Developing Semantics for Supply Chain, Transport and Logistics

White Paper for Digital Infrastructure Logistics and Basic Data Infrastructure

basic data infrastructure

digital infrastructure logistics

Topsector Logistiek

Colophon

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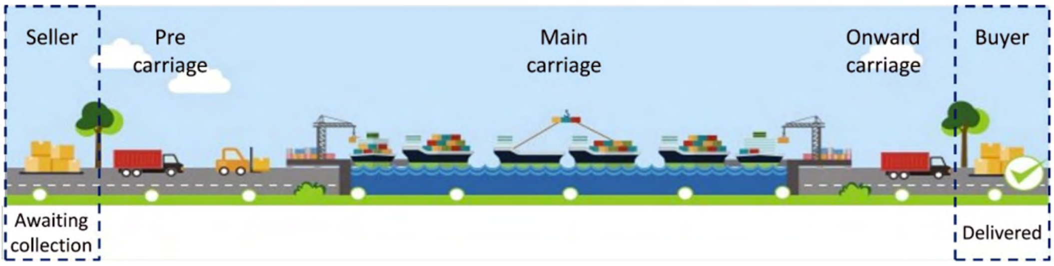
1 Introduction

Whether data is the new oil remains to be seen, however data is a significant resource of the present and the future as the lifeblood of our digital systems supporting our everyday activities. Accessing, managing and integrating this resource across platforms is key to building robust solutions. Timely, reliable, successfully integrated and managed, commercial data is also one of the enablers of optimizing the ecosystems of supply chain (SC), transport and logistics (T&L).
Having a common language plays a crucial role in this context, because participants need to understand each other via a semantic framework for seamless data interpretation.

For the scope within the supply chain on which this paper provides interpretation in terms of semantics, we use UN/CEFACT 'Business Requirements Specification Integrated Track and Trace for Multi-Model Transportation'. In it, the scope of the area to be considered is defined as 'between Seller and Buyer of goods to be transported' (Supply Chain between Seller and Buyer).

Figure 1[1]
Supply chain scope for this white paper



The ecosystem of supply chains, transport and logistics is now convinced that it needs to digitalise many more processes and activities much more to meet the requirements of Beneficial Cargo Owners (BCO) and those of authorities based on new regulations. Many of the new regulations are already known (as well as indications regarding their implementation).
Examples include EMSWe (European Maritime Single Window), ICS2 (Import Control System 2), eFTI (electronic Freight and Transport Information) regulation, USA Stop-Act, USA FMC MTDI (Maritime Transport Data Initiative), eCMR (electronic CMR) and (many) others.
Besides digitisation of processes, the current requirements of BCO and Authorities also force much more cooperation and exchange of data between parties. Such enhanced cooperation is only possible if people start using a 'common language'. That language is called semantics in this white paper.

With a common semantic structure, different data standards within the transport and logistics domains can be integrated and aligned. This facilitates the understanding and interpretation of data coming from different sources and standards.

Development of this common language will have to be an essential part of the Basic Data Infrastructure (BDI) and be developed in base in the ongoing Digital Infrastructure Logistics (DIL) programme.
However, for the above data exchange, semantics alone is not enough. The exchanges will have to happen at the right time, triggered at the right point in the business process in an event-driven fashion.
In this white paper, we will discuss both semantics and this event-driven concept.

1 *Reprinted from UN/CEFACT BRS page 8*
https://unece.org/sites/default/files/2023-07/BRS-IntegratedTrackandTraceforMulti-ModalTransportationv0.1-Final.pdf

The purpose of this white paper is to provide

1. an overview of the 'landscape' of semantics and event-driven thinking for non-experts and
2. an approach to developing semantics that offers the greatest chances that these semantics will actually be widely deployed in the day-to-day practice of market players, various governments and other interested parties.

Who is this white paper written for?

This WP is intended for anyone active in, involved in or in any way interested in the improvements of activities in transport and logistics (T&L) and the supply chains to be served by T&L. For this reason, this White Paper has avoided, as much as possible, the use of jargon and kept the language accessible. The document will, however, refer to sources that may be less accessible in several places.

Structure of this white paper

This white paper consists of two parts. In part 1, we successively describe what semantics is, what you can achieve with it, semantics that are already available, and a start on how one might compare the various semantic models available. In part 2, we look at the challenges around developing semantics and what one can do to deal with those challenges.

In the FEDeRATED project an ontology intended as an upper ontology for the logistics domain was developed. This means that it should provide an interface to all relevant concepts, but it is not intended to cover details of the domain. The ontology is explicitly intended to be extended by domain ontology from the various logistics modalities such as the railways, airways, waterways, and roads. In other words, the main function of upper-level ontology is to support broad inter-operability among many domain-specific ontologies by providing a common starting point for the formulation of definitions. For the further development in the DIL project for the application of the BDI we maintain the centrality of the Event concept from the FEDeRATED model. This ontology contains classes, attributes, relation about logistic Events Work has already been done in the context of DIL and BDI on developing semantics.

Today's logistics networks are proprietary as a result of lack of a common architecture. This lack of a common architecture is partly inadvertent (for some stakeholders) and partly by choice (for stakeholders that wish to control the market).

The Dutch DIL project and the FEDeRATED project co-financed by the European Commission both aim to address the challenges caused by the lack of a common architecture. The two projects have significantly influenced each other. The FEDeRATED project included participants from all over Europe. The challenge that the FEDeRATED programme took on, is achieving open neutral connected logistics and transport services across the European Union (and beyond) and lowering the burden of proving compliance. Semantics were assigned a key role in addressing the challenge. The FEDeRATED project adopted an approach to develop a 'top-ontology' starting from 'Events' that occur within the operations of transport and logistics, in effect an Event-Driven approach.

Within the context of DIL and BDI, based on this history, among others, it was decided that the above-mentioned data exchange will be done on the basis of event (event-driven).

