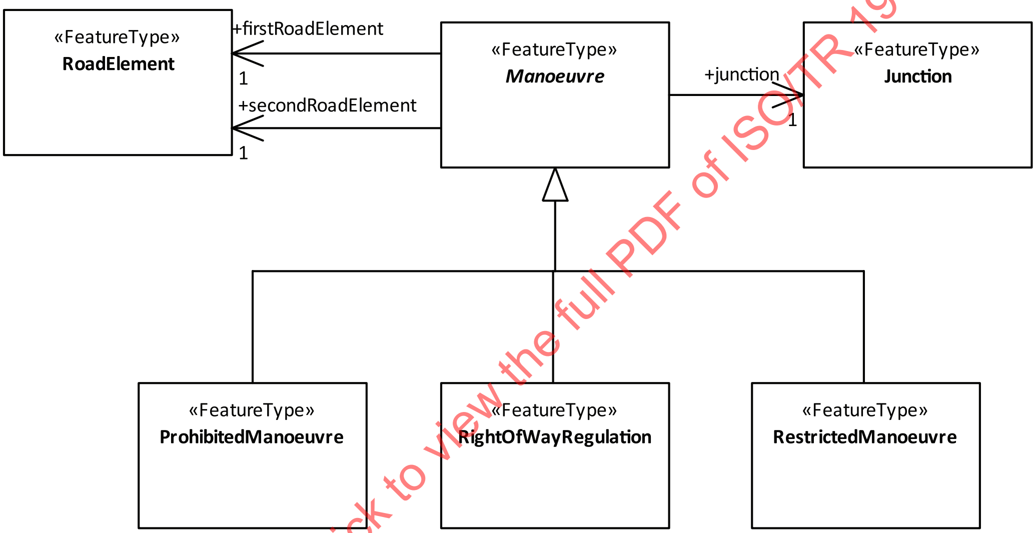



**Figure 22 — Example of Relationship modelled as a FeatureType (adapted from Reference [14])**



Besides, some classes that are defined as Relationships in GDF need to be further evaluated and possibly changed to location references. This includes classes for linear assignment (linear referencing) and classes for logical placement within other classes.

### 7.2.4.3 Recommendation and expected impact

Relationships in GDF represent abstractions of real-world phenomena and can be modelled as feature types with the ISO 19109 stereotype "FeatureType" instead of the GDF stereotype "Relationship". A specific concept for relationship is probably not needed. The FeatureType concept can be used for classes in the Relationship Catalogue as well as the Feature Catalogue.

With the suggested solution, the core Relationship class can be removed from the GDF GDM. The generic class representing features in the Generic Feature Exchange Model (Feature) will also represent relationships, while the superclass for feature classes in the Feature Catalogue will be a superclass for classes in the Relationship Catalogue as well.

Alternatively, if relationships is to be specified as an individual concept in GDF, the same approach as is recommended for features ought to be followed (see subclause 7.2.2.3): one core class for relationships in the Generic Feature Exchange Model, and one specific superclass for relationship classes in the Relationship Catalogue.

In any case, the definition of a Feature in GDF ought to be modified to include real-world phenomena that are not physical. Furthermore, classes for logical placement need to be evaluated and possibly changed to location referencing classes.

### 7.2.5 Album and dataset structure

#### 7.2.5.1 Analysis

Subclause 5.8 in GDF (ISO 20524-1) describes a structure of features within sections, layers, datasets and albums. The conceptual model for the structure is presented in Figure 6. Such a structure is not defined anywhere in the ISO 19100 family of standards.

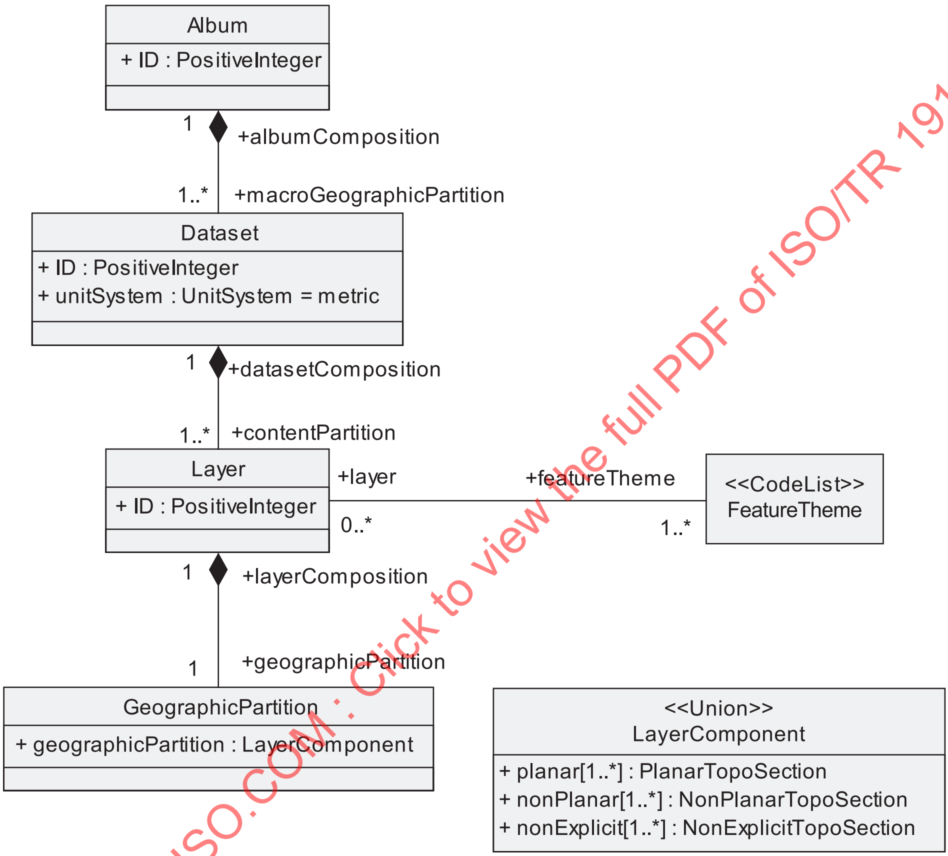



**Figure 23 — The GDF Organization of data (from ISO 20524-1)**



#### 7.2.5.2 Consideration of options

The model in Figure 23 describes a structure that can be defined in an application schema according to rules in ISO 19109, together with the generic feature exchange model described in subclause 7.2.1.

#### 7.2.5.3 Recommendation and expected impact

It is recommended that the model in Figure 23 be defined in an application schema according to rules in ISO 19109. The model ought to include the data organization structure and the generic feature exchange model defined in subclause 7.2.1. An application schema with the data structure model and the generic feature model will enable model-driven implementation in different implementation technologies and improve interoperability with standards in, or based on, the ISO 19100 family.

# 8 Application schemas — GDF Catalogues

## 8.1 The Feature Catalogue

### 8.1.1 Analysis

Clause 6 of GDF describes the GDF Feature Catalogue with the classification of feature classes within feature themes. Feature themes are abstract subclasses of the core class Feature, as shown in Figure 24. GDF A.1 lists all feature themes and feature classes with unique identifiers.

The purpose of the Feature Catalogue is to define feature classes and the relations between them. A few attributes are defined for some feature classes, but attributes are mainly defined in the Attribute Catalogue. Relations between feature classes are described in the UML models, e.g. between road and ferry features as shown in Figure 25. Definitions and constraints for each feature class are described in the text in GDF, Clause 6.

