Initial Evaluation of an Ontology for Transport Brokering

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***Abstract*—Currently there is a lot of interest in developing applications to support the mobility and movement of resources and related features. One notable example is freight transportation management. Ontology-driven multi-agent systems are promising technologies for building systems that provide an intelligent service for freight transportation brokering aiming to create optimal transport policies such that transport costs are reduced to the minimum. We propose a freight transportation ontology and then we define a scenario of transport logistics to validate our proposed ontology. The evaluation is based on the careful examination of ontology concepts and properties that are required for capturing freight transportation requests and resources.**

I. Introduction

During the last years many researchers working in different areas were interested in developing ontologies intended to capture and represent various aspects of interest of the real world. If ontology development will improve in the future resulting in better and more accurately evaluated ontologies then we will be able to build better and more useful applications based on explicit representations of domain knowledge. Nowadays, many web applications are built to support the mobility and movement of resources and related features. One example of such application is freight transportation management. In this paper, we define a scenario of transport logistics domain to validate our proposed ontology for transport brokering. Also this paper describes the ontology concepts and their use in our multi-agent system for freight transportation brokering.

This work complements our preliminary results reported in [3], where we proposed an initial system architecture for a multi-agent system that provides a brokerage service with intelligent logistics. In the follow-up paper [4] we described the initial development of an ontology for semantic modeling of information relevant to freight transportation exchanges.

Before understanding the motivations underlying the development of our proposed ontology, it is necessary to introduce the actual context of our research. Our proposed agent-based system fits within the business model of freight transportation exchanges. It can be defined as virtual logistics platform that operates in the domain of freight transport, where providers of freight, as well as cargo owners are continuously seeking new transport opportunities. Our goal is to provide an intelligent service that is able to create an optimal transport route or policy such that transport costs are reduced to the minimum.

This goal led us to the proposal of an agent-based system [3] and a supporting ontology [4]. The main motivation of the work reported in this paper is to perform an informal evaluation of our initial proposed ontology mentioned above.

According to [8], there are several issues that can be considered when tackling the problem of ontology evaluation or assessment. Our initial work was focused on the informal evaluation of the ontology during the design phase of our multi-agent system, by checking its compliance with the usage scenario of the system.

Good ontologies are those that serve their purpose. Complete ontologies are probably more than what most knowledge services really need to function properly. A possible correct answer to the question "*How do you know if your ontology is good?*" is "*If it works well in your application.*" According to this view, the ontology size, the complexity of the ontology and the vocabulary of the ontology do not really matter for the assessment of an ontology.

The main objectives of this paper are: i) to check the compliance of our proposed ontology with the usage scenarios of our system and ii) to analyze how the proposed ontology concepts are used in the system.

This paper is organized as follows. Section II presents the relevant aspects of our previous work, that are needed to understand the objectives of this paper. Also in this section we provide a general introduction into ontologies and we discuss related works. Section III reviews the changes made to our initial ontology. In section IV we propose the usage scenario and in section V we evaluate the ontology in relation to usage scenarios introduced in the previous section. Future work and this paper conclusions are presented in section VI.

II. Background

A. Previous Work

Previously we formulated our initial proposal of a multi-agent system that aims to improve the competitiveness of logistics companies by increasing the quality of provided logistics services and by reducing logistics costs. During the preliminary system design we identified two main use cases of the system, as well as a set of agent types with specific goals and functionalities for the efficient management of logistics information. For each use case we proposed a sequence diagram that describes the interaction protocols between the agents. Our initial analysis and design provides a good basis for producing a more detailed design to support the implementation of the proposed multi-agent system.

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In [4] we introduced our approach for semantic representation of relevant information in the specific logistic domain. We built the necessary vocabulary for facilitating the connection of the cargo owners with the freight transportation providers through a broker that provides transport services in order to conclude a contract.

B. Ontologies

Ontologies are a formal, shared and explicit declarative description of a domain. An ontology contains an hierarchically organized set of classes or concepts. Subclasses represent concepts that are more specific than their super classes. Each class contains a set of properties describing the features and attributes of the concept. Properties can be characterized by restrictions that constrain the values of the property. An ontology and a set of individual instances of classes represent a knowledge base.

