LoSe ODP - An Ontology Design Pattern for Logistics Services

Michael Glöckner[1] and André Ludwig[2]

[1]Leipzig University, Endowed Chair of Logistics Information Systems, Leipzig
gloeckner@wifa.uni-leipzig.de
[2]Kühne Logistics University, Chair of Computer Science in Logistics, Hamburg
andre.ludwig@the-klu.org

Abstract. Logistics is a service-oriented industry. Trends like outsourcing and concentration on core competencies require logistics service providers to collaborate with each other and compose their services in order to fulfill complex customer demands. The idea of generic logistics service building blocks helps to make composition of logistics services more easy in general. The composition of logistics services from different providers is a challenging task due to the semantic gap of differing wordings, descriptions and IT-systems. With a central ontology design pattern for such logistics service building blocks, the semantic gap can be closed. Data and information (of services) from different providers can be made available, linked and interchanged easily within the network. Virtualized resources and digitalized collaboration are supported and the disruptive paradigm of cloud logistics is enabled.

Keywords: ontology design pattern, logistics, service, composition, cloud logistics

1 Introduction

Logistics is a service-oriented industry. The logistics domain is facing the trends of outsourcing and concentration on core competencies [1, 2] as well as digitalization [3]. The concentration on core competencies requires logistics service providers (LSP) to collaborate with each other in order to fulfill complex customer demands. With an increasing digitalization and the adoption of the cloud principles to the logistics domain, the disruptive paradigm of *cloud logistics* emerges [4, 5, 6], i.e. resource virtualization, ad-hoc reconfiguration, interconnectability via an ontological approach. Taken from cloud computing as well, the idea of reusable cloud blueprints [7] is adapted to the logistics domain in order to create generic building blocks the are interconnectable like *'lego bricks'* [4, 7]. Nevertheless, the composition of logistics services from different providers remains a challenging task due to the semantic gap of differing wordings, descriptions and IT-systems.

Focusing on the essential common characteristics of logistics services and their consolidation within an ontology can help to close the semantic gap. Still, different networks and different industries (e.g. automotive, chemistry) have different logistics requirements. The creation of logistics service building blocks is then dependent on semantic building blocks, so called ontology design patterns (ODP) [8]. Hence, a reusable content ODP (CP) describing logistics services is needed. Such a CP further supports the aspects described in cloud logistics paradigm, i.e. virtualization of resources and their inter-connectability. The research question arises: *How can essential aspects of logistics services be represented in an ontology design pattern?* It is refined through the following sub-questions:

- SQ_1: What is an appropriate ontology engineering method in order to create reusable ODP?
- SQ_2: What are existing logistics ontologies and what are essential concepts of logistics services the could be re-used?
- SQ_3: What is a suitable ontology design pattern for logistics services?

In the following section, the applied method is presented. Afterward in section 3, related work is presented and the pattern is formalized and an example usage is given. Section 4 concludes the paper.

2 Method and Structure

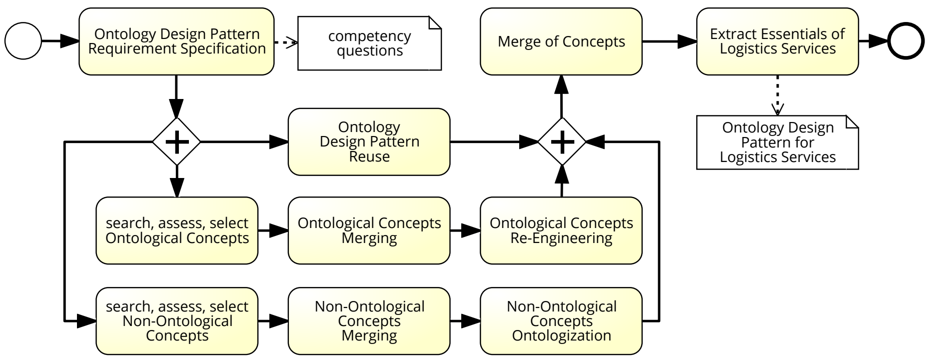

Fig. 1. The method combines the NeOn methodology [9] and the combined approach for definition of ODP [8].

The applied method comprises the NeOn Methodology for Ontology Engineering [9] and the combined approach of ODP definition [8], see Figure 1. First, requirements are specified by creating competency questions. Afterward, concepts are searched, assessed and selected. Those concepts can be found in existing ODP, existing logistics ontologies concepts and non-ontological concepts of the logistics domain. By merging those concepts and extracting the essential aspects of logistics services, the final ODP for logistics services is developed. It is then presented in terms of conceptualization, formalization and an example usage. The combined method presented in Figure 1 answers the first sub-question (SQ_1).

