Common Logical Data Model: Basis for Global ITS Innovation

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OVERVIEW

There are over 25 distinct groups developing open standards and specifications related to Intelligent Transportation Systems (ITS), ranging from internationally recognized standards groups such as the International Organization for Standardization (ISO) to national and regional standards groups such as the European Committee for Standardization (CEN) and informal groups that develop widely referenced specifications such as General Transit Feed Specification (GTFS). These distinct groups are made up of industry experts with common business interests in quickly developing documents; already, these groups have developed over 1,000 ITS standards, specifications and documents, and the number continues to grow. While some cross-pollination of innovative ideas occur, coordination among groups is challenging due to travel costs, copyright issues and the need for timely products versus the time required to build broad consensus. As a result, various groups often develop similar terms and data definitions that can lead to confusion when comparing materials from different sources. In some cases, these differences can potentially have safety implications. ISO/TC 204 (ISO Technical Committee 204) is beginning to address this issue through two work products, a vocabulary and a logical data model. These standards will facilitate the sharing of Probe Data to facilitate global interoperability of ITS. The vocabulary document, which includes a formal concept model, is currently under development on GitHub allowing input from industry experts worldwide. Furthermore, using an open GitHub environment allows this effort to more easily reflect the entire ITS community rather than just the perspectives of a group of experts within a standards development organization (SDO). The resulting, broadly-accepted concept model will then serve as a baseline for developing a more detailed logical data model which ISO/TC 204 hopes to develop in a similar manner while coordinating this development with even larger efforts related to Smart Cities and the Internet of Things (IoT). The result will be a model of ITS data with clear rules on translating data from one data format to any other data format through the common logical data model formats. The Industrial Internet Consortium (IIC) can proactively influence the work through liaised relations with ISO.

ITS – Enabler for the Future of Transportation

Since its inception, there have been continuous efforts to improve the safety, efficiency, sustainability and comfort of automobile travel. Initially, the improvements focused on vehicle occupants and primarily addressed safety, reliability and performance concerns.[1] Over the past forty years, the transportation industry has been revolutionized with the application of information technologies. Initially, these technologies were used largely to detect vehicles and provide better traffic management; but as the technologies evolved, so did their uses. Today, the application of information technologies to the surface transportation domain is an industry known as Intelligent Transport Systems (ITS) and includes a variety of applications including traveler information, navigation, traffic management, public transport management, emergency management and freight management. For over twenty-five years, ISO has been working with other standard development organizations (SDOs) to develop standards and technical reports to document best practices and promote interoperable systems that can facilitate ITS deployment activities and reduce costs to the public.[2]

In addition, new technologies continue to emerge. Over the past few years, the automotive industry has been introducing Advanced Driving Assist Systems (ADAS) into new vehicles; this technology uses a variety of sensors onboard the vehicle to help drivers to stay in the lane, maintain a safe distance with the vehicle ahead and avoid collisions with vehicles from the blind spot. Emerging technologies promise data sharing among vehicles and other roadway users and, eventually, to realize the full automation of vehicles. However, a key to enabling many of these advances is to ensure that applications have timely access to the necessary data to perform their services. To make sure that this occurs, we will need standards to define the data format and sharing of the data.

However, there remain challenges in achieving this goal. There are over 25 distinct groups developing open standards and specifications related to ITS, ranging from internationally recognized standards groups (i.e., ISO) to national and regional standards groups (i.e., CEN) and informal groups that

[1] "History of Automobiles", https://en.wikipedia.org/wiki/History_of_the_automobile

[2] ITS Standardization Activities of ISO/TC 204: 2019, ISO. https://isotc.iso.org/livelink/livelink/fetch/-8846111/8847151/8847160/ITS_Standardization_Activities_of_ISO_TC_204.pdf?nodeid=19964169&vernum=-2

develop widely referenced specifications (i.e., GTFS).[3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29] Each of these distinct groups

[3] ISO/TC 204 Intelligent transport systems, https://www.iso.org/committee/54706.html

[4] ISO/TC 22 Road vehicles, https://www.iso.org/committee/46706.html

[5] ISO/TC 104 Freight containers, https://www.iso.org/committee/51156.html

[6] ISO/TC 211 Geographic information/Geomatics, https://www.iso.org/committee/54904.html

[7] ISO/TC 268 Sustainable cities and communities, https://www.iso.org/committee/656906.html

[8] ISO/IEC JTC1/SC41 Internet of things and related technologies, https://www.iso.org/committee/6483279.html

[9] ISO/IEC JTC1/SC42 Artificial intelligence, https://www.iso.org/committee/6794475.html

[10] ISO/IEC JTC1 WG 11 Smart cities, https://jtc1info.org/sd_2-history_of_jtc1/jtc1-scs-and-groups/wg-11-smart-cities/

[11] IEC SyC Smart Cities, https://www.iec.ch/dyn/www/f?p=103:186:5222255226409::::FSP_ORG_ID,FSP_LANG_ID:13073,25

[12] ITU-R Study Group 5 Terrestrial Services, https://www.itu.int/en/ITU-R/study-groups/rsg5/Pages/default.aspx

[13] ITU-T Study Group 16 Multimedia, https://www.itu.int/en/ITU-T/studygroups/2017-2020/16/Pages/default.aspx

[14] ITU-T Study Group 16 Multimedia, https://www.itu.int/en/ITU-T/studygroups/2017-2020/16/Pages/default.aspx

[15] World Wide Web Consortium (W3C) Automotive Group, https://www.w3.org/auto/wg/

