LoSeMa ODP - An Ontology Design Pattern for Logistics Service Maps

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Abstract. Cloud logistics comprises the virtualization of logistics resources from different logistics service providers. Those resources are pooled, combined and encapsulated within customer-specific modular logistics services. The pooling within networks comprises a high quantity of available logistics resources and services. Domain-specific structuring with the concept of the logistics service map helps to retrieve specific requested services from that quantity. The structuring of resources and services is a challenging task based on the semantic gap of differing wordings, descriptions used by different providers. The developed ontology design pattern for domain-specific structuring of logistics services can help to close the semantic gap as well as to enable the concept of the logistics service map. Structuring data and information of services from different providers can be made available, linked and interchanged easily within the network. Digitalized collaboration is supported and the disruptive paradigm of cloud logistics is enabled.

Keywords: cloud logistics, ontology design pattern, resource virtualization, service structuring, service management

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1 Introduction

The disruptive paradigm of *Cloud Logistics* [16,7] is based on the virtualization and pooling of physical and non-physical logistics resources from different logistics service providers (LSP). According to customer-specific demand, resources are taken from the pool, are combined with each other and encapsulated within modular cloud logistics services. This modular approach enables the logistics industry to face the continuous trends of outsourcing and concentration on core competencies [21] in order to meet customers' demand for increased flexibility [9]. Further, digitalization of logistics, as an enabler in the context of the Internet of Things [20], is pushed forward. The most difficult challenge of connecting different LSP is the semantic gap because of different structuring, naming, descriptions and IT-systems that results from a strong heterogeneity of LSP [11,30,35]. Cloud logistics adopts the basic principles of cloud computing, i.e. resource virtualization, ad-hoc reconfiguration, and interconnect-ability, via an ontological approach [16] in order to handle the heterogeneity.

One central challenge of cloud logistics is the management of the large amounts of logistics services available in big networks. This comprises on the one hand the retrieval of suitable resources and services from several LSP that are participating in the network. On the other hand, it comprises the customer-oriented combination of the resources and services from several LSP in order to create complex logistics services. The Logistics Service Map [14] is a conceptual framework for domain-driven structuring of services as well as their retrieval and combination in order to create complex logistics services. However, the semantic gap between different LSP exists also for the structuring of resources and services. Hence, an ontological approach for service structuring is needed to close the semantic gap in order to facilitate management and retrieval. However, different networks and different industries (e.g. automotive, chemistry) have different logistics requirements and descriptions. The structuring of cloud logistics services is dependent on semantic building blocks, so called ontology design patterns (ODP) [34,12], that enable the structuring of resources from different LSP. An ODP represents the elementary trunk of a generic ontology for a specific purpose. It has to be extended for actual usage but gives essental guidance for the creation and usage of an ontology in that specific field of purpose. Next to logical or architectural ones, there are content ODP (CP) [34] that encode conceptual pattern solving design problems for domain-related classes and properties. In summary, a reusable (CP) for the structuring of logistics services is needed. Such a CP further supports the aspects described in cloud logistics paradigm, i.e. the pooling, encapsulation and combination of logistics resources from several LSP. The research question arises: *How can essential structurings of logistics services be represented in an ontology design pattern?* It is refined through the following sub-questions:

- SQ_1: What are existing logistics ontologies and what are essential structuring concepts of logistics services that could be re-used?
- SQ_2: What is a suitable ontology design pattern for the structuring of logistics services?

In the course of the paper the 'NeOn Methodology for Ontology Engineering' [39] is applied and complemented with the approach of ODP definition [34], see Figure 1. In section 2, competency questions are presented in order to specify

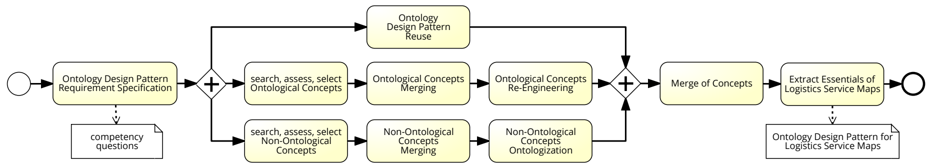

Fig. 1. The method combines the NeOn methodology [39] and the combined approach for definition of ODP [34].

requirements. 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 service structuring, the final ODP is developed. The ODP for logistics service maps is conceptualized, formalized, graphically represented and evaluated with the help of applied service structurings from real world use cases. Further, sample queries are given by the former competency questions. Section 3 concludes the paper and gives an outlook on future research.