During our research we decided to adapt an ontology initially developed by the project InterLogGrid [5], [12] for our proposed system. The aforementioned ontology was used as a basic skeleton where we could add or remove concepts in order to better represent freight transport scenarios. However due to numerous and significant changes, the two ontologies are now substantially distinct.

Our aim was to provide the necessary vocabulary for the development of a freight transportation broker with the purpose of connecting cargo owners with the freight transportation providers through appropriate contracts.

The proposed logistics ontology consists of four parts. We preferred to present them separately, for a better analysis of the problem domain. Each part describes concepts such as transportation resources, transportation requests, freight and messages exchanged by agents.

The four proposed ontologies are: *Transport Request Ontology*, *Transport Resource Ontology*, *Freight Ontology* and *Messages Ontology*. *Transport Request Ontology* describes the elements of a transport request issued by a logistic customer, *Transport Resource Ontology* describes transport resource capabilities provided by logistic companies, *Freight Ontology* describes the freight that must be transported and *Messages Ontology* is used for describing the messages exchanged by agents in the system. Therefore, the main concepts of the logistics ontology are *Logistics Customer*, *Logistics Company*, *Transport Service*, *Logistics Resource* and *Logistics Object*.

For the development of the ontology we used Protégé[1] – one the most popular ontology development environments and for presentation of ontology we prefer to use the Manchester OWL syntax [14], see Listing. 1, which is more readable and user friendly for non-logicians, as well as supported by ontology editors such as Protégé.

More details about the description of the ontology can be found in [4], therefore in this section we will focus on the classes and properties that are the relevant for our usage scenario.

[1]Available at http://protege.stanford.edu

```
Class: <lob#VehicleDimensions>
SubClassOf:
    <lob#hasVehicleWidth> exactly 1 xsd:double,
    <lob#hasVehiceHeight> exactly 1 xsd:double,
    <lob#hasVehicleLength> exactly 1 xsd:double,
    <lob#LogisticsResource>
Class: <lob#NonDedicatedVehicle>
SubClassOf:
    <lob#DedicatedVehicle>
DisjointWith:
    <lob#OversizedVehicle>
```

Listing. 1. Example of a primitive classes in the *Transport Resource Ontology*

```
1: lob:flatdors rdf:type lob:Freight
2: lob:flatdors lob:hasPointOfDispatchName
       "Simpson Door Company"
```

Listing. 2. Representation of a freight and its supplier in RDF format

C. Ontology Use

When we use an ontology, we utilize ontology concepts for defining new instances and/or new classes. For instance, let us assume that we want to describe a product (e.g. flat doors) which is an individual (i.e. instance) of *Freight* class. Suppose this product is supplied by *Simpson Door Company*. Concepts and instances are defined as RDF resources that are identified using URIs (Uniform Resource Identifier). So we will need a new URI for identifying *flatdoors*, for example http://domain/flatdoors, abbreviated as *lob:flatdoors*. Here *lob* denotes the namespace (also defined as an URI in the ontology) that is necessary to disambiguate terms with the same name. Defining namespaces as XML named entities (for example *lob*) improves the readability of the ontology definition.

Let us consider for example the definition of *lob:flatdoors* class instance, as shown in Listing. 2. The class *Freight* is reused for defining the new instance. In line 1, for the definition of a new instance, we use the predefined *rdf:type* property that associates the new URI that identifies the new instance with the class, here denoted as *lob:Freight*. As URIs are supposed to be universal, it is clear that whenever this URI is used, we are referring to the very same term as the one defined in the ontology. Moreover, if the ontology follows Linked Data [15] best practises, the URI of the class should be differentiable, so that when we look up the URI with an HTTP GET operation, we will get a definition of the term.

