

# IT-Enabled Resilient, Seamless and Secure Global Supply Chains: Introduction, Overview and Research Topics

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**Abstract.** This paper is the introduction to the fourth Workshop on *IT-enabled Resilient, Seamless and Secure Global Supply Chains* (WITNESS 2015). In the paper, we present a synthesis of the innovation agendas of a series of international research, development and demonstration projects that seek to make supply chains more efficient and more secure. From this agenda, we highlight three main innovation areas that are central to the current transition in the domain of logistics and international trade. Against this background, we introduce the five papers that are part of the WITNESS 2015 workshop. The papers primarily cover IT related innovations and include topics such as data quality and data governance, the development and interoperability of platforms that together present an IT innovation in international trade, and serious gaming for making key players aware of the potential of the innovations. We finalise with the suggestion to put more emphasis on the non-technical parts of the innovations, as that is what is ultimately needed to ensure wide uptake of the innovations, in order to make them really count.

**Keywords:** Information infrastructure · International trade · Collaboration · Innovation · Supply chains · Security · Information society · WITNESS

## 1 Introduction

Due to globalisation and automation, international supply chains have become more dynamic and more complex over the recent years. The commercial transactions, organisation of logistics and execution of transport are performed by multiple layers of organisations, all connected by contracts of sale and carriage [1]. Furthermore, as a consequence of efficiency developments like the introduction of sea container transports and consolidation of cargo, more and more goods are concealed from supply chain visibility, negatively impacting the ability of businesses and governments to assess the security of internationally shipped cargos [2]. Concepts like outsourcing of activities, consolidating cargo from multiple shippers and transporting across multiple modes of transport (sea, air, road, rail, river) have complicated the organisation and control of the chain and demand more from the involved companies in terms of collaboration and information sharing.

In this context, enhancing supply chain security whilst preserving trade- and logistics-related economic growth, and at the same time safeguarding societal values, is a major topic on the agendas of global and national players, both public and private. To achieve this, various projects, both international and national, have focused on studying, developing and demonstrating innovations to this end.<sup>1</sup> The projects aim to enhance the efficiency, speed and reliability of trade and logistics. At the same time, they seek to enhance the effectiveness and efficiency of supervising global trade, safeguarding supply chain security and integrity and safeguarding society against illegitimate trade and criminal threats. Hence, they seek to achieve both business and societal objectives. Balancing the needs for better security with safeguarding economic and public, requires two major transitions:

- Industry and the business communities aim to regain and retain control over fragmented supply chains and need to develop and apply new collaborative ways of supply chain risk management, going beyond the scope of existing enterprise risk management frameworks and building resilience into their supply chains. IT innovations need to support their supply chain visibility and control.
- Governments and border control authorities need to understand and recognise this and develop chain based control and supervision models that are both effective and result in lower compliance costs for legitimate and trusted traders. For governments, this requires a complete paradigm shift from transaction-driven control to system-based control and from a focus on national borders to understanding supply chain dynamics and impact of interventions.

A large part of the solutions currently being developed to support these transitions are IT (-related) innovations. This includes architectures and delivery infrastructures for data sharing in interoperable ways against minimum costs. Innovations are currently being undertaken to enhance data sharing and improve the timely availability of accurate data in global trade networks [3]. This requires business information infrastructures for data sharing. In addition to business-to-business information sharing, global trade networks are highly regulated and for purposes of compliance to e.g. duties and security regulation, companies are required to report a variety of information to various government organisations. This requires intensive information exchange in which a company interacts with, among others, customs authorities. Inter-organisational information systems play a key role in the simplification and harmonisation of cross-border control procedures, where paper-based procedures are replaced by electronic procedures and IT-facilitated inspection and supervision concepts.

