

Improving sustainability through intelligent cargo and adaptive decision making

Simon Dalmolen^{1,4}, Erik Cornelisse¹, Arjan Stoter¹, Wout Hofman², Harrie Bastiaansen², Matthijs Punter², Frank Knoors³

¹ Logica, Prof. W.H. Keesomlaan 14, 1183 DJ Amstelveen, The Netherlands

simon.dalmolen@logica.com, erik.cornelisse@logica.com, arjan.stoter@logica.com]

² TNO, Brassersplein 2, Delft, The Netherlands

wout.hofman@tno.nl, harrie.bastiaansen@tno.nl, matthijs.punter@tno.nl

³ Logit Systems, Cipalstraat 3, B-2440 Geel, Belgium

f.knoors@logit-systems.com

⁴ University of Twente, School of Management and Governance,

Po box 217, 7500 AE Enschede, the Netherlands

Abstract. In the current society, logistics is faced with the challenge to meet more stringent sustainability goals. Shippers and transport service providers both aim to reduce the carbon footprint of their logistic operations. To do so, optimal use of logistics resources and physical infrastructure should be aimed for. An adaptive decision making process for the selection of a specific transport modality, transport provider and timeslot (aimed at minimisation of the carbon footprint) enables shippers to achieve this. This requires shippers to have access to up-to-date capacity information from transport providers (e.g. current and scheduled loading status of the various transport means and information on carbon footprint) and traffic information (e.g. city logistics and current traffic information). A prerequisite is an adequate infrastructure for collaboration and open exchange of information between the various stakeholders in the logistics value chain to obtain the up-to-date information. This paper gives a view on how such an advanced information infrastructure can be realised, currently being developed within the EU iCargo project. The paper describes a reference logistics value chain, including business benefits for each of the roles in the logistics value chain of aiming for sustainability. A case analysis is presented that reflects a practical situation in which the various roles collaborate and exchange information for realizing sustainability goals, using adaptive decision making for selecting a transport modality, transport provider, and timeslot. A high-level overview is provided of the requirements on and technical implementation of the supporting advanced infrastructure for collaboration and open information exchange.

Keywords

Sustainable logistics, carbon footprint, adaptive decision making, up-to-date information, collaboration open information exchange.

1 Introduction

For shippers of goods, sustainability becomes an ever more important criterion in selecting a carrier (European Commission 2003). As such, sustainable logistics aims to balance several optimisation criteria as part of the decision-making process for shippers to select a specific transport service. These optimisation criteria include carbon footprint in combination with price and time.

1.1 Adaptive decision making for sustainability

The carbon footprint of transport depends on several factors. These are often not controlled by a shipper. Rather, they are controlled by for instance carriers or parties that coordinate various

transport modalities, generally known as Logistic Service Providers (LSPs) (Christopher 1999). Hence a shipper that uses sustainability as a criterion for selecting a carrier depends on information provided by carriers and LSPs. This information may for instance be on the degree that transport capacity is efficiently being utilised. This information changes continuously as carriers and LSPs consolidate bookings to optimise load capacity.

Adaptive decision making enabling shippers to realise their sustainability goals through adaptive decision making requires that carriers and other service providers in the logistic value chain provide the shippers with 'up-to-date'¹ views on the information needed, such as capacity information (e.g. current and scheduled loading status of the various transport means), carbon footprint information and traffic information (e.g. city logistics and current traffic information). This information enrichment improves the quality and accuracy of decision-making in the planning and execution process for achieving sustainability goals, especially on low carbon footprint.

1.2 An infrastructure for information exchange

Adaptive decision making requires a 'plug & play' exchange of information within the logistic network. Full visibility is required between all interacting stakeholders. Also, a mechanism is required to aid the decision making in order to consolidate bookings. Finally, as conditions change over time, new stakeholders (e.g. shippers, logistic service providers) must be able to join the communities of collaborating stakeholders.

Today, most information exchange is carried out through EDI-messaging, whereby an EDI-message is sent to make a booking and receive status updates afterwards. To realise adaptive decision making, we need to rethink the way information is exchanged in these organisational networks:

- Before a transaction can take place, full visibility is required on the available transport services and their respective offerings (in terms of price, schedules and carbon footprint). These offerings can change overtime, as bookings are consolidated.
- A more advanced mechanism is required to decide upon the best transport service and/or to reschedule (if possible) to improve sustainability (amongst other criteria).
- During the execution of the transport service full visibility (e.g. updates on delays) is required, to schedule the next leg in the logistic chain.

The above requirements indicate the necessity of an open architecture that connects all stakeholders in a community structure.. A community can be a group of organisations operating in a particular port, a group of suppliers to a specific large shipper, or any other group of cooperating organisations. Organisations can be part of multiple communities and will join and exit communities over time, as business conditions change.

Within each community, agreement is required on the semantics and technological implementation of information exchange.

1.3 Objective of this paper

The objective of this paper is to present a view on how adaptive decision-making for sustainable logistics can be improved by collaboration and integration and sharing of information between logistic supply-chain stakeholders. The view presented is currently being developed within the EU iCargo project. The view is illustrated a case analysis and includes a high-level description of the technical implementation.

¹ It is to be noted that 'up-to-date' is a relative measure. In the context of the decision-making process for transport modality as described in this paper, 'up-to-date' may be interpreted as providing 'direct' access to operational data of carriers and LSPs, i.e. typically in the range of several hours. It should therefore not be confused with the term 'real-time' as generally used in information technology and industrial processes, which is generally interpreted in terms of milliseconds.

The current paper builds on the research and innovation work as currently done within the EU FP7 Cassandra² (TNO 2011), Comcis³ and iCargo (iCargo). Figure 1 provides the goal and approach adopted in the iCargo project.