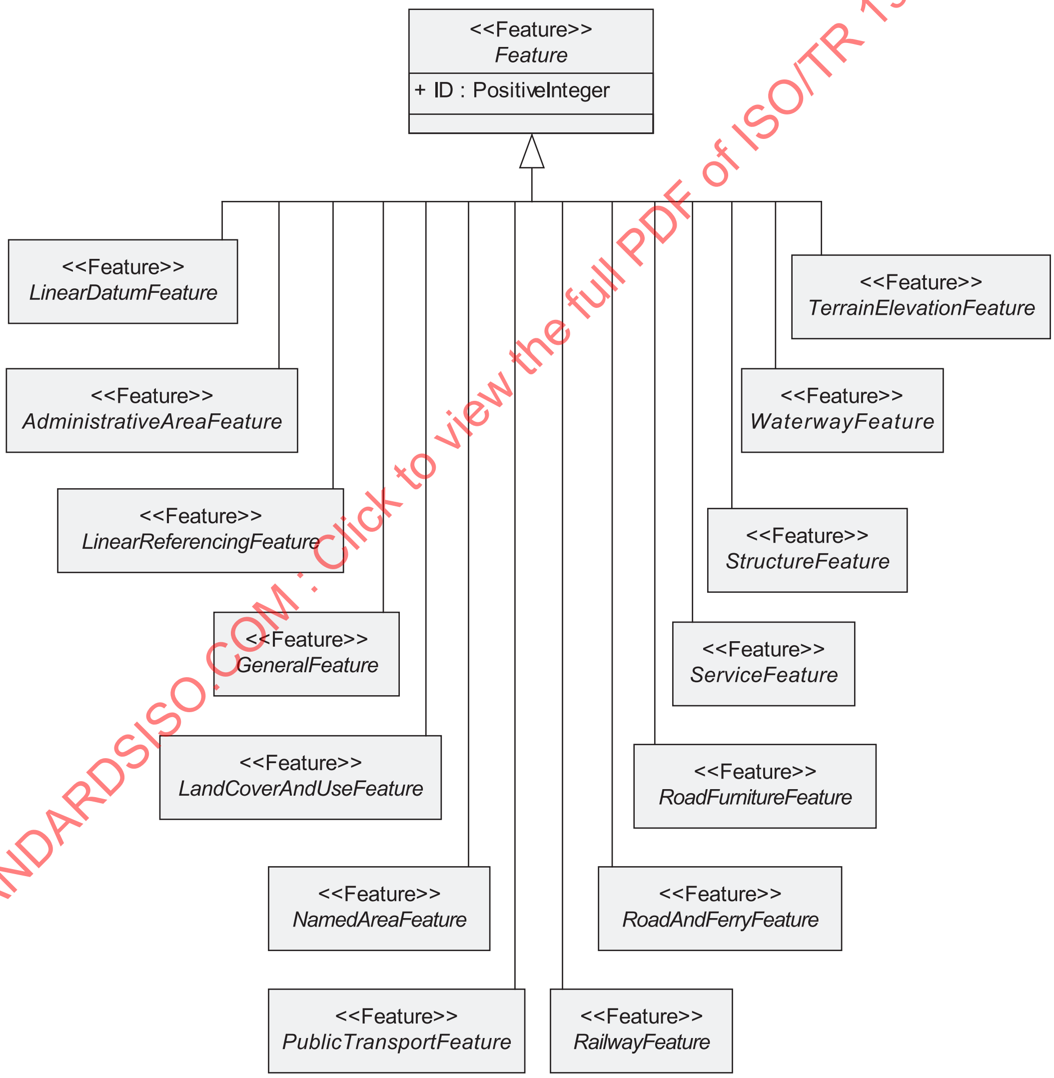



**Figure 24 — The GDF Conceptual Model of the Feature Catalogue**

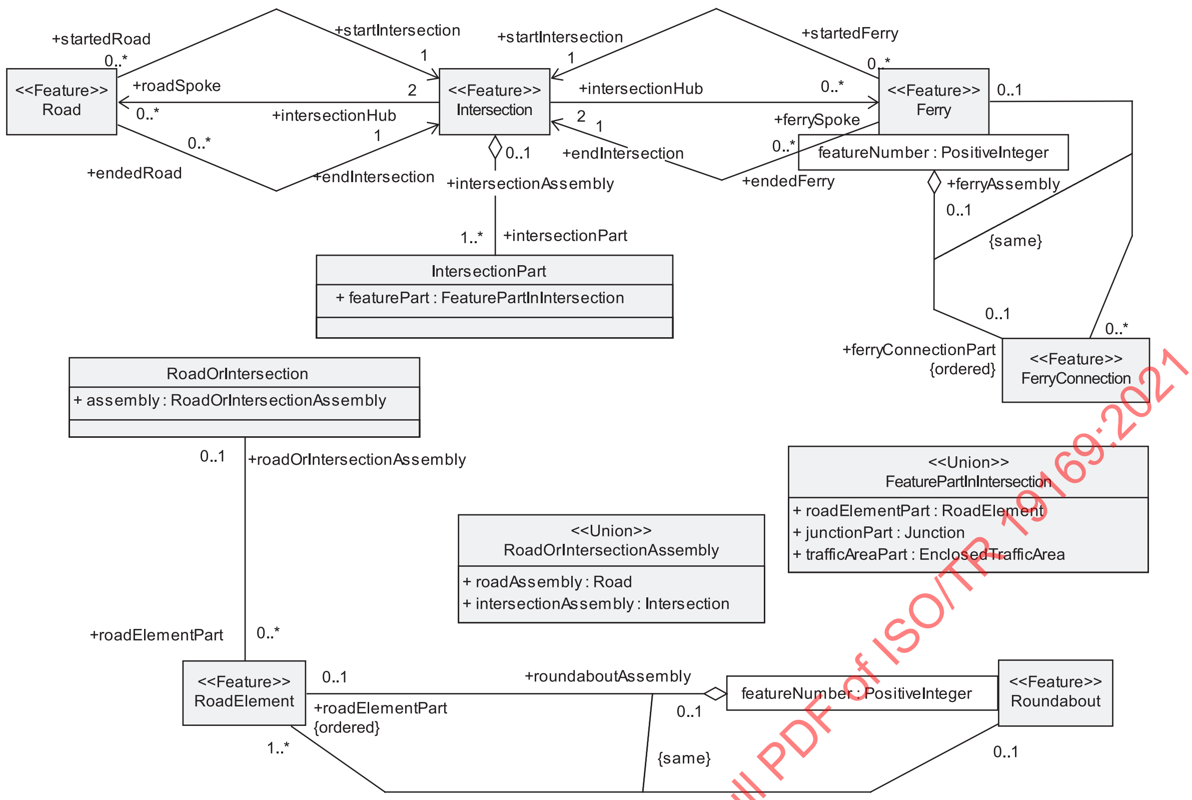



**Figure 25 — Relations between GDF road and ferry features**

The Feature Catalogue is modelled based on concepts from ISO 19103 and ISO 19109, but with feature classes defined by the stereotype “Feature” instead of “FeatureType”. Furthermore, as described in subclause 7.2.2 document, the core class Feature has been used both as a generic class in the GDF GDM and as a superclass for all feature themes and feature classes.

Besides this, only minor conceptual differences from standards in, or based on, the ISO 19100 family can be found, such as missing navigability direction for some associations. The study described in Reference [14] indicated that feature classes from the GDF Feature Catalogue could be implemented in an application schema according to ISO 19109 with only minor modifications, as shown for the feature class PedestrianCrossing in Figure 26.

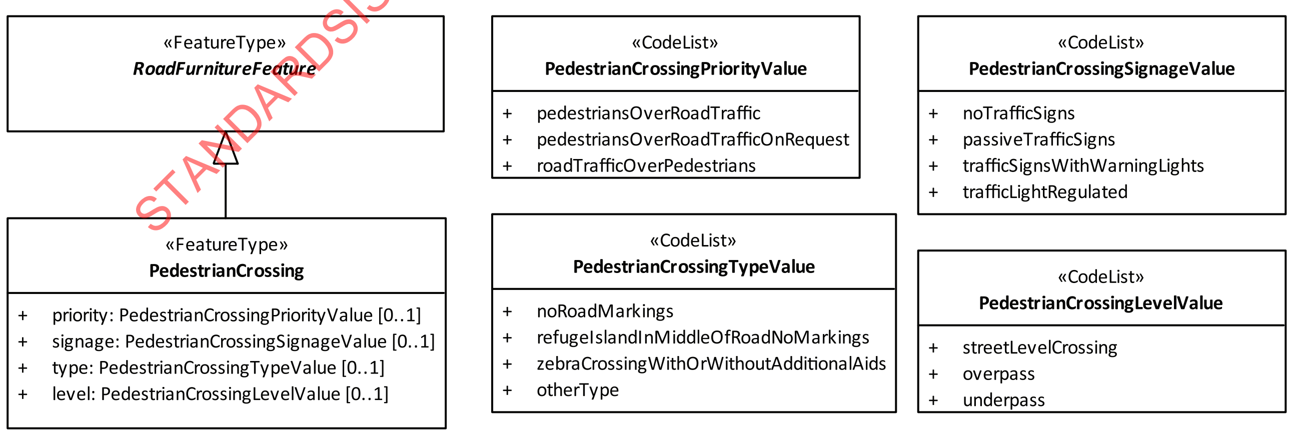



**Figure 26 — ISO 19109 compliant model of PedestrianCrossing (from Reference [14])**

Two feature themes are closely related to ISO 19148 (Linear referencing): LinearReferencingFeature and LinearDatumFeature. The theme LinearReferencingFeature adopts the concepts from ISO 19148, but the relationship is not clearly described.



### 8.1.2 Consideration of options

The use of the stereotype "Feature" was discussed in subclause 7.2.2 of this document and recommended to be replaced with the ISO 19109 stereotype "FeatureType". Furthermore, the duplicate usage of the core class Feature was recommended to be avoided by defining a specific class as a supertype for the Feature Catalogue.

