About quality of semantic data for the city logistics domain: A comparison with the stakeholders' perspectives

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ABSTRACT

City logistics is characterized as a distributed decision making system due to its heterogeneous stakeholders and their conflicting objectives. To understand the complexity of interactions among these stakeholders, the first step is taken by developing an ontology for city logistics domain. Ontology is a powerful way to express domain knowledge in a structured way and it can be treated as a knowledge meta-data model. To utilize this powerful knowledge model one needs to have confidence in its structural and relational information. Confidence in using ontology can be built by validating the ontology for its scope, structure and knowledge representation. In this paper, quantitative evaluation and qualitative validation of generic city logistics ontology is performed. Quantitative evaluation estimates ontology parameters such as depth, breadth, inheritance richness, relationship richness and attribute richness. To check the quality of the ontology, we propose to validate system components and knowledge representation in the ontology. For this purpose, we use the data collected from interviews consisting 12 real-world stakeholders as well as more than 30 urban freight models and various other urban freight literature. More specifically, we explore how (and how many of) these rules and processes found in the real world domain are incorporated in the city logistics ontology. Finally, in the case of city logistics, we conclude that the ontology covers a wide scope of the domain and its generic nature allows flexibility of use for the purpose of knowledge sharing, querying and modelling.

Keywords: Ontology, City logistics, Validation

1. INTRODUCTION AND MOTIVATION

City logistics (also known as urban freight transportation) is a process for totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic environment, the traffic congestion and energy consumption within the framework of a market economy [1]. Urbanization has caused densely populated areas in cities, which in turn has elevated logistics activities due to high demand and varieties of goods. Problems due to the increase in city logistics activities have to be understood and solved for better livelihood of people and creating economically and environmentally friendly cities.

City logistics is characterized by large number of heterogeneous stakeholders with often conflicting objectives. These stakeholders are, often, unaware or disinterested in urban goods movement related activities other than those affect them directly. Hence, they do not share information with other stakeholders and are interested in achieving their own objectives [2] and hence act autonomously. These stakeholders, due to their distributed decision making processes adds to the complexity and unpredictability of the large city logistics domain. This complexity of city logistic domain and diverse interests of various stakeholders demand a well-designed consultation and an active participation for effective city logistics policy making process [3].

The first step towards the understanding of such complexity is developing a knowledge data model that describes the CL domain. Such knowledge model should present the city logistics information in a structured way so that the effects of different components (e.g. Stakeholders, decision making process, municipal regulations etc.) on each other and on the system can be understood clearly and efficiently. This understanding can lead us to make effective regulations, policy measures or incentive structures for problems of city logistics domain. Similarly, Wigan et al. [4] emphasis on quality and structure of data for sound transport and policy related research. The article concludes that for easy and efficient exchange of data among researchers and practitioners its structural issues must be addressed.

Ontology is such a knowledge model that can systematically represent the domain information. Ontology addressee these structural issues by defining not only standard vocabulary but also relations among the data for urban freight transportation domain. The need of ontology for specific domain arises from the need to gather information about a domain in a structured way. This structure does not only represents a group of concepts as a vocabulary or terminology of the domain but also contains specific knowledge relationships among them. Thus there is a clear distinction between “vocabularies” and “ontologies” as the latter is the more complex version of the former and every term in the ontology is no stand-alone term but linked with other terms to characterize knowledge about the domain it represents.

Ontology is essentially a collection of classes and relationship among these classes. The complex structure of an ontology can be used in multiple ways and the use depends very much on the user. For example, a person new to the domain can easily browse through the ontology to get acquainted with the components of a system as well as can learn how these components affect each other. As the information is presented in a highly structured way it can cater to a specific knowledge-acquiring. One can analyse the domain and get informed about the facts of a domain using sophisticated query techniques and reasoning features embedded in softwares available for ontology browsing [5]. Furthermore, an expert of domain can use the same ontology for a quick development of a new complicated model. Ontologies are also extremely useful for the conceptualization and specification of simulation modeling and lifecycle-analysis, in particular for the problem analysis and conceptual model design phases [6]. Therefore, ontology is developed for variety of domains including agriculture [7], asset management [8], emergency notification [9], mobile (e.g. [10], education [11], intellectual property rights protection [12] etc.