3 The LoSe Pattern

In the following subsections general modeling issues, the competency questions as well as the regarded concepts are presented. Afterward, the concepts are merged, visualized as well as informally and formally described and evaluated.

3.1 Ontological Modeling of the Logistics Domain

The logistics domain has not received much attention from the semantic web community yet. Some approaches of ontologies exist in literature that deal with logistics topics. However, none of them can be considered linked data in terms of the W3C-standard[1] as there are no URI (Unified Resource Identifier) nor machine-readable XML files. By now the ontologies are only available in schematic and/or graphic way. The existing ontologies are not standardized nor inter-linkable and thus they are customized and they can not be re-used due to proprietary formats. Further, conceptual overlaps can be found, which also means there are concepts significantly and frequently re-appearing in the ontologies so far. Eventually, this paper presents the first approach towards linked data representation of logistics service by bringing the ontological concepts of logistics services together within one ODP.

Competency Questions are leading the development of the pattern and are partly taken from [10, 11]. They help to evaluate the developed ODP in the end:

CQ_1: Which actors are involved in providing a specific logistics service?
CQ_2: Which logistics services provide a specialized capability?
CQ_3: What are legal constraints that have to be considered by a composition?
CQ_4: Which resources are needed in order to fulfill a logistics service?
CQ_5: Which logistics services provide a specific transformation of conditions?
CQ_6: Which information is required to provide logistics services adequately?
CQ_7: Which LSP and transport logistics services offer a capacity of more than 7,5 t?

Related ODP In terms of reusing *existing ODP*, the existing *time interval CP*[2] [12], *Material Transformation CP*[3] [13] and *TransportPattern CP*[4] [14] are taken into account.

[1] https://www.w3.org/standards/semanticweb/data
[2] http://www.ontologydesignpatterns.org/cp/owl/timeinterval.owl
[3] http://www.ontologydesignpatterns.org/wiki/Submissions:Material_Transformation
[4] https://wiki.auckland.ac.nz/download/attachments/52016791/TransportPattern.owl

Re-Used Ontological Concepts Main input for the analysis of *existing ontologies* in the context of logistics (and supply chain management) is a literature review of Scheuermann and Leukel [15] with a total of 16 ontologies. Via further research, another 12 paper were found presenting ontologies of logistics or supply chain management (or parts of it). Those ontologies were analyzed towards possible contributions to a logistics service ODP. The adopted concepts of the influencing ontologies are briefly described in the following list:

- A distinction into *physical resources* and *informational resources*, whereas the latter one is occasionally further detailed into documents and information systems, can be found in [16, 17, 18, 19, 20]. Physical resources, such as transportation and manpower [11, 21], are abstracted to capabilities as well as functional and unfunctional [sic] parameters [22].
- *Logistics objects* that are able to contain other logistics objects are described by [4, 6, 10, 23]. They are seen as passive entities (goods or passive resources, such as packaging or containers) that are transformed by active entities (active resources, such as trucks or information systems).
- Performance measures and logistics *KPI* are outlined in the publications of [10, 11, 18, 23, 24].
- *Location* as a crucial aspect of logistics is emphasized by [10, 20, 25].
- *Time* plays a crucial role in all logistics activities [20, 26].
- Different Roles and *Stakeholders* are described in [10, 11, 20, 24].
- *Objectives of logistics* are refined into social, environmental and economic [24].
- *input* and *output* of logistics activities are outlined and partly refined into resources, materials and information [27]
- an event-focused perspective focuses on the crucial points of location where an agent is acting on an entity with the help of a distinct equipment [25]. From this, a distinction between *active resources* (acting agents) and *passive resources* (used equipment) can be derived.
- *Policies* are integrated by [26]
- distinct *goods* are described in the approach of [28]

Non-Ontological domain-specific Concepts Additionally, other data models and non-ontological resources, e.g. basic service models and essential logistics characteristics, are taken into account in order to create the logistics service ODP. The creation of an ODP of logistics services has to deal with general domain-independent service aspects as well as with domain-specific aspects of logistics. Hoxha et al. [11] break down the model of a logistics service to inputs and outputs as well as Preconditions and Results (i.e. conditions, constraints, effects). General service definitions, such as [29, 30], emphasize the usage of resources and the application of knowledge and skills within activities or processes in order to generate benefit for another entity or for the entity itself. Further, the direct interaction with the receiving entity in order to solve an existing problem is outlined. Shortly, using ones resources for the benefit of another entity is defined as service. Hence, at least the following aspects have to be conceptualized for the logistics domain: benefits (transformation of conditions), resources and interactions (input and output).

