Data sharing requirements of supply – and logistics innovations – towards a maturity model

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Abstract. Supply - and logistics innovations require data of different, heterogeneous sources. Supply chain resilience for instance requires visibility of goods flows and data of planned infrastructure maintenance and unforeseen accidents or incidents that may cause delays. Technically, there are different ways to share this data, e.g. the messaging paradigm for business transactions and event-driven architectures for visibility. Based on an IT typology, this paper presents an assessment methodology for data sharing supporting supply – and logistics innovations. An interoperability infrastructure will need to implement these technical protocols. One of the findings of this paper is the requirement of an innovation maturity model driven by IT application complexity.

Keywords: resilience, agility, IT application topology, maturity model

1 Introduction

Data driven innovation is mentioned as one of the most important technology trends, contributing growth to our society and economy [1], [2]. The traditional focus of supply and logistics was on data exchange for service delivery [3], but is shifted to meet market demands correctly, rapidly, and profitably. The impact of this shift of focus on logistics is an increased demand on visibility and agility for mitigation of any delays, including those caused by accidents or incidents [4]. Synchromodality [5] is addressing these issues and introduces innovative planning and scheduling concepts. The concept of the Physical Internet [6] presents an alternative approach that is expected to boost profits by 100 billion US dollars and cut emissions by 33% in the U.S. (http://www.sustainablebrands.com).

Data availability and – accessibility is part of interoperability, mostly discussed as semantic and syntactic integration of technical platforms [7]. Open standards for web services, messages, and events supporting the Service Oriented - [8], Event-Driven- , and Messaging Architecture have been developed. With the introduction of the Semantic Web, innovative approaches based on data crawling for data collection are introduced [9]. Since there is a variety of technical protocols for data sharing, the research question of this paper is: which technical protocols could best meet data sharing requirements of supply – and logistics innovations. Answering this question provides input for developing a so-called Internet of Data[1] for supply and logistics meeting demands of the Physical Internet [6]. Firstly, an overview of supply – and logistics innovations and technical protocols is given and, secondly, a methodology to assess requirements and construct a mapping between supply – and logistics innovations with technical protocols is proposed. Finally, conclusions are presented.

2. Analysis of the aspects of the domain

The objective of this paper is to assess a proper technical solution for data sharing for a particular supply chain innovation. This section lists the current relevant supply chain innovations requiring data sharing and available technical protocols for data sharing.

[1] http://www.techradar.com/news/world-of-tech/forget-the-internet-of-things-the-internet-of-data-is-where-it-s-really-at-1302978

2.1 Supply chain innovations

Table 1 lists the supply chain innovations considered in this paper.

Table 1. Supply chain innovations.

Supply chain innovations	Targeted explanation
Internet of Things: effective and less-intrusive security technologies in supply chains [10]	Deploy innovative sensor/actuator technologies such as Container Security Devices (CSDs) and tracking and tracing technologies in less-disruptive ways, detecting any changes in the physical condition and movement of goods.
Supply chain visibility [11]	Awareness of and control over end-to-end supply chain information – including insight in sources of data and whereabouts of goods – enabling agile, resilient, sustainable as well as compliant and trusted supply chains.
Supply chain agility [11], [12]	The ability of an organization to quickly respond to a changing environment, such as market responsiveness and delivery reliability.
Supply chain resilience [13] [11]	Increase the capacity of the supply chain ecosystem to respond to disturbances by resisting damage and recovering quickly.
Bundling [14]	The capability to combine shipments or transport capacity.
Synchromodality [5]	The ability to select the best modality to meet customer requirements at the latest stage, considering potential delays caused by the environment of that modality during its execution (e.g. predicted traffic density and weather forecasts).
Coordinated border management [15]	Alignment of controls and formalities to be carried out by different enforcement agencies at logical moments and places in the supply chain and recognize each other's security programs and risk assessments
System based approach [15]	Maximize piggy backing on the business and chain control mechanisms already in place in the commercial domain

2.2 Technical protocols

Table 2 provides an overview of data sharing technologies from a business process perspective. Business processes of collaborating organizations can be coupled or decoupled. In case of coupled processes, a sender of data halts its process until a reaction is returned. In decoupled business processes, sender and recipient run their processes independently and act on the latest available data they have shared.