Similarly, to take advantage of these very many benefits, Similarly, a generic ontology of city logistics (henceforth also GenCLOn - acronym for Generic City Logistics Ontology) domain has been developed by Anand, Yang, Van Duin and Tavasszy [13] using ontology development software Protégé[i]. Developing ontology is a very useful step for the domain of interest. However, since ontology is constructed by a person or a group of people, it is undeniably shaped by their perceptions. Therefore, it is essential to validate the ontology by gauging the ontological data with respect to real world concepts and showing how much (quantity) and how good (quality) the ontology model is compliant with the real world. The evaluation and validation, in fact, can help deciding the usage of ontology for various purposes. With this background, we state the objective of the paper as to systematically validate the quality of city logistics ontology by using knowledge available from real-world stakeholders. We also

address the issue of a qualitative evaluation by gauging various ontological parameters. In research there is reluctance in using ontologies among practitioners and researchers. In our opinion, systematic evaluation and validation of ontology can essentially generate confidence among researchers for its usage.

The remaining paper is structured as follows. Section 2 briefly reviews other works about ontology evaluation and section 3 gives evaluation and validation framework overview. Section 4 validates the city logistics ontology against domain stakeholders' perspectives. Section 5 describes the qualitative validation of GenCLOn. In section 6 results of the validation are presented following discussion. Finally, section 7 gives conclusion about the entire exercise of validating city logistics ontology.

2. STATE OF THE ART

The consequential issue after developing ontology is its validation. Confusion prevails in distinguishing evaluation and validation for an ontology. Often these words - "evaluation" and "validation" - are used in place of each other. In our opinion, validating ontology is a process of determining the degree to which the scope, scale, content and knowledge relations are accurate representations of the real world from the perspective of the intended user(s). Thus, the validation of ontology involves some kind of comparison with the external data. On the other hand, the evaluation of ontology is a process of computing quantitative information of some key characteristics of a certain (possibly partial) design. Most of the ontology validation literature, in fact, deals with evaluation of ontology by assessing ontological parameters such as depth, breadth. In an article from 90's, Gómez-Pérez [14] explored the idea of evaluating ontology. The article states that the most important features for the evaluation of the ontology are its structure, contents, syntax, and a set of semantic properties that guarantee the coherence, completeness, consistency and conciseness of the definitions. Most of the literature for ontology evaluation suggests this theme but present many different approaches. For instance, Fox et al. [15] proposed various set of criteria for assessing ontology manually. Guarino and Welty [16] proposed various notions such as identity, unity, essence, rigidity etc. to define a set of meta-properties to evaluate different properties, classes, and relations of an ontology. Brewster et al. [17] introduced a data driven approach that compares an ontology with a given text corpus[ii] in order to determine how appropriately knowledge of domain is presented in the ontology. The approach uses probabilistic setting to evaluate the "best fit" between a corpus and the ontology.

A task based approach, which usually applied to ontologies that are tightly integrated with an application, suggested by Porzel and Malaka [18] explore the ontology quality for insertion, deletion and substitution features. Gangemi et al. [19] presented a framework for evaluation that considers depth, breadth, tangledness as quantified parameters measuring the quality of ontology. Similarly, Tartir et al. [20] introduced evaluation technique called OntoQA. In this framework the authors evaluate an ontology based on schema metrics and knowledge metrics, where the former evaluates richness, width, depth, and inheritance of ontology and latter evaluates the effectiveness of the ontology design and the amount of real-world knowledge represented by the ontology. The approach is effective for measuring the quality of the ontology in terms of quantified information; however, it cannot evaluate the knowledge representation error since the knowledge metrics only calculate how many relations are present in the ontology and don't check whether these relations are correctly embedded in the ontology.