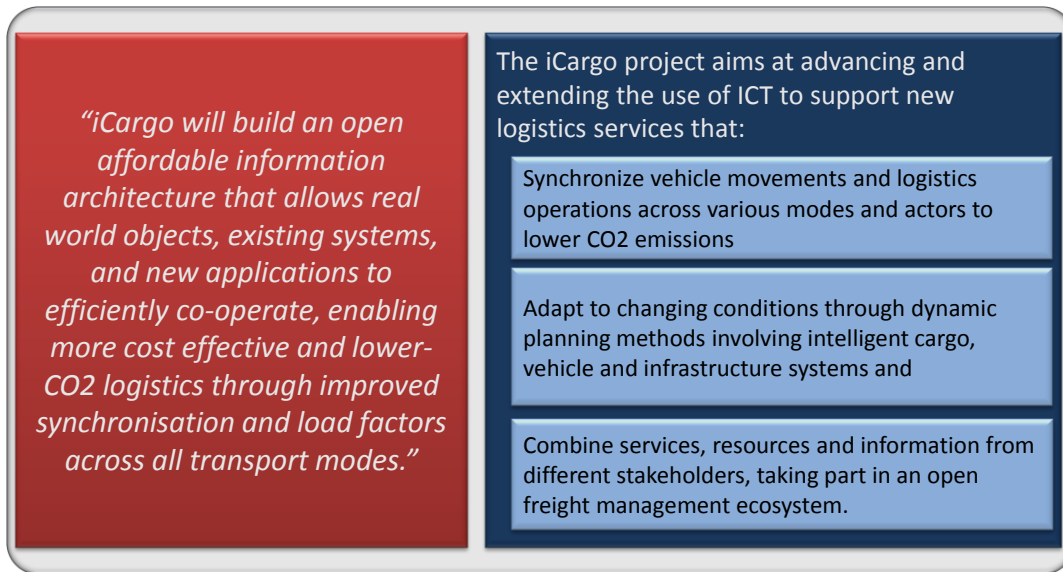


Figure 1. Goal and approach of the iCargo project (citation from [ICARGO]).

1.4 Contents of this paper

The paper has the following structure:

- Chapter 2 describes the business context. It contains a reference logistics value chain and describes for each of its roles the business benefits of striving for sustainability. It provides a case analysis, reflecting a practical situation in which various roles in the value chain collaborate and exchange information for realizing sustainability goals. Additionally, it describes the main challenges on the supporting ICT.
- Chapter 3 elaborates the technical implementation. It provides the basic requirements for an advanced collaboration and information exchange infrastructure. It presents a high-level view on the architecture for the implementation, both from a technical and organisational perspective.
- Chapter 4 concludes this paper with conclusions and future work.

2 Business context

In this chapter the business context for sustainability in logistics value chain is described. The business context is the basis for further elaboration of the technical implementation in the following chapter of this paper.

The subsequent sections of this chapter respectively describe a reference logistics value chain, a use case (describing a practical case on how stakeholders interact in striving for sustainability), the benefits of striving for sustainability for the various roles in the value chain and the main challenges on the ICT infrastructure.

² The EU FP7 project CASSANDRA, <http://www.cassandra-project.eu>

³ The EU FP7 project COMCIS, <http://www.comcis.eu> (to be launched).

2.1 The reference logistics value chain

A logistics value chain consists of many organisations with various roles, e.g. forwarder, shipper, and carrier. These roles can be further abstracted to two basic roles of customer and service provider. Other approaches distinguish three roles, customer, service provider, and operator (Schumacher, J, Rieder, M, en Masser, P 2010). In this paper we use the reference logistics value chain as adopted by the iCargo project. This reference logistics value chain is depicted in Figure 2.

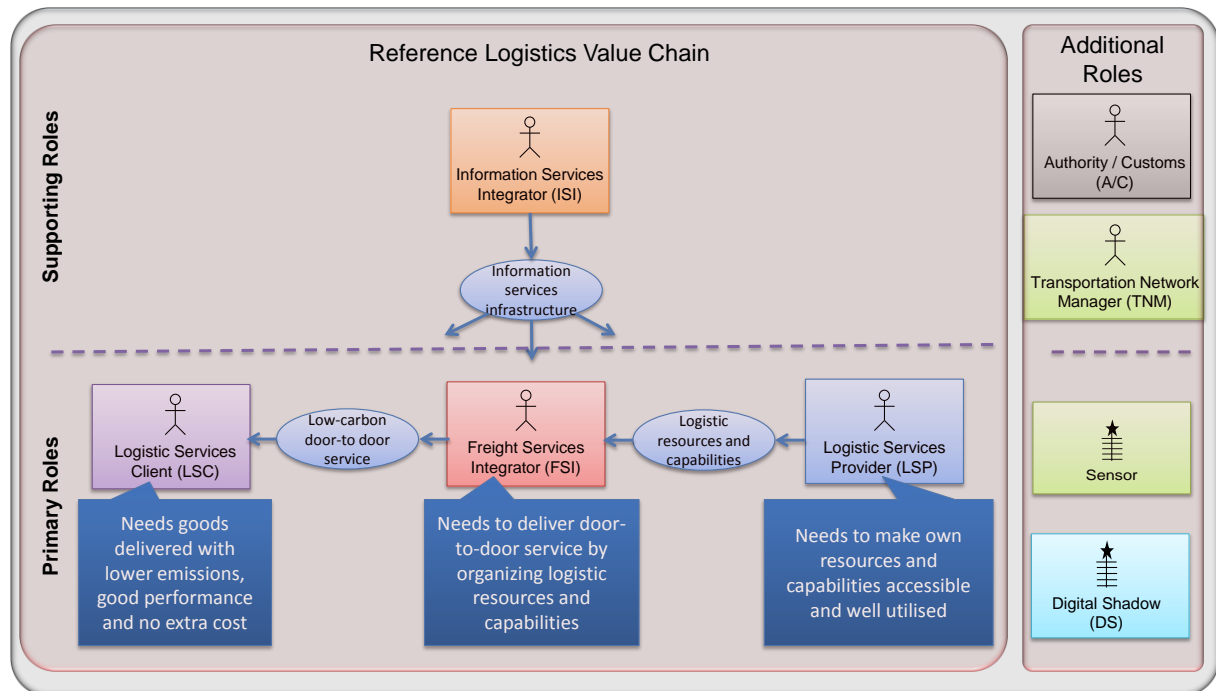


Figure 2. The reference logistics value chain.