The fourth Workshop on *IT-enabled Resilient, Seamless and Secure Global Supply Chains* (WITNESS), organized at the 14th IFIP Conference on e-Business, e-Services and e-Society (I3E 2015), focuses on innovations in the architectures and governance of smart information infrastructures, platforms and ecosystems. Amongst others, the domain deals with the challenges of interconnecting business information infrastructures

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<sup>1</sup> For example, European projects in these areas include INTEGRITY, Smart-CM, e-Freight, SUPPORT, LOGSEC, IMCOSEC, CASSANDRA, COMCIS, CONTAIN, SAFEPOST, RISING, ECSIT, ITAIDE, ACXIS, and CORE.

to digital government infrastructures, inter-organizational partnerships, governance and collaboration models. This year's workshop features five papers related to innovations in the architectures of smart digital infrastructures for global supply chains. As an introduction to the workshop, this paper describes recent developments in this domain in terms of an innovation agenda, an overview of the papers, and finalises with a suggestion for additional research topics in need of attention.

## 2 Making Global Supply Chains Smarter: An Agenda

Among the main innovation drivers in international trade is the need to improve security of international trade supply chains. Security is hampered by a deficient information system, where supply chain actors do not or cannot always fully inform the next actor in the chain, for example about who the original shipper is, and what precisely is in a container [2]. As a consequence, the visibility that for example the consignees have on the goods being shipped to them, is limited. Also, parties further down the supply chain cannot seamlessly integrate goods flows due to a lack of accurate and timely information. What is more, as official declarations are based on transport documents that are not from the actor that really knows the specific goods being shipped, authorities such as customs have to supervise the supply chain with second-hand information that is frequently inaccurate [2].

To make supply chains more secure and to enable parties in the supply chain to enhance supply chain resilience and the effectiveness of operations, innovations that aim to smarten-up international trade are under development. ICT has a big role to play in making supply chains smarter. For instance, innovations in the ICT's used by supply chain actors enable electronic connections and information exchange between the information systems of supply chain actors, thereby enabling or improving access and re-use of these original trade data by other actors in the supply chain [4].

As indicated in the introduction, one place where these innovations are developed and tested is in research and development projects, such as a host of projects funded by the European Commission. As many of these projects are now underway or have finished already, in this section we look at these projects to see what the main innovation categories are to make supply chains more resilient, seamless and secure. We find that three main types of innovations bind these projects:

- Technology innovations;
- New supply chain risk concepts, and;
- New collaborations and supervision concepts.

In the remainder of this section we discuss the main topics that come up in the goals of a selected set of European projects and discuss the abovementioned types of innovations in more detail.

### 2.1 The Innovation Agenda: Main Topics in Recent EU Projects

There is a series of related EU funded projects that aim to improve the security and economy of international supply chains, by leveraging (information) technology innovations. In this paper, we focus on the following projects: CORE, CASSANDRA,

CONTAIN, SUPPORT, SAFEPOST, EUROSKY, E-FREIGHT, I-CARGO and LOGICON<sup>2</sup>, all funded by the European Commission under the 7<sup>th</sup> Framework Programme. There are many more projects, also outside of Europe and in and by individual countries or stakeholder groups, but we focus on these as they form a ‘family’ (of sorts) of projects and are funded under the same programme.

A synthesis of the main goals of all aforementioned projects yields the following innovation agenda across these projects:

- Interoperability, information exchange and data sharing;
  - New IT infrastructure and ecosystems (e.g. for air in Europe, for containers globally, for ports);
  - Developing an information backbone; improving security through information-sharing;
- End-to-end supply chain visibility and visibility of supply chain risks;
- Advanced supply chain risk management;
  - Targeted screening (new solutions), improved threat handling;
  - Developing new risk models, from a supply chain perspective;
- System based supervision;
  - A systems approach to design and implement measures for a broader context (e.g. collaborating business in a chain);
  - Risk-based approach to supervision;
- Integration of effective, less-intrusive security technologies in supply chains;
  - Integrating various existing solutions;
  - Container integrated sensors, surveillance system, smart seals and other security technologies;
- Supply chain resilience;
  - Resilience capabilities of organisations and in supply chains;
- Strategic management and governance models;
  - Coordinated border management;
  - Business models for IT infrastructure, supply chain risk management and resilience;
  - Public-private governance models.

Note that optimisations in operations (which has been one of the key topics in supply chains for a long time) are often posited as a derived benefit of these innovations, and not an objective or research component itself, in these projects. Typically, these projects also aim to re-use technologies and innovations that are already present, by selecting the ‘best’ and integrating them.