2 The LoSeMa 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.

2.1 Ontological Modeling of the Logistics Domain's Structuring

The logistics domain has only received little attention from the semantic web community yet. In literature there are some approaches of ontologies that deal with logistics topics. ODP in the context of logistics and SCM in general are not existent until 2014 [38]. However, only one of them can be considered as linked data in terms of the W3C-standard[3] as there are machine-readable XML files and URI (Unified Resource Identifier), i.e. the ontology design pattern on logistics service (LoSe_ODP) [15]. The other ontologies are only available in schematic and/or graphic way. The existing ontologies are customized and thus they cannot be re-used due to their proprietary formats. Accordingly, they are neither standardized nor inter-linkable. Further, conceptual overlaps can be found, which also means there are concepts that are frequently re-appearing in the ontologies so far. Eventually, this paper presents the first approach towards linked data representation of logistics service maps by bringing together concepts of existing ontologies and domain-specific aspects of logistics service structuring within one ODP.

[3] https://www.w3.org/standards/semanticweb/data

Competency Questions are leading the development of the pattern and are partly inspired by [15,37,19]. Their purpose is to give potential users of the ODP an idea of the field and issues that can be approached with the help of the ODP [39,34]. Further, they can be taken to evaluate the developed ODP in the end:

- CQ_1: Which services enable the transport of dangerous goods on rail in southern Europe?
- CQ_2: Which value-added services are available in Denmark?
- CQ_3: Which value-added services are not available (and thus point out new business opportunities)?
- CQ_4: Where are hubs for gas handling with tanks and ship loading possibility?
- CQ_5: Where are inter-modal hubs in Germany for open sea to rail transshipment?
- CQ_6: Which services offer inbound and block storage for packaged goods?

Related ODP which has already been published and that will be reused is the existing *LoSe_ODP*[4] [15].

Re-Used Ontological Concepts are mainly taken from the literature review on *existing ontologies* of Scheuermann and Leukel [38] in the context of logistics (and supply chain management). They found a total of 16 ontologies. Via further research, another 14 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 map ODP. Unexpectedly, the majority of the analyzed concepts only focused on services concerning physical goods and objects. Accordingly, information-centric services in logistics, such as inventory optimization, consulting, or network strategy development, are underrepresented. The adopted classes and properties of the influencing ontologies are conceptualized and briefly described in the following list:

- Domain-driven structuring focuses on (1) *character* of the logistics function of a service, i.e. either *informational* or *physical* [15,2,19,27]; (2) on special *condition* implying legal permissions or special equipment for operation [6,13]; and (3) further *dimensions* that describe the physical characteristics more detailed [24,6,25,2,19,5]
- Within the class of special *condition* the idea of integrating an ontology or another ODP, respectively, on hazardous goods is taken from [37]. Further, as stated in [6], *Cooling*, *Living*, *Guarded*, and *HeavyDuty* are further special conditions that either require special legal permission and/or special equipment or skills to be operated
- The physical functionality of logistics services is regularly distinguished between 'classic' function, such as *Transportation*, *Handling*, and *Storage* on the on side [8,24,25,37,19,2]. On the other side, classic functions are more

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

and more complemented in terms of more specialized, more complex and customer-oriented *Value-Added* functions, such as *Packing*, *Sorting*, and *SpecialServices* are outlined [24,25,19,6].