### 8.1.3 Recommendation and expected impact

The Feature Catalogue is recommended to be modelled as fully ISO 19109-conformant application schemas conformant to requirements in ISO 19103 and ISO 19109. Classes in the two themes that are related to ISO 19148 (LinearReferencingFeature and LinearDatumFeature) ought to describe how they implement the concepts from ISO 19148.

A core superclass to replace the use of the class Feature in the FeatureCatalogue ought to be defined. A suggestion is to define a generic abstract class IdentifiedClass, as illustrated in Figure 27.

The use of a generic feature exchange model like the GDF GDM requires that all feature classes have a unique ID as listed in GDF, A.1. This identification can either be based on the feature class name as suggested in Reference [14], or it can be added to the classes as tagged values. The listing in GDF A.1 ought to be a report from the UML model, in order to maintain consistency.



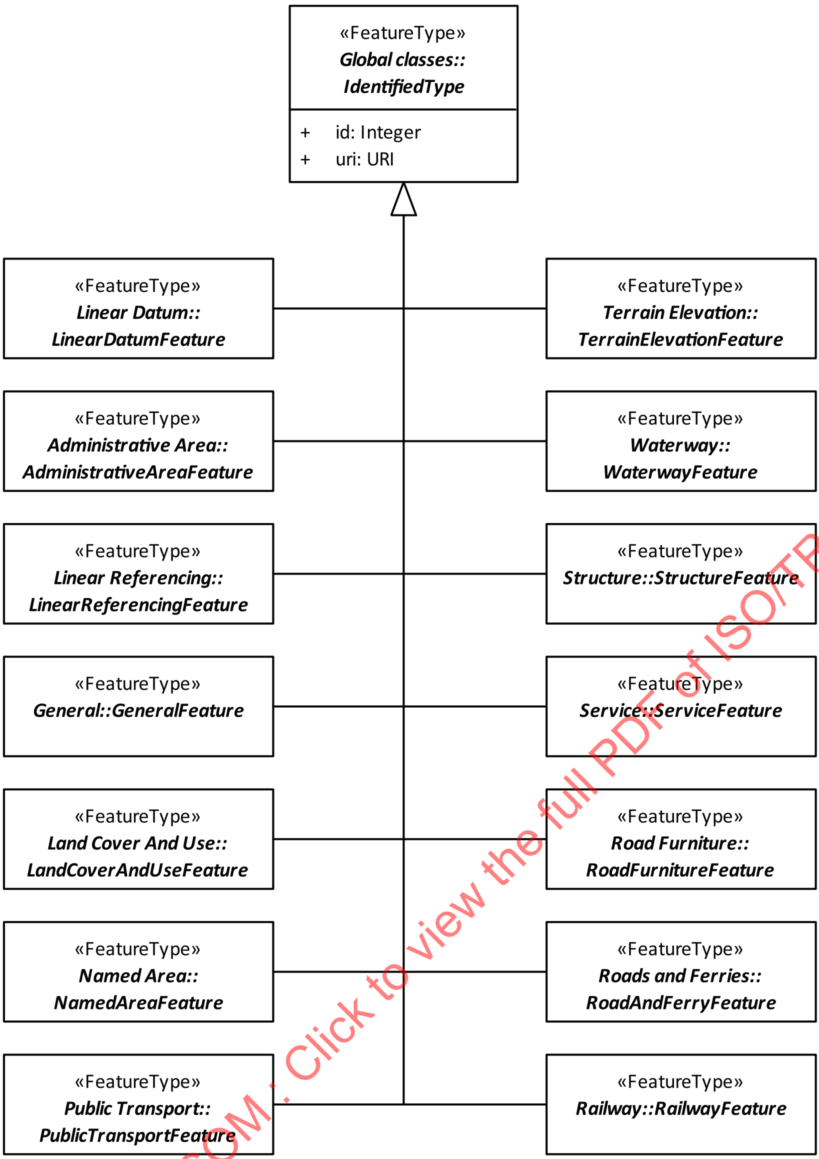



**Figure 27 — IdentifiedType as abstract superclass**

## 8.2 The Attribute Catalogue

### 8.2.1 Analysis

Clause 7 of GDF describes the GDF Attribute Catalogue with attributes that can be applied to GDF Features and the value domains of attributes. An example of the model for general attributes is shown in Figure 28. Attributes are assigned to feature classes in cross-tables and in UML diagrams, for example for feature classes in the Road and Ferries theme as shown in Figure 29.

