TECHNICAL REPORT

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Intelligent transport systems — Systems architecture — Harmonization of ITS data concepts

Systèmes intelligents de transport — Architecture des systèmes — Harmonisation des concepts de données SIT

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Foreword

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In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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ISO/TR 25100 was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems*.

Introduction

The objective of this Technical Report is to provide user guidance for the harmonization of data concepts where there are similarities in definitions, including semantics.

Harmonization has been discussed by several groups and there has already emerged some preliminary guidance and principles for the effective harmonization of data concepts for intelligent transport systems [ITS].

It should be clearly recognized that harmonization is not essential for interoperability, which can usually be achieved given sufficient investment of knowledge and resources. Nevertheless, this generally leads to duplication and other unnecessary, even futile work being undertaken. This also assumes that there are unlimited resources available to achieve the desired interoperability, whereas, in practice, time, budget and shortage of skilled personnel often cause compromise. Additionally, interoperability in one aspect is sometimes achieved by the lack or loss of interoperability in another. Harmonization is intended to reduce the inconsequential work, increase efficiency and thereby reduce the incidence of errors and faults.

This Technical Report describes a proposed process for harmonization of data concepts to arrive at preferred definitions for use in formal standards, specifications, technical reports and information architecture (data) models. The proposal is based on consideration of the harmonization process used by three international groups involved in transport and logistics information and control systems.

Harmonization provides a means by which to improve efficiency and effectiveness of ITS, by helping to remove duplication, inefficiency, ambiguity and confusion, and thereby improve clarity, comprehension, safety and efficiency.

Intelligent transport systems — Systems architecture — Harmonization of ITS data concepts

1 Scope

The scope of this Technical Report is the harmonization of data concepts that are being managed by data registries and data dictionaries such as those described in ISO 14817:2002.

2 Terms and definitions

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

core component
aggregate information entities and the embedded entities within them

data concept
data dictionary structures defined in this Technical Report (i.e. object class, property, value domain, data element concept, data element, data frame, message, interface dialogue, association) referring to abstractions or things in the natural world that can be identified with explicit boundaries and meaning and whose properties and behaviour all follow the same rules

harmonization
process to resolve differences in synonymous terminology when expressed precisely in syntactic form

3 Abbreviated terms

ACC	aggregate core components
CEFACT	United Nations Centre for Trade Facilitation and Electronic Business
CCC	change control committee
CCTS	core components technical specification
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
ITS	intelligent transport systems
TBG17	UN/CEFACT Trade and Business Processes Group working group 17
TC	technical committee
TICS	transport information and control system
TIH	transport information highway (UK)
UML	unified modeling language
UN	United Nations

UTC coordinated universal time

WD working draft

WG working group

4 Background issues

Development of information systems and networks supporting business processes for transport and logistics frequently encounters multiple similar data concepts, any or all of which may be in widespread use. The need for harmonization of these synonymous concepts has been acknowledged to enhance interoperability and reusability, but there are significant issues to be overcome.

Current approaches to achieve the data interoperability are principally to write ad-hoc data interface programs for each pair of communicating systems. Experience shows that development and maintenance of these programs is expensive in terms of both time and money. If you consider this problem and its cost implications further, it can be seen that the total effort required increases with the square of the number of communicating systems.

4.1 Proprietary data concepts

The first issue is that many data concepts are proprietary or are deeply embedded in proprietary systems, which work well within their intended domain but are not freely accessible for broader use. There is an opportunity cost for a system whenever there is a similar but nevertheless separately defined and implemented concept in use in another domain that is not applied to the subject system.

4.2 Semantic differences

A second issue is where the concepts are subjects of widely used standards, but are not identical and have subtle semantic differences in their use. In this case, the standards development organizations (SDO) have generally been protective of their own approaches out of concern about the cost of enforced changes to already deployed systems. This has resulted in diminished success in harmonization processes (in the USA for example).

