

CHAPTER 6

Towards a Shared European Logistics Intelligent Information Space

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Background and Business Context

Towards Smart, Green and Integrated Transport and Logistics

Transport and logistics (T&L) is a major component of modern production and distribution systems and is a key contributor to macroeconomic development, accounting for over 10% of gross national product (GNP) in most countries (Savy 2016). The T&L sector is experiencing substantial change (Christopher 2016), influenced by factors such as globalisation, smart specialisation, population growth, business competition, and consumer interest for products from all over the world (Clausen, De Bok & Lu 2016; Leinbach 2007). The sector is also heavily influenced by customer expectations for fast goods delivery, with increased flexibility, at low or close to zero delivery charges. Alongside this, the growth of e-commerce has incited digitalisation in the T&L sector, where, over the past decade, technological advances have been exploited and integrated across the T&L value chain as a whole

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(PWC 2019) to minimise supply chain dwell times and costs. This, in turn, has driven an increasingly competitive landscape where a growing number of supply chain (SC) actors are striving to optimise their SC and/or T&L configurations (Geissbauer et al. 2013; Manners-Bell 2016), often differentiating them according to their customer segment, to achieve more efficient and fine-grained control over their SC performance, as well as better economic, operational and environmental performance.

From a macroeconomic perspective, the European Commission's (EC) strategic vision for Europe also recognises that the T&L sector represents approximately 15% of global GDP annually, with substantial potential for innovation-led initiatives that can incentivise new value imperatives (Savy 2016). Logistics is also one of the most dynamic sectors of the EU economy, contributing to economic growth and international competitiveness. Europe is currently a leader in logistics (World Bank 2014) and, with the steady growth in freight volumes throughout Europe, the long-term forecast is 80% growth in freight transport by 2050 (EC 2015a). With this predicted growth, a pertinent and ongoing challenge is to raise the efficiency and competitiveness of the logistics sector while reducing environmental impacts. Market intelligence confirms that the sustainability of the logistics sector is challenged by its energy consumption and greenhouse gas (GHG) emissions. In order to reduce emissions, logistics actors have started to implement environmentally friendly collaborative strategies addressing supply chain integration, multimodal transport, consolidation of deliveries and reverse logistics (EC 2015b).

However, the sector has several challenging inefficiencies, e.g. a context where only 10% of logistics services are represented by pure transport services and the balance of 90% represented largely by inefficiencies in matching demand and supply of goods and low utilisation of T&L resources (such as empty journeys, idle times, loading and unloading). Consequently, underpinning the EC's strategic vision is the acknowledgement that ICT-driven innovation to date has been hindered by legacy T&L ICT management systems and solutions (thousands) that have evolved incrementally (and oftentimes in bespoke ways) over many years to yield a highly fragmented cross-sectoral logistics ICT landscape across the European SC sector. This challenging context largely resulted in the prevailing T&L ICT solutions that are (today) deeply rooted in legacy technologies and incompatible electronic data interchange (EDI) systems that evolved over many years, and which have not been designed or redesigned in the context of anticipating or supporting collaboration logistics models or cross-sectoral collaboration within or outside Europe. Consequently, today's T&L actors need to contend with multiple tools and solutions covering different aspects of the supply chain, as well as patchy views of their logistics businesses that are difficult, or perhaps

impossible, to reconcile and unify into one consolidated business perspective. The implementation of such strategies frequently requires reactive and proactive coordination based on information exchanges between collaborating actors, to optimally match supply and demand for logistic resources. This necessitates real-time monitoring of supply chains, generating vast amounts of data and requiring sophisticated analysis, in order to support tactical and strategic decision-making, creating winning advantages for both businesses and authorities.

In this context, the EC's strategy for Smart, Green and Integrated Transport and Logistics highlighted the need for a common communication and navigation platforms for pan-European logistics. Likewise, a central goal asserted by the Commission was to boost the competitiveness of European T&L industries and to achieve a European transport system that is resource-efficient and environmentally friendly, as well as safe and seamless for the benefit of all citizens, the economy and society. This strategy recognised that advances in the sector have evidenced new international/intermodal repositories and data pipelines being created, management systems being deployed, and new data mining capabilities being developed to deal with the data flood needed for logistics decision-making (European Commission 2015c).

Central to the EC's strategic vision for Europe was steering attention to architectures and open systems for information sharing and valorisation, in pursuit of connecting key stakeholders with information and expertise on the basis of trusted business agreements. More fundamentally, the EC's vision for T&L recognised that the prevailing landscape challenged this strategic view, on the basis that the sector comprised a complex spectrum of different data types and usages that involved disparate and oftentimes legacy information systems that over the years had matured independently and differentially across the EU SC sector's actors, resulting in different user requirements, different business models, different deployment trajectories and incompatible systems that could not share data or intelligence in ICT-driven ways. This broader prevailing digital landscape evidenced an obstacle for inter-sectoral and cross-sectoral information sharing in significant ways, as well as impeding the deployment of pan-European logistics solutions accessible by logically related actors in the transport sector, its users and public authorities.

Thus, the evolving T&L landscape set the scene for creating innovative collaboration-driven supply chain optimisation, supported by services that take into account network status and service level agreements (SLA) for optimising cargo flows against throughput, cost, speed, time, utilisation of resources and environmental KPIs between and across European T&L SC actors. This prevailing context underpinned the innovation imperatives for the SELIS project, which aims to present a solution to these issues.