2 The concepts of 'Event', 'Top-ontology' and 'Event-Driven' will be explained further below in this White Paper.

2 Part 1 - Semantics in context

2.1 Interoperability and Semantics

The European Commission in their 'European Interoperability Framework' defines interoperability as:

> *'The ability of organisations to interact towards mutually beneficial goals, involving the sharing of information and knowledge between these organisations, through the business processes they support, by means of the exchange of data between their ICT systems'.*

This definition fits seamlessly with objectives of the DIL project and BDI. Whereas the EIF definition can in principle be applied in all areas of society, DIL and BDI focus on transport, logistics and supply chain. Semantics and interoperability thus have a relationship with each other. We elaborate on this relationship below.

2.1.1 Types of interoperability

The European Interoperability Framework (EIF) distinguishes four layers. In addition, the framework provides for a Governance function. Within this White Paper, we will refer in various places to semantic interoperability, technical interoperability, organisational interoperability and also management (governance). The EIF describes legal interoperability as 'about ensuring that organisations operating under different legal frameworks, policies and strategies are able to work together.'
Legal interoperability will not be discussed in this White Paper[3].
The EIF describes organisational interoperability as 'the alignment of activities, responsibilities and expectations between parties to achieve their commonly agreed and mutually beneficial goals'.
The EIF describes semantic interoperability as 'ensuring that the exact format and meaning of exchanged data and information are preserved and correctly understood by all exchanges between the parties involved'.

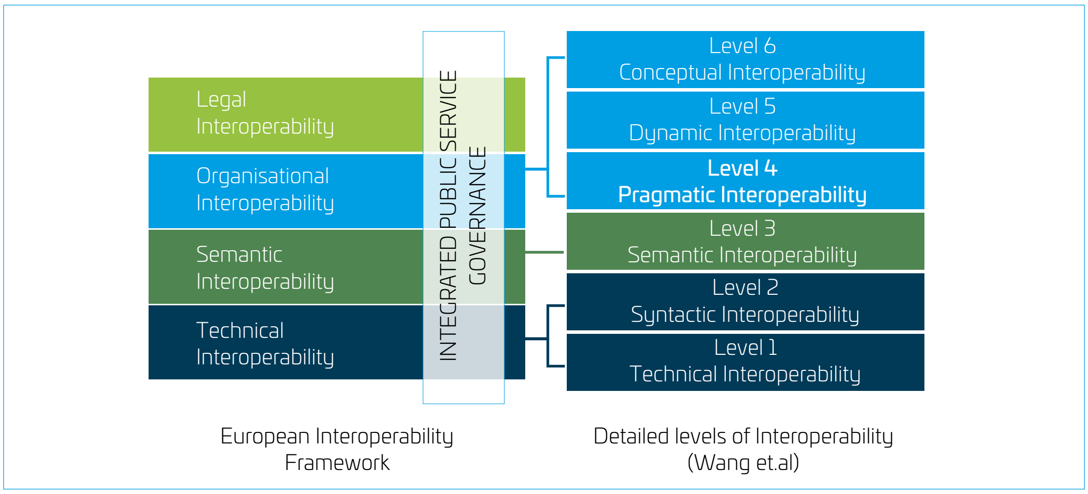
The EIF sums it up succinctly as:

> *'Ensuring what is sent is what is understood'.*

EIF considers syntax as part of semantic interoperability, where syntax describes exactly how exchanged information should be structured and formatted.
The EIF describes technical interoperability as 'the ecosystem of applications (applications) and infrastructures through which IT systems and IT services can be linked'.
The EIF definitions are quite broad. Scientists such as Wang et al distinguish 6 layers of interoperability that can be associated with the EIF layers as shown in the figure below.

3 The legal frameworks tend not to have a direct relationship with semantic or technical interoperability.

Figure 2
Interoperability frameworks[4]



In this figure, it is immediately noticeable that Wang et alia classifies 'syntactic operability' under technical interoperability. We will discuss this further below.

2.1.2 What is the significance of semantics for interoperability as a whole?

How do semantics relate to other interoperability layers?

The EIF assigns an essential role to semantics to achieve interoperability as shown in the concise summary above. Also, the US standards development organisation ASTM has within its F49 group for 'Digitalised Information in the Supply Chain' a subgroup entirely dedicated to 'Terminology' (semantics)[5] among other subgroups that can also be associated with the various layers in the 'Interoperability Frameworks' figure.
Within the ASTM F49 group, there is constant interaction between the various subgroups and also always with the Terminology group.
The IPIC 2023 Paper 'PI Data Sharing Infrastructure', links semantics to the 'Business Collaboration Protocol'[6]. In this context, any party wishing to collaborate with another party must provide at least one business activity, describing how the other parties can interact with this business activity. Besides semantics, according to the IPIC paper, this also requires the layers Pragmatic, Dynamic, and Conceptual from Wang's model (all of which fall under Organisational within EIF). Within the ASTM F49 group, the subject of Business Collaboration is addressed in the subgroup 'Recommended Practices, Guides, and Specifications'.
One may also speak of a 'business choreography' for this combination of topics: a sequence of activities, interactions and business events[7] that multiple parties have agreed with each other to better align linked business activities efficiently and effectively.
In short, without semantics, one cannot therefore enable 'Business Collaboration'. In this sentence 'semantics' refers to any agreed set of terms & definitions regardless of the format in which they are recorded. See also the section 'How does semantics relate to ontology?' below.

4 *EIF brochure Figure 3; https://joinup.ec.europa.eu/sites/default/files/inline-files/eif_brochure_final.pdf#page=22 Wang, W., Tolk, A., & Wang, W. (2009). The levels of conceptual interoperability model: applying systems engineering principles to M&S. Spring Simulation Multiconference. Society for Computer Simulation International*
5 *https://www.astm.org/get-involved/technical-committees/committee-f49/subcommittee-f49*
6 *https://repository.gatech.edu/server/api/core/bitstreams/d3b99362-fc61-4585-b987-283174009076/content#page=4 contribution to IPIC 2023 (International Physical Internet Conference) by Wout Hofman, TNO.*
7 *Events in the context of this document covers both technical (IT) occurrences and business occurrences.*

What is the relationship between semantics and technical interoperability?

This relationship is subject to debate within information technology science and practice. That discussion focuses on syntax (the data structures and formats).
It is certainly possible to develop semantics (concepts, definitions and relationships between them) that can be understood unambiguously by people and also by machines. However, data exchange between systems requires more than unambiguous concepts. As an example, take a date noted as 9/11/2001. It is perfectly clear that this is a date (semantics). But it is not clear how to interpret this notation of the date.
Is this 9 November 2001 (as we would read it in the Netherlands) or is this 11 September 2001? Without standards agreed between parties, this date will often be interpreted differently by different parties.