As Figure 2 illustrates, the reference logistics value chain consists of three primary roles⁴, each with their perspective on sustainability:

- The *Logistic Services Client (LSC)* represents an organisation purchasing a door-to-door transport service, typically a manufacturing or distribution company. The LSC is also referred to as 'shipper' or 'consignee'.
- The *Freight Services Integrator (FSI)* (European Commission 2003) represents organisations providing combined door-to-door transport services to LSCs, typically a freight forwarder, a third party Logistic Service Provider (3PL) (Lai, Ngai, en Cheng 2004) company or the shipper itself through its logistics department.
- The *Logistic Services Provider (LSP)* (Christopher 1999) represents organisations providing - and possibly operating- transport and logistic services.

These three primary roles in the reference logistics value chain can each contribute to increase sustainability, as is described in section 2.4.

In addition to the roles of LSC, FSI, and LSP in the reference logistics value chain, there is an additional supporting role that is not directly involved in the provision of transport services. Rather it provides the information infrastructure required by the primary roles for optimizing transport; The Information Services Integrator (ISI) provides the information infrastructure for the value chain, which is required by the LSC, FSI, and LSP roles in performing their activities. This information infrastructure will enable collaboration and

⁴ It is to be noted that the reference logistics value chain as depicted in Figure 2 represents roles and not organisations. A real-life organisation may fulfil several roles.

open information exchange to match the goals of LSCs with services offered by FSIs and LSPs. In addition, an ISI also provides interoperability services with the IT systems of LSCs, FSIs, and LSPs. The basic requirement for this supporting role is to enable collaboration and information sharing between various stakeholders involved in adaptive decision making to achieve sustainable logistics.

In the right part of Figure 2, additional stakeholders are included, which are not part of the reference logistics value chain but play an important role in logistics chains:

- The *Transportation Network Manager (TNM)* is in charge of managing a transportation infrastructure sustaining the door-to-door flow, e.g., rail infrastructure provide, port authorities providing access to quays and city traffic managers. These organisations are not directly involved in providing transport but provide traffic and infrastructure status information (static or dynamic) to FSI's and LSPs with the objective to optimise infrastructure utilisation and reduce environmental impacts.
- The *Authority / Customs (A/C)* for governing the goods flow based on (inter)national laws and regulations. There is a variety of authorities, each with their own specific requirements on information exchange, e.g. customs, inspections, and river police. Over ten agencies are for instance involved in handling vessels in ports and on sea (Van Stijn, Evelien, Klievink, Bram, en Tan, Yao-Hua 2011).
- The *Digital Shadows (DS)* that are the digital representations of entities in the logistics supply chain, e.g. cargo, resources (trucks, vessels, containers, ...) and stakeholders. Digital shadows are part of a so-called Entity Centric approach . The concept of Digital Shadows and entity centric approach were part of the EU Euridice project (FP7 EU Euridice). The concept involves autonomous decision making by agents that represent actual (cargo-) entities within the logistics supply chain (Dalmolen, S, Moonen, H M, en Cornelisse, E 2012). The entity centric approach is further described in chapter 3.
- The *sensors* providing information on the physical status of cargo at specified time- or location intervals (e.g. location,. Temperature, ...) to stakeholders in the logistics value chain.

2.2 (Business) use case: port of Rotterdam

Here we demonstrate by means of a use case how various stakeholders may engage in a collaborative business process. The case analysis reflects a practical situation in which various roles in value chains collaborate and share information for realizing sustainability goals. This case illustrates the challenges to IT implementations. It underpins the benefits in striving for sustainability, as further described in the following section.

The use case focuses on global container logistics transport from Asia to Europe through the Port of Rotterdam (taken as port of discharge) with a particular focus on the transportation from Rotterdam to the hinterland. The use case involves two stakeholders: a logistics services client (LSC) who is the principal stakeholder⁵ for planning and executing transportation, and secondly two logistics service providers (LSP) who are resource-based operators that deliver hinterland transport services by rail (LSP 1) and road (LSP 2).

The aim of the LSC is to minimise the carbon footprint, while maintaining an acceptable lead time and a competitive price. For the purpose of this paper the focus is on carbon footprint as the only optimisation criterion for the LSC, which of course is not the case in the real-world. Traditionally the LSC will make a booking at the LSPs at some time before the ocean vessel arrives in Rotterdam.

⁵ It is noted that according to the reference logistics value chain (as depicted in Figure 2) the Logistic Services Client (LSC) may outsource the process for planning and executing door-to-door transportation to the role of the Freight Services Integrator (FSI). For simplicity of the use case however, this option is not elaborated.

The actual carbon footprint that can be delivered by the two LSPs (a traditional road haulier and a rail LSP) depends on the capacity-utilisation of their resources, which implies that it is difficult to estimate the carbon footprint long in advance. If the LSC selects road transport, he might overlook the carbon-friendly rail option, if the latter appears to be executed as a fully booked rail service where the carbon footprint can be shared among many individual containers.

One of the LSPs is a traditional road haulier. Communication is being done by rather traditional means. The LSC is aware of its lead-time and its average carbon footprint, and confirms a booking using a traditional booking system.

The rail LSP uses a service provided by the ISI to publish its transport service offering electronically. The service is characterised by a set of service parameters, and carbon footprint is the parameter that will be to the focus of the use case. The rail LSP is continuously optimizing the routing of its wagons and the allocation of individual containers on these wagons based on reception of provisional bookings in real-time from its customers, our LSC being one of them. As a result of these optimisation activities, the rail LSP is able to update in “real-time” the carbon footprint of its rail service, specified per departure timeslot. As it becomes apparent that he will have a high degree of loading, his carbon footprint per container is decreasing.

The LSC continuously compares the transport alternatives that he may use. Experience has told him that he needs to freeze his final choice half a day before departure of the container. As the booking deadline approaches, he becomes aware that the estimated carbon footprint of the rail service decreases, which makes it more interesting than the road alternative. When the cut-off time arrives, he chooses the rail services over the road services and finalises the booking process.

2.3 Benefits in striving for sustainability

The benefits for the participating stakeholders are clear. More transparency will be created on the logistics marketplace, which will offer more sustainable logistics alternatives, which will result in a decrease of average carbon footprint per container. .