Industry Requirements

Supply chain actors across Europe and globally (producers, retailers, shippers, logistics service providers, authorities) need a secure and trusted vehicle to share data and information for better horizontal and vertical supply chain collaboration and optimisation. Key business imperatives include the need to surmount the organisational and associated (often internal) structural barriers to collaboration (Figure 6.1), as well as to see progress on a range of operational aspects (Fawcett 2015; McKinsey 2021) including increased speed and efficiency, greater flexibility, improved insights through transparency and granularity, improved prediction and accuracy and improved sustainability.

Principally, SC actors are seeking ways to extract value from shared industry data as well as maintain full control over their own commercially sensitive data, including whom they share data with, the duration of time data is shared, and the ways shared data is used, managed and exploited. Consequently, supply chain actors across Europe and globally (producers, retailers, shippers, logistics service providers, authorities) need a secure and trusted vehicle to share data and information for better horizontal and vertical supply chain collaboration and optimisation. However, although the need for collaboration and data sharing is well understood by the SC and logistics sector, resistance remains high and aligning innovation to industry readiness is very important in moving forward.

The Shared European Logistics Information Space (SELIS) Project

The SELIS project is part of the European Union's Horizon 2020 Research and Innovation Programme and was funded under 'Call MG-6.3-2015' for common communication and navigation platforms for pan-European logistics applications. The project began on 1 September 2016 and was conducted over a

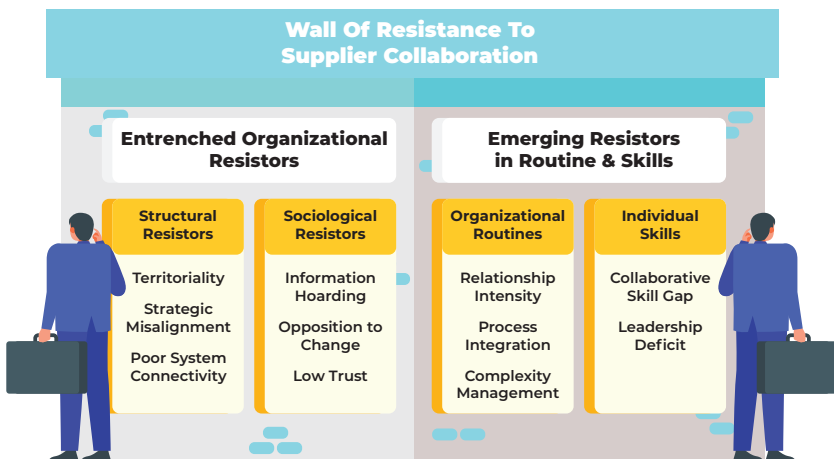


Figure 6.1: Obstacles to better horizontal and vertical supply chain collaboration.

three-year period, finishing on 31 August 2019. The project team comprised 38 separate partners spanning the range of supply chain actors.

Supply Chain Community Nodes (SCNs)

The SCN Premise

The principal innovation from the SELIS project is a directory of logistics collaboration models (LCMs) (Figure 6.2) and connect–share–optimise open-source software components enabling stakeholders in the logistics sector to create and maintain collaborative SC intelligence-sharing platforms, referred to as SELIS community nodes (SCNs). SELIS's approach and contribution towards a 'pan-European logistics intelligence-sharing platform' emphasise intelligence sharing through SCNs in a way that inspires trust, facilitates collaboration and enables connectivity and data-driven optimisation of T&L operations. Extensibility is catered for through a cloud computing platform that accommodates a SC modelling framework for business applications. SCNs can be used to build T&L collaboration solutions that are resource-efficient and environmentally friendly.

Further, federated SCNs provide a solution for the EC's strategy for Smart, Green and Integrated Transport and Logistics through a single European logistics information space that is accessible by actors in the transport sector, its users and public authorities. The SELIS approach is consistent with the Digital Transport and Logistics Forum (DTLF) federated network of platforms

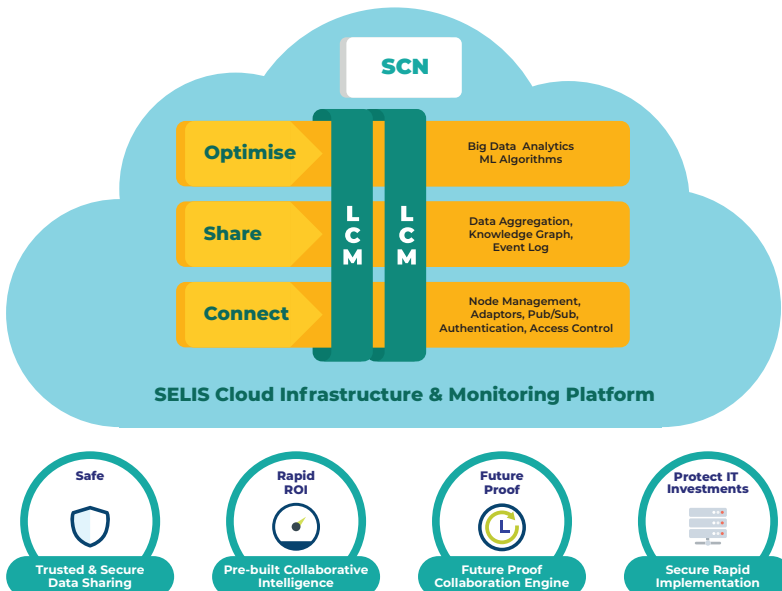


Figure 6.2: The SCN concept.

concept (DTLF 2018) and provides a route towards the realisation of a physical internet (PI)-inspired transport system, aimed at transforming the ways physical objects are packaged, transported, distributed and delivered (Simmer et al. 2017). In essence, from its proposal stage, SELIS has advocated that a promising route to realising the PI vision is through federation of SCNs, a subject that is further discussed later in the chapter.