Going further with our example from Listing. 2, in line 2 we can see the definition of the supplier "Simpson Door Company" of flat doors. Note that here we do not use an URI for the definition of the company name, but rather a simple character string. Again, for defining the supplier name we simply reuse the property *lob:hasPointOfDispatchName* defined in the ontology. Here *lob* denotes a namespace that represents our proposed logistics ontology for brokering of freight.

D. Related Works

Ontologies are increasingly used in various fields [13] such as knowledge management, natural language processing, linguistics [6], e-commerce, intelligent information integration, education; and in new emerging fields like the Semantic Web. Many researchers proposed and analyzed frameworks for developing, evaluating and deploying ontologies.

The author of [8] proposes the following three issues as relevant for ontology evaluation: (i) mistakes and omissions in ontologies can lead to the inability of applications to achieve the full potential of exchanged data, (ii) people constructing an ontology need a way to evaluate their results and possibly to guide the construction process, as well as any subsequent refinement steps and (iii) local changes in collaborative ontology engineering may affect the work of others. In our paper we actually focused on the first issue, by analyzing the compliance of our ontology with the proposed usage scenario.

The authors of [1] and [2] modify and extend an existing ontology *CoreGRID* with the aim to facilitate ontologically-driven resource management in the grid. Besides the proposed scenario and description of the developed *AiG* (Agents in the Grid) Ontology, the authors present two examples of resource descriptions in order to evaluate their proposed ontology. Moreover, the authors utilize the ontology to describe contract conditions as well as content of messages exchanged by software agents. Therefore, the purpose of the *AiG Ontology* has many similarities with our *Logistics Ontology*.

Paper [9] looks at existing ontology-evaluation methods from the perspective of their integration in one single framework. Therefore we have used some methods used in the previous mentioned paper to evaluate our ontology.

The management of an innovative and modern supply chain (in our case transport services) requires the use of appropriate logistics performance. More about logistics performance can be seen in [7] where the authors indicate the relevant and important indicators and performance metrics for intelligent and sustainable supply chains.

III. Updating the Ontology

In this section we review the updates that we performed to our initial proposed ontology. The ontology was improved for providing better support to our proposed scenarios. Therefore we introduced new classes, transformed some classes, and reused existing ontologies such as: *AddressHomeLocation*[2], *WeightOfFreightUnitOfMensurement*[3] or *MarketPriceOfFreightCurrency*[4]. Another issue in the process of ontology generation is determining which of object property or datatype property are more appropriate for describing the properties of our concepts. Protégé can incorporate both notions: *Object Properties* and *Datatype Properties*.

If a property relates individuals to individuals, then it must be defined as an object property (i.e. object properties represent binary relations between individuals) and if it relates individuals to literals (i.e. data), then it must be defined as a datatype property (i.e. datatype properties represent binary relations between individuals and primitive data values).

Let us consider that the transport company needs on insure the cargo transported, which in turn depends on the cargo's value. In our ontology the economic value can be expressed through the class *MarketPriceOfFreight*, which in turn has a data property *hasMarketPriceOfFreightValue* (double value), as well as a class that represents the currency as an instance of the *MarketPriceOfFreightCurrency* concept (imported from the *Currency Ontology*). Other concepts present in our ontology have also similar structures, by expressing quantifiable parameters, for example *VolumeOfFreight* and *WeightOfFreight*. Note that we use data properties for representing quantifiable values of concepts.

The *Transport Request Ontology* proposed here suffered few updates. For example, the classes *DateOfCharge* and *DateOfDischarge* become data type properties i.e.: *hasStartMomentOfCharge* and *hasFinishMomentOfDischarge*. Moreover, the class *Product* was renamed into the class *Freight* from the *Freight Ontology*.

Furthermore, *Freight Ontology* suffered a few changes as well. For example, the classes *TimePeriod*, *ExpirationDate*, *DescriptionContent*, *NameOfFreight*, *LogisticsLocations* (including *PointOfDestination* and *PointOfDispatch*) and *QuantitativeValue* were removed. Instead, we added new properties (e.g. *hasDescriptionOfFreight* and *hasTypeOfAnimal*).