Semantic clashes are clashes between concepts of different standards, or more precisely, between specific conceptual models or ontologies behind different standards. Typical semantic clashes are completely different concepts, different naming of concepts or different granularity.

4.3 Structural differences

Structural clashes are caused by the heterogeneity of representation which is possible with many techniques, such as XML representation. For example, using XML format the same concept can be expressed in several different ways.

(ISO 24531, *Intelligent transport systems — System architecture, taxonomy and terminology — Using XML in ITS standards, data registries and data dictionaries, provides assistance in these respects for the use of XML in the ITS sector.*)

XML schema enables constraining of XML documents, but this was designed for constraining the content of XML documents, not the conceptual representation. Within XML, structural clashes are mainly caused by the different usage of specific constructs, for example a different usage of attributes, rather than embedded elements, or by expressing concepts in enumeration values.

Usually freely designed XML documents used for specific application purposes do not provide sufficient information about the semantics of the data. The semantics of XML elements used by web applications is hard-coded into the applications and is typically not available in machine processable form. This applies also to documents with available structural schemata (XML schema), which in the most cases define the syntactical structure of XML documents without unified implicit representation of their meaning.

Other forms of representation, with the possible exception of ASN.1, allow similar clashes to exist.

4.4 Difficulty of application of existing data concepts

A further issue is that there is the requirement in addressing a new application domain to reuse concepts that already exist as proprietary or open standards but for which the mechanism to render them usable is unclear. This generally results from semantical differences or uncertainty in the application of the concept, or because significant domain knowledge is required for the successful reuse of a data concept from a different domain.

4.5 Report of investigation

Harmonization is often touted as the means to resolve these issues, but has been much more difficult to achieve than expected. This Technical Report is based on an on-going investigation being carried out on behalf of ISO/TC 204/WG 1 [*Intelligent transport systems, Architecture*] into various approaches used for harmonization. This Technical Report presents tentative conclusions regarding the effectiveness of the approaches for general use in intelligent transport systems, and the wider sector of transport and logistics.

5 Harmonization — General discussion

5.1 Introduction to harmonization

Harmonization is a process to resolve differences in synonymous terminology when expressed precisely in syntactic form. However, successful achievement of the harmonization process remains a problem in many areas. Members of ISO/TC 204/WG 1 have been considering this matter for some time and propose solutions to the requirement for effective harmonization at syntactic, relationship and semantic levels. These solutions are provided in this Technical Report for harmonization.

Progress in this respect has also been achieved in the United Nations office for trade facilitation and electronic business (UN/CEFACT) by the Trade and Business processes working group (TBG), specifically TBG17, as discussed below.

5.2 Illustration of the need for harmonization

It is helpful to consider the nature of the problem to be resolved. Take for example the need for integrated use of travel information in an advanced national traveller information service (NTIS). One class of information for the traveller information system will be timetables for various travel services. To take an example from Australia where two timetables are to be merged but the times of service departure are expressed differently:

— Travel service A departure time format: local time in New South Wales (time zone UTC+10 h or UTC+11 h), 12-hour clock, subject to daylight savings time (Concept A).

— Travel service B departure time format: 24-hour clock based on Western Australia (time zone UTC+8 h) and not subject to daylight saving time (Concept B).

Of course, if the travel service were totally local, and travellers had no mobility, the only criteria would be local custom. However, as the object of travel is mobility, we may expect a traveller to move from one locality to another, or a travel provider to be providing travel information to traveller information systems elsewhere, or, in these days of Internet, we may expect direct enquiries from elsewhere. There is, therefore, a significant benefit to be gained from harmonization. It will be apparent that there is a need for a series of conversions and business rules to be applied to arrive at a compatible format, which could be in either of the proponent formats. Alternatively, a third (preferred) option could be the use of a standard time such as UTC (Concept P) with the conversion to the time format as preferred by the person making the enquiry (query) to be made at the time of a query.