– The informational functionality of logistics services comprise (1) *ProcessRelated* functionality with a rather operational focus, such as inventory management or track and trace [6]. There are also functionality with a more strategic focus, such as network strategy and inventory policy like Just-in-Time (JIT) [2,4]. Further, (2) *Knowledge* intensive functionality is outlined such as transport flow improvement, consulting, reorganisation of network strategy, inventory modeling, research and development [2].
– The *StateOfGoods* plays an important role especially for the transport, handling, and storage. Possible classes for distinction are: *Packaged*, *Solid* (e.g. Bulk Goods), *Liquid*, and *Gas* [6,32].
– The Supply-Chain operations reference (SCOR) model[5] developed by the 'supply chain council' is often the theoretical foundation for structuring of logistics services, e.g. see [31,26,36,22,17,10]. However, recent publications [16,15,23] found a lack of suitability of the SCOR model in terms of applicability on detailed and rather fine-granular logistics services. Hence, a rather logistics-focused and simplified view is adapted from SCOR in terms of *PhasesOfProcess*, i.e. *Production*, *Outbound*, *Transport*, and *Inbound*, are derived to be integrated in the ODP [24,19].
– The *ModeOfTransport* is an important structuring dimension as it influences the means of transport, physical resources, handling devices, infrastructure and used interfaces. Hence, *Land*, *Sea*, *Air*, and even *Pipe* as a mode of transport for gas or liquids are mentioned [25,24].
– *Location* as a crucial dimension of logistics servcies is emphasized by [8,24,37,6,13,2].
– As time plays a more or less crucial role in all logistics activities [6,41], an additional dimension in terms of *Speed* can be derived to distinguish *Express*, such as KEP Service Providers' services from services with *Normal* speed [19].

Non-Ontological domain-specific Concepts are taken into account in order to complement the found classes and properties of the re-used ontological concepts. This comprises other data models and logistics concepts, e.g. generally accepted structuring frameworks and essential logistics characteristics, in order to create the logistics service map ODP. Additional ValueAdded service structurings are taken from one of the biggest annual studies amongst 3rd Party Logistics Providers [21]. ValueAdded services are in general more complex than just handling and transportation functionality. They have higher informational requirements as additional information is needed for fulfillment and thus deserve an own structuring sub-class of physical logistics functions. Those value-added services with a strong focus on physical operation are e.g. *Labeling*, *Packaging*, *Assembly*, and *Kitting* [21]. Further, other informational focused structurings

[5] `http://www.apics.org/apics-for-business`

that specify ProcessRelated structurings more detailed are e.g. *Customs Brokerage* and *CustomsService*, *TransportationManagementAndPlanning*, *FreightBillAuditingAndPayment*, *FleetManagement*, *ITServices* [21]. The ModeOfTransport can be further refined for land-bound means of transport into *Road* and *Rail* as well as for sea-bound means of transport into *OpenSeaShipping* and *InlandShipping*, see Ref [18] and further statistics[6]. For the structuring of storage services *StorageType* as well as *StorageStrategy* are important criteria in order to find appropriate services [18]. Whereby, different types of storage are warehouses and facilities for e.g. *Bulk*, *Block*, *HighRack*, or *Tank* for gas or liquid goods. Storage strategy has three main principles for distinction, i.e. chaotic or fixed for the *Allocation* of goods within the warehouse and the chronology and *Sequence* of handling, i.e. first in - first out (FIFO) or last in - first out (LIFO), and eventually strategies for *SafetyStock* and replenishment [18]. Further, *legal constraints* are important to the logistics domain, e.g. permission to handle dangerous goods [1]. The analyzed ontological and non-ontological concepts of the logistics domain form the basis for the essential concepts for the structuring of logistics services within the logistics service map and answer the second sub-question (SQ_1).

2.2 Merging the Concepts into the Pattern of LogisticsServiceMaps - LoSeMa_ODP

The several concepts are analyzed and the essentials of structuring the logistics domain, especially logistics services, are integrated into the ODP for logistics service maps[7]. The schematic view can be seen in Figure 2. The pattern is formalized with OWL 2 Web Ontology Language (OWL) [29] and modeled with the tool Protégé[8] and expressed further detailed in description logic [3].

