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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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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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].

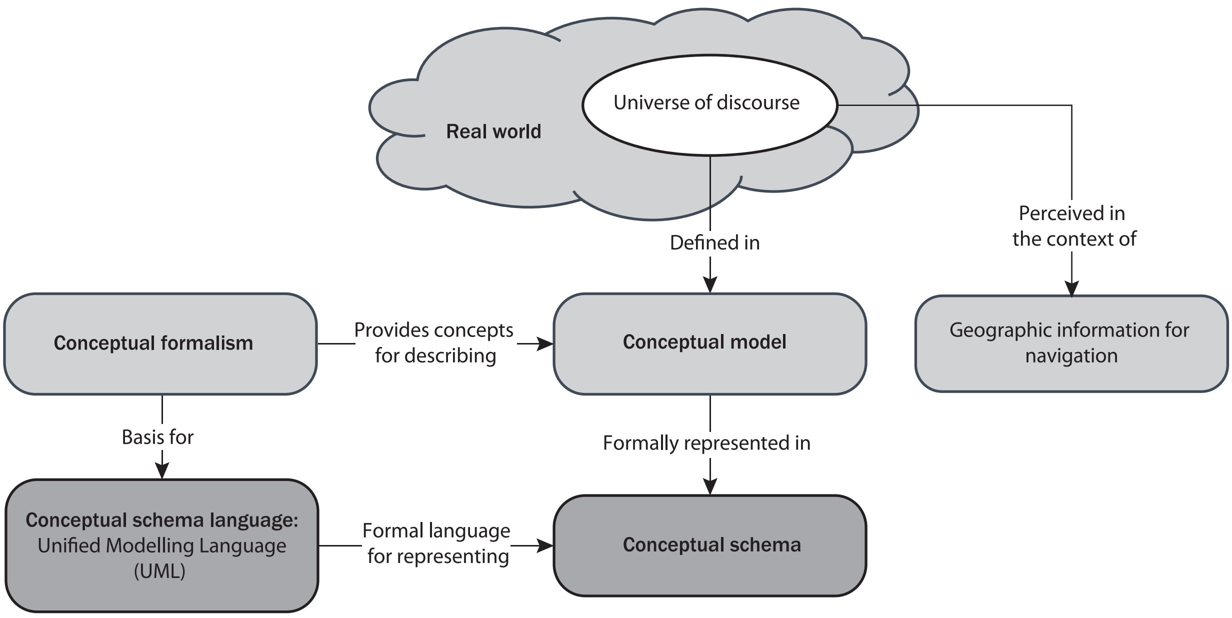

Figure 1 — Information modelling (adapted from ISO 19103)

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.