A success factor for increasing sustainability based on an advanced collaboration and information exchange infrastructure, entails that each business role has business benefits by collaborating on sustainability.

As such, the following business benefits for each of the three primary roles in the reference logistics supply chain are identified:

- *Business benefits for LSCs*

An LSC can meet the end-user expectations on Corporate Social Responsibility (CSR) in terms lower emissions and still meeting performance demands. An LSC will be able to realise those benefits by electronically sharing data with many LSPs, accessing “real-time” information on service parameters as offered by these LSPs, and deciding in real-time which transport alternative to use. It will also benefit those LSPs that offer good service parameters and have the best operations in order to optimise these parameters.

- *Business benefits for FSIs*

Based on visibility supplied by sensor data, an FSI is now able to integrate, plan, and coordinate different logistic services into an effective and efficient door-to-door solution. An FSI is able to adapt to bookings of particular transport modalities (co-modality) in a later stage based on availability of real time data provided by these sensors.

- *Business benefits for LSPs*

By making available resource-capacity accessible to other organisations in logistic chains, an LSP may be able to increase the load capacity (more full truck loads) by combining shipments of different LSCs and FSIs. Using the proposed information exchange

infrastructure, an LSP can offer services like co-modality and handling with a real-time dynamic planning of resources⁶.

An ISI is a new role in the chain enabling information sharing through the chain. Making use of state of the IT e.g. Cloud and Semantics, an ISI can offer seamless integration and data sharing between the different stakeholders. The role and benefits of the ISI will be elaborated further on this article.

2.4 Challenges on supporting ICT

The abovementioned scenario has a number of implications that are not easily solved by current use of ICT. In this section we will touch on a few.

The rail LSP needs to evaluate in “real time” the impact on carbon footprint per container based on a number of factors: total amount of containers that will be booked, wagons allocated, required movements of empty wagon, required number of tractions based on the total load, etc. As to the total amount of containers that will be booked, this is not certain since its customers may take different decisions just before the cut-off time. As a result the LSP needs to optimise its resource allocation based on analysis of past behaviour as a prediction of future demand. Furthermore it needs to adapt these provisional planning to real-time demands and share that information with its customers enabling them to also make real-time decisions.

The LSC has a virtual transport network at its disposal from which it may choose specific (combinations of) modes, providers and timeslots – thereby using the best alternative from a carbon footprint perspective. In order to make the “right” choice, the LSC needs to dynamically update this network based on real-time information received from its individual LSPs. In addition it needs to plan the best transport option in real-time. This is being complicated by the fact that the availability of its container for hinterland transport may be uncertain, depending on the exact moment that the container has been discharged from a vessel, customs clearance was arranged, and the container has received a commercial release from the shipping line.

It should be possible for LSCs and LSPs to engage dynamically in varying communities for data sharing, resolving technical and semantic differences between their systems without the need for long and costly integration processes, while safeguarding secure access to their information.

In sum the challenges in the current situation to be overcome with an advanced ICT infrastructure for collaboration and open exchange of information are: (1) isolated use of information, (2) reactive instead of proactive planning, (3) single company optimisation instead of value chain optimisation, (4) traditional inflexible systems instead of interorganisational systems and (5) lack of standardisation.

3 Technical Implementation

This chapter describes the technical implementation of an infrastructure for the collaboration and open information exchange between the roles in the reference logistics value chain, enabling the stakeholders to achieve their sustainability goals. This chapter starts with an identification of the basic requirements, followed by a high-level description of the technical and organisational perspective on the architecture for the implementation. The concluding section of this chapter provides a description of the tooling.

3.1 Basic requirements on the infrastructure

The basic requirements of the are derived from the use case, as described in the previous chapter. Especially, section 2.4 addresses the issue of the required supporting ICT infrastructure

⁶ There are commercial issues linked to this benefit that need to be solved, like competition and pricing strategies, since disclosing resource capacity might decrease prices and increase costs (e.g. because extra locations have to be called upon).

for collaboration and real-time information exchange. It identifies the basic requirements on the ICT infrastructure:

- *Common peer-to-peer communication infrastructure*

The infrastructure should support direct connections between partners without the need to develop and implement proprietary gateways.

- *Dynamic configuration of (logistics) business communities*

To meet a high level of dynamics in logistics value chains (with ever changing relationships between stakeholders), the dynamic configuration of business communities is required. The purpose of these business communities is to exchange information more efficiently and effectively by creating and using a common terminology, set of rules and business message protocols on how to cooperate with each other. Participants of a community share the same knowledge base, i.e. terminology/semantics, security, "goals".

- *Controlled access to information (authorisation)*

Communities should safeguard every stakeholder's information by providing the function for each stakeholder to control access to their information. Controlled access is of the utmost importance before organisations are willing to share information. Not only should a proper authorisation mechanism be present, the mechanism shall also provide a clear overview of the accessibility of the data and a simple mechanism to control access across business domains.

- *Semantic interoperability*

This requirement encompasses a common and shared interpretation of business messages to lower the semantic barrier between organisations when exchanging information.

The requirements enumerated above together constitute the functionality to exchange up-to-date status information in logistics supply chains, across business domains. The following section describes (the technical and organisational perspective on) an architecture that meets these basic requirements.

3.2 The architecture for the implementation of the infrastructure

This section provides a high-level description of the architecture for the implementation of the infrastructure for the collaboration and open information exchange between the roles in the reference logistics value chain. The following subsections describe the technical perspective and the organisational perspective on the architecture, respectively.

The technical and organisational perspective on the architecture described in this section are not defined by means of specific systems. No specific implementation solutions are enforced by the architecture. As such, the description of the architecture is completely IT-independent and leaves stakeholders free in implementation choices for realizing it.

3.2.1 Technical perspective: the three pillars

The basic requirements as identified in the previous section, are translated into a vision on the technical implementation, as depicted in Figure 3. This vision on the technical implementation is based on one hand on the business vision of adaptive decision making as described in the previous sections. On the other hand, it is based on the knowledge obtained in the previous EU project Euridice (FP7 EU Euridice). The technical vision can be realised using currently available technology.