[16] oneM2M, http://www.onem2m.org

[17] CEN TC 278 Intelligent transport systems, https://itsstandards.eu

[18] ETSI TC ITS, https://www.etsi.org/committee/its

[19] SENSORIS, https://sensor-is.org

[20] American Public Transportation Association, https://www.apta.com

[21] IEEE Vehicular Technology/Intelligent Transportation Systems, https://vtsociety.org

[22] Institute of Transportation Engineers (ITE), https://www.ite.org/technical-resources/topics/standards/

[23] Institute of Transportation Engineers (ITE), https://www.ite.org/technical-resources/topics/standards/

[24] National Transportation Communications for ITS Protocols (NTCIP), https://www.ntcip.org

[25] Organization for the Advancement of Structured Information Standards (OASIS), https://www.oasis-open.org

[26] Open Geospatial Consortium (OGC), https://www.ogc.org

[27] Society for Automotive Engineers (SAE) V2X Communications Steering Committee, https://www.sae.org/servlets/works/committeeHome.do?comtID=TEVCSC

[28] General Transit Feed Specification (GTFS), https://gtfs.org/gtfs-background

[29] Work Zone Data Working Group (WZD WG), https://github.com/usdot-jpo-ode/jpo-wzdx/wiki/Work-Zone-Data-Working-Group-Charter

are made up of their own set of industry experts that have common business interests to quickly develop documents to address specific industry needs. Already, these groups have developed over 1,000 ITS standards, specifications and other documents, and this number continues to grow. While some cross-pollination of innovative ideas occur, coordination among groups is challenging due to travel costs, copyright issues and the need for timely products versus the time required to build broad consensus. As a result, various groups often develop similar terms and data definitions that can lead to confusion when comparing materials from different sources. In some cases, these differences can potentially have safety implications. For example, while the industry has generally agreed on using WGS-84 [30] latitude and longitude at a one tenth of a micro-degree resolution (which provides roughly one-centimeter resolution), there are still aspects of ambiguity around location data including:

- Where is the reference location of a car? Most European standards place this at the "front-center" of the vehicle while American standards place this as the "middle center." The industry needs a way to identify these variations among standards along with clear rules on how to transform data in one format to another.
- Does the mapping information reflect current conditions? In other words, the data has to support all operational scenarios including the use of movable barriers, changes to infrastructure due to collisions and other scenarios that change the roadway geometry or roadway furniture. Vehicles traversing the network have to be aware of current conditions as they change.
- How accurate is the data for stationary objects and maps? While vehicles will be equipped with global navigation satellite system (GNSS) receivers, stationary roadside elements (i.e., curbs, parking spaces, etc.) are likely to be positioned once and left to advertise their location as needed. However, as tectonic plates slowly (or at times quickly) shift, this data becomes less reliable. The industry needs clear guidelines on how to handle these types of anomalies that are so easy to overlook; specifically, the industry needs a central resource that can be used to share best practices among the different standardization bodies.

This paper introduces efforts by ISO to overcome these issues by promoting the development of an industry-wide logical data model.

THE IMPORTANCE OF DATA SHARING

More and more attention has been paid to safety, comfort, mitigation of impacts on the environment and energy efficiency in

[30] World Geodetic System, https://www.unoosa.org/pdf/icg/2012/template/WGS_84.pdf

transport systems. To date, most existing ITS applications have been designed under the assumption that they would collect their own data with minimal data sharing among applications; however, sharing data among systems is considered a key factor in making additional progress to address the above issues.[31]

Traditionally, to collect information in a specific part of the vehicle, each system has collected its own probe data for their specific purposes; however, the collection of this data has been a major cost factor for these systems. As systems become more advanced, ubiquitous and interconnected, the advantages of sharing information between systems blossom. Even when a system has a requirement to collect its own data, being able to validate its readings against those collected by a second source and to identify any suspect readings from its own equipment can be valuable. For example, sharing probe data among service providers enhances the quality of service of each service provider.

Sharing data can reduce overall costs while increasing quality. For example, the current status of a stretch of curbside (i.e., whether a car is parked, waiting, etc., or whether the curbside is clear) can be determined through a variety of technologies including roadside detectors, sensors from passing vehicles, cellular triangulation of cell phones, etc. Each technology will tend to have its own advantages and disadvantages; however, in many cases the weakness of one technology can be overcome by the strength of another—and since many of the technologies will be in place for other reasons, the cost for acquiring the incremental data will likely be low—as long as the various devices are able to share the valuable information; and better yet, the data are presented in either a common format or an easily interchangeable format.

The framework of data sharing

There are various systems deployed and successfully operating on their own; while these systems often collect data, they often only use the data for a single application without sharing with others. For example, Probe Data from transportation systems are typically not used effectively for smart city services to solve other smart city mobility issues.

It is suggested that the vehicle probe data be shared among authorized stakeholders—and those sharing could, as a result, support various potential services for smart city service applications using a common data base; however, this level of data sharing also requires consideration of data ownership, data access rights and privacy protection. These issues are to be addressed as a part of the logical data model to ensure that all users of the data agree to the rights associated with the data.

The conceptual framework of a vehicle probe system is provided in Figure 1 below. The framework consists of the vehicle, the roadside (including roadside units that collect data from probe vehicles and roadside sensors that directly capture their

[31] ISO 22837:2009, Vehicle probe data for wide area communications, ISO, 2009. https://www.iso.org/standard/45418.html

own data), road authority and service provider.