A second example can be taken from a European project (Harmonise) for the Conceptual Normalization of XML Data for Interoperability in Tourism. This project studies problems in using XML data in the tourist industry and, while much of its harmonization resolution is very specific to XML, it provides a methodology that in process (if not in detail) is similar to that proposed in this Technical Report, and provides some good examples of the problems involved. These are shown clearly in Table 1 and Table 2.

Table 1 — Sample of semantic clashes

Different naming	PostCode vs. PostalCode
Different position	Postcode in Address rather than in ContactInfo
Different scope	TelephonePrefix and TelephoneNumber separated vs. PrefixTelephoneNumber as a single concept

The example in Table 2 shows three technically correct, according to the standards, but different ways of expressing the concept *PostalCode* in XML.

Table 2 — Structural heterogeneity of XML

<ContactInformation> <Address **PostalCode="X-1220"**> Wannaby Street 59, Dreamtown</Address> </ContactInformation>
<ContactInformation> <Address> <Street>Wannaby Street 59</Street> <City>Dreamtown</City> **<PostalCode>X-1220</PostalCode>** </Address> </ContactInformation>
<ContactInformation> <Address> Wannaby Street 59, **<PostalCode>X-1220</PostalCode>** Dreamtown </Address> </ContactInformation>

Harmonization has thus to deal with issues at a semantic level, at a structural level, and at a content level.

5.3 Harmonization scenarios in data modelling terms

The essential process of harmonization is to resolve the differences between two or more data concepts in an agreed manner that has wider usage than merely the original data concepts. In simple terms this is shown in Figure 1:

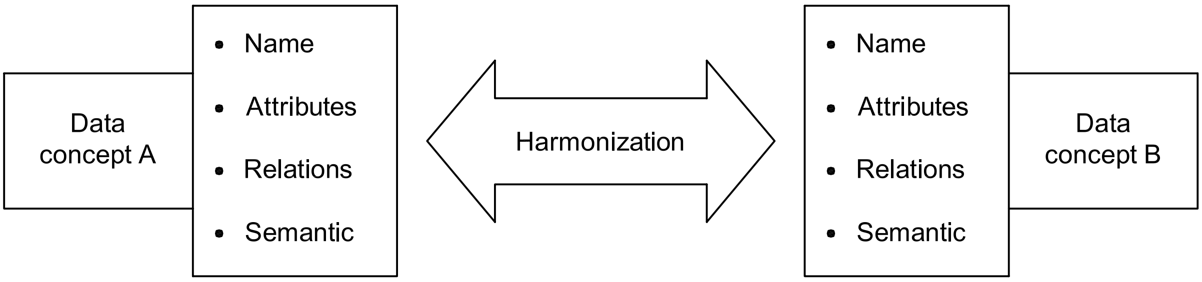

Figure 1 — Simple illustration of harmonization

Harmonization can then be defined as follows:

> For any pair of data concepts (*A*,*B*) harmonization is the selection of preferred concept *P* based on the attributes, relationships and semantics for individual data concepts *A* and *B*
>
> $P = h(A,B)$ where *h* is the harmonization preference function.

For the example above, the following scenarios apply to the harmonization function *h*.

5.3.1 Scenario 1: *h*{ [name(A)], [name(B)] } ⇒ name(P)

Harmonization shall generate a preferred name for the preferred data concept.

However, in generating the 'name' a process of 'conceptual normalization' (source: 'Harmonise' project) is an intrinsic part of this first part of the harmonization process.

By first agreeing a preferred name, an agreed basis for the object of the data concept is agreed at a highly abstracted level, without getting concerned at this early stage with the structure of the concept.

The separation between semantic and structural clashes indicates the need for a distinction between corresponding steps in the overall transformation process. This step enables a separation of semantic mapping (resolution of the semantic clashes) from the concrete physical representation of data being transformed. If different physical representations are used in the future, the semantic mapping definitions will still remain valid.