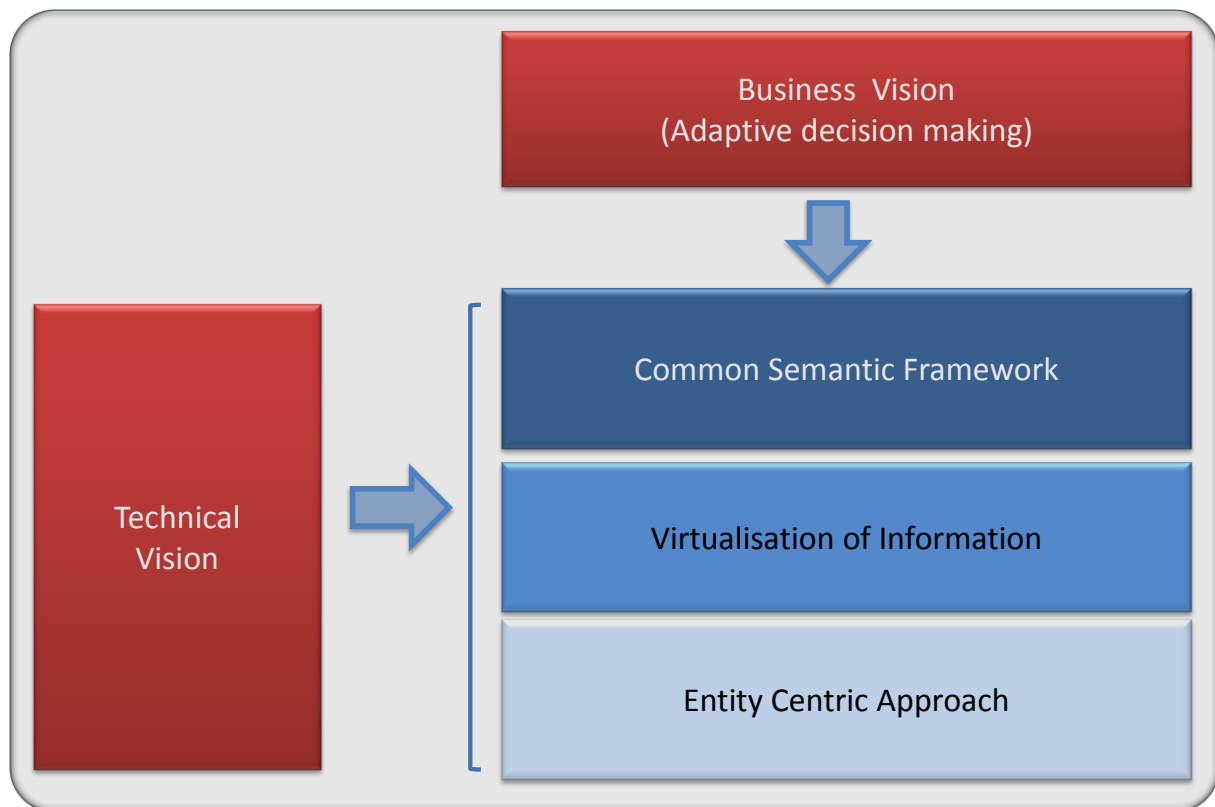


Figure 3. Technical perspective on the architecture for information exchange.

The figure illustrates that the high-level technical perspective on the architecture is founded on three pillars:

- *Common semantic framework*

The common semantic framework supports the right interpretation of information based on message standards as described in a Common Framework [CF] and implemented in semantic communities. Organisations often adopt and implement different technological solutions to achieve their specific goals. The common semantic framework enables semantic interoperability among such organisations with heterogeneous information systems in order to facilitate the communication, understanding and exchange of resources and information.

- *Virtualisation of information*

A practical barrier today is the diversity of systems, devices and protocols being used in logistics supply chains. Virtualisation of information provides the means for a technical infrastructure that abstracts the user from all the technical complexities of interoperability for collaboration and open exchange of information within communities. It allows easy and seamless communication by increasing the accessibility of data but with strict authorisation control. It enables the dynamic configuration of communities to exchange information efficiently and effectively. The concept of virtualisation of information is about controlled access to information without the need to know how and where the data is stored and which type of hardware, operating system and database are being used. The information can be accessed via a single access point even if the data is being stored in multiple databases.

- *Entity-centric-approach*

The goal of the entity-centric-approach is to reduce the complexity of the supply chain into individual and smaller parts. The information about each entity is being collected, stored, processed and shared by one software component that acts and serves in the best interest of that entity (Dalmolen, S, Moonen, H M, en Cornelisse, E 2012).

Building upon the EURIDICE concept of a cargo-centric approach (FP7 EU Euridice), the extended concept of an entity-centric-approach can be used. Basically this means that

information is being collected per entity instead of being scattered across multiple isolated systems. The objective is to realise an ecosystem where information from multiple sources about one specific subject, can be accessed through one access point, without the concerns about the type of hardware, network, operating system and databases being used. This is what virtualisation of information is about.

These three pillars of the vision on the implementation are strongly entangled. Virtualisation of information may use an entity centric approach and requires the common semantic framework before it becomes useful. The entity-centric-approach relies on semantics to process data into information before it can be shared with other entities and organisations.

3.2.2 Organisational perspective: Functional Interfaces

The previous subsection described the key concepts (the three pillars) of the technical perspective of the architecture. These pillars are to be implemented in the organisational context of the logistics reference value chain as described in section 2.1. Hence, it is to be defined how the various roles in the logistics reference value chain can interact when implementing the technical architecture. In this interaction, special attention goes to the role of the Information Service Integrator (ISI), which provides the enabling infrastructure for collaboration and open exchange of information between the primary roles in the reference logistics value chain.

Figure 4 illustrates that the organisational perspective on the architecture is defined by means of the various roles in the reference logistics value chain and the functionality they provide to support collaboration and information exchange. This functionality on its turn is defined by means of interface descriptions, where these interfaces are accessible as part of the access point (AP) of a specific role.