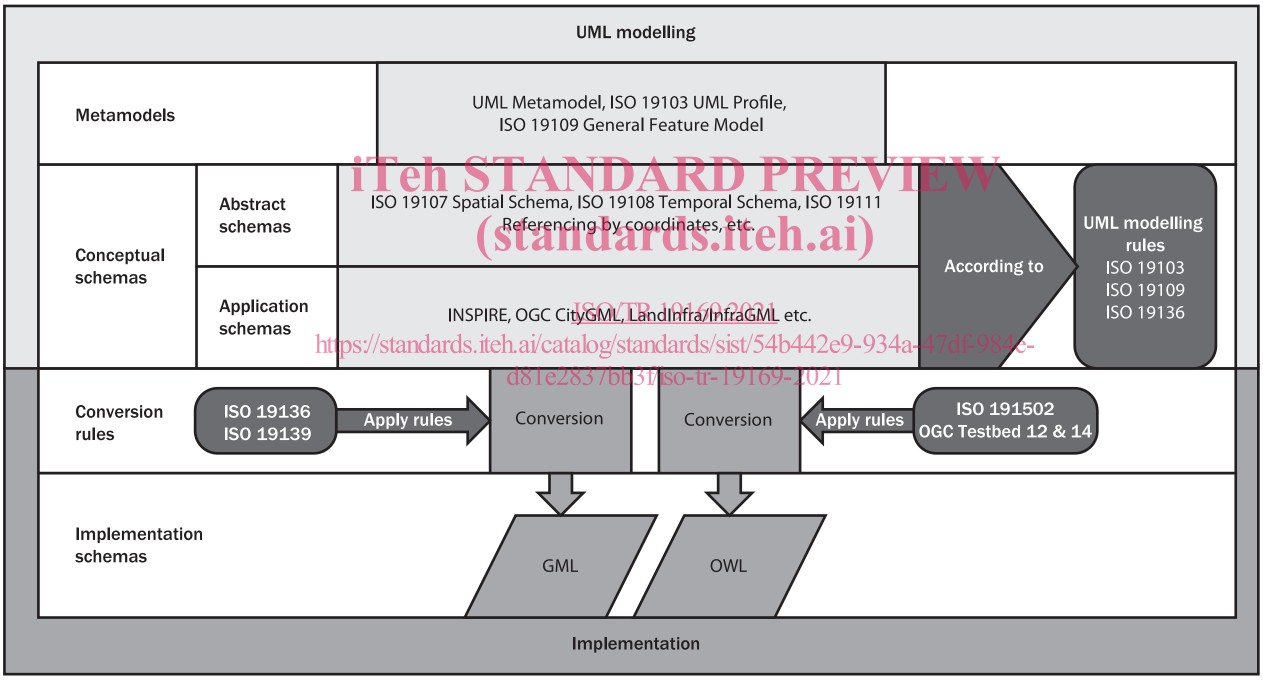

Figure 2 — Model Driven Architecture (MDA) as defined in ISO 19103 (adapted from Reference [12])

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.

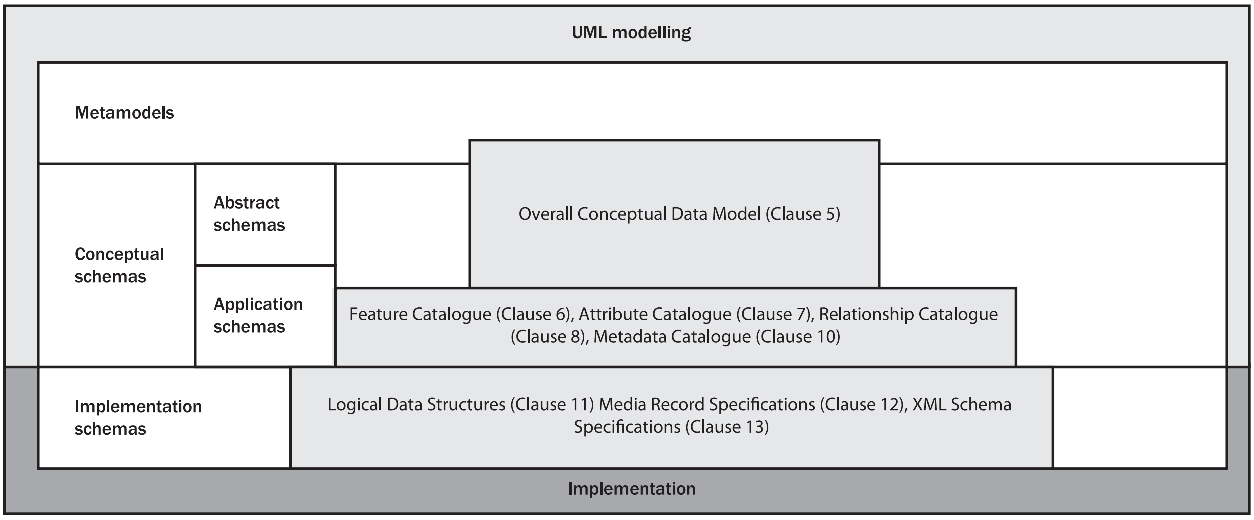

Figure 3 — Suggested mapping of GDF clauses to ISO 19103 MDA structure

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.