Table 2. Technical protocols for data sharing.

Business processes	Technical protocol	Features
Decoupled	Messaging	A sender duplicates data to a recipient. In supply and logistics, messages are (mostly) equivalent to electronic business documents. Data formats are for instance XML or EDI.
	Event Driven Architecture (EDA) [8]	IT systems of organizations can subscribe to events published by sensors (IoT – Internet of Things), IT applications, or platforms. An event either has sufficient data, e.g. the location and speed of a truck are given by the event, or refers to data available in an IT application. EDA provides the capability of users to subscribe to only those state changes in logistics that are of interest to them, e.g. container milestones like 'loaded'.
	Data Crawling [9]	An IT application accesses periodically (in a controlled way) several data sources. The period between crawling can differ per source, whereas a source can specify any access restrictions to data. Supply chain resilience with data analytics can apply data crawling.
Decoupled/ coupled	Link evaluation [9]	Data has links to other data with a URI (Uniform Resource Identifier), potentially stored in external data sources. Evaluating links directly accesses data. Resource Description Framework (RDF) is a representation of linked data.
Coupled	Service Oriented Architecture (SOA) [8], [16]	Capabilities of IT applications are published as services consisting of a service call and a response. Web Service Definition Language (WSDL) or REST based Application Programming Interfaces (REST APIs) are technical protocols with a data format.

One might consider Electronic Product Code Information Services (EPCIS, [17]) as an implementation of Linked Data. However, EPCIS references can only be used to query data from other systems in a traditional manner (like database queries) and do not support link evaluation. REST APIs can support crawling and SOA, but a query language like SPARQL (SPARQL: Simple Protocol And RDF Query

Language) can also be applied. In that particular case, an IT application has to provide a so-called SPARQL endpoint producing data in RDF format.

3. Assessment methodology

A mapping of a supply – and logistics innovation to a technical protocol provides an overview of the required technical protocols for particular innovations. However, IT applications will support innovations. Each organization can implement a particular IT application meeting requirements and considering its IT maturity level [18]. First, we will argue why we propose a methodology to decouple an innovation from a technical protocol via IT applications, in line with architectural frameworks that consider a mapping of business processes to IT applications and their data requirements [19], and, second, an IT applications typology is presented. The next section provides the mappings between innovations, IT applications, and technical protocols.

3.1 Overview of the methodology

Assessment of a data sharing technology for supply chain innovations should be made on functional requirements like data quality parameters (completeness, correctness, consistency, and volatility of data [20]) and non-functional requirements like performance and security. 'Time' (past, present, and future) is important for decision-making in logistics, just like the way an innovation will be applied by business (e.g. strategic for network planning or operational based on real time data). For instance, business performance analytics runs as batch process requiring high data quality with low performance requirements for collecting data. This type of analytics could be implemented by messaging, where a message represents a database dump. Visibility and resilience on the other hand are examples of processes requiring real time data with a low volatility, that can be applied to improve operational planning of resources (stock levels, personnel, etc.). The data quality property volatility is defined as 'the duration between a state change in the real world and accessing it via an IT system'. High volatility implies a long duration, decreases the quality of decisions, and therefore reduces the ability to dynamically reconfigure chains in logistics and supply networks (synchromodality, agility, and resilience). A low volatility means that relevant partners have real time access to state changes in the real world, like a forwarder knows the time of discharge instantaneously. This definition of volatility for visibility implies collecting sensor data, where access to these sensors might be restricted. An alternative could be the implementation of the EDA paradigm, where IT systems publish (aggregated and/or anonymized) sensor data.