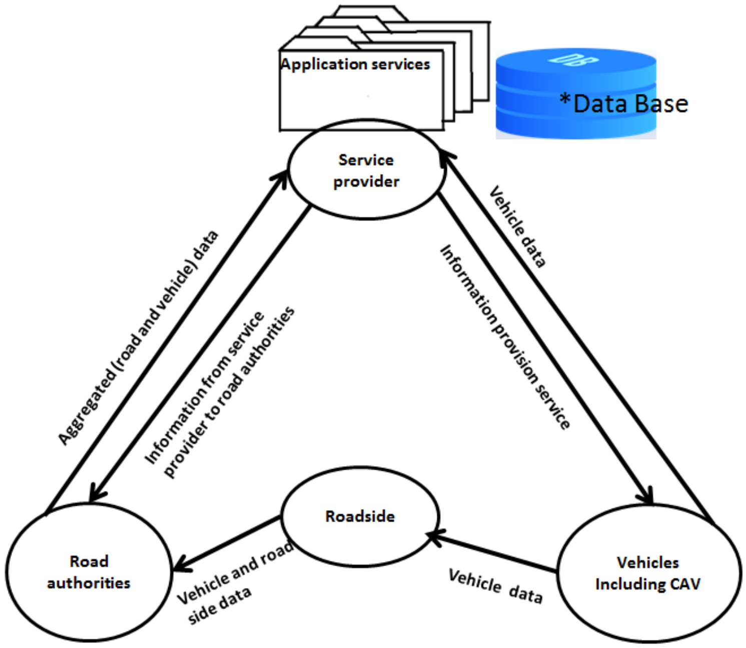

Figure 1: The conceptual framework of a vehicle probe system

The service provider collects relevant, low-latency data from probe vehicles and stores the data in databases; applications and services analyze the information gathered and provide updates to the vehicles as appropriate. Data collected by the roadside and/or service providers are shared with the road authority. Likewise, the road authority might aggregate data from multiple sources and send the results to service providers.

While standards exist for exchanging information across each of these links, seamlessly sharing the information largely remains an elusive goal due to the lack of a common data model. Each of the interface standards have been developed separately, which often resulted in subtle differences in the data that requires significant integration efforts to resolve.

Data sharing of vehicle probe data

Today, many agencies in different countries are collecting probe and roadside data to improve public safety and operational efficiency. ISO TC 204 is engaging an effort to inter-connect and share this data. The data shown on the left of Figure 2 represent collections of data from different service providers such as probe services, Electronic Fee Collection (EFC) services, information provision services and other services. As the automotive services are growing with many innovations, the type of data and the granularity of the data will be added to the databases. The rate of data exchanges between vehicles and roadside stations will be another factor to determine how close the database for a type of service should be placed.

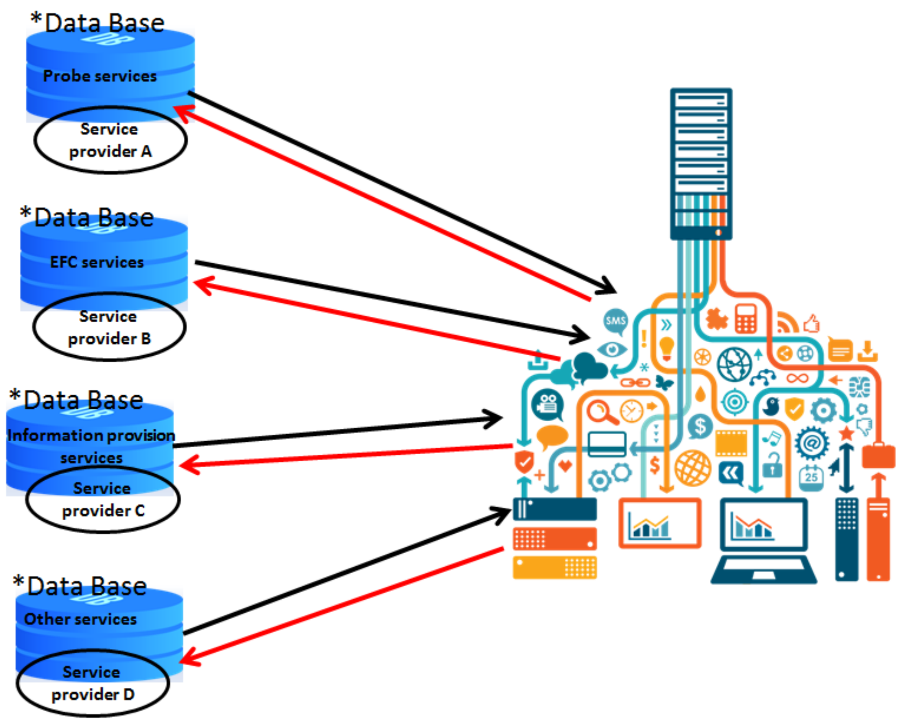

Figure 2: An image of the concept of data sharing of a vehicle probe system

Sharing probe vehicle data among current and future service providers allows the creation of new application services. The new services will be able to use and enhance the existing probe data standards, data sharing policies and meta-data sharing policies already defined by the local authority.

LOGICAL DATA MODEL FOR ITS

Interoperability is defined as "the degree to which two or more systems, products, or components can exchange information and use the information that has been exchanged."[32] In order for two systems to successfully use the same information, there must be an agreement of what the underlying data means. For example, if a moving vehicle is to report its location, the

[32] ISO 25010:2011, Systems and software engineering – Systems and software Quality Requirements and Evaluation (SQuaRE) – System and software quality models, ISO, 2011. https://www.iso.org/standard/35733.html

vehicle and all of the recipients of the information must agree on:

- What coordinate system is being used (i.e., a specific global coordinate system or perhaps a coordinate system based on the center of an intersection)
- What reference point on the vehicle is being used to locate the vehicle on the coordinate system
- How accurate the data claims to be
- How timely the data claims to be

As mentioned above, within the ITS industry, there are dozens of standards development bodies that are actively defining the details about such interactions. Each of these groups have their own market interests as well as their own business pressures to produce quality documents in a timely manner. However, the complexity involved in many of these technical issues makes it difficult to address all integration issues within the timeframes desired to meet business objectives.