'What is sent is NOT what is understood'

Such misunderstandings can arise for many different data such as data where a unit of measure is to be used (metre, litre, kgm, kgm/cm^2 etc. versus yards, gallons, pounds, PSI=Pounds per square inch, etc.). So for well-understood data exchange between IT systems, unambiguous syntax is also needed.

As long as both elements (semantics and syntax) are well described and available, people can communicate with each other unambiguously in the day-to-day practice of logistics and supply chain, including between IT systems.

Thus, within the context of DIL and BDI, both aspects will have to be fulfilled. This will require a degree of separation of these aspects although (as with ASTM) there will also need to be constant coordination between the two.
Current standards and tools for creating and managing formal semantic models focus mainly on the concepts, definitions and relationships between concepts. Current standards and tools for creating and managing syntax (data models and data formats) do not yet support formal semantics well.
Within DIL and BDI, one is likely to want to establish a pragmatic separation between semantics (at least for the short and medium term) that may be based on the above considerations, among others. As the aforementioned tools evolve (rapidly), that pragmatic separation may change at some point.

How does semantics relate to ontology?

The terms semantics and ontology are often mentioned in the same breath. In the field of information technology, ontology is defined by Wikipedia as:

> *'a representation, formal naming, and definitions regarding categories, properties, and relations between concepts, data, or entities within one or more areas under consideration'.*[8]

This definition is very similar to that of semantics but semantics is basically purely about meaning and the form in which the meaning is represented is not important.
Wikipedia then goes on to explain that:

> *'ontology is a way of representing the properties of a considered field as a set of terms and expressions that describe the relations between the entities in the field'.*

This is where the aspect of 'formal expressions' that can be systematically processed comes into even sharper focus.

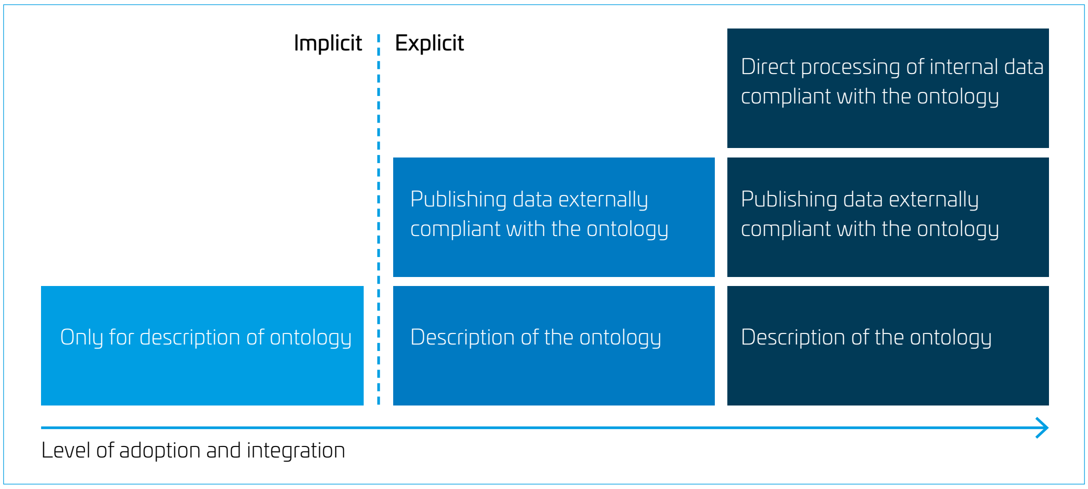
8 https://en.wikipedia.org/wiki/Ontology_(information_science)

In the context of digitalisation of logistics and supply chains, this formal aspect is important. By definition, ontology also always focuses on a specifically considered area. Logistics and supply chain are very diverse activities in which large numbers of sub-areas can also be distinguished. So one can develop an ontology by sub-area.

The Wikipedia definition indicates that it is also possible to develop an ontology that encompasses several sub-areas. That ontology will then also have to include the ontology of each of the included subfields. In principle, one can thus build an infinitely deep hierarchy of ontologies. The whole of that hierarchy is then a representation of the semantics for the total area under consideration.

The below 'level of adoption and integration model' for the application of semantics as depicted in figure 3 below (translated from Dutch language).

Figure 3
Levels of implicit/ explicit application of semantics



The starting point for the model is that semantics technologies (formal expressions) are used for the creation of ontologies.
At the most basic level of the growth model the representation to the user is still in the form of a common language (textual); the ontology is only present implicitly.

Within BDI, the intent is to take the level of semantics application to a higher level and use semantics and ontology also in the exchanges of data; the data shared/published will also comply with the common ontology, thus making the use of the ontology explicit.
Organisations may decide to also design and implement their internal data/IT-systems compliant with the ontology, as indicated in the box top-right.

What benefits for parties can be achieved with semantics?

A lot can be said about the benefits that application of semantics in transport, logistics and supply chain practice can bring. In this WP, we limit ourselves to four groups.

- Improve the quality of data exchanged
  The common language makes it clear to everyone exactly what data is meant when it comes to initial capture, processing, exchange and processing after receipt. In healthcare, for example, all parties working with medical data must have a unified understanding of each. If not, the consequences could be very serious. Something similar also applies in the transportation of hazardous materials.

- Increasing the efficiency of operations
  Through semantics (and syntax), data exchange becomes unambiguous and the exchanged data can be processed much faster and more accurately. This provides efficiency in automated processing. More importantly, business operations based on that data also face fewer errors and therefore can also operate more efficiently.

- Improving decision-making
  Decision-making benefits greatly from the availability of accurate and well-understood information and data. The data exchanged based on semantics is often further processed by the recipient by various tools such as business intelligence and Artificial Intelligence (AI). Such tools work much better if the basic data is available in accordance with common semantics. The tools can make use of the common semantics and additional semantics to combine data from various sources as part of decision-making processes

- Improve regulatory compliance and reporting
  More and more organisations have to comply with more and more regulations (e.g. ESG - Environmental, Sustainability, Governance). This often requires data to be provided by other organisations. A common semantics can ensure that all parties involved correctly understand what data is required for compliance and reporting and therefore that this data is also correctly available from the various organisations.