Features of SELIS Supply Chain Community Nodes (SCNs)

The SCN creates a shared intelligence ‘data space’ configured to address the needs of a logistics community, aggregating information flows in various industry standard formats that are generated by the operational systems of the logistics participants, and also through interfaces to IoT devices and gateways.

An SCN combines collaboration, connectivity, communication, privacy and data protection capabilities with analytics and visualisation tools, enabling end-to-end visibility across value chains towards the management of business and green logistics KPIs. In SCNs, the connections between the SC participants are managed by rules that describe relationships from the outset and based on their semantic properties such as their role in the SC, rather than on hard-coded connections and data. In this way, an SCN can be considered a multiparty collaboration intelligence-sharing gateway, alleviating the need for costly, isolated and fragmented point to point connections between individual participants in the SC.

In consequence, as the SC evolves (i.e. participants join and leave) the SCN can readapt and reconfigure autonomically to address the evolving and changing circumstances. The result is near-real-time insights and enhanced visibility such that the stakeholders in the logistics value chain can improve their operations, plans, policies and strategies, as well as quality of service aspects central to their business KPIs.

Specifically, an SCN supports T&L communities to (Figure 6.2):

1. Connect: allowing data to be collected from heterogeneous sources, thus creating a single data-sharing intelligence space in the cloud, which physically consists of distributed connected data sources from SC actors. Connectivity tools include: intelligent adaptors such as translators to a common SCN data model; a publish/subscribe system for many-to-many communication of events with the ability to restrict who can subscribe to what data artefacts; and authentication and monitoring services. A single-sign-on federated-enabled authorisation system is provided for services or data sources, such that participants can deploy services via secure APIs, on the basis that SELIS is designed to support SOA and micro-services deployment for SCN-based applications.
2. Share aggregated data: allowing the creation of a shared situational picture linked to a knowledge graph and event log. Where appropriate, shared data from the event log is transferred to a blockchain ledger, thus increasing

trust levels on the use of the data with full traceability, auditability and immutability underpinning SC data transparency principles.

3. Optimise operations: through analysing the available aggregated data using the SELIS big data analytics module, offering generic analytics algorithms in the form of 'recipes' that can be easily configured to execute typical optimisation operations such as matching transport demand with available resources and route optimisation. Predictive and optimisation analytics can be also used to cover smart contracts associated with route and mode decisions in synchromodal transport.

Rapid implementation of SCNs is based on pre-built collaborative intelligence provided by configurable SELIS LCMs that are customised for specific logistics communities in global and regional SCs including last-mile distribution. SELIS has produced a library of models supporting European green logistics strategies (EGLS) that facilitate the composition of LCMs. An LCM service catalogue is used when setting up and configuring the connectivity semantics of the message broker by mapping LCMs to existing business semantics (participants, services, events, agreements). Importantly, LCM models use the currently existing standards for SCs and their data models and include WCO, UN/CEFACT, GS1 and UBL. SELIS liaises with the United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT), drawing upon the vast experience and content available on international trade standards.

An important innovation is the use of knowledge graphs (KGs) to capture the SCN semantics based on relationships of entities relevant to a collaboration logistics model such as organisations, logistics objects/assets, resources and locations (Figure 6.3). KGs integrate spatial, business-social and temporal data. KGs are used to represent LCMs and provide the SC context to incorporate methods, services and tools to facilitate the better understanding and analyses of data. To this end, KGs support the efficient aggregation, ingestion and cleansing of data arriving from different sources, i.e. operational back end systems, databases, services and APIs, IoT controllers (e.g. joins, filtering, schema transformations, inferred links creation in graphs of data and events).

The SELIS Cloud Infrastructure and Monitoring Platform supports monitoring (performance, scalability, usability) and security (encompassing the cloud platform security and identity management component). Important operational aspects such as SLA, uptime, high availability, network throughput and bandwidth are constantly monitored through the monitoring platform, which in turn provides early alerts in impending problems and orchestrates corrections if needed. The monitoring platform allows SCN operators and administrators to ensure that each SCN and the various infrastructures and services they depend upon are functioning correctly and performing well. As such, it provides an overall monitoring solution for one or more SCNs as an independent supervising platform and infrastructure monitoring entity to SCNs managed as a service.

The SELIS Project Methodology

The SELIS project methodology (Figure 6.3) combines a business and a technology innovation stream in creating the key elements of SCNs described earlier. Innovations are business-driven, capturing stakeholder needs, while at the same time exploring, exploiting and generating new ideas and ways to meet business metrics utilising the EGLSs. EGLSs can be applied in different stakeholder settings and focus on synchromodal transport involving rail, ship, barge, truck and terminal collaboration, as well as its application in urban and last-mile logistics.