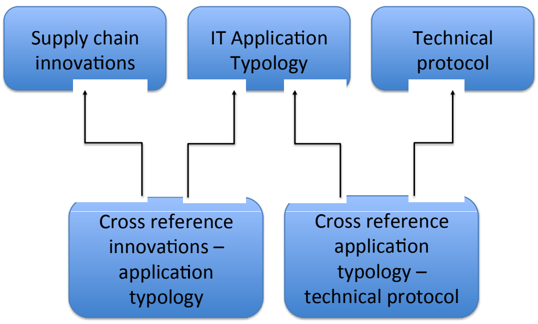

Fig. 1. Overview of the assessment methodology.

There is thus dependency between data availability, the way an innovation is implemented by an organization, and an ideal (set of) IT application(s) supporting a particular innovation. This issue is addressed by introducing an IT application typology for supply chain innovations. IT applications have specific requirements with respect to technical protocols for data sharing. The following figure shows the proposed assessment methodology based on an IT application topology. By selecting a particular IT application, a particular technical protocol can be applied. Figure 1 visualizes this approach.

3.2 IT application typology

Basically, data is collected for decision-making resulting in an action, where actions can or need to be shared with external partners in the environment. Decision-making is mostly expressed in terms of a decision like physical inspection a container, selection of a carrier, and adjustment of temperature setting of a container. The following table presents an IT application topology inspired by a typology for analytics[2, 3] [21] and the role of decision-making in situational awareness [22]. Table 3 has an implicit dimension: model based - and data driven applications. Whereas model based applications try to capture experience in a computational model, data driven applications learn by processing and classifying large amounts of data. Model based applications are difficult to adapt to changing requirements; data driven applications are able to adapt based on learning algorithms. This implicit dimension implies that IT applications in the table are not disjoint, e.g. clustering algorithms can be part of planning software.

Table 3. Application typology

Typology	Description	Remark
Descriptive (registration)	A representation of the real world situation by an IT application including data of various resources, e.g. social media, news feeds, IoT, etc.	The primary focus of these applications is registration, but they might also contain decision support functionality. They support various other types of applications like Customer Relationship Management (CRM); we will not distinguish those separately.
Transaction management	Order management applications, supporting decoupled business processes.	Transport Management System (TMS), Enterprise Resource Planning (ERP), Declaration management systems, etc.
Visibility	Visualization of the real world status requiring low volatility. Preferably, business processes are coupled.	Visibility dashboards based on maps. They can be complex, in case they consider for instance sentiment mining of social media.
Diagnostic	Data is interpreted and presented as information to an end-user.	Examples are warnings that particular goods flows can be affected by accidents or incidents (resilience) and detection of delays. Diagnostics includes all types of algorithms, e.g. statistics, image -, and language processing.
Business Analytics	Analytics of the behaviour of an organization by analysing order data.	Typically, management dashboards with data warehouses for KPIs (Key Performance Indicators).
Business Intelligence	Analysis of the environment of an organization and its impact on ones own behaviour by mining external (open) data.	Inclusion of for instance sentiment mining of social media, but also analysis of competitor and customer behaviour for product – and service development, pricing, and production optimisation.
Complex Event Processing (CEP)	Combining events from one or more data sources, potentially including historic or already known data and generating new events for action.	An example is to analyse the effect of an accident with respect to delays, causing potentially re-planning of a chain (agility and resilience). It requires information on expected/planned behaviour and evaluates potential delays. Enterprise Service Busses [8] provide CEP functionality.
Clustering	Clustering can be applied to cluster orders with particular properties for planning or compares real time data with patterns in historic data to detect any changes to past behaviour.	Particular orders can be grouped to optimize capacity utilization of transport means like trucks. Actual trade flows can be compared to past behaviour and known trade patterns detecting patterns for risk analysis.
Rules	Conditions specified as rules applied to data to detect mismatches of expectations. Rules can be shared with for instance an open standard like Rule Interchange Format (RIF).	Rules can be used for risk assessment, where these rules are based on past behaviour. Rules can also be applied to detect situations like 'too late' arrival of goods at a location. A TMS might have implemented these types of rules.
Predictive	Prediction of (near) future behaviour based on descriptive and diagnostic behaviour.	The most prominent example is data-driven ETA prediction (ETA: Estimated Time of Arrival) based on incomplete data sets of for instance vessels, barges, and

[2] http://www.gartner.com/it-glossary/predictive-analytics
[3] See also various articles on Wikipedia by searching for instance prescriptive analytics, analytics, data mining, etc.