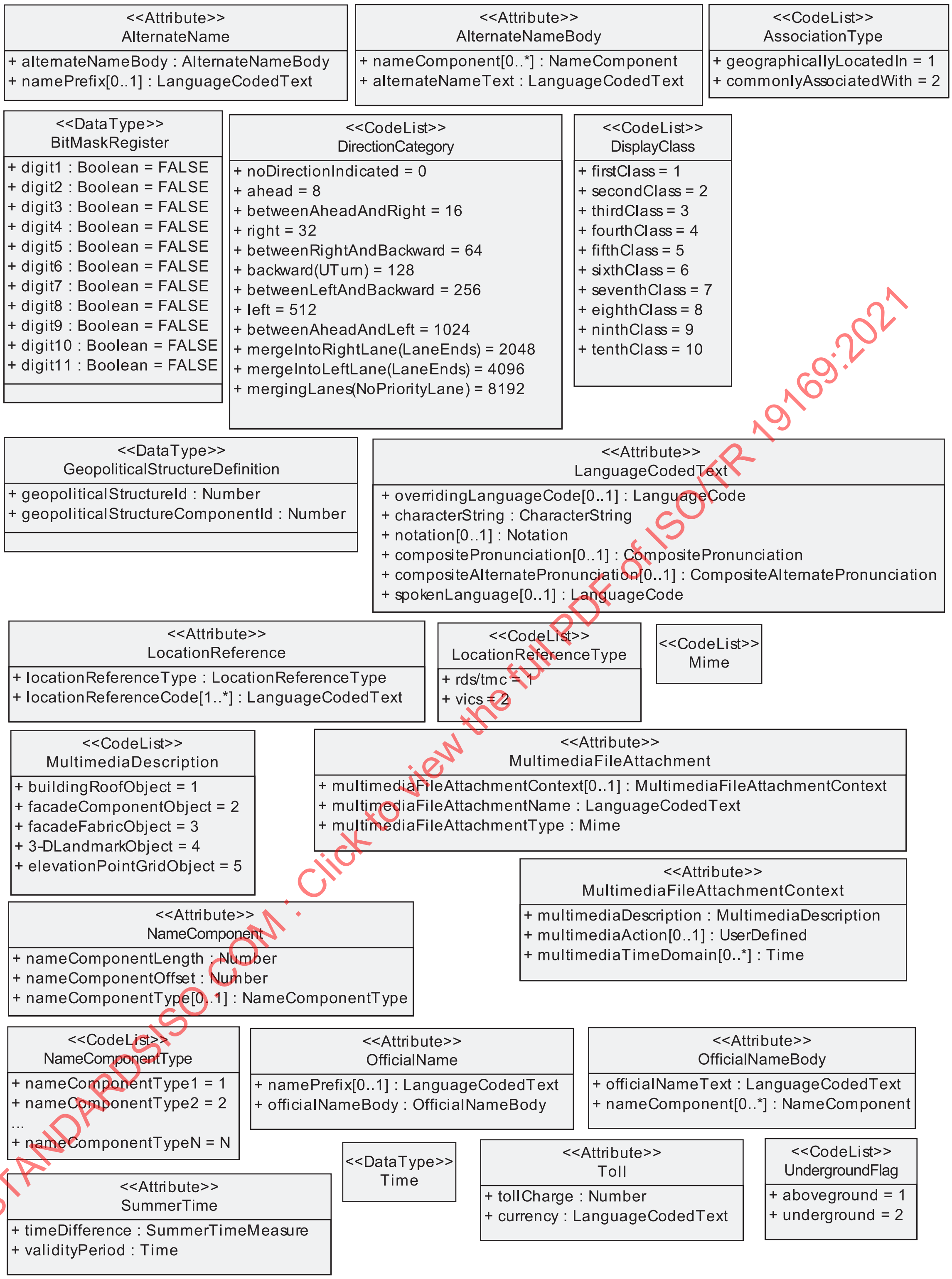





**Figure 28 — A part of the GDF Conceptual Model for General Attributes**

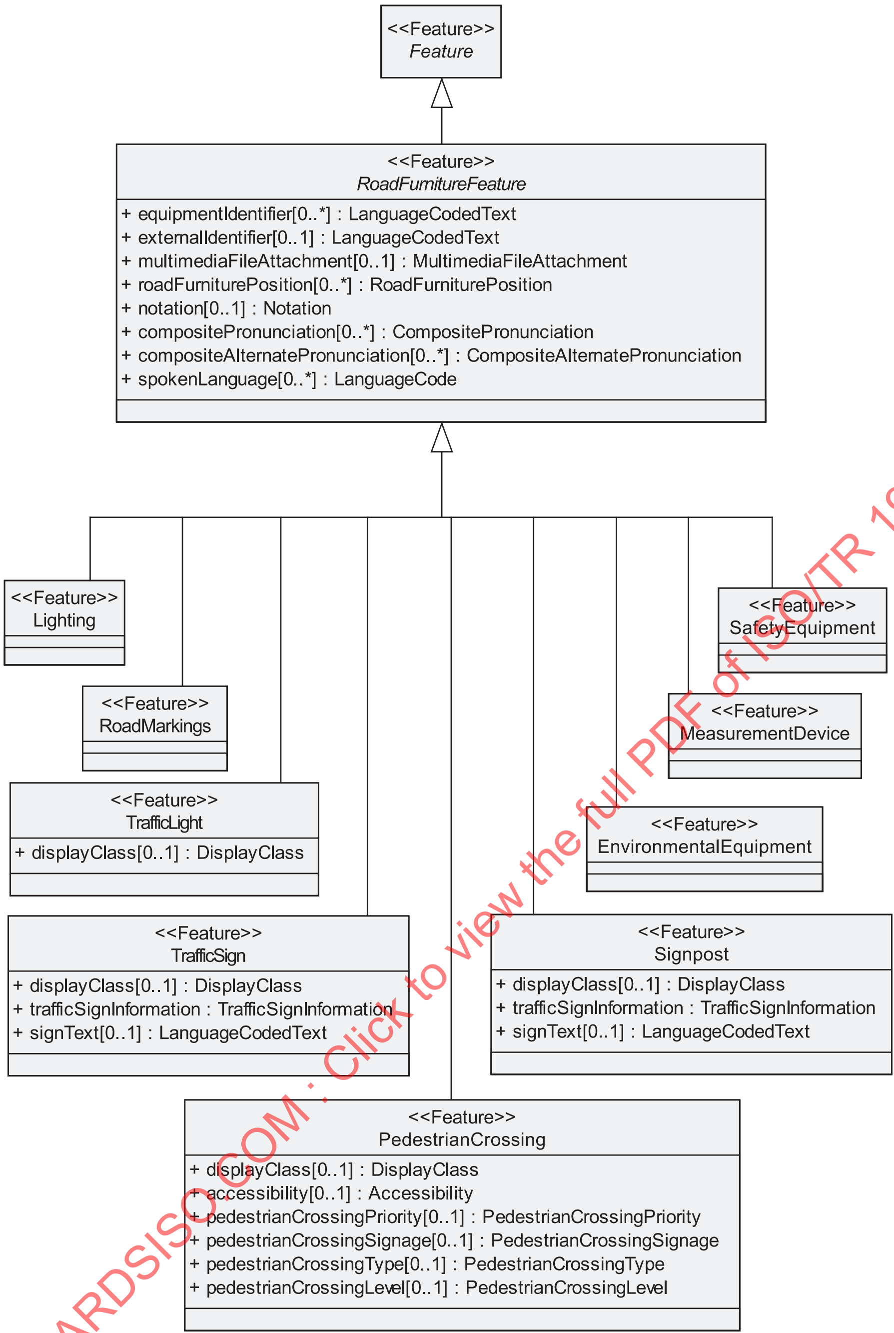





**Figure 29 — The GDF Conceptual Model for attributes of Road Furniture**

The Attribute Catalogue is modelled based on concepts from standards in the ISO 19100 family, but with the stereotype “Attribute” for some value domains, as described in subclause 7.2.3 of this document. Besides this, only minor conceptual differences from standards in the ISO 19100 family can be found, such as a lack of reuse of data types already defined in the ISO 19100 family. The study described in Reference [14] indicated that attributes defined in the GDF Attribute Catalogue could be assigned to feature classes from the GDF Feature Catalogue and implemented in an application schema according to ISO 19109 with only minor modifications, as shown for the feature class PedestrianCrossing in Figure 26.

One important aspect is the use of global attribute types in GDF. The GDF Attribute Catalogue defines global attribute types that are reused in many Feature Classes. For this purpose, GDF, A.2 lists all attribute types with unique identifiers. The concept of global properties is well known from the semantic web and is defined in the feature catalogue model in ISO 19110 as well.

### 8.2.2 Consideration of options

The use of the stereotype “Attribute” was discussed in subclause 7.2.3 of this document and is recommended to be replaced with the ISO 19109 stereotype “FeatureType”.

In order to enable derivation of implementation schemas based on MDA, all attributes need to be assigned to their respective classes as shown in Figure 29. A possible approach for modelling globally reusable attributes is described in Reference [12] and illustrated in Figure 30. This approach could also be applied to the GDF Attribute Catalogue.

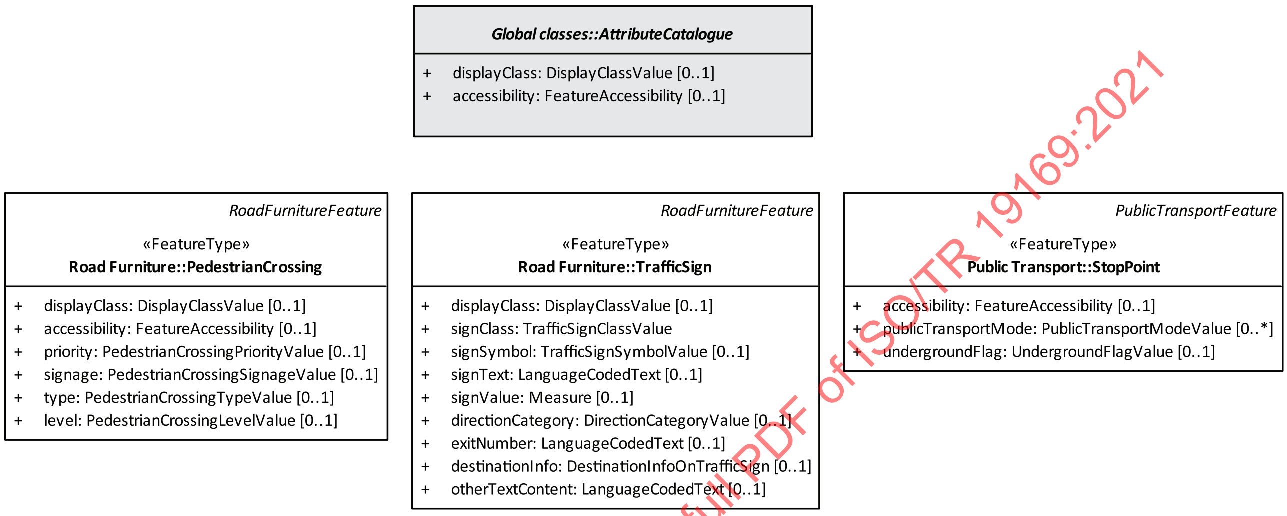



**Figure 30 — Example of modelling global attributes (from Reference [12])**

### 8.2.3 Recommendation and expected impact

As for the GDF Feature Catalogue, it is recommended that the Attribute Catalogue be modelled as fully ISO 19109-conformant application schemas conformant to requirements in ISO 19103 and ISO 19109. This would include to use stereotypes according to ISO 19103 and ISO 19109, and reuse core data types from standards in the ISO 19100 family. In particular, it is recommended to use core primitive datatypes, measure data types, name types, etc. from ISO 19103. The use of the stereotype “Attribute” is recommended to be replaced with the stereotype “FeatureType”.

Concepts for defining attributes for reuse in several classes would improve the structure of the GDF Attribute Catalogue model. The approach suggested in Reference [12] can be a basis for defining global attributes in GDF.

The use of a generic feature exchange model like the GDF GDM requires that all attributes have a unique ID as listed in GDF, A.2. This identification can either be based on the feature and attribute class names as suggested in Reference [14] or it can be added to each attribute as tagged values. The listing in GDF, A.2 ought to be a report from the UML model, in order to maintain consistency.

Finally, to enable identification of instances of attributes, it is recommended that the same core superclass as suggested in subclause 8.1.3 of this document be applied for identifiable attribute types as well.

## 8.3 The Relationship Catalogue

### 8.3.1 Analysis

Clause 8 of GDF describes the GDF Relationship Catalogue with models for relationship classes. GDF, A.3 lists all Relationship classes with unique identifiers. Like the Feature Catalogue, the purpose of the Relationship Catalogue is to define relationship classes and the relations between them. In addition, attributes from the Attribute Catalogue have been assigned to relationship feature classes, as shown in Figure 31.