Focus and top-level class of the current paper is LogisticsServiceMap. By linking the ODP to other ODPs, its full potential can be utilized. The pattern of LogisticsService (light blue) is described in the *LoSe_ODP*[9] [15]. This pattern describes logistics services in terms of their essential flows, capabilities as well as the consumed resources for their operation. The link to an ODP concerning *hazardous materials and goods* enables the detailed description and requirement of specialized resources for handling, transport and storage as well as the requirement for legal permissions and internationally authorized structuring scheme. The link to *GeoArea* ODP, which deal with the allocation, relation and semantic description of geographic concepts such as cities, regions, countries, and continents, helps to narrow down results of service retrieval for a specific area. The extension with zipcodes and street names could further increase the level detail.

[6] `http://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2015_en`

[7] `https://github.com/Michael-Gloeckner/LoSeMa_ODP`

[8] Protégé is the ontology building software used for LoSeMa_ODP. For more detail see: `http://protege.stanford.edu/`.

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

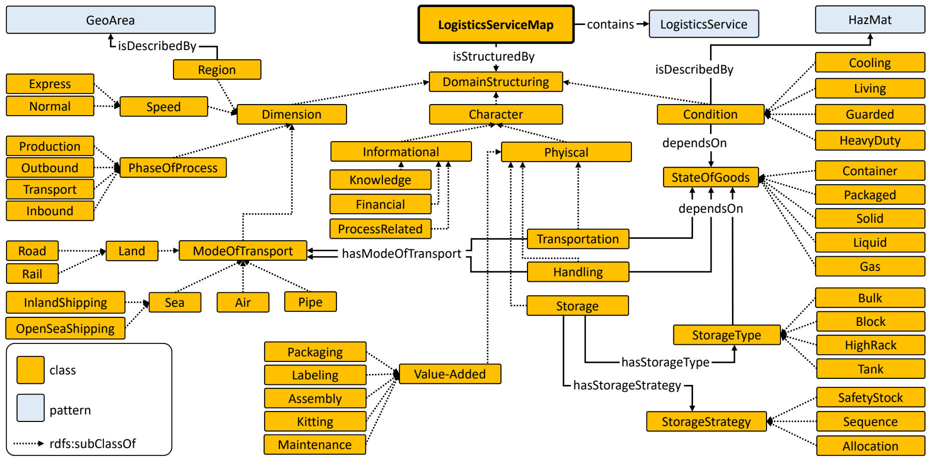

Fig. 2. Schematic view of the ontology design pattern for logistics service maps.

Logistics services are structured by the logistics service map by three main concepts, i.e. (1) *Condition* of goods and customer requirements, (2) functional *Character*, and (3) *Dimension*. Additional sub-concepts, see Figure 2 and the former subsection, allow for more detailed structuring with the help of several subClasses (rdfs:subSclassOf). The *StateOfGoods* influences the *Condition* of logistics services, and all the three classic physical logistics services: *Transportation*, *Handling* (both directly) as well as *Storage* via the *StorageType*. The implemented *StorageStrategy* is important structuring criteria e.g. because of a higher informational requirement on chaotic storage. Informational logistics services: *ProcessRelated* services could be: customs clearance, invoicing, incoterms broking and operative management, track and trance, warehouse management, as well as transport management. *Knowledge* services could be: consulting, training, IT management as well as research&development. Examples of *Financial* logistics services could be: real estate brokerage and management, insurance, leasing, strategic incoterms management or strategic fleet management.