The survey of techniques for ontology evaluation by Brank et al. [21] gives an overview of different approaches for ontology evaluation. According to the survey, ontology can be evaluated at different levels and each layer can be separately evaluated by the application of a different approach. TABLE 1 shows the overview of the approaches.

TABLE 1 An Overview of Approaches To Ontology Evaluation (Source : [21])

	Approach to evaluation			
Level	Golden standard	Application based	Data driven	Assessment by humans
Lexical, vocabulary, concept, data	x	x	x	x
Hierarchy, taxonomy	x	x	x	x
Other semantic relations	x	x	x	x
Context, application		x		x
Syntactic	x			x
Structure, architecture, design				x

- Golden standard : comparing the ontology to a "golden standard", which may itself be an ontology (e.g. [22])
- Application based: using the ontology in an application and evaluating the results (e.g. [18])

- Data driven : comparing ontology with source of data (e.g. A collection of documents) of the domain (e.g. [17])
- Assessment by humans : evaluation is done by humans who try to assess how well the ontology meets a set of predefined criteria, standards, requirements, etc. (e.g. [23])

Another review by Obrst et al. [24] divides ontology into three levels : language level, concept level and instance level. The review discusses issues and problems in ontology evaluation, describes current strategies, and suggests some further approaches. Giving an example of gene ontology [25], the review concludes that the ultimate evaluation of an ontology is in terms of its adoption and successful use, rather than its consistency or coverage.

As discussed above, there are multiple approaches existing for ontology evaluation and validation where each has some pros and cons and therefore the usability of the approach depends on its use and user(s). In this paper we want to validate generic ontology for city logistics domain. The generic nature of the ontology demands validation from the point of view of scope and scale to accommodate sizable concepts and relations among them observed in the domain. This suggests that ontology needs to be evaluated for quantitative information. The frameworks proposed by Gangemi et al. [19] and Tartir et al. [20] are used for evaluation since it computes all important parameters helpful to comment on the numerical structure of the ontology.

Apart from numerical information about the ontology, it is also essential to validate whether the details about these concepts and the knowledge represented by its relations mirrors real world practice. We assert that ontology validation is usually the only way to ensure the precision of the knowledge presented in the ontology. We also believe that most of these approaches require close cooperation of domain experts and that the validation often cannot be performed automatically due to the complexity of the domain and the data presented in ontology.

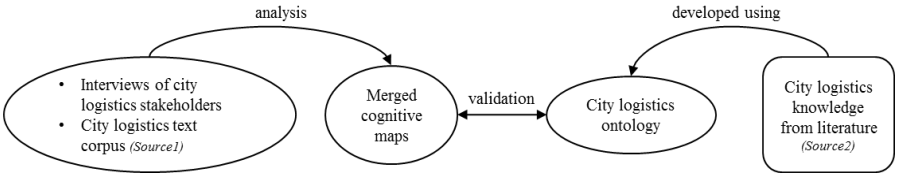

FIGURE 1 Overview for qualitative validation of city logistics ontology

There are attempts in other domains to validate the ontology by domain experts [26-28]. In the case of city logistics we incorporate information of real world stakeholders from in-depth personal interviews and domain text corpus to generate cognitive maps. These maps are then used to examine the precision of the ontology (i.e. Quality validation) by manually checking the details (e.g. System component, knowledge representation) of ontology. The overview of qualitative validation of city logistics ontology is presented in FIGURE 1.

3. GENERIC CITY LOGISTICS ONTOLOGY

Fundamentally, an ontology consists of classes, its attributes and relationship among the classes. The classes represent system components of the domain for which the ontology is being developed (city logistics in this case), and the relationships portray knowledge relationships among the system components (see FIGURE 2 - a). Ontology can be divided into two broad categories from the point of view of its scope, 1) Generic ontology and 2) Case specific ontology. The generic ontology includes general or basic concepts and relations necessary for doing knowledge representation and modeling the physical world or problem-solving [29]. The generic ontology describes the high level classes while in the case specific ontology more detailed subclasses, that give specific information about the case, are added. As per van Dam and Lukszo [30] “The case specific ontology is a specialization of the generic one and on the other hand the generic ontology is a generalization of all underlying case specific classes”. FIGURE 2-b gives indication of difference between generic and case specific ontology.