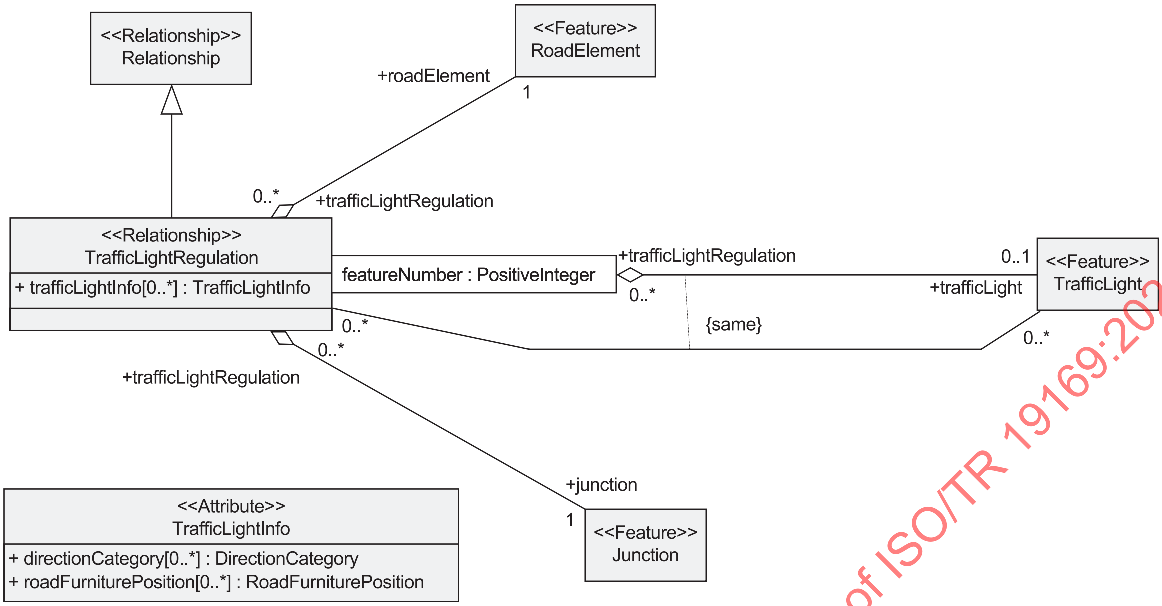



**Figure 31 — The GDF Conceptual Model for the Traffic Light Regulation Relationship**

Like the Feature Catalogue, the Relationship Catalogue is modelled based on concepts from ISO 19103 and ISO 19109, but with classes defined by the stereotype “Relationship” instead of “FeatureType”. Furthermore, as described in subclause 7.2.4 in this document, the core class Relationship has been used both as a generic class in the GDF GDM and as a superclass for all relationship classes.

Besides this, only minor conceptual differences from standards in, or based on, the ISO 19100 family can be found. The study described in Reference [14] indicated that relationship classes from the GDF Relationship Catalogue could be implemented as feature types in an application schema according to ISO 19109 with only minor modifications, as shown for the relationship Manoeuvre in Figure 22.

Three relationship classes implement concepts from ISO 19148 (Linear referencing): LinearAssignment, MultiPointAssignment and ExclusiveMultiPointAssignment.

### 8.3.2 Consideration of options

The use of the stereotype “Relationship” was discussed in subclause 7.2.4 and recommended to be replaced with the ISO 19109 stereotype “FeatureType”. Furthermore, the duplicate usage of the core class Relationship was recommended to be avoided by defining a specific class as a supertype for the Relationship Catalogue.

### 8.3.3 Recommendation and expected impact

It is recommended that the Relationship Catalogue be modelled as fully ISO 19109-conformant application schemas and conformant to requirements in ISO 19103 and ISO 19109. As stated in the recommendation from subclause 7.2.4 in this document, relationships can be considered as a kind of feature types. The use of the stereotype “Relationship” is recommended to be replaced with the stereotype “FeatureType”.

In principle, a specific Relationship Catalogue is not needed. Instead, relationship classes can be defined in the Feature Catalogue. Furthermore, the recommendations regarding the Feature Catalogue apply to relationships as well: use the core superclass IdentifiedObject, add identification of classes to the model and generate the listing in Annex A as a report from the UML model.



## 8.4 The Metadata Catalogue

### 8.4.1 Analysis

Clause 10 of GDF describes the GDF Metadata Catalogue with definitions of metadata information that are to follow a GDF delivery. The metadata is to be provided as a part of the overall delivery, at different levels: Album, Dataset, Layer and Section. The content of the GDF Metadata Catalogue is described in text only; except for one figure with codelists from ISO 19115-1 there is no UML model for metadata in GDF.

The ISO/TC 211 standard ISO 19115-1 defines a metadata structure for geospatial information. The standard is modelled in UML and implemented in an XML schema based on MDA and rules defined in ISO/TS 19139-1. The XML implementation has been widely used in the GIS domain. ISO 19115-1 defines a minimum set of metadata information consisting of a point of contact, dataset identification and date information.

The GDF Metadata Catalogue is defined as conformant with ISO 19115-1. A table in GDF, Clause 10 describes a schema crosswalk between ISO 19115-1 elements and GDF Metadata Catalogue elements. The relations are partly based on the adoption of ISO 19115-1 elements into the GDF Metadata Catalogue, and partly through a mapping between elements. The schema crosswalk shows that the mandatory content from ISO 19115-1 (point of contact, dataset identification and date information) is covered by the GDF Metadata Catalogue.

### 8.4.2 Consideration of options

A basic improvement of the GDF Metadata Catalogue could be to define the catalogue in a UML model and enable MDA-driven implementation. The textual description of the GDF Metadata Catalogue relates the metadata elements to the album and dataset structure. It would therefore be natural to define the metadata UML model as a part of the application schema suggested for the album and dataset structure (see subclause 7.2.5).

Furthermore, a UML-model for GDF Metadata ought to reuse concepts from the ISO 19115-1 UML model. A reuse of concepts from ISO 19115-1 could be done in at least three ways:

— Reusing individual elements from ISO 19115-1 in GDF.

— Reusing larger portions of ISO 19115-1 in GDF by defining a GDF profile (further refinement) of ISO 19115-1.

— Reusing the complete ISO 19115-1 model as-is.

One possible approach has been used in the European CEN TN-ITS specification[18], where a specific simple set of metadata elements and added an optional connection to the ISO 19115-1 core class MD_Metadata in addition, as shown in Figure 32.




**Figure 32 — Metadata in CEN TN-ITS (from Reference [18])**

### 8.4.3 Recommendation and expected impact

The GDF Metadata Catalogue is recommended to be defined in a UML Model, as a part of the album and dataset structure. As recommended in subclause 7.2.5, the UML model ought to be defined as an application schema according to ISO 19109, and thereby enable MDA-driven implementation. Elements defined in ISO 19115-1 ought to be preferred for reuse in the UML model instead of defining specific GDF metadata elements. This approach would reduce the gap between GDF and ISO/TC 211 standards and increase the interoperability with GIS.

A simple approach is to associate the ISO 19115-1 core class MD_Metadata with the different structural levels of GDF files as in the CEN TN-ITS Specification. This approach is illustrated in Figure 33. Alternatively, a profile of ISO 19115-1 could be used instead of the ISO 19115-1 model, to include specific GDF elements and remove irrelevant parts from the ISO 19115-1 model.