The underlying concepts in SELIS approach include the following principal considerations:

1. In SELIS, all models and solutions have been tested in the SELIS Living Labs. Each Living Lab is connecting its community to at least one (primary) SCN and, per the Living Lab set-up, possibly to additional (secondary) SCNs for very active or organisationally extended community members, per (sub)community needs. The infrastructural SELIS components are composed in a set of coherent solutions, integrating best current open-source solutions, introducing SELIS innovative extensions for better configurability and easy deployment, considering the specific needs of the T&L domain. EGLS are strategies (e.g. synchromodal transport) supported by generic business models, used as guidance for the creation of a simulated environment, where collaboration solutions are tested and validated before being customised and implemented in real operational environments in the Living Labs.
2. The LCMs are composed for specific communities based on EGLS and logistics message exchange standards.
3. SCNs' ICT infrastructure comprises open-source software components that support logistics communities in implementing an LCM.
4. Each SELIS Living Lab sets up a stakeholder-centred ecosystem, for the systematic evaluation of innovative ideas and technological solutions in real-life use cases. Therefore, the Living Labs are evolving experiments for specific logistics communities, testing instantiations of LCMs. In the Living Labs the LCMs address the specific T&L community requirements, enabling the experimentation and testing of both business and technology innovations.
5. An SCN may include virtual subspaces for each Living Lab. Virtual spaces are created based on a 'cooperation agreement' that defines who will share, what nature and type of data, with whom under and what circumstances.
6. The messaging and communications based upon the pub/sub protocol is the vehicle to allow actors to publish and subscribe to data and events.
7. The KG in its simplest function is a service that acts as a database for storing historical facts and the current state of a SC. T&L applications can

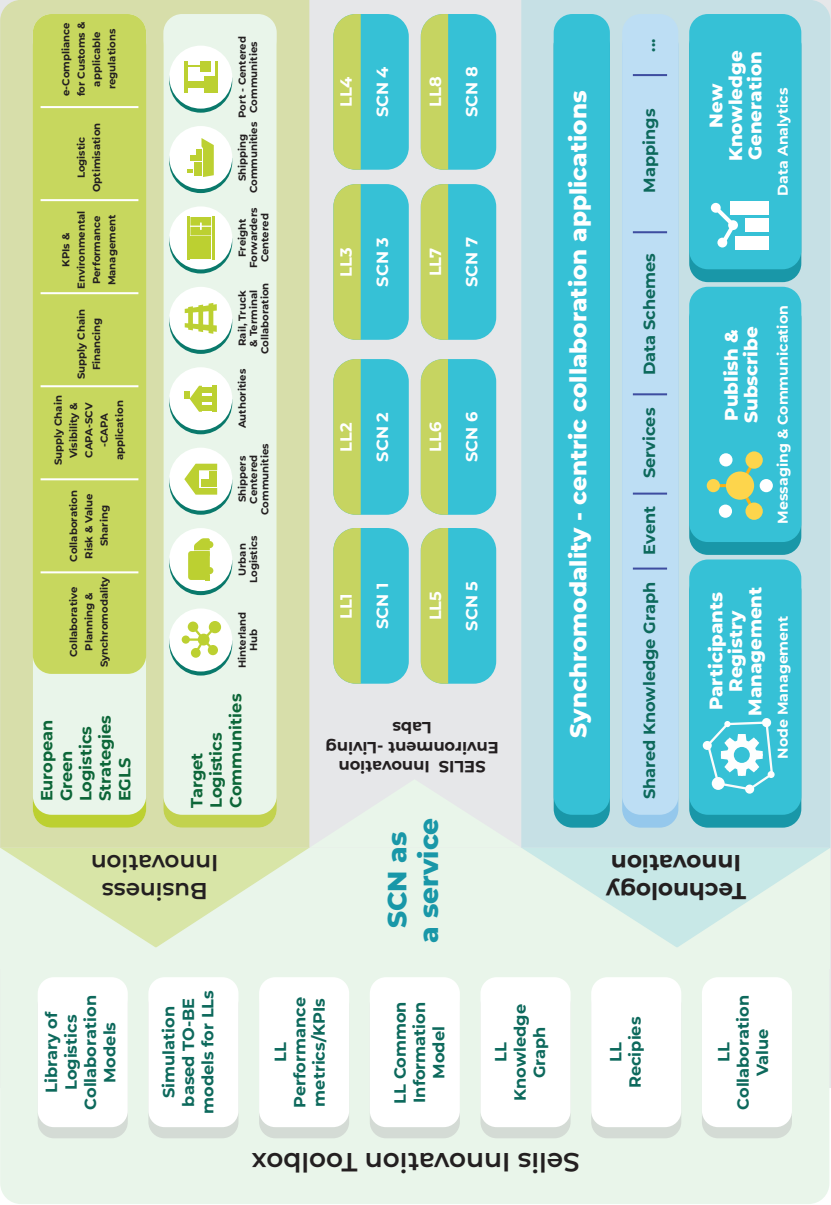


Figure 6.3: The SELIS research methodology.

query the KG and get insights on the state of the SC. The KG is also used for semantic data transformation and for the aggregation of data that is published from external and legacy systems.

8. An SCN incorporates a 'node controller' for node management, listening to events and populating the KG and data analytics. Deep learning techniques can then be used to discover new actors or refine relationships that also extend the KG.
9. The SCN data analytics enable complex analytics to furnish easy-to-understand business KPIs.