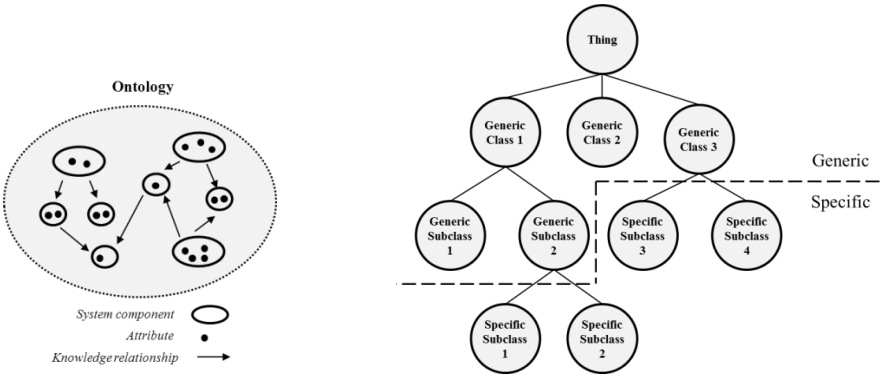

FIGURE 2 (a) Representation of an ontology structure

(b) Generic versus Specific ontology (source: [30])

GenCLOn is a generic ontology as the city logistics related concepts and the relationships among them were included at generic level. The generic level of GenCLOn is due to the extensiveness of the domain it tries to represent as well as the relatively low importance of instance-creating. It is developed with the objective to cover important and fundamental concepts of city logistics and incorporate the relations among each other. Extensive information and knowledge has been collected from relevant literatures as the theoretical foundation of GenCLOn. After a series of information processing including sorting, refining and summarizing, the domain of City Logistics is classified into following general classes, namely Stakeholder, Objective, KPI, Resource, Activity, Measure, and R&D.

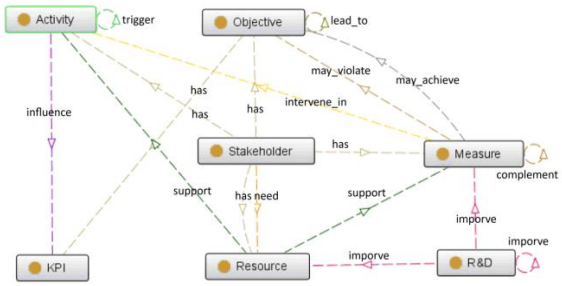

FIGURE 3 Top level hie: archy of GenCLOn (Source:[13])

These classes represent the fundamental and important aspects of city logistics and the naming convention shows that they represent classes from the upper ontology. These main classes are further divided into sub-classes (at various levels) to represent the city logistics domain. FIGURE 3 illustrates these key classes and main possible relations among them. The objective of developing GenCLOn at generic level is to express the case specific parts of the domain in terms of the generic description to create a strong framework that can form the foundation for a flexible modelling platform for city logistics domain [30]. However to fulfil this objective, it is essential to ensure that the coverage and quality of the content of the ontology are adequate. For this purpose we evaluate GenCLOn for its quantitative and qualitative properties.

In the quantitative evaluation the task is to assess dimensional parameters (e.g. Depth, breadth etc.) of city logistics ontology using frameworks developed by Gangemi et al. [19] and Tartir et al. [20]. These parameters answer questions such as *how big is the ontology? How many relations are covered? How many attributes classes do the ontology contains?* and so on. While in the qualitative validation of GenCLOn, the system representation and knowledge representation in the ontology with respect to the domain information from real life will be checked. The qualitative validation answers questions such as *does the ontology covers topics related to city logistics domain* and if yes, *does it covers the relations between the classes correctly?* In the following sections we structurally carry out the task of qualitative validation and quantitative evaluation for GenCLOn.