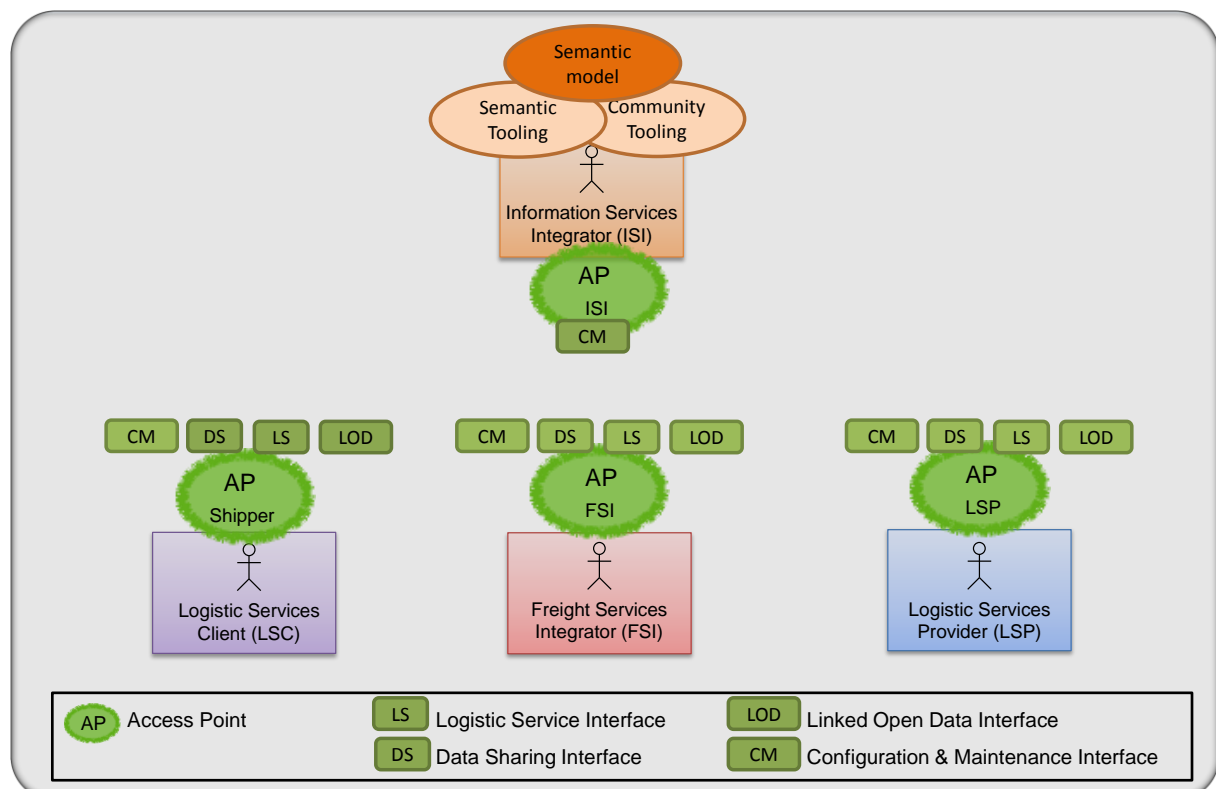


Figure 4. Organisational perspective on the architecture for information exchange.

The information to be exchanged between the primary roles will be based on a 'peer-to-peer' mechanism for information exchange. The stakeholders expose 'their' specific information through an appropriate interface. Hence, there is no centralised database in which the information of all stakeholders is gathered for further distribution. The 'peer-to-peer' mechanisms for information exchange are enabled by the concept of virtualisation of

information as described in the previous subsection, and implement on an infrastructure provided by the ISI.

The interfaces that are distinguished in the organisational perspective on the architecture for information exchange are the Logistic Service interface (LS), the Data Sharing interface (DS), the Linked Open Data interface (LOD) and the Configuration & Maintenance interface (CM).

The LS-interface, the DS-interface and the LOD-interface are for the actual exchange of information between the stakeholders in the primary logistics supply chain. The CM-interface is for the configuration of the infrastructure, with a special role for the ISIs, which provide the enabling IT services.

The interfaces of the organisational perspective on the architecture for information exchange are elaborated in the table

The Logistics Services Interface (LS Interface).	
	<p>The LS interfaces exposes (uni-directionally) the service profile of stakeholder in the logistics supply chain. The service profile of an FSI or LSP describes the logistic services provided by a stakeholder in terms of specific business activities being conducted, together with its message interaction pattern (choreography), the semantics, and the technical support for data sharing.</p> <p>Similarly, an LSC (shipper) can have a Customer Profile describing the logistic services required. The Customer Profile may be exposed on a similar LS-interface to allow FSIs and/or LSPs to provide adequate services.</p>
Data Sharing Interface (DS Interface).	
	<p>The DS Interface is used for (bi-directionally, real-time) information sharing between stakeholders in the logistics supply chain during normal operations to conduct business transactions, e.g. Service Booking, Service Execution, and Service Cancellation.</p>
Linked Open Data Interface (LOD Interface).	
	<p>The LOD Interface is used for (uni-directional, authorised) retrieval of information by other stakeholders in the logistics supply chain for various purposes. In the context of this paper, the purpose is the retrieval of information for realizing sustainability by LSC's, e.g. current and scheduled loading status of the various transport means, carbon footprint information and traffic information (e.g. city logistics and current traffic information).</p>
The Configuration and Maintenance Interface (CM Interface).	
	<p>The CM Interface encompasses the functionality as required by the stakeholders in the logistics supply chain to be able to 'peer-to-peer' interconnect with other stakeholders by configuring the infrastructure for collaboration and open exchange of information as provided by an ISI.</p> <p>As such, the information exchanged over the CM Interface supports the configuration processes for dynamic community configuration, controlled access to information (authorisation) and semantics and ontology enforcement.</p>

It is to be noted that there is a level of flexibility in defining the interfaces for the actual exchange of information between the stakeholders in the primary logistics supply chain (i.e. the LS-, the DS- and the LOD-interface). Each of these interfaces could as well be modelled identically under the single heading of Linked Open Data Interface, e.g. the Logistic Service Interface also is on publishing data. However, as the table explains, the interfaces as identified in the organisational perspective on the architecture are distinguished on basis of the functionality they support.