The result is that each standard developed tends to develop its data to meet its isolated business objectives, often resulting in limited coordination among different standards groups. As a result, we end up with competing definitions for the reference point of a vehicle between the European and American communities—even though most automobile manufacturers operate globally and will end up having to produce vehicles that conform to both standards.

Even more challenging is the fact that this information sharing is envisioned to be exchanged between vehicles and nearby pedestrians through smartphones. In order to interoperate, that smartphone needs to agree on the vehicle's location even if the smartphone app is from a different part of the world.

From a theoretical, idealistic viewpoint, we would develop the standards in a slow, considered manner, analyzing all business needs before finalizing any data definitions or data interface; but that approach would not meet the real-world business needs. A more viable alternative is to allow each market segment to continue the development of their specific data interface standards while promoting the concept of a higher-level model that will define how to share data among the different interchange formats.

Data Model Framework

The proposal to develop a harmonized higher-level model that provides for interoperability includes a three-layer design as presented in Figure 3:

- A conceptual model that defines the vocabulary for the industry using a formal ontology
- A logical data model that defines the standardized generic representation of data using object classes and attributes
- Physical data models that represent each interface standard

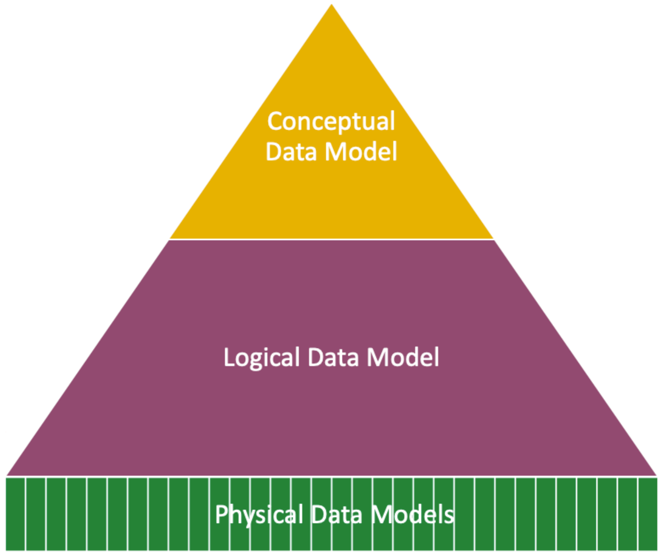

Figure 3: Data Model Framework

Each of these layers is described further below, in the expected chronological order of their development.[33,34,35]

Physical Data Models

Practical business needs are generally the driving factor behind the creation of interface standards. When these business needs arise, the stakeholder community providing funds for the development of a solution is usually less interested in undertaking large cooperative efforts that engage with tangential business interests; instead, there are typically strong motivating factors to keep a tight focus on their primary business interest. The result is that interface standards are developed by industry experts who might have a great deal of experience in tangential business areas but who are focused on developing an interoperability solution for one specific need in a timely manner.

Every interoperable solution for exchanging information has an associated physical data model, either explicitly or implicitly defined. This data model simply identifies the data structures and data elements exchanged across the interface. These structures can be represented in numerous ways including XML schema, ASN.1 modules and UML class diagrams, among others. This paper uses UML class diagrams as a useful way to easily compare alternative solutions. For example, Figure 4 provides an example of a portion of

[33] The Enterprise Data Model: A Framework for Enterprise Data Architecture, 2nd Edition, A. Graham, Koios Associates, Ltd., 2012.

[34] Data Architecture: From Zen to Reality, Charles Tupper, Elseview Inc., 2011.

[35] Enabling Things to Talk: Designing IoT solutions with the IoT Architectural Reference Model, A Bassi, et al., Springer, 2013.

the physical data model for the cooperative awareness message (CAM) as defined in ETSI 302 637-2, the main European standard for defining how to exchange vehicle location and motion data within Europe.[36]