4. QUALITY OF SEMANTIC DATA FOR URBAN FREIGHT TRANSPORTATION DOMAIN

Qualitative validation of ontology involves two checks 1) System component validation 2) Knowledge representation validation (refer FIGURE 2 - a). Qualitative validation of an ontology, performed with respect to the information needs of various users of the ontology, essentially generates confidence among its users [31]. Since ontology represents domain knowledge, it is apparent that domain experts/users should be involved directly or indirectly for validation. There are mainly three groups within the domain of city logistics who are potential users of this ontology: 1) City logistics experts 2) City logistics modeler and 3) City logistics stakeholders from the real-world. Incorporating the diversity of the groups also assures validation of relational orchestration among the classes presented in the ontology. Considering this, we use information collected from stakeholders' interviews and from the text corpus of city logistics literature for the validation purpose.

For the interview part we are using information gathered from in-depth personal interviews[iii] of 4 trucking firms and 8 administrative authorities concerning city logistics domain [32]. Each interview was digitally transcribed and afterwards information from the interviews was analysed using cognitive mapping technique called Strategic Options Development Analysis – SODA [33]. For each stakeholder, a cognitive map is developed using the mapping software Decision Exploreriv [34]. For the details about interviews and its analysis please refer to [32]. For this research, final outcome – the merged cognitive maps of stakeholders - were used. Quotes from stakeholder interviews are included in the cognitive map. Theses individual cognitive maps are combined to make a merged cognitive map, which reflects the central view point of the entire stakeholder group. Using the statistical scoring techniques available in the tool, the relationships among the concepts are analysed and mapped by linking these concepts. FIGURE 4 shows the merged cognitive map of the stakeholder carrier based on 4 carrier interviews.

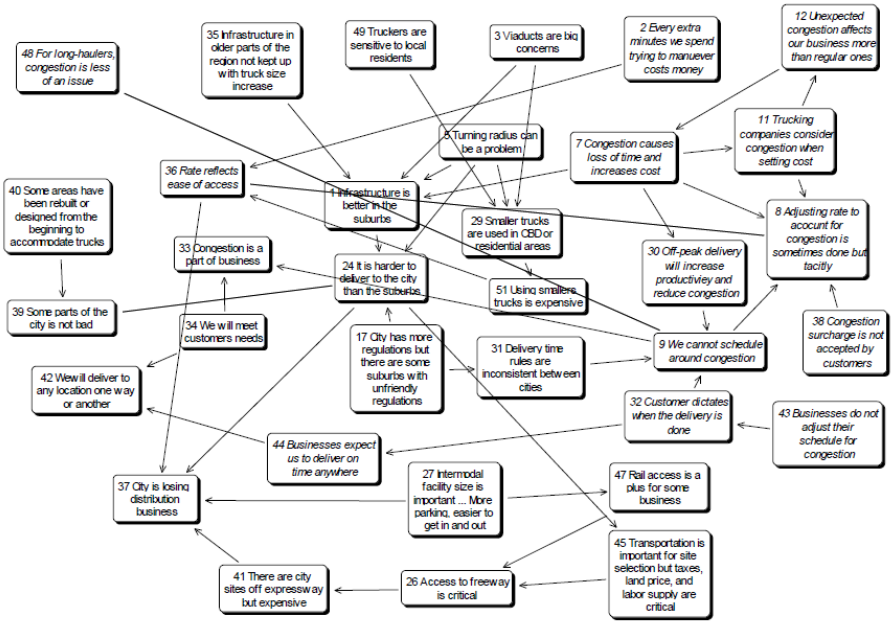

FIGURE 4 Merged cognitive map of carrier (i.e. Trucking firm) (Source [32])

The interview approach for collecting information is important to include real life stakeholders from the city logistics domain. Furthermore, to capture the perceptions and knowledge of city logistics modelers and experts, we compiled a text corpus for the city logistics domain. This corpus consist of reviews, city logistic models, articles describing the part(s) of city logistics domain, reports of projects aiming at improving city logistics activities and literature survey of city logistics related projects. Similar to the collection of quotes from interviews, details related to particular stakeholder are collected from the literature corpus to create individual cognitive maps. Finally, merged a cognitive map of the stakeholder is created following the procedure analogous to processing of interview data.