All of the above may be achieved to some extent using traditional semantic products intended for human readers. Formal, machine-interpretable semantics promise to further realise the full potential benefits of using semantics.

2.1.3 What are the principles for semantics within DIL - BDI?

As indicated above, work is underway within DIL on how pragmatic, semantic interoperability across the various data standards for the various sub-areas of logistics and supply chain can best be achieved among others by using the existing knowledge of data standards and available data. In the following sections, we discuss already existing principles and some proposed new ones.

9 *https://www.gs1.org/standards/epcis; https://www.gs1us.org/content/dam/gs1us/documents/industries-insights/by-industry/food/flyer/EPCISSharing-Event-Data-During-a-Products-Lifecycle.pdf*

'Event-Driven Model'

This approach is the basis for development of semantics in the DIL project. Events to be shared among stakeholders are the result of things occurring in a business activity such as 'Actual Time of Arrival at berth' (ATA at berth). Thus, business activity occurrences (events) are triggers for the related exchanges of information (technical IT events). In daily practice, people have been talking about statuses, milestones, locations, organisations, entities, data elements, transaction data (orders, invoices, transport documents et cetera), master data and so on for many decades. So people are completely familiar with such terms, which does not apply so much to the more theoretical way of identifying relationships with uniformly defined Events as a means of describing context.

Yet there is no real conflict between 'practice' and 'theory'

In daily practice, participants already connect an Event like 'ATA at berth' to many various other things like the location, the vessel, and then to transport document(s), organisations (vessel owner/operator, terminal operator, parties named on the transport documents etc.). The occurrence of an Event can also mean that a certain status or 'milestone' has been reached (e.g. Import Container can be collected from the maritime terminal). In practice, those links are usually provided in descriptive text documentation.
In the Event-Driven model (as also represented in FEDeRATED), connections are made in a 'formal' way. That formal way can be made available to IT systems in various ways that allow those systems to make automated use of those connections.

This cannot be done with connections captured in the textual semantic documents that are now common in practice. Figure 4 below illustrates how looking at an Event naturally also leads to all those objects and entities that practitioners are used to looking at in the 'traditional' way of modelling T&L and supply chains.

The choice to start from the Event is very logical from the perspective of aligning activities in transport, logistics and supply chain. That alignment is very often started with the exchange of information related to a relevant business event. That could be the sending of a Purchase Order by a Buyer to a Seller, the arrival of the ship at the berth of a terminal, the delivery of a parcel to the recipient (usually the Buyer). In addition, there are many other business events about which various parties want to exchange information with each other because that event has important implications for their business activities.

According to EPCIS (ISO/IEC 19987)[9] an Event contains at least the following 4 aspects:
'What, Where, When, Why (and How)'.

- What
  To which object or entity does this Event primarily relate (e.g. pallet, order, truck, wagon, etc.)?
- Where
  At which location did the event take place (warehouse receipt door, terminal access)?
- When
  On what date and time did the event take place?
- Why
  Why (in which business activity exactly) did the event take place (goods receipt, freight collection, transport document definitively agreed, etc.)?
- How
  It may also include the 'How' aspect. In what state (how) are or was the cargo being transported at the time of the event?

Wherever possible, EPCIS uses globally unique identification codes for objects and entities. This not only makes it possible to unambiguously determine the right type of object but also to unambiguously search for and access information about the specific object or entity based on the globally unique identifier. This idea of automated linking to additional data located elsewhere is also known as the 'Linked Data' approach.

Figure 4 brings together the ideas of Event-Driven as also used in FEDeRATED and the EPCIS standard (which is almost 20 years old and used in practice in transport, logistics and supply chain).
The Event is central in the figure, it is linked to a location (Where), to a logistics service (Why) and to a (physical) object (What). Although not explicitly shown, the Event in the figure also has a date and time.

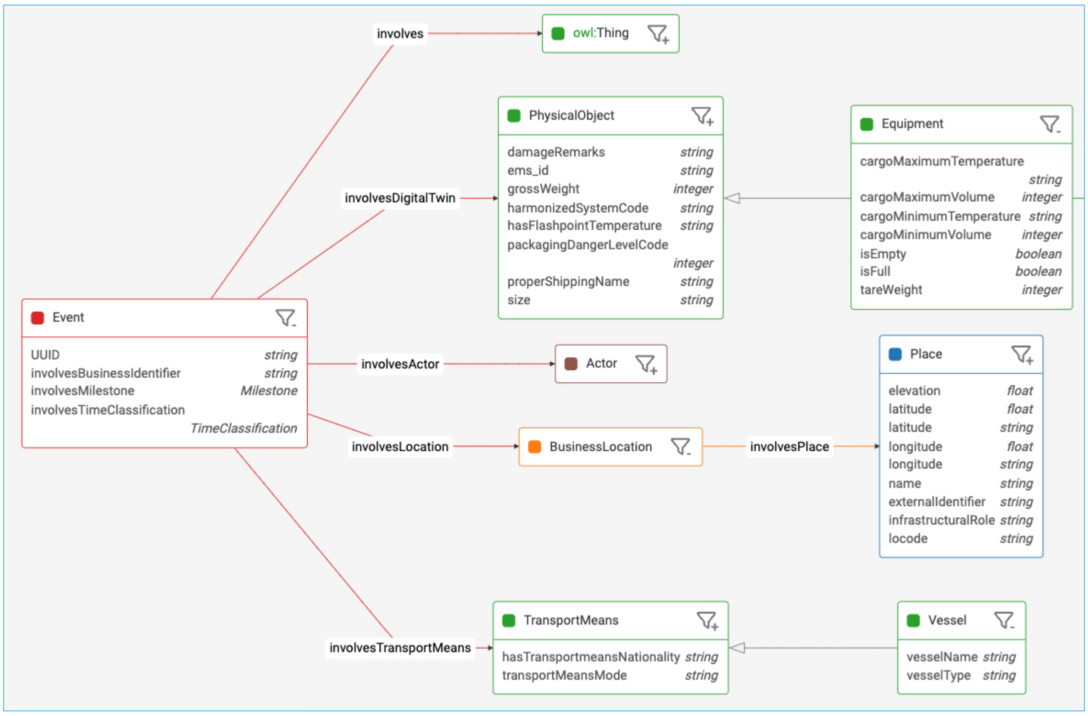


Figure 4
Event Driven view on logistics and supply chain

Since there are also quite a few connections beyond the figure's boundary, it will be clear that the Event-Driven model can be extended to any level. In fact, the model is never completely finished. Management (governance) is always needed to ensure that the model fits well with current practice.