Collaboration Logistics Models (CLMs)

The SELIS Reference T&L Collaboration Framework

The SELIS Reference T&L Collaboration Framework (Figure 6.4) assumes that T&L communities are involved in three types of transport chains:

1. Global SCs characterised by a long shipping leg (and increasingly rail) and therefore important to deal efficiently with customs and other regulatory formalities.
2. Regional/continental SCs mainly linking manufacturers with regional retailers and increasingly a direct distribution of their products purchased from their own e-commerce channels.
3. Urban logistics and last-mile distribution, which are usually integrated with the previous two chains.

SCNs represent communities that can be linked to provide end-to-end SC ICT collaboration enablement, via solutions with reduced cost and improved environmental performance. A federation of SCNs can be used to support corridor-level collaboration and optimisation. Finally, inter-corridor collaboration will lead to collaborative networks towards realising the PI vision. The specific logistics community models developed in SELIS to support this are bound to the European green logistic strategies and capabilities, which are described in the following section.

SELIS EGLSs

The core rationale for EGLSs is that SC visibility enables SC performance management. Collaborative planning and synchronomodal transport represents an operational strategy to improve performance (particularly environmental) by exploiting visibility through the synchronised deployment of logistics resources in a collaborative way.

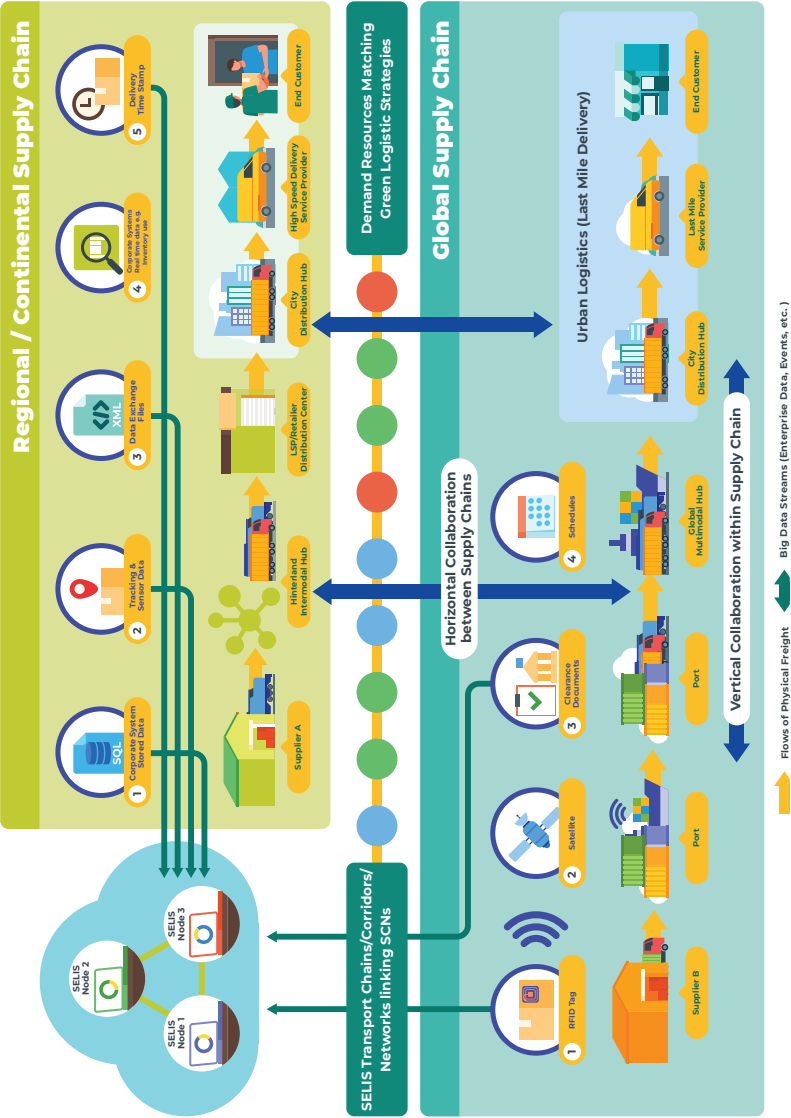


Figure 6.4: The SELIS T&L Collaboration Framework – high-level view.

SELIS EGLS descriptors

EGLS1: Collaborative planning and synchromodality. Depending on the specific context, there are different opportunities for collaboration, for sharing transportation capacity, warehousing capacity, aggregation of orders in the last-mile and innovative bundling at regional level. SELIS brings together approaches where infrastructure capacity is allocated to traffic flow, and where vehicle capacity is allocated to containers that need to be transported, and will support vertical integration of transport services (e.g. deep-sea transportation, terminal handling operations and land transportation).

EGLS2: Collaboration risk and value sharing between supply chain partners is gaining attention as a means to remedy sub-optimal logistics and yield significant business benefits such as inventory or cost reduction and improved asset utilisation. However, the lack of gain-sharing models defining the allocation of costs, investment, resources, benefits and risks between stakeholders are major barriers for the collaboration solutions (Eye for Transport 2010). Real-life operational data from SELIS community nodes allows greater transparency on collaboration by displaying KPIs to monitor in real time the business impacts of the collaboration and further refine compensation and risk-sharing rules.