IV. Usage Scenario

Now, let us present a usage scenario of transport resource descriptions that use our ontology. We start with a basic simple case and then expand it into a more complex scenario with more transportation options.

Let us assume that there is a request for transporting flat doors from the city of Sibiu to Bucharest issued by *Trans LTD*. Such a request is contained by a message exchanged by the Customer Agent – *CAgent* and the Freight Broker Agent – *FBAgent* in our system. The message is expressed using the underlying Agent Communication Language that is abstracted away in this paper. We assume that the request is issued on December 30th and it is available, i.e. "pending", for 24 hours. The goods must be picked up on January 1st and have to be discharged no later than January 2nd. In order to transport the flat doors we are constrained to use pallets. The total weight of the transport is 3000kg. No special freight transport conditions are necessary, as the doors are made out of solid materials that are not perishable.

The vehicle chosen for this job has a width of 2.55 meters, a length of 12 meters and a height of 4 meters. The total transport volume that this type of vehicle is able to carry is of 60 cubic meters. The Diesel truck used is parked nearby the city of Sibiu, in Şelimbăr village.

For this base case several issues are ignored. For example, we do not consider the fact that the truck has to return to its initial home location (Şelimbăr, 3 Principal St.) Also we do not consider any legal constraints that may delay the transport, e.g. a truck driver is not allowed to drive for periods longer than 4 hours without a break. You can see a representation of the request in this scenario in Listing. 3.

Note that in more realistic scenarios, the vehicle used for transportation has to return to its home location before a reasonable deadline. This time interval depends on the existing contract agreed by the brokerage company and the freight

[2]http://daml.umbc.edu/ontologies/ittalks/address
[3]http://idi.fundacionctic.org/muo/muo-vocab.html
[4]http://www.daml.ecs.soton.ac.uk/ont/currency.daml

```
Individual: lob:#request1
Types:
        lob:#LocationPoints,
        lob:#PointOfDestination,
        lob:#GpsCoordinatesDestination,
        lob:#AddressDestination,
        lob:#PointOfDispatch,
        lob:#GpsCoordinatesDispatch,
     lob:#AddressDispatch,
     lob:#Request,
Facts:
  lob:#hasPointOfDestinationName  "PRACTIC LTD",
  lob:#hasStartMomentOfCharge  "02.01.2015",
  lob:#hasOwnerID  "1",
  lob:#hasRequestID  "1",
  lob:#hasDestinationLongitude  "26.007344",
  lob:#hasDispatchLongitude  "24.178083",
  lob:#hasStartMomentOfCharge  "01.01.2015",
  lob:#hasDispatchLatitude  "45.773270",
  lob:#hasFinishMomentOfCharge  "01.01.2015",
  lob:#hasFinishMomentOfDischarge  "02.01.2015",
  lob:#hasDestinationLatitude  "44.410910",
  lob:#hasTTL  "03.01.2015",
  lob:#hasOwnerName  "TRANS LTD",
  lob:#hasPointOfDispatchName  "TRANS LTD",
  lob:#hasDateOfRequest  "01.01.2015",
  lob:#isJuridicPerson  "True"
```

Listing. 3. Example of a request in Owl Manchester representation

TABLE I. ENHANCED SCENARIO

	SB	SE	B	CR	TM	BV	IS	CJ	CT	BZ
SB			01-02							
SE										
B				02-03		03-04	02-04		02-04	
CR					03-04					
TM	04-05							03-04		
BV	04-05									
IS	04-06									
CJ		04-05								
CT										04-05
BZ	05-07									

- This option represents the optimal choice, as there are no stationary days or long itinerary without any cargo;
- This route implies a stationary day in B (day 02);
- This colour represents a transport option that is not valid, as the cargo type from IS to SB can not be transported with the current vehicle;
- Although this route returns back to SE, it implies an itinerary from B to CJ without any cargo;
- This option is valid and returns the truck in SB, but the time needed (7 days) exceeds the available time for the truck (6 days.)

transportation provider. In order to reduce transportation costs, the brokerage company has to ensure that the movement of the vehicle without cargo is kept minimal. In our case the broker has to study all possible comeback routes from B (Bucharest) to SB (Sibiu). If there are no suitable comeback routes then the vehicle must be sent back to SB without cargo. The main problem is finding matching cargo for the vehicle.