3.3 Tooling

The focus in this section is on the tooling for enabling collaboration and open information exchange to achieve sustainable logistics, based on the architectural perspectives as described in

section 3.2. As illustrated in Figure 4, this tooling may be part of the enabling IT-infrastructure as provided by an Information Service Integrator (ISI), including:

- the semantic model,
- the semantic tooling, and
- the community tooling.

These three element are further described in the next subsections

3.3.1 The semantic model

To achieve their specific goals, organisations mostly adopt and implement different technological solutions with differing internal data formats. Hence, to communicate with each other there is a need for semantic interoperability, allowing organisations with heterogeneous information systems to communicate and exchange (understandable) information. The purpose of a semantic model is to enable stakeholders to interpret the meaning of the exchanged information across business domains.

Within iCargo, a semantic model is a conceptual data model to describe the relevant business objects and their interactions that enables stakeholders to interpret the meaning (semantics) of the exchanged information. The semantic model describes business objects and their relations but doesn't contain information about individual instances. For example, a truck will be described in terms of its characteristics with attributes like the license plate for identification and geo-data attributes to specify its location and movements. The semantic model will not contain license plates, nor real GNNS positions of trucks, but will describe how a position is expressed for a specific business process or business domain.

Figure 5 shows a layered approach for semantic interoperability, in which the layers of the pyramid reflect the various organisational levels on which agreements are applicable on a specific semantic model.

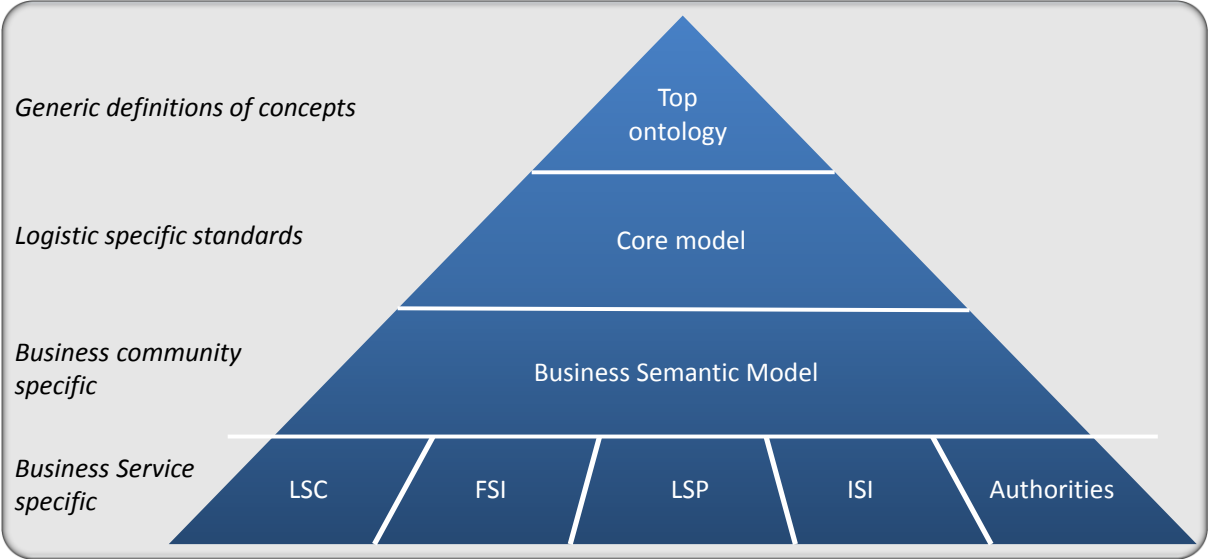


Figure 5. Layered approach for semantic interoperability.

An agreed upon (networked) ontology provides the means to achieve the required semantic interoperability. The (networked) ontology entails the set of (business) concepts (entities) within the logistics domain and the relationships between those concepts. The (networked) ontology will implement the Core Model.

Different organisations can have different views on the core model. For example, some organisations can be interested in concerns related to the transport of dangerous cargo, while

customs organisations may want to look into details of import/export declarations. For the information exchange for sustainable logistics as discussed in this paper, the view on the entities related to capacity information (e.g. current and scheduled loading status of the various transport means), carbon footprint information and traffic information (e.g. city logistics and current traffic information) become more eminent.

Within the logistics domain, several global standardisation bodies for information exchange in logistics supply chains exist, including UN/Cefact, the World Customs Organisation (WCO) and GS1. (Parts of) these standards will be incorporated within the (networked) ontology / Core Model.

The further elaboration of the core model itself into a networked ontology matching the requirements on information exchange for sustainable logistics is outside the scope of this paper. The focus in this article will be on the supporting semantic tooling required to define, manage, expose and use the (networked) ontology.

Within the iCargo project, the terminology of 'semantic model' and 'knowledge base' are synonyms but used at different occasions. The term semantic model is used in a functional context to define a common understanding of the business processes while the term knowledge base is used in a technical context referring to an instance of a specific version of a semantic model.

3.3.2 The semantic tooling

To support the implementation of the semantic model for realizing semantic interoperability as described in the previous section, semantic tooling is required. As part of the semantic tooling, two types of IT-environments can be distinguished:

- *An Ontology Specification Environment that supports the design and extension of the logistics semantic core model, e.g. in case a new business model and its supporting technical model should be supported.*

The specification environment contains (graphical) tools to support development and maintenance of the logistics semantic core model with its technical representation. A technical representation of (a view of) the Logistics Core Model has to be constructed as a hierarchy to compose an XSD or map to an EDifact UNSM (United Nations Standard Message).

As described in the previous subsection, the approach of a (networked) ontology is used for realizing semantic interoperability. In this approach, semantic models can refer to other models which can be stored on the same or other locations, even on a web site or FTP-server, as long as the model can be addressed as an URL.

The (specification of a) semantic model is under control of exactly one community. A semantic model will have multiple versions in most cases but users will only use a specific version. To lower the barrier for collaboration and to stimulate the Open Data philosophy, semantic models are by default publicly accessible but can be restricted to community members only.