10 *Screenshot van FEDeRATED Visualization pagina voor het Event-Driven data model https://federatedplatforms.eu/index.php/products/developer-portal/visualization*

2.2 What are important existing semantic standards for DIL - BDI?

It is impossible within the limitations of this white paper to cover or even identify all potentially important semantic standards. Here, a brief overview of standards that DIL and BDI are sure to encounter in use in T&L and supply chain will suffice for now. This overview in no way pretends to be exhaustive.

As logistics spans the globe, we first mention here a number of standards that are used worldwide and also have semantic products. Global Standards Development Organisations (SDO) that meet the criteria of the de WTO such as the ISO (International Standards Organization), UN/CEFACT, GS1, IMO (International Maritime Organization), IHO (International Hydrographic Organization), IATA (aviation standards organisation) and WCO (World Customs Organization) all provide terms, definitions and descriptions of how the relationships between them lie (semantics). ISO manages thousands of standards covering a multitude of sub-areas also far beyond transport, logistics and supply chain. Other standards organisations such as UN/CEFACT and GS1 build on the ISO standards (and, conversely, constantly contribute to them). UN/CEFACT and GS1 do explicitly choose specific sub-areas in logistics and supply chain.

UN/CEFACT (Centre for Trade Facilitation and Electronic Business) is known for its Buy-Ship-Pay (BSP) Reference Data Model (RDM). As the name suggests, this model focuses on supply chain (or in UN/CEFACT terminology 'Trade').
This BSP RDM has seen a further elaboration of the 'Ship' part in the Multi-Modal Transport (MMT) Reference Data Model. The UN/CEFACT standards form the basis of the data structures for the eCMR.

The UN/CEFACT BSP and MMT models are also used by many other standards-developing organisations. GS1 (known for the barcodes on products one buys in shops) also focuses on supply chain and 'transport and logistics'. GS1 and UN/CEFACT have both contributed a lot to each other's standards and continue to do so. The standards of the two organisations partly overlap but they achieve a good level of alignment through the 'exchanges' between the organisations[11].

Both GS1 and UN/CEFACT also offer their standards in (Web) Vocabularies and additionally via GitHub. In GitHub, they also offer them in 'formal' formats such as RDF Turtle and JSON-LD[12].
IMO, IHO, IATA and WCO standards support parties in their specific sub-areas (maritime, maritime, aviation and customs respectively). IATA, through its 'ONE Record' initiative, also offers a modern approach to data sharing that extends to a large number of users of the ONE Record approach.

> *'ONE Record is a standard for data sharing and creates a single record view of the shipment. This ONE Record standard defines a common data model for the data that is shared via standardised and secured web API.'*

IATA also offers this standard in 'formal' formats such as Turtle and JSON-LD. In addition, one can also access the ontology on-line[13].
The other three offer semantics in traditional formats. The IATA ontology also uses elements of the UN/CEFACT data models and ontology.

There are also organisations such as DCSA (Digital Container Shipping Association) and ICC (International Chamber of Commerce) that also work globally to promote standards development.

11 *See also presentation: https://unece.org/sites/default/files/2023-11/PPT_Item6b_GS1_Piergiorgio_0.pdf*
12 *GS1 Web Vocabulary: https://www.gs1.org/voc/ ; UN/CEFACT vocabulary: https://vocabulary.uncefact.org/about*
13 *https://onerecord.iata.org/ns/cargo/index-en.html*

DCSA (a collaboration of global maritime container carriers) focuses exclusively on standards for container transport[14]. This exclusive focus may be viewed as quite valuable also for the entire ecosystem of transport, logistics and supply chain. It ensures that the DCSA semantic products overlap as little as feasible with those from other areas, which facilitates the alignment of DCSA results with other semantic products. Furthermore, DCSA relies heavily on the standards of the UN/CEFACT MMT RDM, thus further facilitating the alignment.

ICC (best known for the INCOterms) focuses on promoting trade (Trade) across borders. That is why ICC, together with the World Trade Organisation (WTO), published the 'Standards toolkit for paperless trade'. This toolkit of standards is not in itself a standard. The document contains a good and broad overview of standards from various organisations that should be used in various combinations to enable the ICC goal of paperless trade. ICC is also the manager of the Digital Standards Initiative (DSI)[16], which brings together a wide range of organisations. This initiative aims to:

> *'develop a globally harmonised digital environment for international trade to enable dynamic, sustainable and inclusive growth'.*

DSI looks at documents used in international trade and the key data elements on those documents (Key Trade Documents and Data Elements - KTDDE). On that, DCI has currently published two reports (describing a total of 21 documents)[17]. A third report will describe a further 16 documents.

At European level, UNECE publishes the standards of UN/CEFACT. UNECE is also active with regard to standards outside logistics and supply chain, but these are beyond the scope of the White Paper. CEN/CENELEC is the official standards organisation for 34 countries counted as Europe.
CEN also manages standards for transport that may be of relevance to DIL and, for example, those for Intelligent Transport Systems. In addition, mention should also be made of CEN TC331, which deals with standards for mail and parcel transport. At a time when the transport of parcels is ever-increasing and globally runs into the hundreds of billions of parcels per year, this type of transport should not be missing in the context of DIL and BDI. Especially not since these parcels are also increasingly being transported in traditional transport modes for at least part of the supply chain between Buyer and Seller. CEN TC331 and the Universal Postal Union (UPU) both manage various standards for this sub-area of mail and parcels logistics. UPU does so on a global scale for 'designated' postal organisations. There is therefore a formal liaison and ongoing alignment between these two organisations to keep the standards of both aligned.