4.1 System component validation

System component validation checks if the all the important classes and their attributes are correctly presented in ontology. If both criteria are not satisfied, then the use of the ontology may lead to incorrect knowledge representation and application. The core of system component validation is to check first its presence and then its presentation. Component validation checks and confirms tacitly whether all-domain people understand and utilize the class in the same manner. The cognitive maps developed by using stakeholders' interviews give insight into the important concepts and relationships between them. A single phrase in the cognitive map consists of multiple concepts. For example, in phrase from point 30 (see FIGURE 4) we can identify concepts such as *'off-peak delivery'*, *'productivity'* and *'congestion'*. Similarly, in point 29, the phrase mentions '*small truck'* as one of the concepts, which is a type of vehicle. Thus, using phrases of cognitive maps we collect all the concepts to validate city logistics ontology. Next, we use the query function (provided in Protégé) to query for those classes to check their existence in city logistics ontology. It is possible that some concepts are present in the ontology but with slightly different naming convention. For example, there is no class with name *'vehicle'* is present but more specific *'Freight_vehicle'* class is present. However, we can safely assume that this class should be available under the class 'Resources'. Therefore we can query class '*Resource*' and can browse that specific class to check presence of vehicle class. The query function also allows you to see other connected classes such as subclass, superclass and variants of classes. Once the concept is found in the ontology, a further analysis is performed to check whether the concept has appropriate attributes. FIGURE 5 shows the framework for the content validation

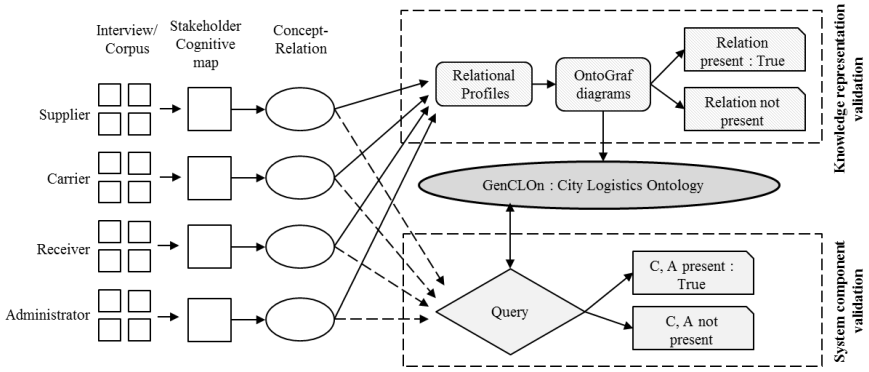

FIGURE 5 Schema for system component and knowledge representation validation

One important aspect of validation is a perspective of concept description as it can help deciding the querying location in ontology. For example, point 7 states that *'congestion causes loss of time and increases cost'*. In GenCLOn, there are 7 main classes and all sub-classes fall under these classes. One can assume here that congestion is a problem and should have the indicator. By querying the KPI class in GenCLOn, we found that congestion is represented as *'Congestion_indicator'* class which has property *'Avarage_delay'*. Thus the concept found in the cognitive map (i.e. Congestion) is present in GenCLOn as *'Congestion_indicator'* class and also represent the same effect in city logistics ontology. **Error! Reference source not found.** gives example ofthe cognitive mapntifthe carrierm cognitive map of carrier and on the right side of the list their respective class found in city logistics ontology.