An important part of all of these projects is that they aim to demonstrate and refine the innovations in various demonstrators, focusing on container (CASSANDRA), postal (SAFEPOST) and air (EUROSKY) supply chains, including multimodal supply chains

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<sup>2</sup> <http://www.coreproject.eu/> | <http://www.cassandra-project.eu/> | <http://www.containproject.com/> | <http://www.supportproject.info/> | <http://www.safepostproject.eu/> | <http://www.euroskyproject.eu/> | <http://www.efreightproject.eu/> | <http://i-cargo.eu/> | <http://www.logiconproject.eu/>.

(CONTAIN). From the perspective of the workshop and similar to the CORE agenda, the innovation agenda can be grouped in three main types of innovations, which will be discussed next, based on plans and reports of the projects.

## 2.2 Technology Innovations

A number of technology innovations act as enablers for the innovation agenda. One of the key enabling technological developments of interest for this workshop are the advancements in ICT. In various ways, the projects mentioned above focus on capturing data from the source, i.e. from the handling actors in activities upstream the supply chain, such as container consolidation and stuffing, and ensuring reuse of high quality data through effective control and validation processes. Most of the papers in this workshop also deal with issues and developments of IT to enable many of the innovation agenda's topics primarily through data sharing. These papers are accompanied by various real demonstrations of such solutions, making the IT innovation an accelerator creating momentum for the other innovations on the agenda.

Reliable source data is a necessary ingredient for realising (amongst others) end-to-end visibility on supply chains and supply chain risk. Such visibility is required to improve company and supply chain performance (by enabling e.g. Vendor Managed Inventory), by supporting and enhancing decision-making processes, agility and resilience. Enhanced visibility promises huge benefits [5], but requires some form of seamless data interoperability and a supporting information infrastructure, for example in the form of an ecosystem (as in e.g. CORE) or a data pipeline (as in e.g. CASSANDRA). The nature of international trade requires a 'federated system-of-systems approach, that connects disparate systems (in supply chains, physical instruments, communities, supply chain security controls) in a global architecture providing effective access to supply chain security related information and services from anywhere within that system' [6].

Seamless data interoperability is aimed at reducing the (transaction) costs involved in searching for and exchanging information and sharing data, in both business-to-business and business-to-government relationships in international trade and logistics. Apart from yielding benefits for businesses, it is expected to contribute to enhanced effectiveness in government control. Lack of interoperability is one of the causes for poor data transformation along the value chain.

Finally, technologies such as detection, scanning and cargo screening technologies, automatic identification and data capture technologies (such as smart container security devices), and tracking and tracing technologies can also contribute to supply chain security and resilience, provided the information generated by all these systems is shared timely and securely.

## 2.3 New Supply Chain Risk Concepts

Supply chains face various threats and vulnerabilities, ranging from external events to systemic vulnerabilities (such as the information problem discussed before), and now accompanied with concerns about cyber risks, and insurance and trade-finance costs. The visibility that can be provided by IT innovations should also be applied in the portfolio of supply chain risk management options, which is the key to advanced supply

chain risk management. Control over the supply and value chain are hampered by the fragmentation of these chains in terms of actors and interests. Visibility is a key instrument for parties to regain control over the chains they are involved in. Hence, as part of a supply chain wide risk approach and supported by IT innovations, control over and insight in the chains are required for improved alignment of supply chain processes and for supply chain optimisation. However, there is also another economic justification for being in control of the chain; the intrinsic commercial and compliance value of forming a trusted and integrated supply chain. Gartner [7] identifies this as the key trend under Supply Chain Leaders in 2014. Supply chain wide visibility and control over risks across the chain form the foundations for supervision models that are based on the level of business control over the supply chain, which could lead to a lower administrative burden and higher predictability. In any case, a shared risk vocabulary is required, as is improved data and information sharing across supply chain actors (including with government), and building greater agility and flexibility into resilience strategies.