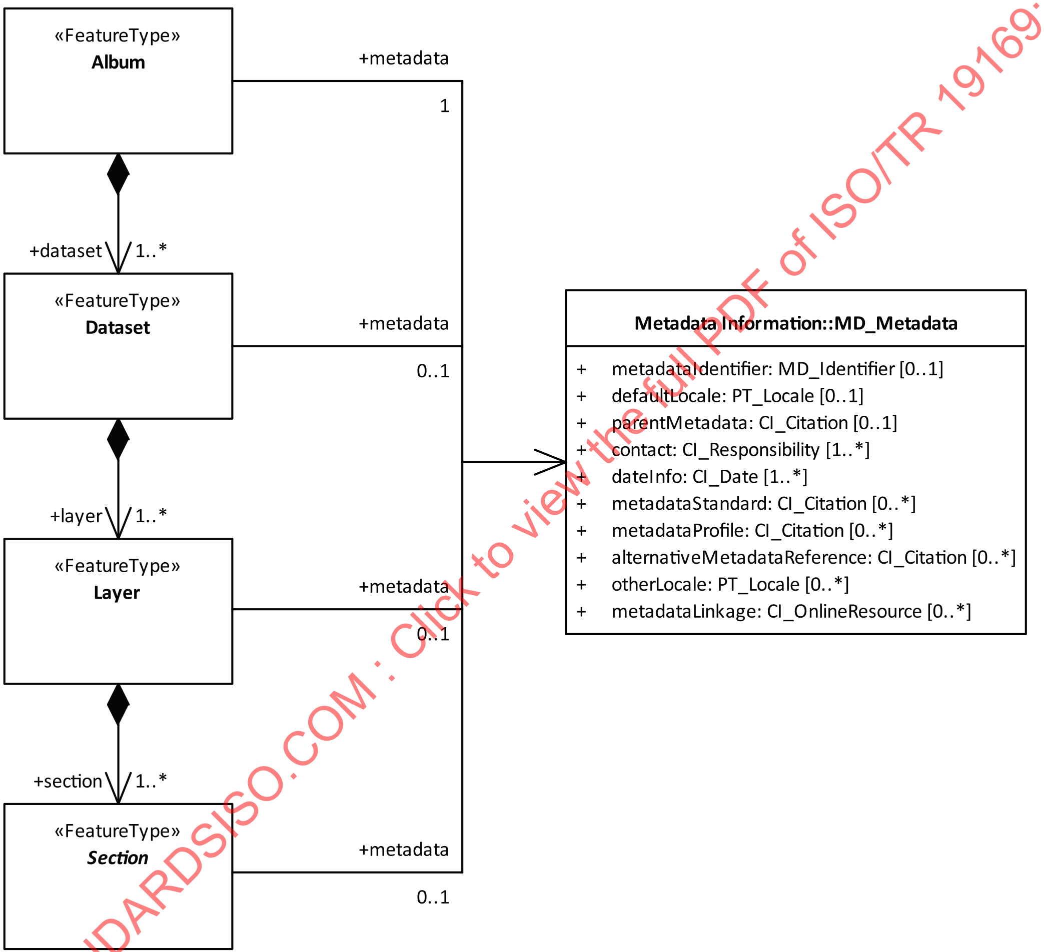





**Figure 33 — Simple reuse of the ISO 19115-1 model**

## 9 Encoding rules

### 9.1 Analysis

The derivation of implementation schemas from UML models requires models that are specified according to profiles and modelling rules, as illustrated in Figure 2. Furthermore – as shown in Figure 2 as well – specified rules for conversion from UML to implementation schemas must be defined.

Rules for conversion of UML models according to the rules in ISO 19103, ISO 19109 and ISO 19136-1 are defined in ISO 19136-1, ISO/TS 19139-1 and ISO 19150-2. ISO/TS 19139-1 specifies rules for conversion to XML; ISO 19136-1 specifies rules for conversion to the XML-based format GML, while ISO 19150-2 specifies rules for conversion to the Semantic Web format OWL. UML models that follow the rules in ISO 19103, ISO 19109 and ISO 19136-1 can be converted to implementation schemas for GML and OWL by applying the conversion rules.

GDF has two implementation formats with described encodings: the Media Record Structure (MRS) is described in GDF, Clause 12 while XML schemas with conversion rules from UML to XML (GDF-XML) are described in GDF, Clause 13. The encodings are not derived from the GDF UML models; they are described manually.

The conversions from UML class names and property (attributes and associations) names to the MRS and GDF-XML encodings are based on abbreviations and concatenated names. The relation to the UML model is not obvious. For example: a layer in a GDF file contains feature data of one and only one topology type (non-explicit, non-planar or planar). The two UML classes PlanarTopoPointFeature and NonPlanarTopoPointFeature represents point features in different explicit topology types and are both implemented as the XML class “Point_feat_explicit”. The conversion from the two UML classes to a single XML class with a new name is not clearly described in GDF. Likewise, the two XML attributes “point_feat_ID” and “line_feat_ID” are different representations of the attribute Feature.ID the UML model. The conversion from the single UML attribute to two XML attributes is not described. The same issues can be found for the MRS encoding.

The differences between the UML models and the GDF encodings are challenging for exchange of information based on GDF. The UML models do not describe the actual model that is used for exchange. Anyone delivering or receiving data in MRS or GDF-XML needs to understand the differences to be able to understand the data. Furthermore, though the MRS and GDF-XML is commonly understood and used for exchanging map databases in the ITS domain, neither of them is a format commonly known for GIS applications, which makes it challenging for GIS applications to deliver information based on GDF models.

In the case of the MRS format specified in GDF, attributes are limited in the format and/or range of values in which they can be presented. This constraining of the values is beneficial as it sets a clear requirement for the provision of data in conformance with GDF. The use of constrained values, format lengths and in some cases input masks is widespread across many implementation standards, both within the ITS domain and other domains. Such requirements for the content of attributes is seen as an important tool to aid implementation interoperability through conformance with standards. The ISO/TC 211 modelling and conversion rules do not currently support the definition of requirements for attribute format or range in GML.



## 9.2 Consideration of options

The proposed UML modelling of GDF according to rules from ISO/TC 211 standards will enable derivation of GDF implementation schemas in the GIS format GML as well as the Semantic Web format OWL. The implementation encodings will then be as aligned and coherent with the UML model as technically possible. As long as the UML models are developed according to the specified modelling rules, no further actions are required to enable implementation in GML and OWL, which will make information exchange easier in general, and in particular with the GIS domain. However, the lack of modelling and conversion rules for requirements on attribute content is a limitation for the use of UML and GML. The models and the GML implementation can be improved by adding rules for modelling such requirements and rules for conversion to XML facets in GML implementation schemas.

The derived GML schemas can replace the specific GDF-XML encoding. If a specific XML encoding for GDF is to be maintained additionally, specific conversion rules will also need to be developed. Likewise, conversion rules from UML to MRS will need to be developed in order to maintain the MRS encoding.

## 9.3 Recommendation and expected impact

The primary recommendation is to develop GDF as UML models according to the ISO/TC 211 MDA approach.

In order to enable handling of requirements for attribute content in GML, it is recommended that ISO/TC 211 seek to revise ISO 19109, ISO 19136-1 and ISO 19136-2 to facilitate requirements for attribute content.

Furthermore, if the two existing implementation encodings are to be maintained, it is recommended that they be derived from the UML model, based on conversion rules. Such rules will then need to be developed.

## 10 Other issues arising

### 10.1 Introduction

This clause covers a number of items that have arisen during the preparation of this document. Strictly speaking, some of the issue items listed below do not arise from a direct comparison of GDF with the ISO 19100 family of standards, but have been items that have arisen during earlier recent ballot comments made on the latest releases of GDF (v5.1, both ISO 20524-1 and ISO 20524-2) that have not been addressed within revisions of the latest releases, or from comments made against earlier versions of this document.

### 10.2 Temporal referencing

Comments made by AFNOR, BSI and Standards Norway in a 2018 ballot on ISO 20524-1 noted that the approach used for defining the Syntax for Time Domains (Annex D), only partially refers to the ISO 8601 series and that redefinition of this syntax could bring GDF into greater alignment to existing ISO standards, namely the ISO 8601 series and ISO 19108.

It is recommended that a detailed analysis of the syntax characteristics supported by GDF and a comparison to the characteristics offered by the ISO 8601 series and ISO 19108 be undertaken in advance of preparation of future revisions of GDF, with the aim of adopting ISO 8601 series- and ISO 19108-conformant syntax mechanisms.

### 10.3 Geodetic location referencing

The latest version of GDF (ISO 20524-1:2020, 10.6) defines geodetic parameters. ISO 20524-1:2020, B.1 defines fixed code lists for geodetic parameters. It has been recommended that future versions of GDF refer to ISO Geodetic registry codes instead.

Location reference using coordinates refers to a coordinate reference system (CRS) that is either 'static' or 'dynamic', as defined in ISO 19111. In a static CRS the CRS is fixed to the surface of the earth and coordinates do not change with time. In a dynamic CRS, coordinates are fixed to the earth as a whole and coordinate values at a location on the earth change with time. Static CRSs move relative to dynamic CRSs over time, so differentiating CRS and its dynamic nature is critical for the highest accuracy. Subclause 10.6 of GDF (ISO 20524-1) specifies the datum origin as being WGS 84. Coordinates referenced to the WGS 84 coordinate reference system used by the GPS satellite navigation system are 'dynamic'. Therefore, at a location, WGS 84 coordinates do change with time, and specification of the epoch (time reference) is also required. Concern has been raised that GDF needs to differentiate use of 'static' and 'dynamic' coordinate reference system, and add the epoch value in referencing to 'dynamic' CRS.

NOTE A good explanation of this issue is provided at https://youtube/IKM-bR6SwVs[22].



# Annex A
(informative)

# Comparison of terms and definitions in ISO/TC 204 and ISO/TC 211

## A.1 Introduction

### A.1.1 Overview

ISO 19132:2007, Annex E presented a comparison of defined terms and their definitions found in GDF and ISO 19100 family of standards presented in a tabular form. The basis for the content of this annex is drawn from ISO19132:2007, Annex E. This content has been updated to both reflect current terms and definitions found in the latest available editions of GDF and standards within the ISO 19100 family. Where the recommendations made in this document would result in modification of these defined terms and definitions, this has been highlighted.