Let us expand the base case with diverse constraints. Table I presents detailed information about the transportation requests available for a certain time period. We assume that the requests and the time allocated to them is in accordance with Romanian transportation laws. We take into consideration 10 Romanian cities and thus we created a 10 by 10 matrix. Each matrix element can contain data about the day of departure and arrival of a potential trip, but only a part of these elements are usually filled-in.

For example, let us consider the element at the intersection of row SB with column B. It should be interpreted as follows: there is a freight request departing from town SB on day 01 that must arrive in town B on day 02. To simplify reading we shall use the words *vehicle* and *truck* interchangeably as an abbreviation for *logistic transport vehicle*. Furthermore, we suppose that the truck's home location is not in the city of SB, but in a nearby city called SE (Şelimbăr). The truck can travel between SB and SE in less than an hour. Initially the vehicle is dispatched from SE and sent to SB, as SE it is the closest vehicle base near SB.

Before continuing with the description of the scenario, we must clarify the other abbreviations denoting other cities as transit points used in this scenario: CR – Craiova, TM – Timişoara, BV – Braşov, IS – Iaşi, CJ – Cluj, CT – Constanţa and BZ – Buzău. All these acronyms represent cities, excepting BZ which represents a farm in the county of Buzău.

Let us continue on the basis of the simple scenario. Once arrived in town B, see Table I, there is no direct return possibility to SE or SB. A possible return trip involves sending the vehicle from B to CT on days 02-04 (see the blue cells in Table I). Furthermore, a cargo request from CT to BZ (day 04-05) and another from BZ to SB (day 05-07) could also be serviced. However, although the truck would return to SB, which is nearby the vehicle home location, this route is not eligible. We assumed that the truck is only available for 6 days out of 7 days (necessary for this route). Such a constraint can be expressed in our ontology through the *hasVehicleAvailabilityStartTime* and *hasVehicleAvailabilityFinishTime* data properties, having as domain the *LogisticsVehicle* class. The aforementioned data properties define a time period when the vehicle is available for the current broker.

Another option is to send the vehicle from B to CJ such that it can take a cargo from CJ to SE (day 04-05), see the red cells in Table I. Although the vehicle returns directly to its home location, the truck has to travel form B (day 02) to CJ (day 04) without any cargo. Thus the broker has to support all the expenses during this period. This option is even less profitable than the first one. Sending the truck from B to IS (day 02-04) and then from IS (day 04-06) to SB is not a valid option (see the orange cells in Table I) because the freight transportation requirements from IS to SB can not be accommodated on the current vehicle. Between B and IS the medications have to be transported, which also fit onto pallets and do not require any additional conditions than flat doors. But between IS and SB frozen vegetables have to be transported, inside a frozen chamber, which our vehicle is not suited for.

Transporting a load from B to BV (day 03-04) and then from BV to SB (day 04-05) is a better option, as there is no significant movement of the vehicle without a payload. But the broker has to pay for the stationary (day 03) and for the load free trip from SB to SE, see the yellow cells in Table I. This option is more convenient than the options that included a longer transport route of the vehicle without a payload, as the fuel consumption is small (SB and SE are nearby).

A better route goes from B to CR (day 02-03) then from CR to TM (day 03-04) and finally from TM to SB (day 04-05), see the green cells in the Table I. Although it is a long route, it is the only option that does not force the broker to pay for stationary days or for moving the vehicle without a payload on long distances. The broker supports just the trip from SB to SE and return. Also all the other constraints referring to the type of cargo, capacity, etc are fulfilled.

In conclusion the most profitable route is: SE – SB – B – CR – TM – SB – SE. Note that other types of goods than flat doors can be transported as long as they do not need any change to the vehicle features, e.g. parts of furniture from B to CV and home appliances from TM to SB, etc.