Further aspects of the logistics domain are taken into account as essential concepts of logistics services. Basic flows of logistics comprise *informational flow* and *physical flow* [31]. Additionally, the *flow of control* is taken into account as an aspect of logistics business objects [4] within the cloud logistics paradigm. Mentzer et al. [32] describe the *7R* as the basic objectives of successful logistics activities that aim at delivering:

1. the Right product
2. with the Right information
3. to the Right location
4. in the Right time
5. in the Right quality
6. in the Right quantity
7. for the Right price

As logistics is in charge to get those aspects 'right', it has to possess the ability to influence those aspects. The manipulation of those aspects implies their *transformation* during the logistics service with regards to the customers' demands and requirements. Further, *legal constraints* are important to the logistics domain, e.g. permission to handle dangerous goods [33] or legal regulations on the allowed period of driving and rest in road transport [34].

The analyzed ontological and non-ontological concepts of the logistics domain form the basis for the essential concepts of logistics services and answer the second sub-question (SQ_2).

3.2 Merging the Concepts into the Pattern of LogisticsService

The several concepts are analyzed and the essential ones are integrated into the ODP for logistics service[5]. The schematic view can be seen in Figure 2. The pattern is formalized with OWL 2 Web Ontology Language [35] and expressed in description logic [36].

Focus and top-level class of the current paper is LogisticsService. The pattern of LogisticsStakeholder (light blue) is to be described in another ODP. Roughly described, a logistics service is measured by service level agreements, has mandatory (such as legal regaulations) and non-mandatory constraints as well as certain capabilities. Logistics services consume resources in order to perform transformations and flows that are connecting them with each other and require active resources (see axiom 1). Information and Control are obligatory (see axiom 2). Both obligatory flows are performed by informational resources (see axiom 3). The flow of goods is performed by physical resources (see axiom 4). Transformations are performed by active resource (see axiom 5). The capability of a logistics service always consists of at least one transformation (see axiom 6). One logistics

[5] https://github.com/Michael-Gloeckner/LoSe_ODP

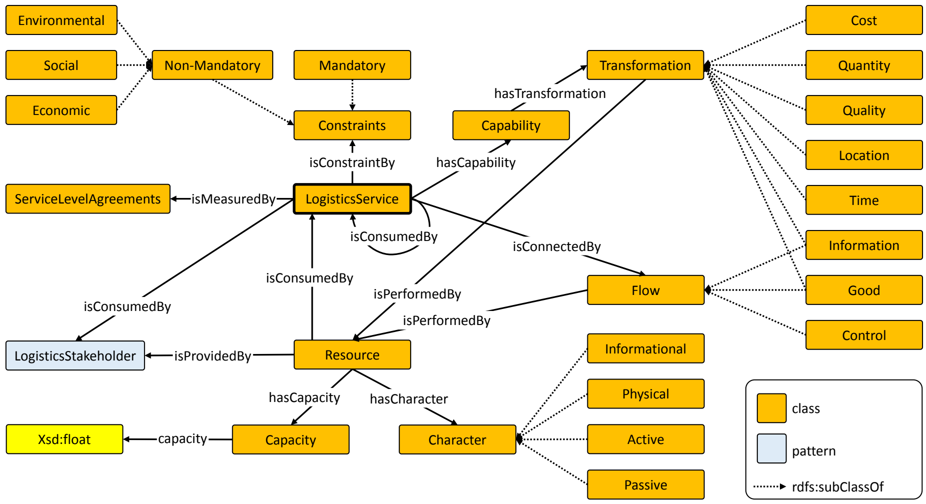

Fig. 2. Schematic view of the ontology design pattern for logistics services.

service is always capable of at least one capability (see axiom 7). Through transitivity, the conclusion that every LogisticsService has to incorporate at least 1 active resource can be drawn (axioms 5 - 7). Resources with an active character (such as trucks, fork lifts, conveyor or sorting machines) are able to move goods actively or to transform information actively (such as Transport Management Systems). Resources with a passive character are e.g. entities that contain goods (such as packaging or containers) or information (such as documents, pick lists, contracts). Constraints that are mandatory (e.g. laws, permissions, regulations) or of other objectives (e.g. ecological or social objectives, such as CO_2-reduced) influence the logistics services. The character of something can be either informational or physical (see axiom 8) and either active or passive (see axiom 9).