NOTE Whereas project 'Harmonise' only dealt with XML schema and proposed taking the conceptual normalization not only to include the name but also to 'provide a unified human and machine understandable description of the concepts of local systems and relations among them', both human and machine understandable description are only possible where there is a high degree of consensus concerning the form of the data concept (i.e. in the project 'Hamonise' context it is already a precondition that it is an XML schema) prior to commencement of the harmonization process. The process recommended in this deliverable takes a more pragmatic approach, and one that, the authors believe will overcome some of the potential weaknesses in agreeing schemata too early at a conceptual level.

5.3.2 Scenario 2: *h*{ [attribute_n(A)], [attribute_n(B)] } ⇒ attribute_n(P)

Each attribute of concept A shall be harmonized with each corresponding attribute of concept B to produce a corresponding attribute of preferred concept P.

Where the complexity of the semantical use of the attribute precludes direct harmonization, each attribute shall be expanded to a new data concept and the harmonization function applied iteratively until resolved (as discussed below).

5.3.3 Scenario 3: *h*[rel(A,X), rel(B,Y)] ⇒ rel(A,X), rel(B,X), rel(A,Y), rel(B,Y), rel(A,B)

Each relationship between the proponent concept and another concept shall be replicated for the other proponent concept. A relationship shall also be defined between the proponent concepts.

5.3.4 Scenario 4: *h*[semantics(A), semantics(B)] ⇒ (business rules for A, B, P)

The semantics of employment of the proponent concepts shall be encapsulated in business rules that include the semantics for the preferred concept also.

These scenarios may be described in a use-case template format as shown in Annex A (format source ISO/TR 25102).

5.4 Iterative harmonization process

Scenario 2 requires that attributes of the proponent data concepts (A,B) are harmonised to produce attributes of the preferred data concept P. This can also be considered as an iterative process as shown in Figure 2.

In this iterative process, existence of recommended data concepts is very important. They are referred, reused, and preferred in the ITS community which contributes to harmonization.

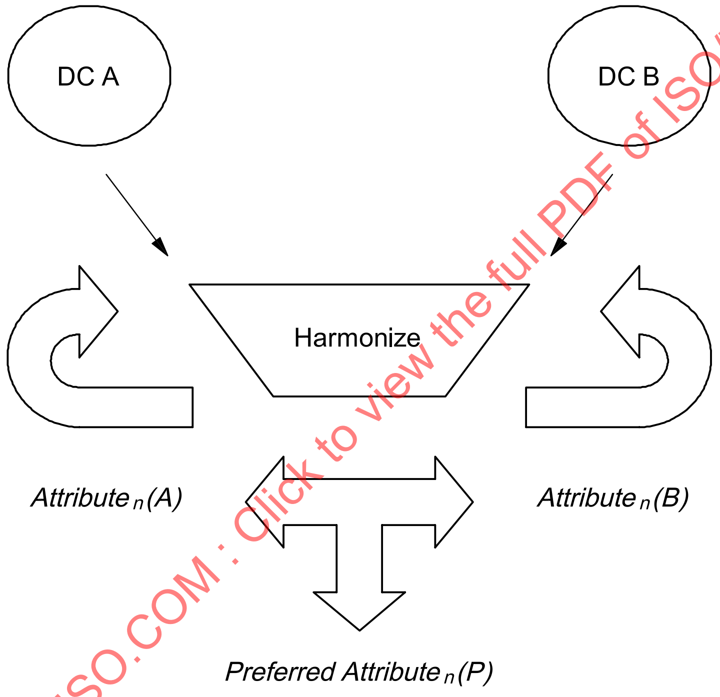

Figure 2 — Iterative harmonization of attributes

6 Current approaches to harmonization in ITS International Standards

6.1 Three approaches

The three approaches to harmonization in the ITS sector discovered in our investigation are described in 6.1.1 to 6.1.3 below.

6.1.1 ISO 14817 approach

The approach developed by ISO/TC 204/WG 1 is described in ISO 14817, *Transport information and control systems — Requirements for an ITS/TICS central Data Registry and ITS/TICS Data Dictionaries*.