Typology	Description	Remark
		thus goods. ETA prediction is required to synchronise individual legs of logistics chains.
Prescriptive	Prescriptions take the effect of a decision into account.	Prescription can be model based or data-driven.
Resource planning	Optimisation of resource utilization. These algorithms are typically model based.	Resource planning requires data from transaction management applications (e.g. transport planning).
Matching	(Dynamic) chain composition. These algorithms are typically model based.	Matching requires access to (a registry of) available logistics services and capacity. A logistics market place or a fourth party Logistics Service Provider (4PL) will have a matching algorithm.
Behaviour optimisation	Optimisation of behaviour of an individual, an organization, or an object based on its state and data collected from similar actors in the (near) environment.	Examples are prescription of behaviour of professional drivers, optimisation of turnaround time of trucks at a terminal, and providing alternative solutions to meet resilience requirements.
Network optimisation	Diagnostics of a (sub)network resulting in behaviour prescription to one or more participants in the (sub)network.	Optimization of corridors between hubs with a large number of participants of different modalities can optimally use available infrastructure for their activities.

Table 3 lists a large number of relevant IT application types for supply - and logistics, but probably requires further completion. For instance, fleet - or asset management applications for maintenance of resources or assets are not listed. Furthermore, the complexity of applications increases from descriptive to eventually prescriptive applications, which is relevant to implementing particular supply chain innovations (see next section). Finally, the distinction between model based (e.g. business analytics and planning) - and data driven (e.g. a type of clustering and behavior optimization) applications will address dynamicity and data quality. Model based applications like planning can provide input to data driven applications like behaviour optimization.

4. Developing a maturity model

Whereas the previous section provides a classification of IT applications, not all innovations will require all functionality. This section presents a cross-reference of supply and logistics innovations with various data sharing technologies according the proposed assessment methodology. It will show that more than one solution is feasible to support a particular innovation. First of all, a cross-reference between innovations and IT applications and secondly IT applications and a technical protocol is given. Finally, the requirement of a maturity model for supply chain innovations is discussed.

4.1 Supply chain innovations and IT application topology

Table 4 presents a cross-reference between a supply chain innovation and an IT application. In case a row has one ‘X’, that particular type of IT application best fits an innovation. IT applications that require data of other IT applications are not considered in the next table. For instance, resource planning and business analytics interface with transaction management applications, where these latter share data with other stakeholders. Some rows have more than one ‘X’, which is to be interpreted as:

- Visualization for IoT can be based on individual sensors or aggregated data of multiple sensors.
- Visibility can also be based on both aggregated data of transaction management applications and an (cluster of) IoT device(s). In the case of aggregated data, visibility innovation provides a more diagnostic solution, combined with for instance rules, which might be implemented in for instance a TMS.
- Resilience requires a combination of IT applications, namely a transaction management system, an IT application predicting the impact of any accidents or incidents, and a prescription like a matching – or behaviour optimisation algorithm that offers alternative solutions.
- Bundling also requires data of several IT applications, for instance transaction management applications of two or more suppliers or resource planning systems of two or more carriers

providing available capacity (in time) and a network optimisation application to prescribe behaviour. 4PL's provide this particular capabilities.

- Synchromodality requires both transaction status, as stored in transaction management applications, and capacity of available transport means, generated by resource planning algorithms, also stored in transaction management applications, but also visibility of the status of the goods flows with a prediction of any delays (CEP) in ones goods flow, matching to select the proper modality, diagnostics and prediction of network utilisation, and potentially network optimisation. In this sense, synchromodality seems to require most IT applications and can thus be considered as complex.
- Coordinated border management consists of individual detection mechanisms, which can be based on anomaly detection or rules, leading to complex event processing to detect any potential inspections of other authorities. Many of the current applications are however transaction oriented with particular rule mechanisms for analysing these transactions ('declarations') on any anomalies generated by clustering applications.