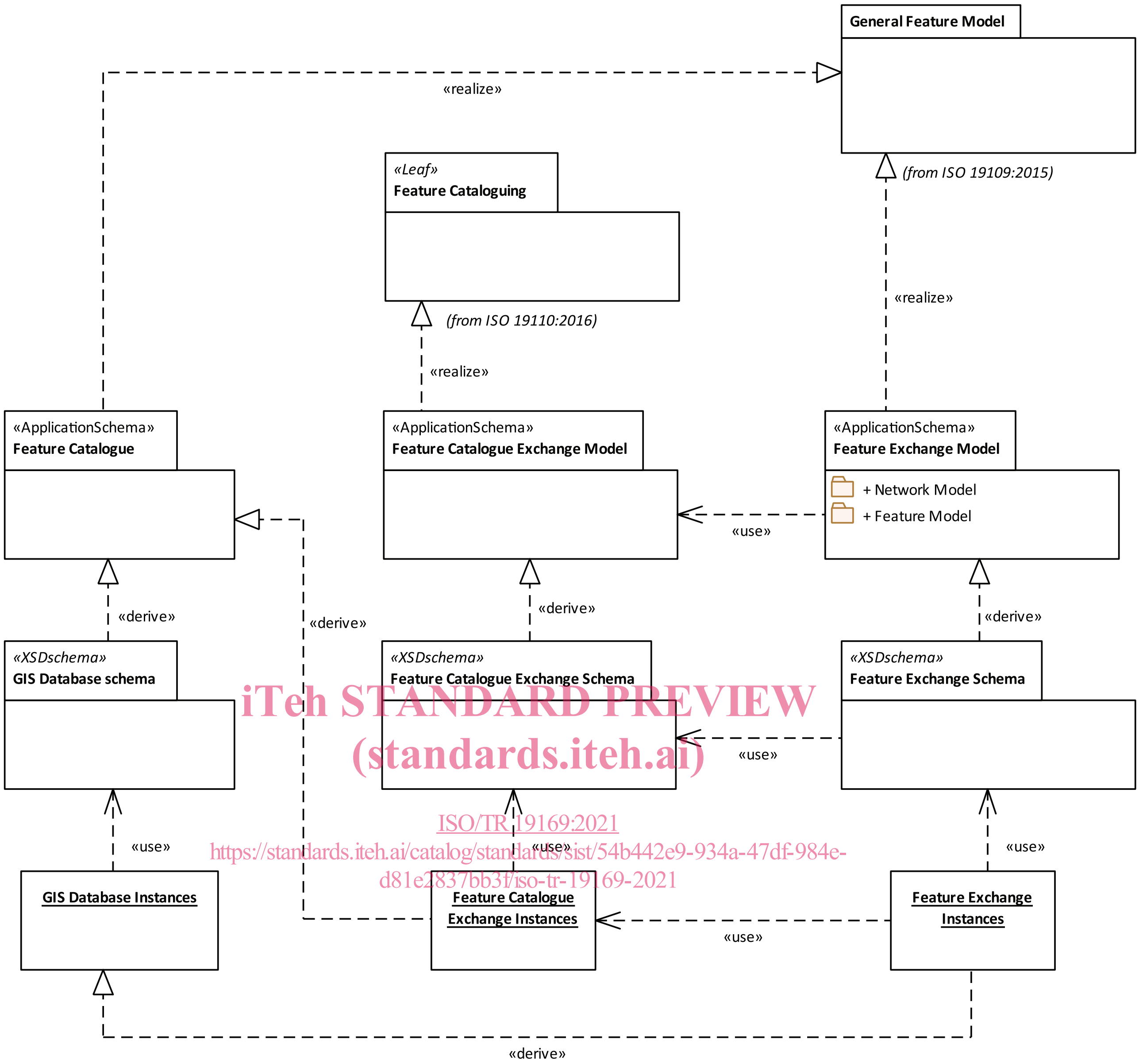

Figure 4 — Suggested modularization of GDF (adapted from Reference [14])