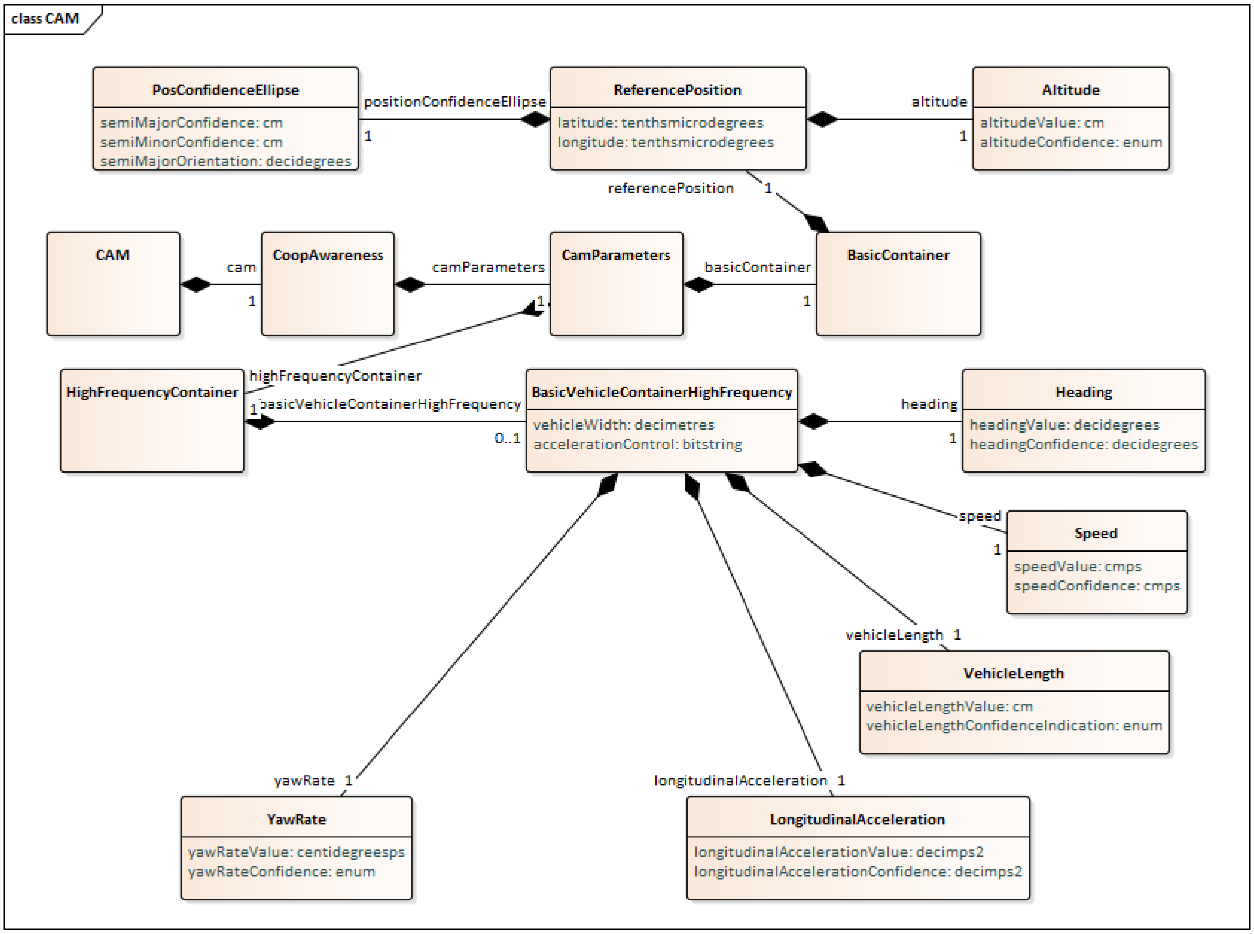

Figure 4: Physical Data Model for CAM

[36] Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service, ETSI EN 302 637-2 v1.4.1 (2019-04). https://www.etsi.org/deliver/etsi_en/302600_302699/30263702/01.04.01_60/en_30263702v010401p.pdf

By comparison, Figure 5 provides the equivalent portion of the physical data model for the basic safety message (BSM) as defined in SAE J2735, which is used in the United States.[37]

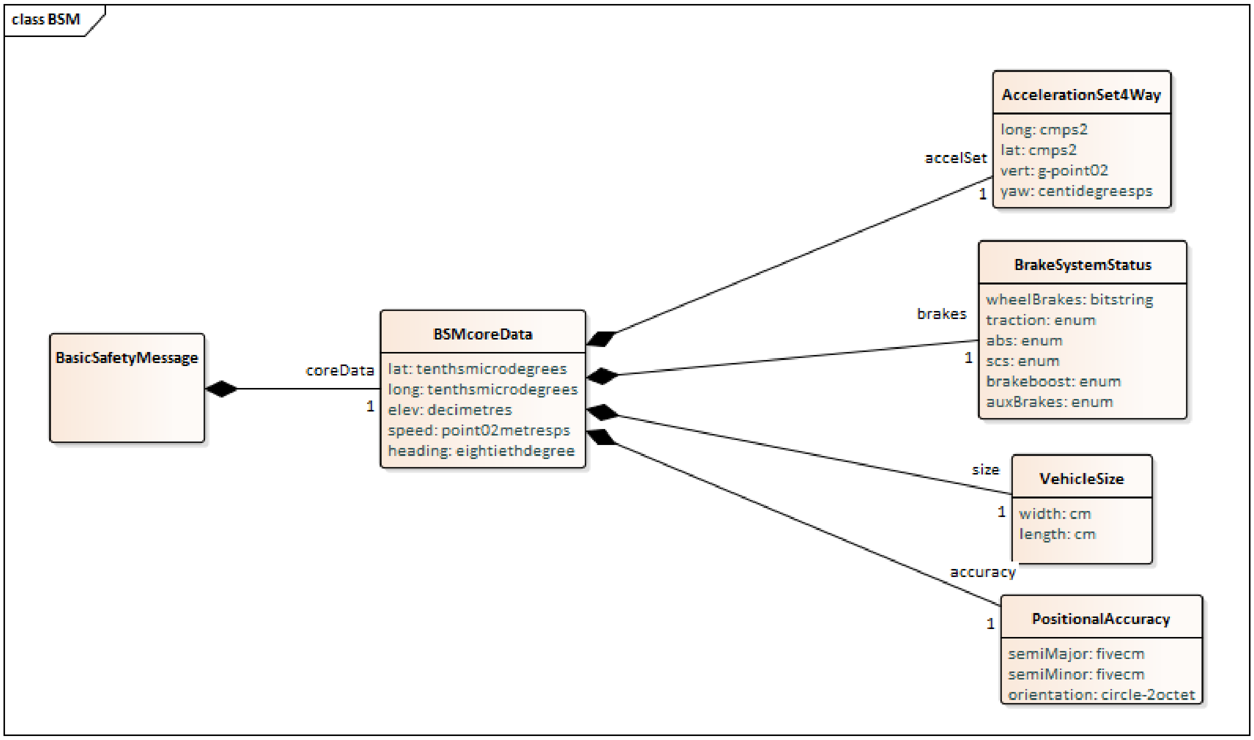

Figure 5: Physical Data Model for BSM

While both standards define very similar information (i.e., latitude, longitude, elevation, speed and heading of the vehicle) for the same purpose (i.e., reporting the vehicle location and motion), the rules and structures used to convey this information are quite different.