Several axioms are developed. Physical *Transportation* always requires at least one possible *ModeOfTransport* (Axiom 1). Physical *Handling* of goods requires 2 ModeOfTransport in terms of a source and a sink from where goods are handled to (Axiom 2). Every *Physical* logistics service needs to state at least one *StateOfGoods* it is capable of serving (Axiom 3). *Informational* services focus on data and *Physical* services focus on the operation of goods. Hence, they have to be clearly distinct from each other (Axiom 4).

$$\mathsf{Transportation} \sqsubseteq\ 1\ \mathsf{hasModeOfTransport.ModeOfTransport} \tag{1}$$

$$\mathsf{Handling} \sqsubseteq\ 2\ \mathsf{hasModeOfTransport.ModeOfTransport} \tag{2}$$

$$\mathsf{Physical} \sqsubseteq\ 1\ \mathsf{dependsOn.StateOfGoods} \tag{3}$$

$$\mathsf{Informational} \equiv \neg\mathsf{Physical} \tag{4}$$

The presented ODP[10] is derived from existing concepts of the logistics domain and is able to structure logistics services. Thus, SQ_2 is answered.

2.3 Evaluation

The 'Framework for Evaluation in Design Science Research' (FEDS) [40] is used for evaluation with *quick & simple* strategy as it appears to be relatively cheap to use publicly available data of the analyzed companies. The developed ODP will be evaluated summatively by an *illustrative scenario* [33]. The Service catalogue of *DB Cargo* is the use case for evaluation. The design goals of *flexibility* and *re-usability* [28] are used for evaluation of the designed ODP, as they are the core ideas of cloud logistics [16] and strongly demanded by customers [9].

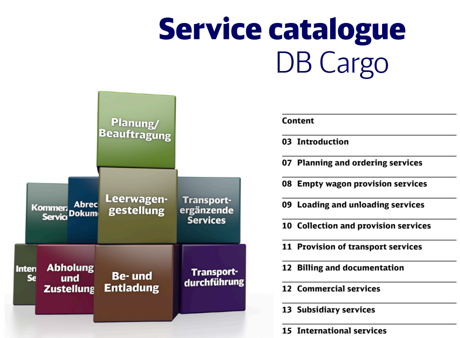

Fig. 3. Overview of Service Catalogue.

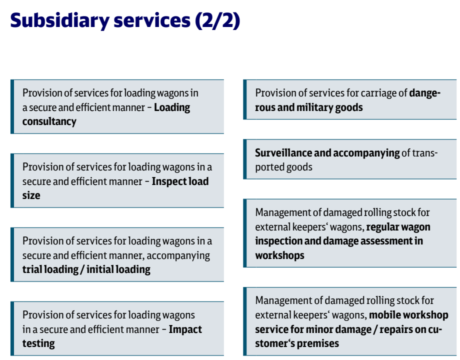

Fig. 4. Subsidiary Services' Catalogue.

DB Cargo's "Service catalogue"[11] is displayed in Figure 3. This Service catalogue structures and presents all available services of DB Cargo provided in Germany and Europe and thus all services are related to rail-bound freight transportation in a broader sense. The majority of the services can be linked to the LoSeMa classes of *Physical* and *Rail*. Parallels can be drawn for instance between the *Handling* class of LoSeMa and the category of 'Loading and unloading services' of DB Cargo's Service catalogue. Further, parallels exist between several provided services of the 'subsidiary' class of the catalogue, see Figure 4. The services 'Loading consultancy' and 'trial loading/initial loading' can be identified with the *Consulting* class of the LoSeMa. Moreover, the services 'Inspect load size' and 'regular wagon inspection and damage assessment in workshops' can be related to *ValueAdded* character. More specific, the latter one can be associated with *Maintenance*. As *Maintenance* is a sub class of *ValueAdded*, the linkage

[10] https://github.com/Michael-Gloeckner/LoSeMa_ODP/blob/master/LoSeMa_ODP.owl

[11] http://www.dbcargo.com/file/rail-deutschland-en/7946484/_2ZqlphcADXzoG0iKgHQY14Ciuw/8799380/data/Service_catalogue.pdf

to the more specific one increases precision of retrieval. Eventually, 'dangerous and military goods' are equated with the HazMat pattern, whereas 'domain' denotes the origin and 'range' denotes the sink of an relating ObjectProperty. The 'Surveillance and accompanying' can be equated with either the *Guarded* class or the *TrackAndTrace* class of the ODP. More detailed information about the content and context is necessary in order to assure an appropriate link.