6.1.2 UN/CEFACT TBG17 approach

This is the approach developed within UN/CEFACT TBG17 as described in TBG17 (2004).

6.1.3 TIH approach

This is the approach taken by working group WG3 of the Transport Information Highway community in the UK.

The three approaches have been investigated to validate the proposed harmonization approach described in this document.

6.2 ISO 14817 harmonization

ISO 14817:2002, describes its harmonization process in Clause A.6, ITS/TICS data harmonization and reuse procedures, of Annex A, ITS/TICS functional operating procedures (for the ITS data registry and data dictionaries).

ISO 14817:2002, A.6.1, Introduction, states "These procedures detail how the 'Change Control Committee' [CCC] and the 'Stewards' execute their responsibilities… regarding identification, reconciliation and documentation of data concept overlaps and duplications…". See Annex B.

ISO 14817:2002, Annex A describes a ten-step process for identification and resolution of issues in overlapping or redundant data concepts arising from analysis of data element names, definitions, common property/object/representation terms and common or similar value domains.

A first stage of analysis is to understand the respective semantics of competing data concepts. If the semantics are different then both concepts should be retained separately.

If the semantics are equivalent then the change control committee and the stewards may decide to use one of them in preference to the other, or to modify one of them for use, to agree on a new concept that replaces both of those under consideration.

ISO 14817:2002, Annex A states that a harmonization listing will be distributed to the members of the change control committee for consideration.

6.3 TBG17 business process & core components

6.3.1 Harmonization team submission guidelines and procedures

The following excerpts provide a summary view of the harmonization processes in use by UN/CEFACT.

'This document describes the process by which business domain groups can ensure the common taxonomy used in one business domain can be interoperable.' [TBG17 (2004) p. 6]

'The Core Components [CC] User Community… requires interoperability of business information. This interoperability covers both interactive and batch exchanges of business data between applications through the use of Internet and Web based information exchanges as well as traditional Electronic Data Interchange (EDI) systems.' (ibid)

'This document will detail each of the steps necessary for a valid submission to the *Harmonization Group*.' [TBG17 (2004) p. 7]

'During its harmonization work TBG17 realised that there is a need for a further clarification of… relationships (between CCTS (CC Technical Specification) object types) and for a description of how to express them using UML.' [TBG17 (2004) p. 12]

'Harmonization should ensure that a single semantic concept is captured in one and only one Core Component structure. This may conflict with different views on that concept in different contexts and it conflicts with the emergence of new submissions.' [TBG17 (2004) p. 20]

'If it is agreed, that there is a need to have two or more core component structures for the same semantic concept, then the core components library administration has to make sure that they refer to each other in order to guarantee that any further development will be a consistent one.' [TBG17 (2004), Clause 4.6.5, p. 20]

TBG17 (2004), Clause 4.6.5, Derived Core Components, provides a helpful diagrammatic explanation of referencing between competing data structures, and several textual examples. From these it draws important conclusions:

'These examples demonstrate that, if all user structures are supported in the library, uniqueness becomes a problem.'

'Flattened data structures can reference to complex data structures without many problems… reference from complex to flat structures would usually not be possible without loss of semantics. This means that the Core Components library… should always be the most complex structure…' [TBG17 (2004), p. 22]

'While inserting the various submitted user structures in the library, in order to avoid redundancy, the simpler core components structures should reference the more complex structures that contain the same semantic concept. This allows the users to keep their (more flattened) models and messages that reference the (more complex) structures in the… library.' (ibid)

'The harmonization team will use the UML concept of "Derived Classes" and "Derived Attributes" for the purpose of referencing by defining "Derived Core Components". The "Attribute"… that has become obsolete is not removed from the library, but is flagged… and an… expression is attached that points to the new structure…' (ibid)

6.3.2 TBG17 submission assessment checklist

The TBG17 'Submission Assessment Checklist' [TBG17 (2004)] supports the assessment of submissions of submitted 'Aggregate Core Components' (ACC) in three steps:

— check submission for completeness;

— check submission for consistency and clarity;

— harmonise submission with existing library.