The presented ODP[6] is derived from existing concepts of the logistics domain and is able to represent logistics services. Thus, the third sub-question is answered (SQ_3).

$$\mathsf{Flow} \sqsubseteq \mathsf{isPerformedBy.Resource} \sqcap \mathsf{hasCharacter.Active} \tag{1}$$

$$\mathsf{LogisticsService} \sqsubseteq \forall \mathsf{isConnectedBy.Information} \sqcap \forall \mathsf{isConnectedBy.Control} \tag{2}$$

$$\mathsf{Information} \sqcup \mathsf{Control} \sqsubseteq \mathsf{isPerformedBy.Resource} \sqcap \mathsf{hasCharacter.Informational} \tag{3}$$

$$\mathsf{Good} \sqsubseteq \mathsf{isPerformedBy.Resource} \sqcap \mathsf{hasCharacter.Physical} \tag{4}$$

$$\mathsf{Transformation} \sqsubseteq \mathsf{isPerformedBy.Resource} \sqcap \mathsf{hasCharacter.Active} \tag{5}$$

$$\mathsf{Capability} \sqsubseteq \;\geqslant 1 \; \mathsf{hasTransformation.Transformation} \tag{6}$$

$$\mathsf{LogisticsService} \sqsubseteq \;\geqslant 1 \; \mathsf{hasCapability.Capability} \tag{7}$$

[6] `https://github.com/Michael-Gloeckner/LoSe_ODP/blob/master/LoSe_ODP.owl`

$$\mathsf{Informational} \equiv \neg\mathsf{Physical} \tag{8}$$

$$\mathsf{Active} \equiv \neg\mathsf{Passive} \tag{9}$$

3.3 Evaluation

The evaluation is conducted with the 'Framework for Evaluation in Design Science Research' (FEDS) of [37]. The *quick & simple* strategy is chosen, as the designed artifact is of small and simple construction, with low social and technical risk and uncertainty. The approach of an illustrative scenario [38] is taken into account in order to evaluate the developed ODP. The evaluation is summative (judge the extent that the outcomes match expectations) and located in the middle between artificial and naturalistic: two anonymized (due to privacy reasons) example processes of internationally operating LSP are are represented with the help of the ODP proofing the concept.

Example 1 *LSP 1* offers the service 'off-loading of long-distance truck transport' within the network. This comprises the removing of all physical entity from the truck and follows the steps of (1) getting freight documents from the driver, (2) identification, scanning and off-loading of package, (3) bringing package to pallet space and (4) scanning and forwarding protocol. The input flows are informational (freight document with goods identification, quantity, shipper, consignee) and physical (pallets containing goods). The control flow is then later on added, when the logistics service is composed with other services. The control flow would be triggered when the truck arrives at the warehouse. The transformations aim at the dimensions of location (truck to pallet space), time (the process takes a certain amount of time), costs (occuring for the provision of the service), information (state of the pallet containing a certain good changes from in transfer to in warehouse, and the location information is changed as well). The necessary active resources for this comprise staff, forklifts, scanners (physical), warehouse management system (WMS) (informational). The passive resources comprise pallets (physical) and freight documents (informational)[7]. Important KPI and SLA comprise the time consumed, the accuracy of identification of goods, identification of pallet space and the matching of the latter two.

Example 2 *LSP 2* offers the service 'order picking air' within the network. This comprises the steps of (1) pallet picking, (2) scanning, (3) transportation to air packing station, (4) loading aircraft container, (5) scanning, (6) transferring aircraft container to outbound, (7) scanning. The input flows are informational (electronic data on handheld: flight number, start time and end time (critical due to flight schedule), aircraft type, terminal, position (aircraft parking space), pallet space) and physical (aircraft containers carrying goods). The control flow

[7] Even though freight documents are physically existent as hard copies, their purpose is to carry information. Since digitalization is an approaching issue, it is likely that such documents will be available in the future as files or database entries only.

is then later on added, the trigger signal would be of timely manner according to flight schedule. The transformations aim at the dimensions of product (the right products have to be collected), location (goods from warehouse to packing station to outbound), time, quantity (certain amount is picked), cost, information (state of the BO pallet from warehouse to packing, state of the goods from pallet to aircraft container, state of the aircraft container from packing to outbound). The necessary active resources for this comprise staff, forklift, tractor unit and scanner (physical) as well as a WMS (informational). Passive resources are pallet, aircraft container, trolley (physical) as well as pick lists and loading document (informational). Important KPI and SLA comprise the time consumed, picking accuracy, throughput. Electronic services are invoked to transfer data, identification of required aircraft container type according to aircraft type.