### A.1.2 Comparative analysis of ISO/TC 211 and ISO/TC 204 terminology and concepts

The following ISO/TC 211 documents are in the scope of this analysis:

— ISO 19101-1:2014, Geographic information — Reference model — Part 1: Fundamentals

— ISO 19103:2015, Geographic information — Conceptual schema language

— ISO 19107:2019, Geographic information — Spatial schema

— ISO 19109:2015, Geographic information — Rules for application schema

— ISO 19110:2016, Geographic information — Methodology for feature cataloguing

— ISO 19111:2019, Geographic information — Referencing by coordinates

— ISO19115-1:2014, Geographic information — Metadata — Part 1: Fundamentals

— ISO 19132:2007, Geographic information — Location-based services — Reference model

The following ISO/TC 204 documents are in the scope of this analysis:

— ISO 14825:2011, Intelligent transport systems — Geographic Data Files (GDF) — GDF5.0

— ISO 20524-1:2020, Intelligent transport systems — Geographic Data Files (GDF) — GDF5.1 — Part 1: Application independent map data shared between multiple sources

— ISO 20524-2:2020, Intelligent transport systems — Geographic Data Files (GDF) GDF5.1 — Part 2: Map data used in automated driving systems, Cooperative ITS, and multi-modal transport

— ISO 17262:2012, Intelligent transport systems — Automatic vehicle and equipment identification —Numbering and data structures

The following International Standards from other sources are in the scope of this analysis:

— ISO/IEC 11404:2007, Information technology — General Purpose Datatypes (GPD)

— ISO/IEC TR 10000 (all parts), Information Technology — Framework and taxonomy of International Standardized Profiles

— ISO/IEC 19501, Information technology — Open Distributed Processing — Unified Modeling Language (UML) Version 1.4.2

These International Standards are aimed at supporting applications with similar functionality. The purpose of this analysis is to guide users of the International Standards in differences in terminology and conceptual models that will help minimize confusion.

## A.2 ISO/TC 211 terms and concepts versus corresponding ISO/TC 204 terms and concepts

The following Tables A.1 to A.6 compare terms and concepts from ISO/TC 211 and ISO/TC 204.

The terms have been subdivided along conceptual lines to facilitate understanding.



**Table A.1 — Data model terminology**

| Term | ISO/TC 204 GDF term definition | ISO/TC 211 term definition | Comment |
|---|---|---|---|
| **Attribute** | characteristic of a Feature which is independent of other Features<br>[SOURCE: ISO 20524-1:2020, 3.4.2] | named property of an entity<br>Note 1 to entry: Describes a geometrical, topological, thematic, or other characteristic of an entity.<br>[SOURCE: ISO 19115-2:2019, 3.1 origin:<br>SOURCE: ISO/IEC 2382:2015, 2121440, modified — Note 1 to entry replaces Notes 1 and 2 to entry.] | Both definitions are consistent with UML, which recognizes the independent storage of attribute values, but allows dependencies between them, usually expressed in Object Constraint Language (OCL). |
| **Attribute Code** | alphanumeric identifier for an Attribute Type<br>[SOURCE: ISO 20524-1:2020, 3.4.3] | | This is an alias for attribute name. ISO 19110 defines aliases for feature types and attributes as part of its schema-describing types (by definition, these types are “metaclasses” and therefore consistent with an extension of ISO 19109). |
| **Attribute Name** | name associated to an Attribute Type<br>[SOURCE: ISO 20524-1:2020, 3.4.4] | | ISO/TC 211 uses the UML naming logic, with which this is consistent. There is some ambiguity between this term and attribute type. In UML, reuse of the type does not require reuse of the name. This is also the case in ISO/TC 204, but the phrasing of this definition leaves some ambiguity. The interpretation here is that the name is in the local namespace of the containing type, and the definition applies only within this namespace. This is consistent with the usual programming language scoping logic and is therefore common engineering practice. |
| **Attribute Type** | defined characteristic of a Feature, which is independent of the other Features<br>[SOURCE: ISO 20524-1:2020, 3.4.5] | | attribute <UML> feature within a classifier that describes a range of values that instances of the classifier may hold<br>[SOURCE: ISO 19150-2:2015, 4.1.7] |
| **Attribute Value** | specific quality or quantity assigned to an Attribute<br>[SOURCE: ISO 20524-1:2020, 3.4.6] | . | ISO/TC 211 uses the UML concept, which is logically equivalent. |

**Table A.1** *(continued)*

| Term | ISO/TC 204 GDF term definition | ISO/TC 211 term definition | Comment |
|---|---|---|---|
| **Feature** | database representation of a real-world object<br>[SOURCE: ISO 20524-1:2020, 3.4.9] | abstraction of real world phenomena<br>Note 1 to entry: A feature can occur as a type or an instance. Feature type or feature instance will be used when only one is meant.<br>[SOURCE: ISO 19101-1:2014, 4.1.11] | The choice of what is and what is not a feature is essentially an application schema issue as defined by ISO 19109. |
| **simple feature** | Feature which is defined with basic building blocks (geometry)<br>NOTE Specified in ISO 20524-1:2020, 6.3.1 | feature restricted to 2D geometry with linear interpolation between vertices, having both spatial and non spatial attributes<br>[SOURCE: ISO 19125-1:2004, 4.18] | These are all specializations of ISO/TC 211 features. This is an application schema profile. It is similar to the profile for MiniTopo presented in ISO 19107. MiniTopo was defined in 1984 and documented a common cartographic practice of classification of features by their symbology type. Features with mixed symbol types on a single map were considered to be aggregates of simpler pure-components and hence "complex features". This hierarchical pattern for feature, feature components and complex features has been used in MC&G, DIGEST and many other standards since MiniTopo's definition. |
| **point** | zero-dimensional element that specifies geometric location specified by one coordinate pair or triplet<br>[SOURCE: ISO 20524-1:2020, 3.2.12] | 0-dimensional geometric primitive, representing a position<br>Note 1 to entry: The boundary of a point is the empty set.<br>[SOURCE: ISO 19136-1:2020, 3.1.47]<br>Also see ISO 19136-1:2020, Annex D. | These are all specializations of ISO/TC 211 features. This is an application schema profile. It is similar to the profile for MiniTopo presented in ISO 19107. MiniTopo was defined in 1984 and documented a common cartographic practice of classification of features by their symbology type. Features with mixed symbol types on a single map were considered to be aggregates of simpler pure-components and hence "complex features". This hierarchical pattern for feature, feature components and complex features has been used in MC&G, DIGEST and many other standards since MiniTopo's definition.<br>Retired in ISO 19107:2019. the new authoritative source is ISO 19136-1:2020. |
| **Line Feature** | one-dimensional Feature defined as a sequence of one or more Edges<br>[SOURCE: ISO 20524-1:2020, 3.2.8] | **line string**<br>curve composed of straight-line segments<br>[SOURCE: ISO 19136-1:2020, 3.1.40] | These are all specializations of ISO/TC 211 features. This is an application schema profile. It is similar to the profile for MiniTopo presented in ISO 19107. MiniTopo was defined in 1984 and documented a common cartographic practice of classification of features by their symbology type. Features with mixed symbol types on a single map were considered to be aggregates of simpler pure-components and hence "complex features". This hierarchical pattern for feature, feature components and complex features has been used in MC&G, DIGEST and many other standards since MiniTopo's definition. |

**Table A.1** *(continued)*

| Term | ISO/TC 204 GDF term definition | ISO/TC 211 term definition | Comment |
|---|---|---|---|
| **Area Feature** | two-dimensional Feature defined by one or more Faces<br>[SOURCE: ISO 20524-1:2020, 3.2.1] | **polygon**<br>planar surface defined by 1 exterior boundary and 0 or more interior boundaries<br>[SOURCE: ISO 19136-1:2020, 3.1.48] | These are all specializations of ISO/TC 211 features. This is an application schema profile. It is similar to the profile for MiniTopo presented in ISO 19107. MiniTopo was defined in 1984 and documented a common cartographic practice of classification of features by their symbology type. Features with mixed symbol types on a single map were considered to be aggregates of simpler pure-components and hence “complex features”. This hierarchical pattern for feature, feature components and complex features has been used in MC&G, DIGEST and many other standards since MiniTopo's definition. |
| **complex feature** | aggregation of Features (simple and/or complex)<br>NOTE Specified in ISO 20524-1:2020, 5.2.1. | **complex feature**<br>feature composed of other features<br>SOURCE: ISO 19109:2015, 4.3 | These are all specializations of ISO/TC 211 features. This is an application schema profile. It is similar to the profile for MiniTopo presented in ISO 19107. MiniTopo was defined in 1984 and documented a common cartographic practice of classification of features by their symbology type. Features with mixed symbol types on a single map were considered to be aggregates of simpler pure-components and hence “complex features”. This hierarchical pattern for feature, feature components and complex features has been used in MC&G, DIGEST and many other standards since MiniTopo's definition. |
| **record** | **data record:** record containing Feature-related data<br>[SOURCE: ISO 20524-1:2020, 3.1.3]<br>**global record:**<br>record that logically precedes the data records and contains control parameters, data definition and documentation necessary to interpret companion data records<br>[SOURCE: ISO 20524-1:2020, 3.1.4] | **record**<br>finite, named collection of related items (objects or values)<br>[SOURCE: ISO 19101-2:2018, 3.32,<br>retired in ISO 19107:2019] | Record is defined in various equivalent forms in ISO 19103 and in ISO/IEC 11404. ISO/TC 204's definition uses a common metaphor that associates a data field (a place) with its content (the thing that occupies that place). While not precisely accurate in a semantical sense, the meaning is so seldom misinterpreted, that it stands the test for a valid definition: low probability of misinterpretation. |
| **Relationship, Semantic Relationship** | characteristic of a feature involving other features<br>[SOURCE: ISO 20524-1:2020, 3.4.23] | **feature association**<br>relationship that links instances of one feature type with instances of the same or a different feature type<br>[SOURCE: ISO 19110:2016, 3.3] | The use of association instead of relationship is from UML. The intent of these is the same. |