These excerpts provide greater detail than in ISO 14817 but unfortunately appear to rely on work processes that still retain some ambiguity and subjectivity.

6.4 UK Highways Agency, Transport Information Highway (TIH) Metadata registry — Review guidelines

TIH WG3 report on their investigation of the UN/CEFACT approach for use in TIH in Mott MacDonald (2004a) and (2004b):

'The key idea that supports harmonization is the separation of "Core Components" [CC], which have no specific business context, from "Business Information Entities" [6].

'This separation of core components… does support the scenario… (with) similar but different classes… (and) to harmonise some but not all details of each class…' (ibid)

'ISO 14817 states no further specific quality requirements, other than naming convention (Annex D). ISO/IEC WD 11179-4 states sensible quality requirements to apply to atomic data definitions. For our purposes we introduce a modified set to suit different kinds of model elements. [9]'

With regard to harmonization activity ISO 14817:2002 says: 'We expect to introduce a rule requiring any overlap with other "Preferred" model elements to be fully justified using our adaptation of the Core Components approach.' (ibid)

Reference [7] also states a desire to mandate the use of metadata for relationships in data concepts (p. 5), which is assumed for this Technical Report.

7 Harmonization as a means to improve efficiency

In ISO/TC 204/WG 1's research of many initiatives around the world to tackle the problem of inconsistent data representation in order to develop this Technical Report, it was interesting to see that in almost all of the projects the resultant costs of inconsistent/incompatible data representation were considered so obvious that the benefits were assumed rather than clearly stated. And indeed they are very obvious and can be summarised in just a few points:

Inconsistent data definition (semantic difference in use of a name) causes data to be misinterpreted (with the consequent and potentially life threatening bad decisions taken on the basis of incorrect information).

Inconsistent data representation causes:

— data to be unusable (with the resultant costs for finding/capturing alternative data);

— data to be misinterpreted (with the consequent and potentially life threatening bad decisions taken on the basis of incorrect information);

— data to be reformatted where a conversion can be reliably made;

— lack of interoperability of data concepts;

— lack of mobility of data across services (and the consequent limitation in the potential provision of such services);

— (significant) duplication and repetition of the cost of developing and defining data concepts for the same semantic objective and also the consequent time delays incurred.

Harmonization provides a means to improve efficiency and effectiveness of ITS, by helping to remove duplication, inefficiency, ambiguity and confusion, and thereby improving clarity, comprehension, safety and efficiency. The net result of data harmonization can be summarised as follows:

— Services are delivered on time and as agreed.

— Data is communicated effectively (unambiguously) to the service.

— Data is unambiguously comprehensible to the receiver.

— Data may be available to other not directly related services to improve their performance, or indeed even enable them to occur at all.

— Data concepts can be stored and addressed using common data registries and data dictionaries.

— The costs and time delays incurred by the duplication of developing and defining multiple data concepts with the same semantic objective are avoided.

8 Conclusions

The business case value of the harmonization of data concepts rests on:

- the provision of services that are delivered on time and as agreed;
- the efficient and unambiguous communication of data;
- the provision of data that is unambiguously comprehensible to the receiver;
- the availability of data to other not directly related services to improve their performance, or indeed even enable them to occur at all;
- data concept storage and addressing using common data registries and data dictionaries; and
- avoidance of the costs and time delays incurred by the duplication of developing and defining multiple data concepts with the same semantic objective.

It is important to recognize that the harmonization process has to satisfy semantics as well as structure.

In respect of structure, simple rules, such as the ISO/TC 204 resolution (and subsequently the Technical Report, now draft International Standard ISO 14813-6) to record all standardized data using ASN.1 are of significant assistance. Such definition does not restrict services to using ASN.1, transfer, and enables for example the use of XML and its variants – and indeed any form of data concept – to be recorded and transferred, but consistent encapsulation of the data definitions in ASN.1 modules (not necessarily in their use and transfer) enables unambiguous comprehension of their definition in a system independent manner, hence interoperability.