Competing solutions such as these should be expected when different groups undertake independent efforts to solve the same or related problems and practical realities prevent real-time collaboration. The methodology presented in this paper accepts the existence of these two solutions as a fact of life and proposes how to overcome integration challenges once competing solutions exist without attempting to impose a new solution. This will be achieved by developing a higher-level,

[37] Dedicated Short Range Communications (DSRC) Message Set Dictionary, SAE J2735_201603, March 2016. https://www.sae.org/standards/content/j2735_201603/

all-encompassing model that can be mapped to all implementations.

Conceptual Data Model

Before the logical data model is developed, the community needs to reach consensus on a vocabulary for the domain as documented through a formal structure such as the Web Ontology Language (OWL).[38] The goal of this effort is to formalize the definition of terms and to clearly and unambiguously identify relationships between terms.

One of the benefits of an OWL ontology is that it defines terminology in a format that can be processed by computers and thereby enable the semantic web. In other words, by formally defining relationships among human terminology in this format, computer systems can more easily process the semantics contained within written text. This is one of the enabling technologies that can enable artificial intelligence through the use of deep learning.

Applying this process to our previous example, we need to formally define all of the key terms related to our data elements. This includes not only the terms directly identified in the names of our data elements (i.e., latitude) but also the other key terms within its definition. For example, the definition of "latitude" in SAE J2735 begins, "The geographic latitude of an object…" In this case, we need to define "object" as well as "latitude." Further, when combined with information from SAE J2945/1, we discover that the type of object of interest within the BSM is a "vehicle." Thus, we also need to unambiguously define what a "vehicle" is.

According to the rules of ISO 704, the formal definition of each term should be based on a formal concept model that defines how this term relates to other terms. This can be shown using the Object Management Group's (OMG's) Ontology Definition Metamodel (ODM), a standard that defines how to describe OWL ontologies using a profile of UML class diagrams as depicted in Figure 6.[39]

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[38] OWL 2 Web Ontology Language Document Overview, W3C, 11 December 2012. https://www.w3.org/TR/owl2-overview/

[39] Ontology Definition Model, Object Management Group, September 2014. https://www.omg.org/spec/ODM

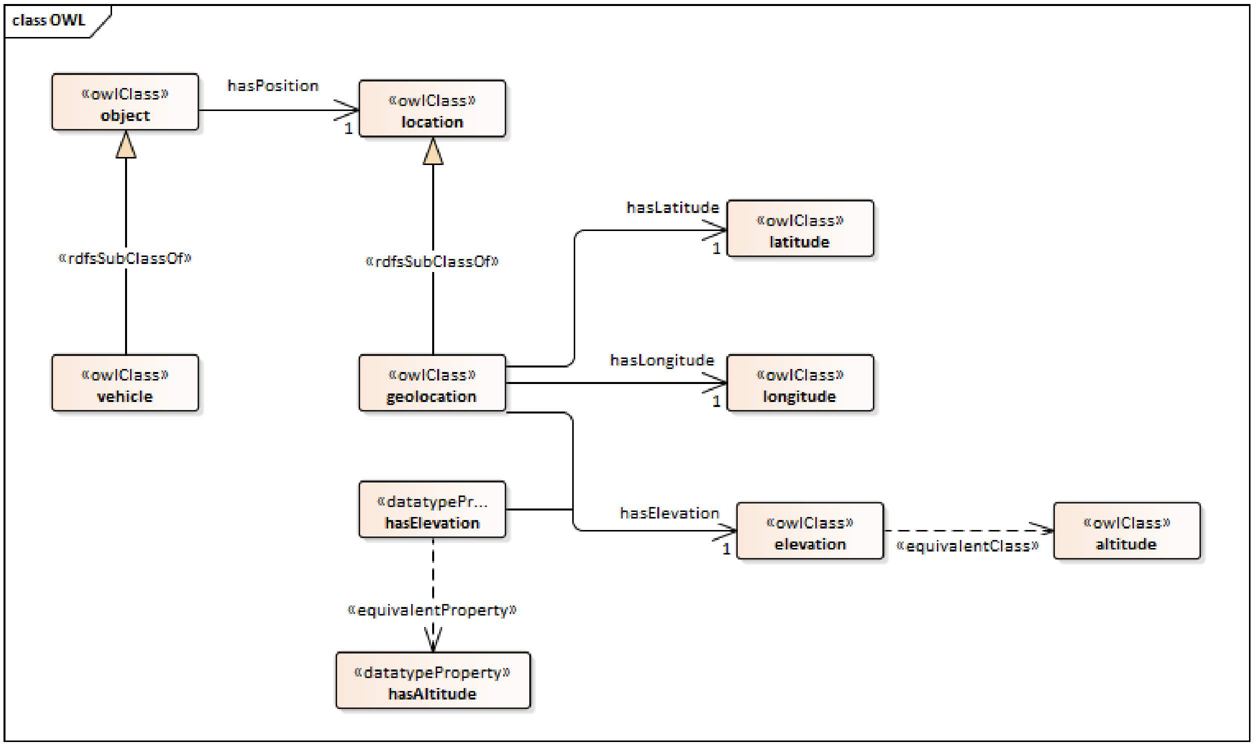

Figure 6: ODM Representation of Vehicle Location

The left side of this diagram indicates that the "vehicle" class (term) is a "subclass of" (a type of) the "object" class and therefore inherits (can exhibit) all of the properties associated with the "object" class.