Within the Netherlands, there are also several initiatives to improve cooperation and data exchange between organisations in logistics and supply chain, also using semantics. These include the Open Trip Model (OTM), DEFlog (Data Exchange Facility Logistics) and 'Data voor Logistiek'.
DEFLog enables data exchange between companies and governments. Companies can also use DEFLog to exchange data between themselves. The standard used for data exchange is the Open Trip Model.

14 Any transport of goods before or after they are transported in containers is not covered by DCSA.

15 https://iccwbo.org/news-publications/news/icc-and-wto-launch-first-ever-standards-toolkit-for-paperless-trade/
https://iccwbo.org/publication/standards-toolkit-for-cross-border-paperless-trade

16 See also presentation: https://www.dsi.iccwbo.org/_files/ugd/0b6be5_d0801fb4d32e47b8b2e9abd09f3060ce.pdf

17 Information regarding KTDDE and its reports may be found at
https://www.tradefinanceglobal.com/posts/2023-icc-dsi-report-14-key-trade-documents/
The report related to the 14 KTD may be found here: https://www.dsi.iccwbo.org/_files/ugd/8e49a6_530a1b-d71a7e481f8485f4772a6854d5.pdf

'Data voor Logistiek' unlocks logistics data from all municipalities in the Netherlands on window times, environmental zones, weight, length, width and height restrictions, parking spaces, preferred routes, dangerous goods routes and loading and unloading bays. Here too, they use OTM. There is probably a relationship with CEN's Intelligent Transport Systems standards and 'Data voor Logistiek'.
The Open Trip Model is not based on any SDO standard. However, it does seem possible to translate the semantics of OTM to those of UN/CEFACT[19].

How to compare standards?

Any comparison requires criteria against which the objects to be compared can be assessed. Based on the principles regarding semantics for DIL and BDI, we propose the following criteria that may be used for semantic products and standards, be they for master data, transactional data, event data or other kinds of data.

Geographical coverage, coverage of logistics and supply chain areas

These give the potential user of the standards and semantics an impression of their relevance to the user's business activities. A road transport operator that transports pallets mainly in north-western Europe between large warehouses of its clients is interested in standards that relate to those business activities.

Market adoption, Solid management, long-term presence and maintenance

Market participants will ask themselves the question:

> *'If I invest in particular standard semantics, how many partners can I work with using this standard?'*

These criteria give practitioner parties confidence that one can safely invest in applying standards (semantics) of this SDO in their systems and operations.

If many of the parties operating in the same field as the user are already using the standards, this gives confidence that they will also work well for the user. Then, if the standards have also been in use for a long time and are regularly updated to comply with current practices and the organisation responsible for them has been doing so for many years, the user may assume that their investment in these standards is also safe into the future.

Technical maturity, support for Event-Driven and Linked Data approaches

Indicates the extent to which the standards can be deployed in an automated way and the extent to which they can already support expected future developments. As already shown in the section above, not all standards and semantic products already follow the modern techniques and methodologies that have emerged in recent years. Support for these (or the lack thereof) may be a consideration within the comparison of standards and semantic products.

The combination of the above criteria gives practitioner parties confidence that one can safely invest in applying standards (semantics) of this SDS in their systems and operations.

> *Without the willingness of market players to invest in this way standards will not be implemented.*

18 https://www.cencenelec.eu/areas-of-work/cen-sectors/transport-and-packaging-cen/

19 See also: From EDIFACT to OpenTripModel: analysis, migration and guidelines based on data from real-world logistics companies (utwente.nl)

Review of large standards by criteria

In this white paper, we do not do a comprehensive comparison of a large number of semantic products that could be deployed within DIL and BDI.

A number of the products mentioned above were compared, however, purely for illustrative purposes. The valuation in each cell is purely indicative and will have to be revisited in a thorough analysis in a follow-up activity within DIL and BDI. This comparison can then serve as a starting point.

Several cells are also deliberately left blank in this comparison because the judgement on them can only be determined in a deeper analysis than was possible for this WP. The comparison below should therefore not be read as a firm recommendation for one or the other combination of semantic products of organisations.

Organi-sation	SC - T&L areas	Geography	Market adoption	Manage-ment/main-tenance	Age (years)	Event-Driven	Linked Data Web standards use	Links to other standards	Openness
ISO	Foundational standards	Worldwide	very broad	very robust lengthy	77	EPCIS	in several standards	Adopt standards from other SDO e.g., GS1& UN/ CEFACT	Fully open via country SDO
UN/CEFACT	Supply chain & Logistiek data-modellen; eCMR	Worldwide	very broad	very robust; variable	27	refereert naar EPCIS in diverse BRS	in several standards	ISO; GS1	Fully open via countries
GS1	Supply chain (Artikel) en Logistiek (Locaties) datamodellen; Event gegevensuitwisseling standaard EPCIS; Unieke identificatie; Linked Data standards	Worldwide	very broad	very robust; variable	50	EPCIS author/ manager	GS1 Digital Link standard (extension of Linked Data standards	ISO; schema.org; UPU; UN/CEFACT	Fully open; directly global
IMO	Maritiem transport goederen en personen	Worldwide	very broad	very robust; very lengthy	65	no			Member States
IHO	Maritieme navigatie	Worldwide	very broad in their sub-area	very robust lengthy	102	no			Member States
IATA	Luchtvaart goederen en personen	Worldwide	very broad in their sub-area	very robust lengthy	78	ONE-record initiative	ONE-record initiative	limited (UN/CEFACT)	Air carriers
WCO	Douane	Worldwide	very broad in their sub-area	very robust; very lengthy	71	nee	nee		Member States
DCSA	Container transport	Worldwide	starting in their sub-area	less robust dynamic	4	Track&Trace standard	electronic Bill of Lading	Strong link with UN/CEFACT	± 10 maritime container carriers
ICC & samen-werkingen	Internationale handel	Worldwide	INCOterms very broad; starting in other sub-areas (MLETR)	Robust invol-vement from SDO & econo-mic operators	104	no	no	Promoot standaarden in het algemeen	Limited via open collaborations
UNECE	zelfde als UN/CEFACT	European	very broad in their geography	very robust; variable	76				Fully open via country SDO
CEN/ CENELEC	Transport - alle modi	European	very broad in their geography	very robust; variable	62				Fully open via country SDO
CEN TC331 - UPU	Pakket en Postale standaarden	European/ Worldwide	very broad in their geography/ sub-area	very robust; variable	62 & 150	limited; Track & Trace			UPU open only to postal organisations

3 Part 2 - How to develop semantics effectively?

The previous section made it clear that it is worth investing in developing standard semantics that will actually be used in day-to-day practice by the various parties. This explicitly includes the large numbers of very diverse market parties (large and small) that actually carry out the transport of goods from Seller to Buyer. In addition, various government organisations, semi-government organisations and other types of organisations will also want to use robust and well-understood semantic products.