Table 4. Cross reference of supply chain innovations and application typology.

Innovation	Descriptive		Diagnostics				Predictive	Prescriptive		
	Transaction management	Visualization	Business Intelligence	Complex Event Processing	Rules	Clustering		Matching	Behaviour optimisation	Network Optimisation
IoT		x		x						
Visibility	x	x		x						
Agility							x	x		x
Resilience	x			x			x	x	x	
Bundling	x			x				x		x
Synchromodality	x	x		x			x	x	x	x
Coordinated Border Management	x			x	x	x				
System Based Approach	x									

Like we stated, complexity of IT applications increases from descriptive to prescriptive applications. It implies for instance that implementation of synchromodality will start with descriptive applications showing visualization and in their final stage include network optimization.

4.2 Application solution typology and technical protocol

IT applications can use various data sharing protocols. The choice of a protocol depends upon requirements and interoperability capabilities of stakeholders involved. Table 5 provides a cross reference between a type of IT application and a technical protocol for inter-organizational integration.

Table 5. Cross reference of application typology and technical protocols.

IT application	**Messaging**	**SOA**	**EDA**	**Link Evaluation**	**Data crawling**
Descriptive					
Transaction Management	x	x	x		
Visibility			x		x

IT application	Messaging	SOA	EDA	Link Evaluation	Data crawling
Diagnostic					
Business Intelligence					
CEP			x		
Clustering	x	x	x	x	x
Rules			x		
Predictive					
Prescriptive	Predictive and prescriptive applications build upon descriptive (planning) or diagnostic systems and can use the same technical protocols.				

Table 5 lists a preferred option for a technical protocol, but combinations of different protocols can provide the same functionality. For instance, the combination of events with a link to data that can be collected by a web service can also support transaction oriented IT applications, however with potentially improved security features since access is controlled by a data source. Visibility solutions could also be constructed on messaging, but the volatility increases which leads to lower quality of decisions. Data driven applications can in fact utilize all types of technical protocols since any new data will be compared with already known patterns.

4.3 Discussion

Like we stated, complexity of IT applications increases from descriptive to prescriptive applications. It implies for instance that implementation of synchromodality will start with descriptive applications like visual dashboards with maps and in their final stage include network optimization. Since synchromodality requires most IT applications identified, it is probably the most complex innovation to implement completely. Therefore, each supply chain innovation will have its particular maturity model, driven by complexity of IT applications.

Table 4 shows that one IT application is able to support different supply innovations. It does not imply that such an IT application will fully meet requirements of all innovations it potentially supports. For instance, visualization may support IoT, visibility, and synchromodality, but synchromodality has additional requirements like optimizing one's own behaviour in a network.

This paper presents an IT application typology. Although many IT applications can be of the same type, providing similar functionality, these IT applications will be implemented and deployed differently to meet particular requirements. An example is to apply a clustering application to detect supply patterns and base production on these patterns, which differs from detecting anomalies from clusters and act on them from a security perspective.

5. Conclusions

This paper lists a number of supply – and logistics innovations and tried to construct a cross-reference with technical protocols for data sharing. Since an innovation is supported by an IT application, where such an IT application will utilize a particular technical protocol and provide a type of decision-support, an assessment method has been developed.

It seems easy to construct a matching between technical protocols for data sharing and IT applications. One can develop underlying connectivity infrastructures and (community and/or federated) platforms supporting these technical protocols. However, this paper shows that implementation of these IT applications to meet particular business innovations is complex. Further research is required in completing the IT application topology and to construct a maturity model for supply chain innovations, resulting also in requirements to IT applications. The IT Capability Maturity Framework^{TM} (IT-CMF^{TM}) might offer such a model [23]. Since particular innovations involve two or more stakeholders, multi stakeholder value modelling is also required.

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