V. Evaluating the ontology

According to [10], an ontology can be evaluated by several criteria such as: (i) its coverage of a particular domain and the richness, complexity and granularity of that coverage; (ii) the specific use cases, scenarios, requirements, applications, and data sources it was developed to address; as well as (iii) formal properties such as consistency and completeness of the ontology based on the language in which it is modeled.

We chose an informal approach based on using specific scenarios to evaluate our ontology, as this work is a preliminary evaluation and the ontology has been designed based on proposed scenarios. Moreover, our approach can be also seen as a cross-validation step of our ontology with the initial design of the multi-agent system. The current version of our ontology is publicly available as a Github repository[5].

Competency questions were introduced by [11] to determine the scope of the ontology, thus acting as a test suite that provides value during analysis and validation stages. The resulted outcome is an overall answer to: "*Does the ontology contain enough information to answer these types of questions?*". During the analysis stage we suggested few competency questions, for example: "*What are the main features of customer requests?*", "*What is the transportation capacity of a vehicle?*", "*What are the features of a request that can not be satisfied by the freight provider?*" [4]. Due to the lack of paper space we can not include all of them here, neither can we answer them directly. Nevertheless, by following the methodology proposed in the paper and the ontology it clearly results that all the competency questions were rigorously solved.

When resolving a freight request we have to focus our attention to each step of this process: i) analyze the request, ii) consider the freight features, and iii) determine the matching available resource(s).

In out latest work we identified four types of agents that represent both external users of the system, as well as internal system components with specific capabilities: Customer Agent (*CAgent*) represents a customer of the transport brokering service, Freight Transportation Provider Agent (*FTPAgent*) represents a provider of a transport resource, Freight Broker Agent (*FBAgent*) represents the transport brokering service and Freight Broker Registry Agent (*FBRAgent*) manages the requests of customers and transport providers.

The choice of available resources matching with a certain transportation request is the result of a complex reasoning about the available transportation options. Moreover, a negotiation process between the freight broker represented by *FBAgent* on the one hand and the provider of transport represented by *FTPAgent* and/or the cargo owner (or customer) represented by *CAgent* on the other hand, can occur. The details of this negotiation and reasoning processes are outside the scope of this paper and they are the subject of future work.

The focus of this evaluation consists in determining if our developed ontology can describe from simple to advanced transport requests, freight and transport resources.

The customer issues a request to the transport broker company and the request details are expressed in the ontology as follows. A transportation request is issued by filling in an input form (details are omitted here). Input data is then mapped to an instance of the *Request* class. Request properties, for example *hasStartMomentOfDischarge* and *hasFinishMomentOfDischarge*, are used to define reference time points that define the deadline of the contract that specifies when the goods must be delivered. In order to capture other details of the request we also use the following properties: *hasTTL* to represent the lifetime of the request (e.g. 24 hours), *hasStartMomentOfCharge* to represent the date of charge.

Usually tax values depend on the type of entity that request a transfer of cargo, therefore we introduced in the *Transport Request Ontology* a data property *isJuridicPerson* in order to capture also this type of information.

The location of the cargo pick up and the location of delivery are expressed using two classes in the *Transport Request Ontology*: *PointOfDestination* and *PointOfDispatch*. A location can be specified by giving its Global Positioning System (GPS) coordinates, using data properties as follows: *hasDispatchLongitude* and *hasDispatchLatitude*. Latitude and longitude are needed in situations when a postal address can not be determined, e.g. the dispatch is in the middle of a corn field or at the ranch. Sometimes an address identifies multiple entities creating confusion, e.g. an industrial park may have one postal address but 10 companies are present at that location. Thus we introduced two data properties: *hasPointOfDispatchName* (domain class *PointOfDispatchName*), *hasPointOfDestinationName* (domain class *PointOfDestinationName*) that represent unique identifiers (e.g. company name) for the pick up entities and discharge entities.