Semantics is a topic that transport, logistics and supply chain have been working with for decades (even if it was not always called that). During that time, it has also become clear that it is not easy to arrive at semantics that are commonly supported across the entire broad field of transport, logistics and supply chain.

3.1 What are the challenges for semantics development?

Wide variety of parties involved and semantic products

The logistics and supply chain ecosystem spans the globe and is very diverse. As a result, there are very large numbers of parties that often only cooperate or even interact with a very limited proportion of the parties in the overall ecosystem. E.g. aviation, rail and inland navigation rarely or never have contact. Maritime still has contacts with the various other transport modes, but most players within maritime only talk to other maritime players. Operational coordination between different transport modes is therefore often problematic'. So there is huge fragmentation in the ecosystem.

There are no semantics shared by all stakeholders in the ecosystem. However, there are lots of glossaries, data dictionaries, vocabularies, and logical data models that are used in various sub-areas (and even there, mostly not by all stakeholders in those sub-areas).
Earlier this year, the ASTM group on 'Digitalised Information in the Supply Chain' did an inventory of semantic products that say something about this area. Many dozens were found and new ones kept being discovered. The group stopped actively searching when more than 50 were found.

Cultural hurdles

Sub-areas often want to stick to the terms (semantics) they are used to. The terms of a common semantics are 'new'; sometimes the same term has a different meaning in the new semantics than in the semantics familiar to them.
The classic example is the term 'shipment'. For the Buyer and Seller (Beneficial Cargo Owners - BCO), it usually means the set of goods sent by the Seller to the Buyer. This shipment is often transported over various modes under multiple transportation contracts. Carriers also use the word 'shipment' but they usually mean the set of transport units to be transported under one specific contract. According to both UN/CEFACT and GS1 the carriers should be using the term 'consignment'. So the BCO and carriers often have misunderstandings about this. Commonly used semantics would resolve this, but many parties do not appear to be very enthusiastic in embracing common terms and definitions.

Few 'formal' semantics descriptions available

Semantics are nearly always only available in text forms written for interpretation by humans (not machines or systems). The ASTM group found only a handful of semantic products that already support systematic use. The lack of such formal descriptions makes it very laborious to compare the various semantic products, translate between them and then reconcile identified 'conflicts' between them.

'Legacy' systems

Supply chain and T&L uses many, often (very) old IT systems. These were never designed based on a common semantics. Translating between business activities that use these legacy systems and business activities that (want to) use common semantics is therefore often difficult. This is true even if the business activities are all within one organisation, but certainly when it comes to alignment between different organisations.

Willingness of organisations to cooperate

Transport and logistics are highly competitive sectors and people often have little trust in each other. Sharing knowledge and data is (too) often seen by individual organisations as 'dangerous'.[20] As a result, it is often not easy to find organisations willing to invest in developing semantics and then implement those in their own practices and IT systems.

How do these challenges manifest themselves in the DIL - BDI context?

In DIL a multitude of standards with the parties involved is recognized and hence the BDI will need to support semantic interoperability to achieve multi-modal data exchange supporting the logistics in the supply chain in a more streamlined manner.

Many definitions of the same element exist. For example the definition of 'estimated time of arrival' is often debated as it is used at various stages of a shipment journey. The sender of the datapoint is often not aware of its recipient and usage. The interpretation by the receiving parties might be different. The context is not shared in the transmission.

3.2 How can we address challenges within the DIL - BDI-context?

3.2.1 Top-down or Bottom-up?

Broadly speaking, one can develop semantics in two ways: Top-down and Bottom-up. Generally, in a Top-down approach, a much (or all) encompassing consistent and coherent model is developed. This is then pushed further into the organisation with the expectation that the lower parts of the organisation will then implement that model correctly and as much as possible.

Top-down approaches have proven successful in the past if a number of conditions were met. Among these are the following two:

1. There is an authority relationship between the higher layers in the organisation and the other parts of the organisation.
2. The leading part of the organisation devotes a lot of attention and energy to rolling out the top-down model and does so over a long period of time.

In a Bottom-up approach, one trusts that parts of the organisation that are closer to the operation will come up with initiatives to develop models that work well for the sub-area in which that organisational unit works.

In many organisations, in practice, many initiatives and models do indeed arise naturally as a result. It turns out that it is not easy to get visibility and keep track of the various initiatives. As a result, it is also not easy to ensure that the various initiatives lead to a consistent and coherent whole.

It is clear from the 'Challenges' section above that in the ecosystem of transport, logistics and supply chain, the conditions for success of a Top-down approach cannot be met. There is no authority relationship, there is little interest in a comprehensive model, nor is there a leading party with the perseverance to get the other parties in the ecosystem to implement a semantic model.

20 See also article online in OECD Library https://www.oecd-ilibrary.org/sites/15c62f9c-en/index.html?itemId=/content/component/15c62f9c-en

In the Bottom-up model, ensuring that the various initiatives lead to a consistent and coherent whole is the main focus. Each initiative basically develops its 'own ontology' for the sub-area in which it is working. To reduce or eliminate the risk of inconsistency with another sub-area's ontology, it is strongly recommended that there should also be an overarching ontology that combines the outcomes of the sub-areas. This may be called a 'top ontology'[21]. The overarching ontology should also be constantly brought to the attention of those who will participate in semantics development initiatives. This increases the chances of keeping the new ones to be developed for the sub-area consistent with the overarching ontology.

