Interoperability challenges for context-aware logistic services - The case of synchromodal logistics

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Abstract

Due to diverse and increased demands, logistics needs to move towards being more context-aware. Logistic planning and execution will benefit immensely by use of (real-time) contextual data, such as data about weather, traffic, and resources. Resulting benefits include better flexibility, lower greenhouse gas emission, reduced costs, and optimum usage of transport modalities. This paper demonstrates the benefits and investigates the interoperability challenges of integrating contextual data in synchromodal transport. A data format for incoming contextual data is presented.

1. Introduction

In accordance with the guidelines and vision of the EU, logistics in Europe has to be made more efficient and flexible. This is necessary to decrease the pressure on roads, better utilize existing infrastructure, and reduce Green House Gas (GHG) emissions. The underlining message of the vision document (European Commission 2011) is improved usage of different modalities of transport.

Optimal usage of different modalities is the idea behind Synchromodal Logistics Services (SLS). In SLS, the decision for a next route or stoppage is taken as late as possible. It implies that although the delivery time of a consignment is usually constrained, the intermediate modes of transport and the number and places of stopovers are not fixed when the shipment begins. Rather, they depend on various factors, including but not limited to weather and traffic conditions, change in demand, consolidation of different shipments (Rivera et al., 2015), road blockages, and other unexpected situations. It allows the Logistic Service Providers (LSPs) to act better in case of unexpected situations. There is a strong impetus from logistic companies to move towards a synchromodal way of working, because it enables LSPs to exploit the use of different transport modalities and be prepared for last minute changes and delays (Singh 2014). Here we use the acronym SLS for conveying the idea of synchromodal logistics – the freedom and ability of LSPs to use transport modalities to fulfil timing and quality requirements – while emphasizing the role of context awareness.

Context (or situational) awareness in logistics is increasingly becoming critical. It means that a route plan is decided taking into account as much as possible the current context, i.e. the circumstances and factors that influence the execution of logistic activities. It also implies that if some unexpected situation occurs, a swift response can be taken and the current route plan can be adapted. Learning from past trends and anticipating future events also falls under context awareness. Context data is made available to logistic companies via different data sources, ranging from devices that produce raw data (e.g. sensors) to information service providers that offer sophisticated information from processed data (see Table 1).

Three basic challenges exist regarding the usage of context data from diverse sources for SLS. Firstly, data is represented with different encodings, use various formats, and are exchanged with different protocols, which raises syntactic or technical interoperability issues. Secondly, data from different sources can actually refer to the same entity or condition. For example, as an unexpected event, assume that traffic is slow due to snowfall. The information for this event can be provided by sensors on the roads, from a weather website in the form of a RSS feed, from a logistics control tower, or even from social media. Still, this data needs to aggregated if used to derive more reliable or complete results. Thirdly, there is a continuous flow of large amounts of data. Most relevant data has to be captured so that necessary deductions can be made from it. Moreover, this has to done preferably in real-time.

Table 1: Different data sources

Data	Source	Situation
Weather	Sensors, 3rd party website, Control tower, Board computer, Government data	Snow, Rain, Poor Visibility
Location	GIS website, Sensor on the vehicle, LSPs	Inaccessibility
Traffic information	Government data, Websites, Sensors on roads	Snow, Blockage, Accident, Traffic jam, Slow moving traffic, Diversions
Water level	Government data, Public data, 3rd party sources, Water sensors, LSPs	The water level is too low or too high.
Disasters	News, Websites	Fire, Accident, Police action etc.

In this paper we focus on the first aspect of interoperability challenges for SLS. We propose a common data format with which contextual information from various sources can be represented in a consistent manner to meet the challenge of technical interoperability. We also demonstrate the usage of the data format by business processes of a typical logistic company using an example case. The rest of the paper is structured as follows: Section 2 presents background information; Section 3 presents the problem analysis; Section 4 discusses our solution approach; Section 5 shows an application of the proposed common data format; Section 6 presents a brief discussion of our results; and Section 7 closes with concluding remarks.