For the purpose of this discussion, there is one property of interest: "hasPosition." The diagram indicates that the "hasPosition" property is represented by the "location" class and that an object only has one position. One type of "location" is a "geolocation" (i.e., a point near the Earth's surface) which has three properties: "hasLatitude," "hasLongitude" and "hasElevation" (with one instance of each).

Up to this point, the notation is very similar to a traditional UML class diagram. However, ODM also defines some useful stereotypes for dealing with ontologies that have to deal with the peculiarities of human language. While the BSM uses the term "elevation," the CAM uses the term "altitude." Both terms are intended to mean the same thing. As a result, Figure 6 indicates that, within the context of CAM, the "altitude" class is equivalent to the "elevation" class. This ensures that any automated process can equate the two terms properly. This same sort of mechanism can be used to identify equivalent terms in different languages.

Finally, the diagram also shows that the "hasElevation" association has an association class by the same name. In fact, every association is associated with this type of class; the others are not shown to keep the diagram simple.

By defining these association classes, the ontology can also create relationships among associations, just as we have shown relationships among classes. While this may seem unnecessary for this example, there are other cases where this can become quite useful. For example, by defining association classes, one could create a formal ontology that defines that one person can be the "wife" of another person and, if so, then the other person is the "husband" of the first. Further, both the "husband" and "wife" associations can be formally defined to be subclasses of the "spouse" property. A computer system equipped with this definition would then recognize that any husband can also be called a spouse.

The conceptual data model therefore becomes a central resource for deep learning in being able to interpret written text. But it falls short in providing a concise view of the information for defining future interfaces or for translating among existing physical data models. For that, we turn to the logical data model.

Logical Data Model

The goal of the logical data model is to provide a "Rosetta Stone" for the industry. It allows data implemented according to one data format (i.e., physical data model) to be transformed to any other data format by formalizing the transformation to a common data format.

By their nature, physical data models deal with constraints related to the environment that they are intended for. For example, physical data models for communication protocols often attempt to compress data to minimize the size of the data that has to be transmitted. Physical data models for databases often try to minimize the number of tables that have to be managed. The logical data model escapes these types of constraints and should be designed to reflect real world artifacts as closely as possible.

The logical data model reflects the conceptual data model as closely as possible. However, whereas the conceptual data model will define equivalent terms and other artifacts that are important to capture for human discussions, the logical data model limits or omits this type of redundancy. In addition, the logical data model defines additional detail regarding the data including the units in which measurements are made and the level of privacy that should be associated with the data.

Standardization Process

Access to the Model

One of the challenges of producing a model that is intended to represent and be used by the entire industry is that it must be readily available to receive inputs from a massive stakeholder community. This necessarily requires that the community:

- Is able to readily access the model
- Is able to readily provide input to the model

Typically, SDOs charge fees for one or both of these functions. For example, ISO offers free participation in the development of standards but charges for access to the resulting standards. OMG charges membership fees for contributing to the standards development but offers the end product to the community for free. The IETF allows for free contributions and free access but charges for attendance at conferences where many decisions are made. The bottom line is that there is an administrative cost to managing the standards development process, and money has to come from somewhere to make this happen.

However, there are some limited exceptions to this model as follows:

- While ISO charges for its standards, it does publish terms and definitions online for free at https://www.iso.org/obp while still allowing for free participation in developing such standards.[40]
- Some online tools (i.e., Github) offer free accounts to not-for-profit entities, and some (mostly) informal groups[28,29] have adopted the use of such tools as a way to minimize administrative costs to the point where free participation in the development of a standard and free distribution of the standard is possible.

ISO/TC 204 is in the process of combining these two exception conditions to gain the benefit of an official ISO deliverable under a free and open process. It is already developing an ITS vocabulary (ISO 14812) using a public Github project (found at https://github.com/ISO-TC204/iso14812). [41] As this is still under development, most of the content is currently under the development branch of the model; but this allows a completely open and transparent process to develop the vocabulary which is essentially the conceptual data model discussed above.

ISO/TC 204 is also in the process of working with ISO central to start a parallel project for the logical data model on the basis that a logical data model is still essentially a vocabulary document, just one that is primarily intended for computer programming rather than for human language.

Model Formats

The expectation is that, once approved, the logical data model will be established under the same Github account (https://github.com/ISO-TC204/) with its own project identifier and use the same basic process being used for the current ISO 14812 project. This project uses Sparx Enterprise Architect as the main development tool for developing and diagramming the model. This content is then uploaded to Github in the following formats:

- Native EAP file: This is the native format for Sparx Enterprise Architect.
- XMI file: This is the major open format for exchanging UML models across different software tools. This is generated directly from the model using a built-in software feature.
- XML file: This is a simple XML file that lists each term with its different attributes; it is primarily intended to serve as an easy way for a human

[40] ISO Online Browsing Platform, https://www.iso.org/obp

[41] ISO 14812 Intelligent Transport Systems – Vocabulary development platform. https://github.com/ISO-TC204/iso14812

user to compare two versions of the project using any off-the-shelf ASCII file comparison tool. This is generated directly from the model using the custom scripting language provided by the software.

- Website: This is the interactive website that can be accessed at https://iso-tc204.github.io/iso14812/development/ and allows users to interact with the model online without any special software tools. It is generated directly from the software tool with minor customizations.

Finally, a secondary toolset exists that allows the development team to generate the standard in ISO format for final approval, but this is not distributed for free.

The goal is to ensure the model content is readily accessible by the community; it is provided in multiple formats to ensure that users are able to access the content in a manner that meets their needs.

Standardization Procedures

The hybrid approach allows industry experts to easily submit comments while ensuring a high-quality end product that is worthy of global recognition as an ISO document.