TABLE 2 Comparing System Component of GenCLOn and Cognitive Map

Concept from Cognitive map	Class found in GenCLOn	Type
Road	Road	Class
Off peak delivery	Off_peak_time_window	Class
Congestion	Congestion_indicator	Class
Delivery Time	Delivery_time	Attribute
Customer	Receiver	Class
Regulation	Restriction	Class

4.2 Knowledge representation validation

Knowledge representation validation checks the structural integrity of the process and ensures that the entity - relationship is properly constructed from a knowledge representation point of view. Thus, the knowledge representation validation will confirm that the concept is related to other concepts in the real world the way it is presented in ontology. Importantly, this validity is a stringent measure to build confidence in using ontology as knowledge for further use. Validating the knowledge relationship among the different classes is much more sophisticated compared to the system component validation. The reason is that the domain ontology maps a wide variety of classes that have multiple relationships with other classes. With multiple connections the task of validating becomes increasingly difficult. Imagine that there are only 50 classes in the ontology and each class has just one relation with other class then the total relations will be combinatorial high (2450 relations). This is true especially in case of GenCLOn as it represents the city logistics domain at a generic level and thus it maps a wide variety of classes and their relations. Even the visual representation of all the classes and their relationship presents quite a convoluted structure. FIGURE 6 shows the UML-diagram generated using plug-in called OWLGrEdv for GenCLOn where each box in FIGURE 6is a class and a line connecting two boxes is the relation between two classes. We can see that validating the entire relationship structure of GenCLOn will be extremely difficult considering multiple connections.

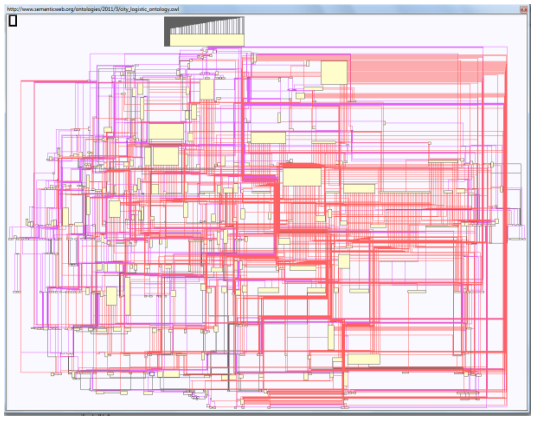

FIGURE 6 UML-diagram generated using OWLGrEd for GenCLOn

Fortunately, OntoGraf, a plug-in for Protégé, allows interactively navigating through different classes and object properties of the ontology. It permits to explore the neighbourhood of specific classes and its relationship(s) with other classes. Thus, for example, if we want to know how road pricing is connected to other classes of city logistics ontology, we can explore the neighbourhood of *'Road_pricing'* class of city logistics ontology. From FIGURE 7 we can see that *'Road_pricing'* is connected with class *'Transiting'* by object property *'intervene_in'*. Thus, road pricing affects the transiting activity in city logistic ontology.

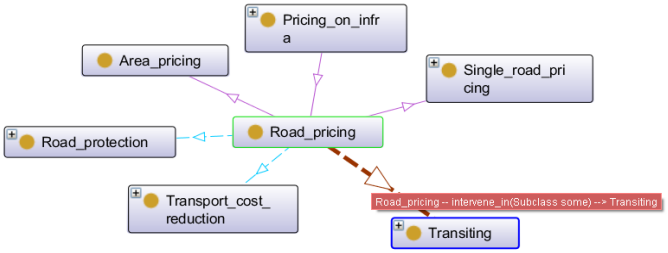

FIGURE 7 Example of relational diagram of OntoGraf

Similar to the system component validation framework, we use the cognitive maps to get the relation between different concepts of city logistics domain, which in turn will be used to create relational profiles of different concepts. Next, using OntoGraf, we explore the ontology to find these relational profiles to validate

knowledge relationships. The entire schema for knowledge representation validation is presented in FIGURE 5. Following statements form an explanation of some of these relation profile examples. Following the merged cognitive map of carriers (refer FIGURE 4) we can see that,

- Point 7 and 30 shows that off-peak delivery is one of the solutions to loss due to congestion.
- Relations between point 34 and 42 states that truckers are willing to make deliveries that customer expect and to stay in the business, it is necessary to be able to do so.
- It is difficult to make deliveries to the destinations in the city boundary (point 25). It is explained by the fact that the unfriendly regulations in city centre affect transiting activity (point 17). At the same time inconsistent time windows for different cities makes routing and scheduling inefficient (point 31).