2. Background

There exist many actors in SLS. Apart from the consignee and the consignor, there are brokers, warehouses, customs, context information providers, and so on (see Figure 1). The business processes of actors are interdependent. For example, LSPs coordinate with warehouses to collect or deliver shipments, but LSPs also interact with context services providers, either following some contractual agreement or using public interfaces, to receive information about the conditions of some planned logistic activity. Frequent transfer of data and process collaboration is required between these actors. The data has to be consistent and interoperable for a smooth logistic flow. For the success of SLS, all actors have to work together during some phase and/or on some aspect relevant to logistic operation. For this purpose, there must be fixed terms of engagement, clear contracts, service level agreements, and also transparent rules for profit-loss sharing between partners. This is so because, by definition, plans (and modes of transport) can change frequently in SLS. If terms of engagement are not clear between collaborating partners, the success of SLS is hampered. The partners must have a common vocabulary for referring to entities and events in logistics domain to avoid semantic errors.
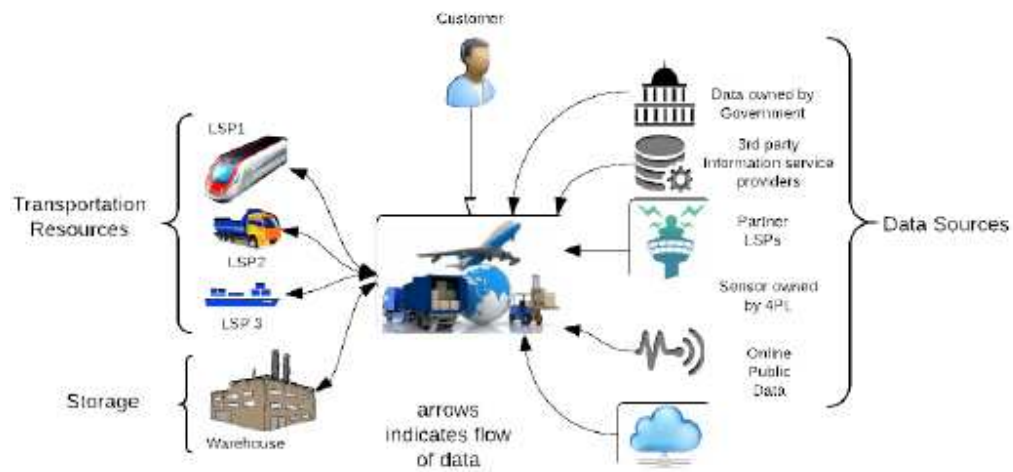
Figure 1: Actors in the logistic domain

A 4PL is a LSP which aggregates logistic services from different partners and offers it to the customer as one integrated service. Based on the discussion above, it follows directly, that a 4PL would have to face serious interoperability challenges in fulfilling a consignment as it uses the resources of different LSPs and context data originating from different data sources and owned by different context service providers. There exist numerous solutions in literature to deal with interoperability problems (in logistics). For example, One Common Framework (Pedersen 2012), GS1 Logistic Interoperability Model (LIM) (www.gs1.org) or the European Interoperability Framework (EIF) (European Commission 2010). Moreover, there exist numerous other solutions to enable technical interoperability, which are being used by consortia and unions of logistic companies. It is impossible to access and analyse all of them. The issue with current approaches is that context awareness is not (fully) considered or exploited. While there exist many and diverse data sources which can be of use for logistic planning, in current practice none or only a small subset is taken into account during the planning phase or to adapt an existing plan. Even if context data is considered during planning, updates about the situational changes are not used during the execution of an order. The decision problems in synchromodal transport are shown in Figure 2. Exception Handling and Real Timing Switching is an important operational decision. When an unexpected event occurs, the current plan for transport may no longer be the most economic (fastest or least polluting) one. In this scenario, the 4PL would have to change the current plan and a new allocation of resources has to be made consistent with the changed situation (Behdani et al., 2014).
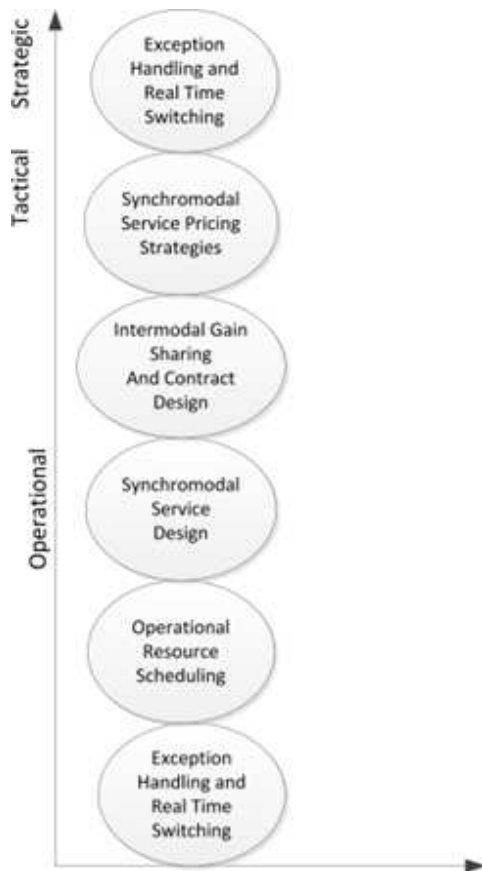
Figure 2: Hierarchy of decision problems in SLS (Behdani et al., 2014)