## 2.4 New Collaboration and Supervision Models

In the EU, DG TAXUD introduced a risk-based approach (RBA) as a customs view on supervision as an alternative to a 100 % scanning approach. Most EU customs organisations already apply an RBA (e.g. by using risk assessment systems). However, these are not always efficient, with up to 30 % of shipments targeted for further evaluation, which results in transaction-based controls disturbing trusted and secure logistics flows. The common framework for Customs Risk Management and Security of the Supply Chain of the European Commission comprises of three parts [8]:

- Identification and control of high-risk goods movements using common risk criteria;
- The contribution of Authorised Economic Operators (AEO) in a customs-trade partnership to securing and facilitating legitimate trade;
- And pre-arrival/pre-departure security risk analysis based on cargo information submitted electronically by traders prior to arrival or departure of goods in/from the EU [8].

Applying such a risk based approach to incoming trade flows highly depends on the quality, accuracy and timeliness of information that supervision agencies receive. From the CASSANDRA project we learned that the data quality of pre-arrival declarations is regularly unsatisfactory. Often, agents or freight forwarders are identified as the consignor and consignee, and customs still does not know who the true consignor and consignee really are. Also cargo related data has quality issues following from these being asked of the ocean carrier, who in many cases does not (even cannot do not want to) know what is inside a particular container.

The RBAs as developed in the projects also cover what businesses do to identify and deal with risk in their supply chain operations [9]. Specifically, it means that businesses assess the specific risks in their supply chains at the *trade lane level*, and document the controls they have in place to address those risks. Based on that assessment, supply chain risks can be identified that are currently addressed insufficiently by the business controls, and additional controls can be identified to enhance end-to-end control over the supply

chains. This will shift operational focus to higher risk business, thus creating a risk-based approach towards supply chain operations.

Again, the IT innovation plays a major role here, as a supply chain RBA is only possible when the data that circulate among the supply chain partners are accurate, timely and of sufficient quality. Furthermore, the types of risks and the specific sets of data that are required to assess and deal with risks are often product-type and trade lane specific. A supply chain wide risk approach by businesses, combined with a higher quality of crucial data elements, enables government organisations to assess the risks of the supply chain better, and apply a different mix of control mechanisms based on that assessment.

Here, other IT innovations can play a major role as well, primarily in the form of Single Windows [10], which can reduce the administrative burden for businesses, but should also act as a stepping stone for Coordinated Border Management (CBM). CBM refers to a coordinated approach by border control agencies, thus eliminating conflicts and redundancies between different policies, regulations and enforcement practices, thus enhancing their effectiveness as a whole.

An information sharing infrastructure (Sect. 2.2) and novel risk approaches (Sect. 2.3) enable government to ‘piggyback’ on data from better sources and on business controls; both should be part of a government risk-based approach to supervision; a system based approach (assessing the business controls) and assessing risks based on the data provided to government (for various forms of piggybacking, see [11]). This information must be reliable for government to assess the security of a goods flow, which reduces the risk of unnecessary inspection interference in safe supply chains (but which could not be assessed as being safe because the data is of insufficient quality). As part of this approach, system based control instruments can complement other instruments (such as scanning or physical inspections) in effective control mix, resulting in potentially lower trade transaction costs and lower control burden traders experience.

### 3 Overview of the Papers in the Workshop

These proceedings contain five papers that are part of the 4<sup>th</sup> WITNESS workshop. Most of them deal with the challenges of data sharing or with ICT solutions to address them. More specifically, two papers deal with the specifics of data in logistics and international trade, one on the effects of governance of data, the other on assuring data quality. Two other papers deal with the information infrastructure to facilitate data sharing among supply chain actors, including businesses (both traders and logistics providers) and governments (e.g. inspection agencies). Finally, one of the papers deals with a topic that is too often underestimated: whereas the technology might be capable of overcoming many hurdles, ultimately the decision to really adopt and use these technologies depends on many other factors, including the awareness that decision makers have both of problems and of potential solutions.