EGLS3: Supply chain visibility and CAPA provide to supply chain players timely information for better decision support. The weakest link in supply chain visibility tends to be in transit status events at shipment level and in particular status updates about ocean shipments (GS1 2019). SELIS aims for end-to-end supply chain visibility (Titze & Barger 2015) delivering controlled access and transparency. SELIS solutions use a supply chain ontology–knowledge graph to link real-time information directly to KPIs improving visibility readiness.

EGLS4: Supply chain financing. The fundamental principle of SCF is that firms can decrease their cost of external financing by effectively tracking events in the physical supply chain and reliably disseminating this information to financial intermediaries in the capital markets. SELIS facilitates SCF solutions that rely on reliable dissemination of supply chain information. SELIS will also enable the promotion of green strategies through SCF programmes.

EGLS5: KPIs and Environmental Performance Management. According to the European Commission (2015b), transport decision makers are presently unable to benchmark available transport services with respect to GHG emissions and the importance of an accepted harmonised emission computation method has become stronger (Davydenko et al.

2014). The Global Logistics Emissions Council (GLEC) aims to create a universal way of calculating emissions (Smart Freight Centre 2019). The result has been the creation of the GLEC Framework to make carbon accounting work for industry.

EGLS6: Logistics optimisation. Previous research in supply chain optimisation has developed integrated models that typically seek to minimise the total production, inventory and distribution costs. An assumption is made with regard to the existence of an SCN acting as central controller/planner who is orchestrating the entire supply chain and has the authority to implement these optimisation strategies. SELIS extends approaches developed by Laporte (1992), Stahlbock and Voß (2008) and Crainic (2000) by including new collaboration synchronomality and visibility models.

EGLS7: e-compliance for customs. SELIS provides compliance solutions as component of integrated and 'smart' international supply chains, which in turn rely on new interoperability support standards and associated connectivity technologies. SELIS provides a technological solution that is based on the concept of using data pipeline principles to collect standardised supply chain data from as close as possible to their original sources, making higher-quality data available earlier to cross-border agency either directly or through the SELIS community node.

SELIS Target Logistics Communities (LCs)

SELIS target LCs represent market segments that will potentially be using similar types of supply chain community nodes, implying similar collaboration logistics models (CLMs).

SELIS LCs descriptors

Transport and logistics authorities. The main challenge for SELIS has been to establish a unified national and trans-border information exchange environment between private and public stakeholder groups, based on the European (DG TAXUD) alignment of regulatory requirements to the World Customs Organization Data Model as foreseen in the new Union Customs Code.

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Shippers- and retailer-centred communities. Shippers and large retailers, who have traditionally contracted 3PLs, are increasingly taking control of SCs by combining external and internal providers, leading to challenging ‘collaborative spaces’; they are increasingly engaging in horizontal collaborations to form transportation and warehousing synergies. SELIS focused on SC collaborations aided by secure/privacy-preserving collaborative services, seeking to identify the key drivers of value chain efficiency across many players to drive end-to-end chain optimisation for a global maximum instead of local (e.g. single player optimisation).

Freight forwarders-centred communities. Freight forwarders (FF) search for opportunities to increase their efficiency and create competitive advantages. SELIS aims to increase FFs’ insight into their customer’s needs and behaviour and to facilitate horizontal collaborations with other logistics service providers, allowing better service quality, increased asset utilisation and economies of scale.

Port-centred communities. Ports are increasingly becoming a key facilitator for synchromodal transport and are expected to play a central role as smart hubs in PI networks. A port SCN can complement existing port community systems (PCSs) or can be used by smaller ports as an alternative to PCSs.

Shipping communities. An undeniable success factor for maritime transport is the seamless integration in intermodal transport chains, providing one-stop-shopping for transport shipping. SCNs improve interaction between ship and port, for optimised terminal resource planning and predictive port vicinity traffic.

Rail, truck and terminal network communities. Road–rail combined transport and transshipments are important for the sustainability of the EU logistics and transportation industry. SCNs support real-time information to allow coordinated slot planning, reduce the crane operations per loading unit, improve resources use and optimise trains use by minimising empty wagons travelling.

Hinterland hub communities. Current trends in maritime logistics often consider the presence of inland freight terminals, where goods are consolidated before shipment, such as hinterland hubs or dry ports. SELIS’s focus is on facilitating synchromodality through the free flow of information between SCNs installed in inland hubs enabling flexible and dynamic routing strategies and operational support.

Urban logistics communities. Urban logistics is characterised by defragmented deliveries, important external constraints (e.g. access-restricted areas, congestion, lack of appropriate unloading infrastructure), and significant environmental and economic externalities. SCNs support urban logistics collaboration and information sharing models, as well as the vehicle to infrastructure architecture, and real-time sensor data consolidation and management, to improve the last-mile delivery visibility and environmental performance

Developing Collaborative Logistics Models

Figure 6.5 shows the main steps towards developing an LCM.

Step 1 involves modelling the SCN community's data sharing needs, using an informal or ad hoc (schema-free) notation, e.g. a graph.

Step 2 involves formalising the shared data model using one of the industry standards that the SCN community agrees upon, e.g. GS1 and UBL. The specification of any necessary adapters to support conversion between data schemas by SCN is also carried out at this stage.