3. Problem analysis

The logistic domain in EU is very fragmented, i.e., there exist many consortia, unions, virtual clusters, and alliances based on the size of companies, national or regional preferences, diverse customer segments, technology usage and type of consignments (Golinska 2013). Such collaborations usually have their own method of data transfer and message formats. Such a diverse landscape leads to interoperability issues between enterprises, especially if these enterprises are not of the same alliance or, say, not of the same size. Moreover, introducing usage of a new technology and adoption of the same standards is impeded. This is one of the major challenges in using context data for logistics. Different companies will have a different definition of what, for example, a disruption is and what needs to be done, in case such an event occurs. Also, two collaborating companies can have different sources of data for getting informed on the same context or situation. These data sources can be external (3rd party services) or also from internal systems (data mining, demand prediction, order consolidation). The problem with numerous data sources is that the content and format (i.e. variety) of data differs greatly. Also the rate at which data is received (velocity) and the amount of data (volume) can cause problems. These concern are common for any big data scenario.

The interoperability concerns for any 4PL will not be confined to technology and information alone, rather they are present at the following levels (Westerheim 2014):

– Strategic Level – The partners should play a role in the collaboration that is in line with some common business goal. They have to agree upon the rules for sharing profit and loss. They also need to know the key service level indicators and have a common business vocabulary.

– Process Level – Processes like planning, bidding and product information have to be aligned so that partner companies and their information systems (IS) can work together. For this a common process choreography is required. The action of each IS in this choreography should be clear.

– Application Level – Process tasks can be automated with IT applications. If these applications share information across organizational boundaries, they should use compatible software and interfaces.

– Information Level – Foremost, information level interoperability is about sharing intended meaning (semantics) between partners. There exist many internationally accepted communication protocols and information standards. However, most standards are option-rich, and different partners may choose different option sets. In addition, partners in a specific alliance, usually have their own formats, additions and versions.

– Technology Level – Usually, there is a large gap between the technologies used by partners. This gap exists owing to the specific business of each partner and the historical suppliers of technology in this business branch.

– Security – Ownership (of resources including data), storage, and usage rules have to be in place and clear to all members. Logistic companies are usually very concerned about loss of control over or sharing information that has strategic significance.

In the following section we provide a simple ontology which can be shared between the 4PL and the LSPs to identify events and disruptions. Also we introduce a data format which incorporates the data from different data sources so that it can be used for SLS.

4. Solution approach

Information about disruptions from various data sources may be of different types and in different formats. To solve this problem, below we first present an ontology for disruptions, which would allow information interoperability. Then we develop a common message format based on requirement of SLS for technical interoperability.

4.1. Disruptions

External data sources make information about various events accessible to the 4PL (Table 1). Not every event requires a renewed plan for shipment. Also, not every event would need manual attention from the 4PL or requires that the 4PL informs the LSPs. We first define an event as an unexpected occurrence which may or may not affect a current or future shipment. A disruption is an event which adversely affects a current or future shipment (Figure 3). For example, a road blockage due to an accident would delay the delivery time of a shipment, therefore it is a disruption. When the roadblock is cleared, that is also an event, but no longer a disruption. Every exception is further classified into Permanent Disruption, Temporary Disruption, and Other Disruption. Temporary disruption and other disruption may or may not require a change in planning. In this case the unavailability time of a route/location is either brief compared to the delivery time (temporary disruption) or is currently unknown, e.g. waiting for customs clearance. A permanent disruption requires a change in planning, because the unavailability time of the route or location is significant compared to the delivery time. In Figure 3 (right side) we show how one disruption might change into another disruption due to a new event (more information).
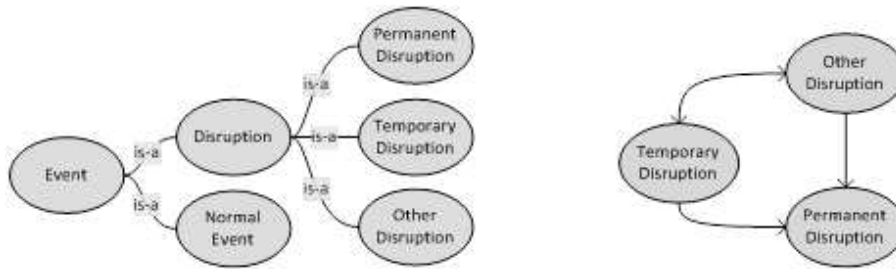
Figure 3: Ontology for events in logistics to support information interoperability