Again, it is assumed that there is an underlying internal ontology existent for the Service catalogue of DB Cargo. Hence, again those structures can be mapped to the designed LoSeMa_ODP via OWL statements. Some examples of the mapping are given in Figure 5. The flexibility is inherent in the approach of ODPs. The re-usability has been shown with the help of the two use cases. Querying is proofed with the help of the competency question $\mathbf{CQ}_5$: Where are inter-modal hubs in Germany for open sea to rail transshipment? of section 2.1. It allows to find a list of services and their operators from the service map and thus enable automated retrieval of services from specific categories that are able to meet the requirements of the customer, see Figure 6. Main feature of the conceptual framework 'logistics service map' is the domain-driven structuring of logistics services in order to retrieve those services that best match the specific capability and functionality requested by a customer. Summarizing, the LoSeMa_ODP is positively evaluated to enable domain-specific structuring of services and to be flexible and reusable.

```
@prefix LoSe_ODP:
<https://github.com/Michael-Gloeckner/LoSe_ODP#>
@prefix DBCargo:
<http://www.dbcargo.com/rail-deutschland-en/products_
services/additional_services/Service_catalogue.html#>
LoSeMA_ODP:Handling rdf:type owl:Class ;
 owl:sameAs DBCargo:LoadingAndUnloading .
LoSeMA_ODP:Consulting rdf:type owl:Class ;
 owl:sameAs DBCargo:Loadingconsultancy ;
 owl:sameAs DBCargo:TrialLoading .
DBCargo:RegularInspection rdf:type owl:Class ;
 rdfs:subClassOf LoSeMa_ODP:Maintenance .
DBCargo:ImpactTesting rdf:type owl:Class ;
 rdfs:subClassOf LoSeMa_ODP:ResearchDevelopment .
DBCargo:Survaillance rdf:type owl:Class ;
 rdfs:subClassOf LoSeMa_ODP:Guarded ;
 rdfs:subClassOf LoSeMa_ODP:TrackAndTrace .
```

Fig. 5. Mapping.

```
@prefix LoSeMa_ODP:
<https://github.com/Michael-Gloeckner/LoSeMa_ODP#>
@prefix LoSe_ODP:
<https://github.com/Michael-Gloeckner/LoSe_ODP#>
SELECT Region
FROM <GeoArea#>
WHERE {
GeoArea:Germany rdfs:subClassOf
 LoSeMa_ODP:GeoArea.
LoSeMa_ODP:Handling LoSeMa_ODP:hasModeOfTransport
 LoSeMa_ODP:Rail.
LoSeMa_ODP:Handling LoSeMa_ODP:hasModeOfTransport
 LoSeMa_ODP:Sea.
}
```

Fig. 6. Querying

3 Conclusion and Future Work

In this paper, an ODP for the structuring of logistics services was developed following the NeOn methodology. The created LoSeMa_ODP (Logistics Service Map Ontology Design Pattern) is based on a large set of incorporated and analyzed ontological and non-ontological approaches. The essential structuring concepts of the logistics domain are distilled into one ODP. Hence, the structuring can be easily mapped and an ontological connection (with owl:sameAs) between similar concepts of different LSP can be set up and the semantic gap is closed. The created ODP is semantically richer than taxonomies or thesauri. The evaluation is done according to the FEDS framework and is based on one applied structuring of a big and influental logistics service provider. The ODP is positively evaluated to meet the functional requirements of structuring and retrieval and further to fulfill the properties of flexibility and re-usability.

The paper presents the first scientific approach towards an ontology design pattern for logistics service structuring. The creation of ODP for logistics holds 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. Implications for researchers is one of the first approaches towards linked data in logistics. Further research steps have to focus on further ODPs, such as *GeoArea*, *HazMat*, or an ODP about roles and stakeholders in the context of logistics, in order to extend the foundation for the ontological development of cloud logistics.

Acknowledgment

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