3.2.2 How can a Bottom-up approach be shaped within the DIL-BDI context?

Starting point 1: Build on the semantics of (global) SDO

Standards Development Organisations (SDO) have often been building their semantic products with large and diverse groups of parties for many decades. These are also often already extensively deployed by organisations in practice. Despite the overlap that the standards of these SDO have with each other, they still form the most solid basis for semantic products that have the ambition to facilitate cooperation between large numbers of parties around the world in all areas of transport, logistics and supply chain. These SDOs have already proven themselves in terms of solid management, long-term presence and maintenance.

The various SDO also often have a leading position in the areas they have focused on in the sense that other SDOs have little (or no) overlap in their area or those 'competing' standards are little used by the parties active in that area. This provides a second starting point.

Starting point 2: Identify which SDO standards are 'leading' in which area

This is also linked to the willingness of market players to invest in standards (semantics). Some work has already been done to identify which SDO standards are leading in which areas in logistics and supply chain for certain sub-areas. Further work is certainly needed to do the same for other sub-areas. This can also be included in the further work of DIL and BDI already suggested above in the standards review section.

Principle 3: Fill 'gaps' with semantics developed by non-SDO

SDOs are not always able to provide standards at the time when parties in specific areas of the supply chain and T&L need a 'common language' anyway. In such cases, those parties often develop their own 'language'. In the best case, they base their work on work that had already been done by SDO (but unfortunately this is not always the case).

The non-SDO generally do not follow the same robust processes for standards development as the SDO. When adopting the semantic products of non-SDO, it is advisable to have those products incorporated into the official SDO standards via the most appropriate SDO before finally incorporating them into DIL. In the meantime, one can already use a 'draft' version of the semantics.

DIL and later BDI can also conduct their own 'review' of the non-SDO semantic products (e.g. comparison with what is already available from SDO, application of general rules and guidelines for semantic products). Thereafter, the non-SDO products can be included in DIL and BDI (after inclusion in official SDO standards, adaptation may be required).

21 *As indicated above, 'top-ontologie' is actually misleading. There is always a higher level of hierarchy within which a 'top-ontology' should fit.*

Principle 4: Develop semantic products 'opportunity-driven'

Earlier, it was indicated that a bottom-up approach to semantics development is necessary. In such an approach, it is strongly recommended for the DIL project and BDI to be involved at a very early stage of a semantics development initiative. This can be done by actively looking for (small) groups of organisations that want to tackle a well-defined common problem (Use Case) (a 'coalition of the willing'). Within the context of DIL and BDI, there are probably also opportunities to co-initiate such initiatives. In this white paper, this is referred to as 'opportunity-driven'.

For acceptance by participants in the initiative, it is desirable (probably even necessary) for DIL and BDI staff to be of service to those participants. One can provide the initiative with advice regarding already available standards, semantics, project management, guidelines for implementation of standards etcetera. One can also point to pilots for similar use cases and tools from standards organisations and others that could be used to solve the common problem faster and better[22]. DIL and BDI should clearly add value to the initiative in the opinion of the initiative participants.

In this way, the semantic products emerging from such initiatives are most likely to be consistent and coherent with the overarching ontology sought by both DIL and BDI. It is also certain that such initiatives will identify gaps in available SDO standards. Therefore, DIL and BDI will need to remain in constant active contact with standards organisations. One can then present the gaps found (and solutions proposed by the initiative) to the most appropriate organisation as additions to that organisation's standards. In the vast majority of cases, those organisations will welcome such requests for additions to the standards.
Once the additions are included by the relevant organisation/s in their official standards, this also ensures their management and maintenance (Governance) for the longer term. This also makes the application of the proposed solution in a (much) larger geographical area more likely, further supporting the interoperability of parties in the global logistics and supply chain ecosystem.

22 *Within DIL, use cases are collected for living labs where there are numerous many-to-many challenges including in the area of semantics. Those use cases (and case studies when the living labs finish) may be very helpful for later implementations of various use cases.*

4 In conclusion

Based on the considerations described above, this white paper arrives at the following recommendations for developing semantics in the context of the Digital Infrastructure Logistics project and the Basic Data Infrastructure in the Netherlands.

An ontology can only become successful if it is supported by a broad user base. Examples of such successes are the semantic products from SDOs UN/CEFACT, and GS1 for the full breadth of logistics and supply chain and IATA ONE Record for aviation. These organisations offer their semantic products in modern ways and also in 'formal' formats. GS1 and IATA, to a large extent, have adopted an event-driven approach to further developing their ontologies. UN/CEFACT is following in their footsteps. One may conclude that event-driven thinking and approaches are becoming 'mainstream'.

The vocabularies/ontologies of these organisations overlap. Each of the three elaborates on sub-areas of logistics and supply chain that are relevant to the user groups of those organisations. One could therefore say that there is no common ontology, but that does not do justice to the real situation. The three organisations are very much aware that they operate in the same large area. Therefore, the three organisations also (increasingly) use each other's semantics in their own ontology. The three organisations also have to constantly adapt and extend their own semantics because they have to support the prevailing 'business needs'. Therefore, it is probably impossible for there to be a single 'top ontology' that encompasses the ontologies of all three in their entirety. Given the trend that they do already increasingly use each other's semantics, though, it is plausible that people will start using the same terms for more and more concepts. And where this cannot be done[23], the equivalence of different terms for the same concept can be established.

So at this global level of SDOs, we already see an 'organic' process whereby these SDOs are increasingly moving towards something very similar to a 'top-ontology'.

This approach can be summarised in the 'algorithm' below.

I. Develop a catalogue of Use Cases that cover the most common processes and activities in transport, logistics and supply chain.
II. Elaborate the Use Cases (at high/medium level).
III. Together with interested market players, determine which Use Cases (also based on opportunities for adoption in the market) to progress.
IV. Set up task groups of experts who will then further elaborate the Use Cases in all the necessary details. Several task groups can work in parallel, each working on their own Use Case. All task groups should perform their tasks based on the previous work.
V. The Semantics group as a whole monitors that no duplication or inconsistencies arise during parallel working. The various Use Cases will also have some processes and/or activities in common. For those, the same semantic products must be used in all Use Cases that use that process or activity.
VI. Repeat these steps from step 'I'.

In this way, it is possible' to grow a consistent set of semantic products that can help solve challenges in transport, logistics and supply chain.

23 This will mostly be because the user group wants to keep using their traditional terms.

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