Prior to the shipment being sent, the 4PL plans the tentative route(s) for the shipment. Then, it requests for the current context data from external sources for those routes which satisfy a set of defined criteria (e.g. least polluting, cheapest, minimum stopovers). The data source would then reply with a message containing the current context data with respect to these routes. Routes which have a disruption at any point along them, would be excluded from final possible routes. The external data sources could also reply with a normal event message indicating no exception along the requested routes. Thus messages from the data sources can be divided into three basic types:

1. Normal event message.
2. Exception message, indicating a disruption at one or more locations.
3. An update message for a previous disruption

Based on these three messages the planning module of the 4PL can either do nothing (i.e. follow the current plan), re-plan, request more information, or request human intervention.

4.2. Data format for disruptions

In Table 2, we propose a common message format for context information from various data sources.

Table 2: Common data format for external source

Header	ID	Time Stamp	Type
Source Information	Source ID		Source Location
Location	Geo Location or Location Name or PIN		Location Type
Time	Start Time	Duration	End Time
Priority	High/Low		
Probability	1/High/Low		
Value	*<number>*		

The fields of this format are such they provide necessary and sufficient information for the planning module of the 4PL.

– Header: Each message should have an unique ID, so that it is possible to distinguish between any two messages. Time Stamp indicates the time at which this message was sent. Type denotes the type of the message, i.e. Update message, Normal event message or Exception Message.

– Source Information: The 4PL would have a list of accepted sources and the kinds of events they can measure. Source ID contains the data source name. The source ID will give information about the authenticity of the data source. Source Location indicates the location of the data source.

– Location: The place where the event has occurred. Geo Location indicates the geographical location (or name of the location) and Location Type mentions what kind of location it is. AN example of the Location field is <Rotterdam, Inland Water Terminal2>.

– Time: Time attributes are Start Time, Duration, and End Time of the event. As events are unexpected, the duration time (or end time) are usually not known in advance. But if it is known or can be determined based on similar historical events then it can used by the planning module.

– Priority: Certain types of events can be more important, and therefore this field can be used to distinguish between different grades of importance.

– Probability: This field is used to distinguish between different levels of probability for the (forecasted, i.e. with a future starting time) event to happen. In case of the event has already happened, like an accident that occurred, the probability field can be set to 1.

– Value: This field contains any value which tells us about the property that the data source measures, For example, if a sensor measures the visibility on the road then a possible value can be 100 m.

5. Application of the data format

In this section, we show the usage of data format by a 4PL process. The example message shown in Table 3, is sent by source S012 which is located at Inland Terminal2 in Enschede. This message informs of an exception, on the same day, starting at 16:00 hrs. and lasting for 24 hrs. The priority and probability of the disruption are high.

Table 3: Example message

Header	M001	2014-11-05T08:15:30+01:00	Exception
Source Information	S012		Inland Terminal2
Location	Enschede, 7545PG		Inland Terminal2
Time	2014-11-05T16:00:00+01:00	24:00	2014-11-06T16:00:00+01:00
Priority	High		
Probability	High		
Value	*<null>*		

The 4PL process regarding the use of the example message is as follows (also illustrated with the data flow diagram in Figure 4):

1. The message is sent from a control tower and is received by the Message Handler which also acts as a temporary storage for the data.

2. The message handler then matches source information (S012) with the List of Sources to check the authenticity and importance of the source.

3. If the data is reliable and of use then the entire message is stored in the Messages Database.

4. The message handler now forwards Priority (high), Type (Exception), ID (M001) and Time Stamp (2014-11-05T08:15:30+01:00) to the Message Mapper.

5. Using the type of the message, the Message Mapper decides on the future action and calls the relevant module(s). If the message is an exception message (as in this case) the Message Mapper forwards the data to Map Location to Order.

6. Map Location to Order requests the list of all current and future orders from the Orders Database.

7. Map Location to Order requests the exception location from the Message Handler. Using the route information of orders, it decides which orders will be affected by the disruption at Inland Terminal2, 7545PG, Enschede.

8. Map Location to Order calls the Inform LSPs module with the OrderID(s) of affected order(s).

9. Inform LSPs requests the list of all LSPs associated with the affected OrderID(s) from the Orders Database.

10. Inform LSPs sends the information of the affected order(s) and the duration of the disruption to the LSPs.

11. Inform LSPs calls the Planning Module. The planning module uses the OrderID, LocationName/Type, Start Time, End Time, and the Orders Database to plan a new route. If no optimum plan can be found, it can happen that the Planning Module decides to continue to with the existing plan.