The *LogisticsObject* class is used to define the features of the freight to be transported using subclasses and properties that represent freight characteristics, for example: *BoxOfFreight*, *hasDescriptionOfFreight*, *PerishabilityOfFreight*, *QuantifiableTraitsOfFreight*, *WeightOfFreightValue*, etc. The *BoxOfFreight* class is used to capture the type of goods packaging. For example, flat doors are transported on pallets, therefore the *Pallet* subclass of *BoxOfFreight* is used. For the number of packages we included the data property *hasNumberOfBoxOfFreight*. Through the data property *hasDescriptionOfFreight*, a textual description of the fright can be introduced. This can be useful, as for example in Roumania the truck driver is required to know what he or she is transporting.

If the cargo must be transported under special conditions then we can capture these special conditions using the *SpecialConditionsOfFreight* class. The following special

[5]http://intelligentdistributedsystems.github.io/FreightOntology/

conditions are represented in our ontology: refrigerated, oversized, dangerous, fragile and controlled temperature. Using the *ControlledTemperature* class and the *hasControlledTemperatureValue* data property we can specify the temperature required for the cargo.

The class *AggregationStateOfFreight* and its subclasses capture the aggregation state of freight, e.g. liquid, gas or solid. For the case involving transportation of flat doors we used the subclass *SolidState*. The *PerishabilityOfFreight* class has two subclasses *NonPerishableFreight* and *PerishableFreight*, thus it is easy to represent goods that have an expiration date. As flat doors have no expiration date we will use the class *NonPerishableFreight* to describe our request. Using the *WeightOfFreight* class we can capture the total weight of the cargo that needs to be transported. The *WeightOfFreightUnitOfMensurement* subclass of *WeightOfFreight* represents an ontology for weight measurements, thus different weighting systems can be used. The numeric value of the weight (double numeric type) is expressed by the data property *hasWeightOfFreightValue*.

The *LogisticsResource* class is a core concept of the ontology that describes transportation resource capabilities. The *LogisticsVehicle* class is used to describe the vehicle capabilities, as required for example by the orange route in Table I. Advanced types of vehicle are supported: a bio-gas powered vehicle that can transport hazardous liquid materials in a tanker under a controlled temperature or an oversized logs truck that has a hydraulic crane as a self charging mechanism. Dedicated vehicles are also supported by the following subclasses of class *DedicatedVehicle*: *AnimalsVehicle*, *CarsVehicle*, *GrainTransportVehicle*, *LogsVehicle*, *TankerVehicle*, *TruckMixerVehicle* and *ValuableTransportVehicle*.

For some locations, the accessibility of the truck may depend on its dimensions. Thus we must capture its dimensions using data properties, for example: *hasVehicleHeight*, *hasVehicleLength*, *hasVehicleWidth*. These properties have as domain the class *VehicleDimensions*. The *TypeOfFuel* class is used to represent the type of fuel used by the vehicle.

The class *VehicleHomeLocation* in *Logistics Object Ontology*, represents the parking address of the vehicle. This class has subclasses, for example *AddressHomeLocation* (an already developed ontology mentioned above) and *GpsHomeLocation* that can accurately describe the vehicle home location.

VI. Conclusions and Future Works

In this paper we presented the main features of 3 proposed ontologies for brokering of logistics services that represent an update of our initial proposal. The ontologies were developed starting from an initial set of requirements resulted from proposed usage scenarios. The scenarios were developed by analyzing real world freight transportation problems.

We acknowledge that our work is still in an initial stage and a lot of work remains to be done until this ontology can be usable into a realistic freight transportation brokerage system. On the short term we aim to expand the current ontology such that it will allow the representation of the semantic content of the messages exchanged by the agents in our multi-agent system. Also we intend to use automated reasoning services to identify different types of transport vehicles, based on given transportation requests. On the long term we aim to provide facilities for automated allocation of transportation resources via a negotiation system between the customer (cargo owner), the freight broker and the freight transportation provider.

VII. Acknowledgments

This work was supported by the strategic grant POSDRU/159/1.5/2/133255. Project ID 133225(2014), co-financed by the European Social Fund within the Sectorial Operational Program Human Resources Development 2007-2013.

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