In the paper “Determining the Effects of Data Governance on the Performance and Compliance of Enterprises in the Logistics and Retail Sector”, Nick Martijn, Joris Hulstijn, Mark de Bruijne and Yao-Hua Tan addresses the important topic of

data governance. More specifically, they seek to offer a way to determine the effects that data governance has on business performance and compliance. This is important as many practitioners see or expect positive effects, but are missing a framework to actually assess the effects. This paper offers such a framework and the expected benefits for retail and logistics. The research offers interesting insights that could be added to existing models, including models that start from broader IT governance or enterprise risk management perspectives.

Another paper dealing with the specific characteristics and challenges related to data is “Data Quality Assurance in International Supply Chains: An Application of the Value Cycle Approach”. In this paper, Yuxin Wang, Joris Hulstijn and Yao-Hua Tan propose a value cycle approach to assuring data quality in international supply chains. Given the numerous issues existing when it comes to data quality in international trade, the insights that the paper offers might be helpful to academics and practitioners looking into ways to ensure and verify the quality of the data that supply chain actors have to work and make decisions with.

In his paper “Towards a federated infrastructure for the global data pipeline”, Wout Hofman offers set of platform services and protocols to allow interoperability of different platforms. Such interoperability is necessary given that global data exchange infrastructures (such as the data pipeline that this paper concerns) will have to be federated solutions, making use of the wide variety of solutions already in place or currently under development. The path to the vision laid out in this paper will not only require time and continued innovation, but will also be in need of new business models to ensure adoption and sustainability of the federated infrastructure.

Thomas Jensen also discusses infrastructure for improving information sharing in international trade, using the Interorganisational Systems (IOS) literature as his starting point. In “Key Design Properties for Shipping Information Pipeline”, he follows a design science approach and presents a set of key design properties for a so-called Shipping Information Pipeline, an information infrastructure for international containerized trade. Not unlike Hofman’s ideas, one of the principles also holds that the idea of the data pipeline is that of a ‘virtual’ infrastructure, whereas the actual physical infrastructure can (and will) be handled by several individual organisations.

Finally, in “Enhancing Awareness on the Benefits of Supply chain Visibility through Serious Gaming”, Tijmen Joppe Muller, Rainer Müller, Katja Zedel, Gerwin Zomer and Marcus Engler discuss a serious game developed for customs-related issues and innovations in international supply chains. The gaming-background of the paper primarily concerns the learning effect, but given the background of the innovation that it concerns (data pipeline, customs innovation), we think that it can also serve other purposes as part of the innovation trajectory, notably by supporting the process of activating and including key stakeholders. The main contribution of this paper is therefore twofold: it discusses the specific game, which covers various topics of the innovation agenda discussed in this paper, but it also shows how serious gaming could (and should) be used to address non-technical aspects of the innovations.



## 4 Beyond the Innovation Agenda: Making Innovations Count

As demonstrated by the innovation agenda of the projects and the papers in this workshop, logistics and international are seeing a series of innovations to make logistics smarter, more competitive, improve supply chain security, enhance control and facilitate information sharing. These innovations have been and are being developed, studied and demonstrated extensively in (inter)national and European projects and are about new ways of controlling risk and collaborating in supply chains, enabled by IT innovations. Combined, these innovations should constitute a transition for the domain of logistics and government. Although the concepts that are central to these innovations are quite well known by now (as demonstrated by the many shared goals of the projects covered in this paper), there still is a big gap between the transition in theory and the actual adoption thereof in the real world. The real uptake and in-depth integration in the actual practices of organisations of what has come from these years of research, concept building, and technical development, is unfortunately limited at times. That some concepts only find limited fertile ground in the sector after the projects finish, presents a major challenge for the coming years. The limited adoption of the ideas and innovations generated by the research projects itself represents a research problem, which cannot be solved only by improving the models and technologies.

Although the European projects devote a lot of time and resources on stakeholder-driven demonstrators (which is a very important step), just how these local innovations combined can constitute a coordinated and balanced innovation for the logistics sector as a whole, is not yet well understood. A major transition through an integrated and coordinated large-scale implementation of key innovative logistics concepts is needed, but the actual adoption by the sector also requires small, local innovations, attuned to the specific stakeholders involved.