- *An Ontology Operations Environment to enable stakeholders to actually exchange information using an agreed upon ontology.*

The ontology operations environment contains (graphical) tools to support stakeholders to integrate their back-office systems with other stakeholders in their community, by deploying and matching to an agreed upon ontology. To this end, interconnection to the access point of an ISI is established using the CM-interfaces. The ontology operations environment contains (graphical) tools to support stakeholders in making agreements within a community on the usage of a specific ontology for data sharing (for both transactions (DS interface) or other types of applications (LOD interface)) and to actually do the exchange of information

according to the agreed upon ontology. As part of the data exchange, it performs data format mapping to an agreed upon (version of an) ontology.

In addition, the Ontology Operations Environment contains a semantic repository. Its purpose is to provide a service which enables stakeholders to store and retrieve multiple versions of a semantic model for a specific group of stakeholders (community).

3.3.3. *The community tooling*

As described above, the dynamic configuration of business communities is required to exchange information more efficiently and effectively with each other by creating and using a common terminology, set of rules and business message protocols on how to cooperate with each other. The topic of business communities in logistics value chains is addressed in the companion paper (Hofman, W e.a. 2012), to which we refer for a further elaboration of this topic.

In the remainder of this subsection, the focus is on controlled access to information (authorisation). Controlled access to information within communities should safeguard every stakeholder's information by providing the function for each stakeholder to control access to their information. A solid authorisation mechanism is required to protect data from competitors or against criminal intentions. A direct consequence is the need for proper authentication before access can be granted or denied.

Within iCargo project three levels of privacy are used in accordance to the ISO/IEC 15408 standard (ISO/IEC):

- Public⁷, free for the world but only supported via a trusted public service;
- Restricted, accessible for registered users (business-to-business);
- Confidential, only accessible for the information owner which is the default configuration.

Information with the privacy classification "public" will be accessible via to the proposed Linked Open Data (LOD-) interface. Information that is publically accessible shall be disclosed as separate and dedicated services to ensure the security, responsiveness and availability of the restricted and confidential information.

Information is confidential by default and will only be shared after explicit authorisation of the information owner. The authorisation rights are part of the semantic model to be used within a business community. This design decision will enable a consistent and uniform security mechanism among different types of business objects. Consistency will increase the user comfort and an uniform mechanism will reduce the amount of software bugs.

The privacy classification "Secret" and "Top secret" will not be supported in the iCargo solution. Information with this classification should be stored and secured by additional systems under control and according to the security measurements of the information owner.

4 Conclusions and future work

This paper has provided the outline of an advanced infrastructure for collaboration and open information exchange between stakeholders in the logistics value chain, which will enable them to achieve their sustainability goals. The process of adaptive decision making by shippers for selecting a transport modality, transport provider and timeslot has been used for a use case analysis. The suggested approach and infrastructure enable shippers to efficiently (in terms of carbon footprint and/or cost) transport goods using the most up-to-date information available.

⁷ Even information that is available for the public, will require authentication to reduce misbehavior and malicious activities. Therefore the "public" privacy class is not referred as "unrestricted" because access will be refused if the identity of the user or services cannot be verified.

Future work is needed to implement the outlined advanced infrastructure into an operational platform, for instance::

- Detailed elaboration of the (business) requirements for the advanced collaboration and information exchange infrastructure.
- Elaboration of the functionality and its implementation for supporting communities of information exchange in logistics value chains, including safeguarding information security and interoperability of protocols for information exchange.
- Issues of semantics, including both the semantic model and the semantic technology.
- Detailed specification of the interfaces of the roles in the reference logistics supply chain, providing access to the collaboration and information exchange infrastructure.

Several of these issues will be subject of research of the current EU iCargo project.

Acknowledgement

The results presented in this paper builds on the current research taking place within the EU iCargo project which is funded by the European Union. The authors would like to thank the participants in this project (and its predecessors) for the evolving knowledge on and insight in advance information infrastructure enabling the optimisation of sustainability goals.

References

- Christopher, M., 1999. *“Logistics and supply chain management: strategies for reducing cost and improving service”*.
- Dalmolen, S, Moonen, H., and Cornelisse, E., 2012. “Information architecture using a cargo centric approach – Digital shadows of real world objects”. Companion article in the proceedings of this eFreight conference.
- European Commission, 2003. *“Study on Freight Integrators”*. http://ec.europa.eu/transport/logistics/documentation/freight_integrators/doc/final_report_freight_integrators.pdf.
- FP7 EU Euridice.
“EURIDICE White Paper, version 0.4f”. <http://www.euridice-project.eu/>.
- Deliverable [D11.1] *“EURIDICE – High Level Architecture Overview”*, version 2.0 of 10th November 2009,
- Deliverable [D11.2], *“EURIDICE – Detailed Architecture Specifications”*, version 1.0 of 13th November 2009,
- Deliverable [D11.3] *“EURIDICE – Integrated Cargo Framework”*, version 1.0 of 11th November 2010”. <http://www.euridice-project.eu/>.
- Hofman, W., 2011. *“Design of large-scale enterprise interoperable value webs”*. In *On the Move to Meaningful Internet Systems: OTM 2011 Workshops*, 122–135. Springer.
- Hofman, W., Bastiaansen, H., Berg van der, J, and Pruksasri, P., 2012. *“A platform for secure, safe, and sustainable logistics”*. Companion article in the proceedings of this eFreight conference.
- iCargo. *“i-Cargo | Intelligent Cargo in Efficient and Sustainable Global Logistics Operations”*. <http://www.i-cargo.eu/>.
- ISO/IEC. *“ISO/IEC 15408-1:2005 - Information technology -- Security techniques -- Evaluation criteria for IT security -- Part 1: Introduction and general model”*. http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=40612.
- Lai, K., Ngai, E., and Cheng, T.,. 2004. *“An empirical study of supply chain performance in transport logistics”*. *International Journal of Production Economics* 87 (3): 321–

331.

Schumacher, J., Rieder, M., and Masser, P., 2010. "*Cargo centric approach for Supply Chain Design - Reference Architecture*". 17th ITS World Congress, Busan.

Van Stijn, E., Klievink, B., en Tan, Y., 2011. "*Innovative ICT solutions for monitoring and facilitating international trade*". Network Industries Quarterly, 13(3).

TNO. 2011. "Cassandra Description of Work".