Step 3 is where the main collaboration use cases are identified and modelled, in order to identify any inconsistencies and gaps in the data modelling activities of the first step.



Figure 6.5: Steps for LCM development.

Step 4 is where the EGLS data requirements are mapped to the shared data model of step 3. From that, the specifications for configuring the various components and subsystems of SCN such as the big data analytics can be derived, as explained in the previous section. Such specifications comprise a configuration script that the SCN administrator can run in order to obtain an instance of SCN.

Information Exchange Models, Semantics and Knowledge Graphs

The SELIS SCN supports a flexible data schema coupled with the execution of specific algorithms. SCN administrators have the ability to define upon node creation (i.e. during the node bootstrapping process) the abstract extensible data model they expect the SCN to support, according to the specific SCN data needs. In essence, to enable extensibility, SELIS identifies two types of data, according to the way it is updated/ingested, namely static and streaming data. Static data (or master data) consists of information that is not expected to change over time and defines specific SCN information.

In the SELIS case, the static information is grouped into ‘entities’. Example of entities can be a track/vessel/train fleet, a list of stations/terminals/warehouses, etc. Static data is being ingested upon node bootstrapping. Streaming data consists of the information that changes over time, and in essence contains the messages that are exchanged between the SELIS participating entities. Message content (e.g. GPS traces, IoT and controller device readings, proof of deliveries) are stored in an append-only data structure backed up by a highly efficient distributed data store that supports high-rate insertions/updates.

The data structure capturing the real-world events is the event log, which captures all the operational data that is exchanged between SCN participants in the form of messages. The data model that is the combination of entities and event log defines a typical star schema approach found in datamarts and it is being used to perform the execution of the analytics algorithms (i.e. the SELIS recipes). Both the schema and the recipes are explicitly defined and configured upon node creation, utilising an easy-to-use API coupled with a comprehensive GUI. Any relations between the entities are captured in the KG, whereas the entity/event log schema facilitates the execution of analytics recipes.

The SELIS tools support the integration of the common information exchange models and metamodels and provides mapping functionality so as to enable cross-schema mapping. Further, it has the capability to create the necessary web services components and deploy the developed connectivity components as micro-services in the SCN.

All defined concepts inserted in the SELIS models may be exported, stored, enhanced and accessed in a graph database, thereby interacting with the SELIS KGs content database. This results in a powerful analysis and homogenisation environment, where, by implementing specific algorithms and queries, it is possible to introduce additional semantic content to the

nodes, to further enhance and enrich the modelled information on the SC and transportation. A semi-automatic mapping tool developed can usefully assist the mapping process in the information exchanges. This tool has been enriched to include content information by integrating properly the standard data types, consolidating with the existing common information exchanges' data model structures.

The use of SC ontologies in message transformations via semantic gateways has been specified and is exemplified in related projects, such as the e-Freight project, in iCargo, and in CORE. Most of the work in ontologies has been based in the LogiCO, which explicitly specifies the main concepts adopted in the logistics domain and LogiServ. The main idea is to use LogiCO as a bridging ontology to map and transform from other ontologies developed, i.e. WCO, UN/CEFACT, GS1, NIEM etc. The SELIS semi-automatic mapping tool is using and extending this approach, by running multiple ontologies to assist mapping.

SELIS Generic Applications and Results from Living Labs

A reference domain model of the seven sub-domains has been produced, as shown in Figure 6.6. This model has been implemented as a number of business models that provide a starting point for creating SC applications in the context of SELIS and beyond. This functionality was provided to the Living Labs stakeholders via a number of application dashboards, such as the stock optimisation dashboard, the barge ETA dashboard and the shipment tracking dashboard.

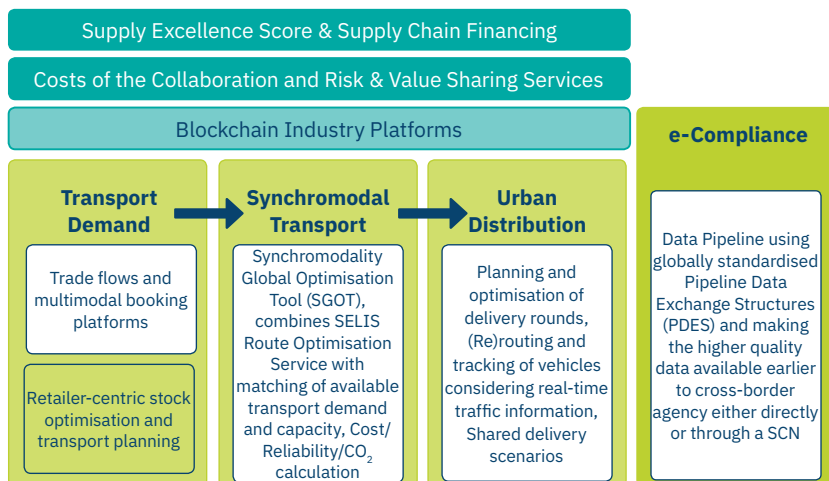


Figure 6.6: SELIS Applications Framework.

Conclusions

The SELIS project has produced key enablers towards a Shared European Logistics Intelligent Information Space with a focus on synchromodality. SELIS supply chain community nodes enable smart collaboration between stakeholders along the transport chain based on information sharing about all available transport modalities in real time in order to switch between transport modes (water, rail and road) in the most effective and environmentally friendly way.