However, harmonization of data concepts requires more than this. While the format of the representation may be consistent, as shown in 6.2 of this Technical Report, the structure and content of the data has to be harmonized. Before this can be achieved, the semantic objective of the data concept has to be agreed/harmonized. In straightforward terms, the harmonization process is as follows.

- First, agree the semantic meaning of the data concept that you intend to harmonize and give it a name.
- Second, agree the format(s) in which the data will be used (XML, EBXML, human readable, binary, etc.).
- Third, agree the form in which the data will be defined in standards, data registries and data dictionaries (normally ASN.1 data definition modules in respect of ISO/TC 204).
- Finally, agree the structure and content of the data concept.

This Technical Report proposes a simple but effective harmonization approach that comprises four scenarios addressing the data concept:

- names (and semantic meaning);
- attributes;
- relationships;
- semantics.

Bearing in mind that there is no comprehensive process definition for use with central data registries for ITS/TICS, this is currently left to the discretion of the registrar.

Developers of ISO, CEN and ETSI standards for ITS and registrars of ITS data registries and data dictionaries are recommended to consider using the 4-stage approach described in this Technical Report in order to harmonize data concepts. It is further suggested that the 'Use Case Template' recommended in ISO/TR 25102 will further assist in this process.

Annex A
(informative)

Harmonization “Use Case”

EXAMPLE:

USE CASE TEMPLATE / OUTLINE TABLE OF CONTENTS	
Use Case Name	Harmonize data concepts
"Use Case" Description	This use case describes the processes to be followed to achieve harmonization of two or more data concepts. Successful harmonization shall result in the specification of a preferred data concept based on the proponent data concept.
"Use Case" Scope	A proposed process for harmonization of such data concepts to arrive at preferred definitions for use in formal standards, specifications, technical reports and information architecture (data) models. The proposal is based on consideration of harmonization processes used by three international groups involved in the ITS sector and in the wider sector of transport and logistics information and control systems.
"Use Case" level	
Target System Release	
Generality/Abstraction level	
"Use Case" Author/Primary actor	Name: Christopher J Skinner Phone: +61 4 1499 0834 Email: cjskinner@acslink.net.au
"Use Case" Stakeholders	
"Use Case" Goal	
"Use Case" Requirements Reference	
"Use Case" Assumptions	
"Use Case" Technology Restrictions	
Relationships to other "Use Case(s)"	
Actors associated with this "Use Case"	Submitter Registrar
"Use Case" Triggers	A second data concept is submitted that is similar to a previously submitted data concept giving rise to the need for harmonization.
"Use Case" Pre-conditions	Two or more similar data concepts have been submitted for harmonization.
"Use Case" Scenario #Scenario.1	**Scenario 1: *h*{ [name(A)], [name(B)] } ® name(P)** Harmonization shall generate a preferred name for the preferred data concept. However, in generating the ‘name’ a process of ‘conceptual normalization’ (source: ‘Harmonise’ project) is an intrinsic part of this first part of the harmonization process. By first agreeing a preferred name, an agreed basis for the object of the data concept is agreed at a highly abstracted level, without getting concerned at this early stage with the structure of the concept.
"Use Case" Steps #Scenario 1. #Steps 1..N	STEPS AS NECESSARY TO COMPLETE SCENARIO #1
"Use Case" Scenario #Scenario.2	**Scenario 2: *h*{ [attributen(A)], [attributen(B)] } ® attributen(P)** Each attribute of concept A shall be harmonized with each corresponding attribute of concept B to produce a corresponding attribute of preferred concept P. Where the complexity of the semantical use of the attribute precludes direct harmonization, each attribute shall be expanded to a new data concept and the harmonization function applied iteratively until resolved.
"Use Case" Steps #Scenario 2. #Steps 1..N	STEPS AS NECESSARY TO COMPLETE SCENARIO #2