Querying With regards to the competency questions in section 3.1 the following 2 queries are presented. The first one, allows to find a list of LSP and their services that are able to perform the process of the first example above:

```
@prefix LoSe_ODP: <https://github.com/Michael-Gloeckner/LoSe_ODP#>
SELECT LogisticsStakeholder LogisticsService
FROM <https://github.com/Michael-Gloeckner/LoSe_ODP#>
WHERE {
LoSe_ODP:staff rdfs:subClassOf LoSe_ODP:Resource.
LoSe_ODP:forklifts rdfs:subClassOf LoSe_ODP:Resource.
LoSe_ODP:scanners rdfs:subClassOf LoSe_ODP:Resource.
LoSe_ODP:Resource LoSe_ODP:hasCharacter LoSe_ODP:Physical.
LoSe_ODP:Resource LoSe_ODP:isProvidedBy LoSe_ODP:LogisticsStakeholder.
}
```

The second query seeks to find a transportation resource (for a transformation of a location) with a capacity higher than 7.5 t. For this example, two classes of trucks are introduced first and aftterwards they could be queried to answer the following competency question CQ_7: "Which LSP and transport logistics services offer a capacity of more than 7,5 t?"

```
@prefix LoSe_ODP: <https://github.com/Michael-Gloeckner/LoSe_ODP#>
LoSe_ODP:Truck_40 rdf:type owl:Class ;
                  rdfs:subClassOf LoSe_ODP:Resource ;
                  LoSe_ODP:hasCapacity LoSe_ODP:Capacity ;
                  LoSe_ODP:Capacity LoSe_ODP:capacity 40 ;
                  rdfs:comment "Truck that can transport up to 40 tons."@en .
LoSe_ODP:Truck_7.5 rdf:type owl:Class ;
                  rdfs:subClassOf LoSe_ODP:Resource ;
                  LoSe_ODP:hasCapacity LoSe_ODP:Capacity ;
                  LoSe_ODP:Capacity LoSe_ODP:capacity 7.5 ;
                  rdfs:comment "Truck that can transport up to 7.5 tons."@en .
```

```
SELECT Capacity LogisticsService LogisticsStakeholder
FROM <https://github.com/Michael-Gloeckner/LoSe_ODP#>
WHERE {
LoSe_ODP:location rdfs:subClassOf LoSe_ODP:Transformation.
LoSe_ODP:Capability LoSe_ODP:hasTransformation LoSe_ODP:Transformation.
LoSe_ODP:LogisticsService LoSe_ODP:hasCapability LoSe_ODP:Capability.
LoSe_ODP:Resource LoSe_ODP:isConsumedBy LoSe_ODP:LogisticsService.
LoSe_ODP:Resource LoSe_ODP:hasCapacity LoSe_ODP:Capacity.
LoSe_ODP:Capacity LoSe_ODP:capacity >=7.5.
}
```

4 Conclusion and Future Work

The creation of a CP for logistics services bears enormous potential to support digitalization and collaboration between various actors of the logistics service industry in general and for the emerging cloud logistics paradigm in particular.

The paper presents an ontology design pattern for logistics services. The ODP describes the essential concepts of logistics services. Since it forms a generic basic building block with standardized connection points (LoSe_ODP:Flow), it enables a kind of 'lego brick' system for logistics services. The disruptive paradigm of *cloud logistics* is enabled with this system, by the virtualization of resources (LoSe_ODP:Resource), their encapsulation and semantic connection to resources of other LSP.

By enabling such a lego brick system, the paradigm of cloud logistics can be made accessible in a more easy and convinient way to practitioners. Implications for researchers is the first approach towards linked data in logistics. Further research steps have to focus on further ODPs in the conctext of logistics.

Acknowledgements. The work presented in this paper was funded by the German Federal Ministry of Education and Research within the project *Logistik Service Engineering und Management* (LSEM). More information can be found under the reference BMBF 03IPT504X and on the website `www.lsem.de`.

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