SELIS has developed and demonstrated how connectivity tools can be integrated with security and privacy-preserving services to enable data-driven collaboration models that result in substantial economic and environmental benefits for a broad range of T&L communities. It has highlighted the importance of specifying logistics collaboration models as an innovation engine and how these models can be used to configure the supply chain community nodes. Central to the SELIS approach and architecture is using big data analytics to establish predictive and optimisation algorithms that provide business value to SCN participants. The design of the SCN comprises the use of shared knowledge graphs to manage interactions of logistics collaboration actors, advanced semantics, security, and analytics components with integrated content based routing that constitute two early patent filings (already awarded in France). At the same time, making these components open source guarantees broader use by European researchers and industry. The later three patent filings on cooperative stock optimisation for integrated SC management, intelligent dynamic container routing and smart contracts reflect the project's vision towards realising a next level of automation in synchromodality in the direction of PI through SCN federation.

From the outset, the importance of synchromodality and strategic capabilities such as SC visibility to support its implementation was well understood and a main workstream was dedicated in this area. This produced a valuable library of models, called EGLSs. It is, however, recognised that real value from this work will come from industry acceptance, use and extension/refinement of these models. Consolidation and governance of logistics collaboration models for efficient low-carbon transport are flagged as important actions for industry forums such as ALICE and standardisation bodies such as UN/CEFACT, with whom SELIS collaborated in a productive way.

In terms of future research, the project experience points to the need for extending the community models tested in the Living Labs as well as in other projects. Classification of collaboration models is needed and further elaboration to reflect different communities' needs in the light of emerging transport innovations such as electric and autonomous vehicles and IoT driven automation as well as infrastructure developments, aligning the innovation road maps across different modes (Figure 6.7).

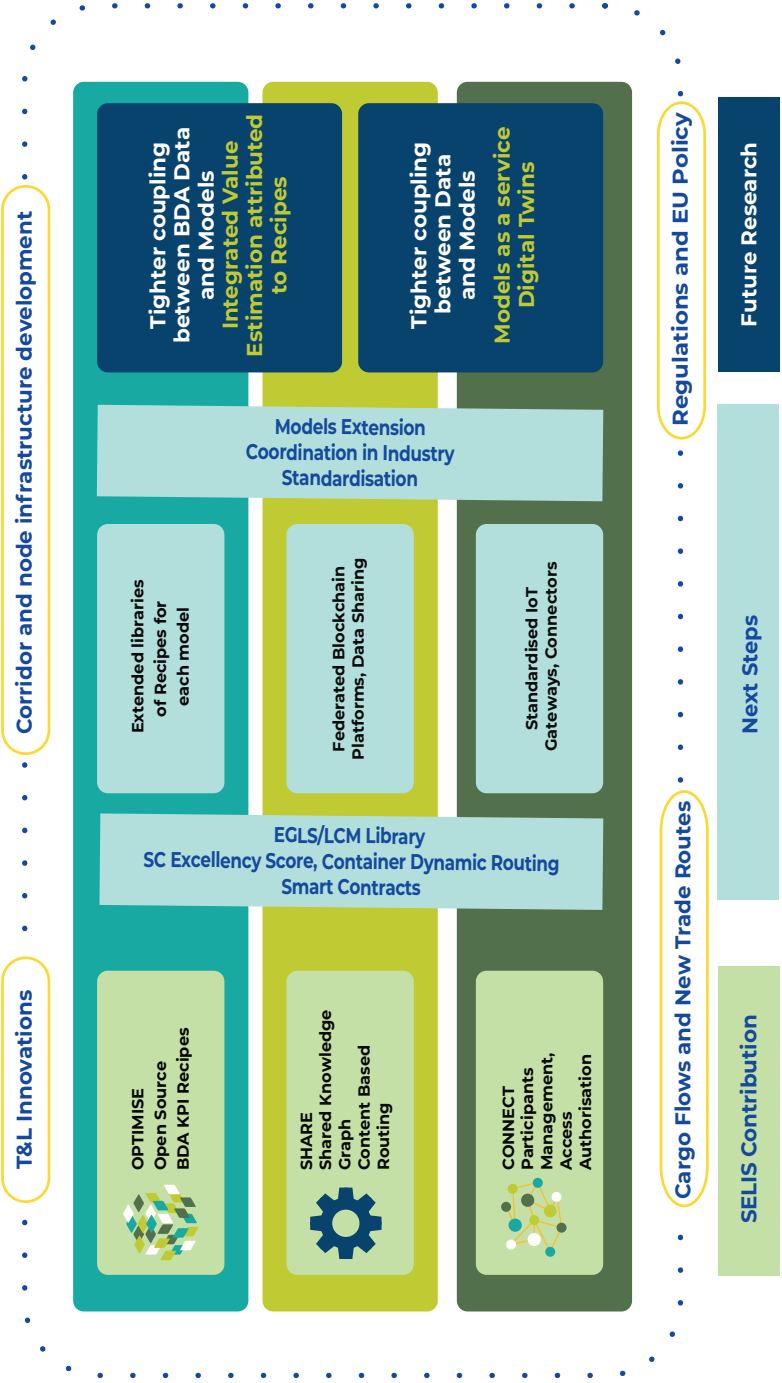


Figure 6.7: Alignment of innovation road maps across different modes.

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