**Table A.1** *(continued)*

| Term | ISO/TC 204 GDF term definition | ISO/TC 211 term definition | Comment |
|---|---|---|---|
| **Relationship Code** | alphanumerical identifier for a Relationship<br>[SOURCE: ISO 20524-1:2020, 3.4.20] | code used as alias as defined for application schemas in ISO 19110. | Same issue as with attributes. The UML definitions are used in ISO/TC 211 and are consistent with the intent and with the usage in ISO/TC 204. ISO 19110 validates the practice of the use of aliases for names. |
| **Relationship name** | name associated with a Relationship Type<br>[SOURCE: ISO 20524-1:2020, 3.4.21] | | Same issue as with attributes. The UML definitions are used in ISO/TC 211 and are consistent with the intent and with the usage in ISO/TC 204. ISO 19110 validates the practice of the use of aliases for names. |
| **Relationship Type** | defined characteristic of a Feature which is dependent on other Features<br>[SOURCE: ISO 20524-1:2020, 3.4.22] | | Same issue as with attributes. The UML definitions are used in ISO/TC 211 and are consistent with the intent and with the usage in ISO/TC 204. ISO 19110 validates the practice of the use of aliases for names.<br>In UML, the type of a relationship refers to the target types of the associations roles. |
| **Section** | spatial subset of a Dataset<br>[SOURCE: ISO 20524-1:2020, 3.4.24] | | These are organizational primitives and have no direct counterpart in ISO/TC 211. "Layer" is often used as a portrayal unit, where the information content criterion is one that controls symbolization choices or priority, but that is at a different level from the ISO/TC 211 standards in question here. "Section" is similar to a database partition. The usual implication in geographic information is that a partition is spatial, but this is not always the case, as partitions can be made on any criteria, including "layer." |
| **Layer** | certain subset of a Dataset based upon information contents<br>[SOURCE: ISO 20524-1:2020, 3.4.16] | | These are organizational primitives and have no direct counterpart in ISO/TC 211. "Layer" is often used as a portrayal unit, where the information content criterion is one that controls symbolization choices or priority, but that is at a different level from the ISO/TC 211 standards in question here. "Section" is similar to a database partition. The usual implication in geographic information is that a partition is spatial, but this is not always the case, as partitions can be made on any criteria, including "layer." |

**Table A.2 — Mathematical terminology**

| Term | ISO/TC 204 GDF term definition | ISO/TC 211 term definition | Comment |
|---|---|---|---|
| **graph** | set of points and a set of arrows, with each arrow joining one point to another, whereby the points are called Nodes of the graph, and the arrows are called the Edges of the graph<br>[SOURCE: ISO 20524-1:2020, 3.2.6] | set of nodes, some of which are joined by edges<br>[SOURCE: ISO 19107:2003<br>Retired in ISO 19107:2019]<br>No other ISO/TC 211 standard using this term. | The definition in ISO/TC 204 is a fairly modern rendition of the definition of a graph. The definitions in ISO/TC 211 (including edge, and node) are a reflection of the original definitions used in the mathematical community universally until the new definitions were introduced in the late 1980s. The purpose for the introduction was to allow for the use of graphs in a very abstract “category theory.” The linguistic issues are of little importance in geographic information, so the utility of the two forms of the definitions are equal. |
| **graph, connectivity** (Transportation Network) | An abstraction (model) of a real-world transportation network that includes navigation-significant topology but not shape. The graph consists of nodes and links. Nodes are connected by directed links and located where transportation elements intersect.<br>NOTE Defined in ISO 20524-1:2020, 8.2.11.1 as follows:<br>Representation of connectivity between lanes across junctions are based on a directed Manoeuvre of the incoming (“From”) Road Element, a Junction to indicate the direction, optional intermediate (“via”) Road Element(s), and the outgoing (“To”) Road Element. | | While not overtly stated in ISO 19133, this is the intent of the use of graph topology in this International Standard. ISO/TC 204 makes this and necessary assumptions in ISO 19133 more inherently explicit. |
| **generalization level** | NOTE Generalization level was a defined term in earlier versions of GDF, but is not expressed as a defined term in ISO 20524-1:2020.<br>Previously its definition was: A subset of features and variable precision often used to represent the real world at different map scales. | | This is common cartographic usage, and while not explicit in ISO/TC 211 standards, is part of the assumed background of the reader.<br>There is an avoidance of tutorial content in the ISO/TC 211 standards, based on the need to make what are naturally verbose standards as concise as possible. |

**Table A.2** *(continued)*

| Term | ISO/TC 204 GDF term definition | ISO/TC 211 term definition | Comment |
|---|---|---|---|
| **geometry** | NOTE geometry was a defined term in earlier versions of GDF, but is not expressed as a defined term in ISO 20524-1:2020.<br>Previously its definition was: Science of the characteristics of spatial figures. | | This difference in view is again based on a metaphor. In this case, the name of the science of spatial figures is used to name the fundamental objects used in that science.<br>Class of object that describes the location, shape or extent of a geographic feature. Various types of geometric classes (each of which is a geometry) are described in the GML 3.0 geometry schemas. |
| **topology** | field of mathematics that deals with characteristics of geometric structures that are preserved after continual variation<br>[SOURCE: ISO 20524-1:2020, 3.1.11] | | This is close to the classical definition of topology. Again, the above metaphor is used. In a strict sense, topology is the study of the characteristics of spatial figures that are preserved under continuous transformation. The metaphorical use of the name of the study to name the objects is apparent. |

**Table A.2** *(continued)*

| Term | ISO/TC 204 GDF term definition | ISO/TC 211 term definition | Comment |
|---|---|---|---|
| **precision** | NOTE Precision was a defined term in earlier versions of GDF, but is not expressed as a defined term in ISO 20524-1:2020.<br><br>Previously its definition was: The closeness of measurements of the same phenomenon repeated under exactly the same conditions and using the same techniques. | **measurement precision**<br><br>**precision**<br><br>closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions<br><br>Note 1 to entry: Measurement precision is usually expressed numerically by measures of imprecision, such as standard deviation, variance, or coefficient of variation under the specified conditions of measurement.<br><br>Note 2 to entry: The 'specified conditions' can be, for example, repeatability conditions of measurement, intermediate precision conditions of measurement, or reproducibility conditions of measurement (see ISO 5725-3:1994).<br><br>Note 3 to entry: Measurement precision is used to define measurement repeatability, intermediate measurement precision, and measurement reproducibility.<br><br>Note 4 to entry: Sometimes 'measurement precision' is erroneously used to mean measurement accuracy.<br><br>[SOURCE: ISO/IEC Guide 99:2007, 2.15] | These definitions are simple recasts of one another. |

**Table A.2** *(continued)*

| Term | ISO/TC 204 GDF term definition | ISO/TC 211 term definition | Comment |
|---|---|---|---|
| **resolution** | NOTE Resolution was a defined term in earlier versions of GDF, but is not expressed as a defined term in ISO 20524-1:2020.<br>Previously its definition was: The smallest unit that can be detected. It fixes a limit to precision and accuracy. | **resolution (of a coordinate)**<br>unit associated with the least significant digit of a coordinate<br>Note 1 to entry: Coordinate resolution may have linear or angular units depending on the characteristics of the coordinate system.<br>[SOURCE: ISO 6709:2008, 4.10] | The ISO/TC 204 definition is more general. The ISO/TC 211 definition was cast in the context of geographic raster data and is the appropriate restrictive definition in that field. In a more general context, the ISO/TC 204 usage is recognized as the usual and customary meaning of “resolution.” |