To obtain the ISO logo, the drafts still follow the normal ISO procedures for approval. This means that formal ISO documents are prepared and balloted through the normal ballot process. ISO national experts can comment on the document at multiple stages during this process, as normal. However, the Github site is also used to gather comments from the community and are fed into working group (WG) discussions. This allows any ITS expert to easily submit comments without having to navigate the sometimes confusing web of hierarchy to be recognized as a national expert. Once submitted, comments are discussed within the WG by national experts from participating member countries. To further minimize barriers, WG discussions rely heavily on web-conferences. While there are typically two in-person meetings per year, these typically offer a web conference connection as well.

The end result is that users from around the world have easy access to provide input and to gain access to the end product.

Standardization Challenges

The process is only part of the problem though. Many have expressed concerns whether it is possible to reach global consensus across all ITS domains for all aspects of a data model. In many cases, the need for simplicity of some data within some systems seems to be in direct conflict with the need for data precision in other systems.

There are three major factors that we believe will be useful for developing useful output in a timely manner:

- Emphasize the distinction between physical, logical and conceptual data models; and only focus on the latter two
- Focus on low-hanging fruit
- Produce interim products

Focus on Logical and Conceptual Data Models

Standardizing on physical data models requires a complete interoperable specification. This is often challenging because in many cases, stakeholders have already developed a solution that they need to migrate to the new solution. These discussions can become quite contentious as different stakeholders debate the merits of various proposals and consider the costs for converting their own systems.

Conceptual data models avoid this discussion completely. They only need to define what terms mean and how terms relate to one another while allowing for synonyms with various levels of similarity. The only real debate point is in the real meaning of terms within different communities; but even here, the meaning of terms can be scoped to specific contexts when needed (although it is highly desirable to standardize as much as possible).

Logical data models begin to define preferred units of data and factors to ensure that data can be semantically understood but do not define how data is exchanged. For example, the conceptual model might define that a vehicle has a location that identifies the point-of-reference on the vehicle, but it does not have to define where the point of reference is or the units used to express this location. The logical data model would extend the definition by designating the point of reference on the vehicle and the units used to express the location but would not define how this information is transmitted. The physical data model would define how the data is transmitted.

As long as a system is able to transform data conforming to a physical data model into the format defined by the logical data model, agreement can be reached fairly quickly. This is even true if the transformation results in a loss of accuracy as long as the logical data model is able to represent the resultant accuracy (which is generally needed anyway). The result is that agreement on a logical model is often much easier because the only systems that need to perform this transformation are those that have a need to span multiple physical data model standards—and for that subset of systems, having a common reference is better than dealing with each physical model separately.

Focus on Low-Hanging Fruit

Another benefit of focusing on the conceptual and logical data models is that they do not need to be completely defined for a benefit to be provided to the community. As a simple example, the industry frequently reports geographic locations using latitude and longitude reported in tenths of microdegrees. This is often but not always based on the WGS-84 coordinate system and accompanied with an elevation reported in decimeters or centimeters.

This should be easy to address within the logical data model. There are known ways to translate locations among different coordinate systems (as long as timestamps are known for the data and recognizing some loss of accuracy). The logical data model would therefore need to allow for identifying the coordinate system used, the timestamp on the data and the accuracy of the source data; it would then support microdegrees for latitude and longitude and centimeters for elevation (when the source data is provided in decimeters, it would be reflected in reduced accuracy).

Documenting the preferred format for reporting geographic locations is useful, even if preferred formats for other data are not defined. It allows new standardization (or even integration) efforts to adopt the formats and thereby minimize transformations where they are not needed. It also allows physical data models to document exactly how to transform data from its format into the common format. Finally, it should be recognized that not all data defined in one physical interface will be needed across a different link—so each piece of data that can be addressed in a logical data model is advantageous for the industry, even if we do not address all data defined in any physical standard. Recognizing this will allow the standards community to focus its efforts where agreement can be reached easily rather than trying to address every detail. The result should be a useful standard in a timely manner—even if it does not solve every problem in the industry.

Produce Interim Products

It is also important to realize that the domain of ITS data is massive. Even if we limit discussions to the low-hanging fruit, developing an all-encompassing logical data model for ITS would likely take decades; in the meantime, industry changes. The development effort must be responsive to the community and provide periodic updates of an interim product. This is the same approach that we are currently using on the ISO 14812 (ITS Vocabulary) document. The first version of this is currently going through an approval process even though we are likely to refine some of the contents, and the document only addresses 300 terms out of the more than 2,000 being used in the industry. The key is that we envision the development effort to continue after this release and recognize that the document may take a decade or more to complete.

Way Forward

Although many SDOs have been interested in standardizing data sharing mechanisms for some time, the progress has been limited due to the tremendous amount of collaboration efforts required by all the stakeholders. Quite often, these efforts would start with an interest in standardizing one area such as “Digital Maps” and ambitiously pursue that topic only to discover that there are many more use cases and user needs than originally envisioned. The initiators of the project then determine that it becomes very cumbersome to address all scenarios and satisfy all the user needs within budgetary constraints. In the end, the initiator of the project determines that it is easier and more economically viable to either standardize in a smaller group or for the initiator to retain rights to the design and release it to others as needed.

In order to break this “norm,” it is better that organizations like the IIC jointly work with an SDO such as ISO to get the ball rolling.

Automotive applications, ranging from peripheral detection for safety (lane change warning) and ADAS to Autonomous Vehicles are the most important ones in ITS. All of these applications are based on IIoT technologies that the IIC has been developing and promoting.

As a collaborative organization, IIC can facilitate discussions through the Automotive Task Group to identify the needs from the members and then coordinate the thoughts through its liaised organizations—and eventually engage ISO. In such a case, the IIC can not only help boost the technology for ITS but also lay a foundation to help roadside authorities to set the necessary regulations to accommodate the standards.

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