Hence, although further refinement and additional development of the topics on the innovation agenda discussed in this paper are both needed and desired, we argue that additional research is needed into the *socio* side of what ultimately are to be socio-technical artefacts. This side has challenges itself, e.g. as the parties involved in logistics and trade, which ultimately will need to adopt the innovations and solutions, have great variety in position, interests and values. To make the innovations work for them, this variety will have to be addressed and taken into account, which can only be done close to those specific stakeholders. This is difficult as the stakeholder field is very fragmented, with interests divvied up along the lines of sectors (e.g. initiatives in the horticulture industry), roles in the supply chain (e.g. transporters, freight forwarders, shippers) and the size of companies. Especially the many small and medium sized operators will have to be involved via e.g. branch organisations and collaborations as they have limited capacity focused on innovation. This complexity can explain, for example, why some of the aforementioned projects have become innovations that rely on government support, whereas they should have been (and in nature are) business innovations.

To create the right incentives for open innovation and establish a vibrant community of companies that are willing provide parts for data pipelines and to ensure that public value is realized, institutional arrangements must be developed and adopted. Typically, these institutional arrangements are developed not only by national government, but also

supra-national organizations should be involved such as the European Commission or the United Nations. Furthermore, as argued by Hofman in his workshop paper, apart from the IT developments and challenges, the federation of platforms requires additional research into the (sustainability of) business models for these platforms. Making combinations of data from multiple parties (both public and private) is essential for developing new commercial services and for supporting new supervision concepts, both creating (economic) incentives for companies to contribute to realizing the innovations. However, there are also risks involved in combining data from multiple sources, especially in a competitive private environment. Some form of governance would help stakeholders (again, both public and private) to create on the one hand a level playing field (e.g. to avoid that one or a few parties can gain an unfair competitive advantage from their access to community data), and on the other hand offers enough economic incentives for businesses to make their adoption of the innovations commercially viable. As the workshop paper by Muller et al. illustrates, much of this starts with making key players aware of the issues and potential solutions. Given such awareness, the right institutional practices, incentives, process support by facilitators and viable business models for parts of the innovations, the field can develop a fertile ground for the innovations to land in, and from thereon find wide support and uptake.

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## References

1. Van Oosterhout, M.: Organizations and flows in the network. In: Van Baalen, P., Zuidwijk, R., Van Nunen, J. (eds.) *Port Inter-Organizational Information Systems: Capabilities to Service Global Supply Chains*, vol. 2, pp. 176–185. Now Publishers, Hanover (2009)
2. Hesketh, D.: Weaknesses in the supply chain: who packed the box? *World Customs J.* **4**, 3–20 (2010)
3. Klievink, B., Van Stijn, E., Hesketh, D., Aldewereld, H., Overbeek, S., Heijmann, F., Tan, Y.-H.: Enhancing visibility in international supply chains: the data pipeline concept. *Int. J. Electron. Gov. Res.* **8**, 14–33 (2012)
4. Tan, Y.-H., Bjørn-Andersen, N., Klein, S., Rukanova, B. (eds.): *Accelerating Global Supply Chains with IT-Innovation. ITAIDE Tools and Methods*. Springer, Berlin (2011)
5. Ngai, E.W.T., Chau, D.C.K., Chan, T.L.A.: Information technology, operational, and management competencies for supply chain agility: findings from case studies. *J. Strateg. Inf. Syst.* **20**, 232–249 (2011)
6. CORE Consortium: *CORE (Consistently Optimised Resilient Secure Global Supply-Chains) Description of Work (DoW)* (2014)
7. Gartner: *The gartner supply chain top 25 for 2014* (2014)
8. European Commission: *Communication from the commission to the european parliament, the council and the european economic and social committee on Customs Risk Management and Security of the Supply Chain* (2013)

9. Cassandra: D2.2 – risk based approach (2012)
10. Keretho, S., Pikart, M.: Trends for collaboration in international trade: building a common Single Window Environment. United Nations (2013)
11. Klievink, B., Bharosa, N., Tan, Y.H.: Exploring barriers and stepping stones for system based monitoring: insights from global supply chains. In: Lecture Notes in Informatics (LNI), Proceedings - Series of the Gesellschaft fur Informatik (GI), pp. 35–42 (2013)