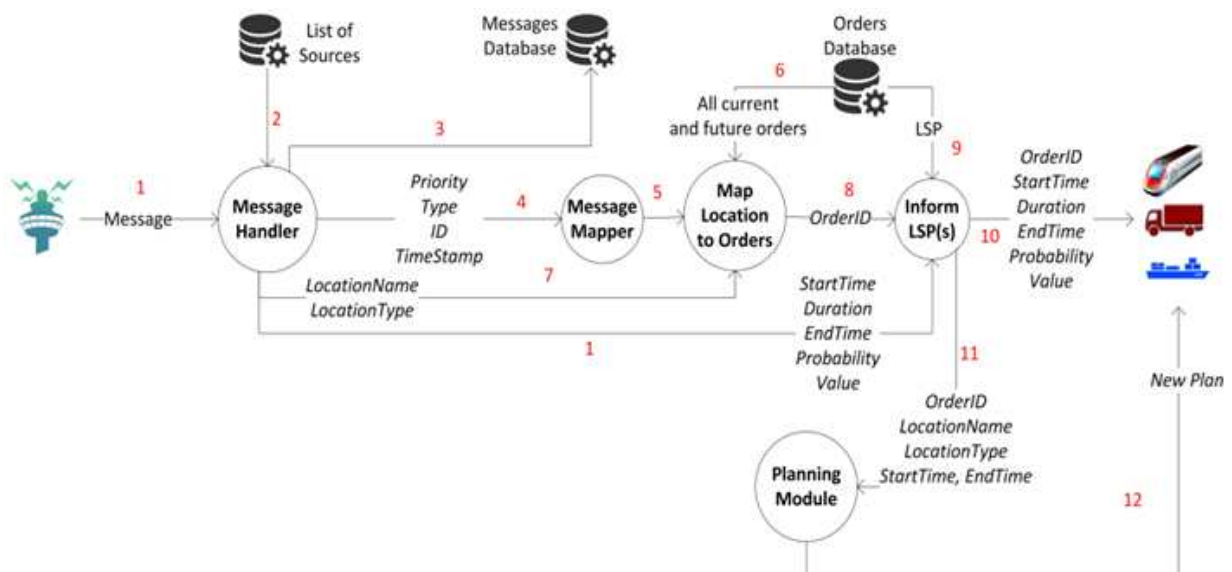12. The new plan is sent to the appropriate set of LSPs.

Figure 4: Example 4PL process for a disruption

6. Discussion

In the preceding sections we have mentioned the need of using context data for SLS. We also commented on major interoperability concerns. We conclude that most interoperability frameworks in logistics are lacking over the use of contextual data for planning and execution. For SLS this data is essential.

Clear decision-making at all levels, as shown in Fig 2, is key for successful SLS. A 4PL organization and its partners must have a common business vocabulary, otherwise it would eventually lead to confusion and loss of trust. The partners should also try to make use of open and clear syntax and semantics (in business, information, and technology), so that entry of a new partners is not impeded. EDI is the de-facto method of exchanging information in logistics. Yet, the messages from data sources must be in XML to make their usage more widely applicable and accepted.

We have made the assumption that while planning a route for an order, the 4PL receives information about events from data sources. There are several patterns that can be used to realize this. For example, the 4PL may poll data sources using a request-response pattern, or it may subscribe to data sources regarding specific events of interest. In the latter case, the 4PL may receive regular updates (time-based) or is only informed when certain criteria regarding the events of interest are met (content-based, e.g. a weather forecast if snowfall of more than 10 cm is expected, or a traffic update if a traffic jam of more than 5 km occurs).

Our data format does not contain an information field regarding the cause of the disruption. This can be implemented in a future extension of the format. The advantage of including the cause of the disruption is that any

recurring cause can be known in advance and appropriate actions can be taken to avoid it. This is an on-going research and using various evaluation methods like interviews and questionnaires with practitioners are planned to make improvements to the data format.

7. Conclusion

In this paper, we have put forward the challenges of using real-time data for Synchromodal Logistic Services (SLS). We discussed our approach for handling large amounts of context data from diverse data sources and also to extract relevant SLS-related information from it. This work is part of is an ongoing research effort and various features will become more clear as the research progresses. We have introduced a data format which can be implemented for various data sources for context data and demonstrated its usage in a 4PL process for SLS with the help of an example.

Acknowledgement

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