In TABLE 3 we can see the list of some of the important concept-relations found from the merged cognitive map of carriers. On the right of the list we can see the axiom/s found in city logistics ontology that represent the similar relationship. It is to be noted that statements in the cognitive map are derived from verbatim. A single statement of cognitive map can be a combination of multiple axioms and may take complicated form in ontological representation. For example, a statement "*Carrier delivers goods to receiver at any location*" can be folded down into:

- Carrier delivers goods
- Receiver orders goods
- Goods are delivered to the location
- Goods are delivered at some time

If we find these multiple axioms in GenCLOn, then we can safely assume that relation profile from cognitive map is present in GenCLOn.

TABLE 3 Comparison of Relational Profile and Axiom

Relation profile from Cognitive map	Axiom found in GenCLOn
Carrier has to deliver within time-window	intervene_in some Ordering_transport_service
Time-window influence the delivery of goods (31,32)	intervene_in some Transitting
Measures influence logistics quality (9,17,31)	Permission on infra may achieve some LQ
Carrier delivers goods to receiver at any location (34,42)	Transitting_is_activity_of_carrier, ordering_goods is_activity_of some Receiver, transitting has_destination some base, transitting has_start_time and has_end_time
Infrastructure is important for goods delivery (1,24)	Transitting performed_at road, permission_on_infra may_achieve some Logistics_quality

5. QUANTITATIVE EVALUATION

Different approaches available in the literature for ontology evaluation. The framework proposed by Gangemi et al. [19] and Tartir et al. [20] are used to evaluate the ontology quantitatively. The parameters evaluated here are depth, breath, relationship richness, inheritance richness and attribute richness. Results of GenCLOn evaluation are presented in the TABLE 4.

- Depth: Depth of ontology is a property related to the cardinality of the paths of ontology tree. It describes at what detail level the main concepts are explained (i.e. Is-a relationships).
- Breadth: Breadth of an ontology is a property related to the cardinality of the levels of ontology tree and it describes at what level the relevant concepts of the domain are covered (i.e. Coverage of domain).

- Relationship Richness (RR): It describes the diversity of the types of relations in the ontology and is represented as the percentage of the non-inheritance relationships (e.g. non-IsA) between classes compared to all the possible connections that include inheritance and non-inheritance relationships.
- Inheritance Richness (IR): It describes the generic (i.e. Shallow) or specific (i.e. Deep) nature of ontology according to high or low value of IR respectively. IR is calculated as the average number of subclasses per class.
- Attribute Richness (AR): AR is describes at what level (on an average) each class is described (e.g. A truck has engines versus a truck has an engine, tires, driver cabin etc.). AR is computed as the average number of attributes (slots) per class.

TABLE 4 Quantitative Evaluation of GenCLOn

A	Value -A	B	Value –B	Evaluation Parameter	Formula	Value
Cardinality of paths	1672	Number of paths	312	Average Depth	A/B	5.36
Cardinality of levels	443	Number of levels	8	Average Breadth	A/B	55.36
Non-IsA relationships	49	IsA relationship	443	Relationship richness (RR)	A/(A+B)	0.099
IsA relationships	443	nonLeaf node	123	Inheritance richness (IR)	A/B	3.6
Total number of attributes	109	IsA relationship	443	Attribute richness (AR)	A/B	0.246

6. RESULTS AND DISCUSSION

GenCLOn - ontology for city logistics domain - is developed with the aim to represent city logistics domain at generic level. Dimensional parameters assessed in the quantitative evaluation process bolster this claim. In this evaluation process of GenCLOn we evaluated various ontological parameters. These parameter values indicate that GenCLOn contains wide (breadth) variety of concepts from city logistics; however these concepts are not expanded in very much detail (depth). Furthermore, high IR indicates the shallow nature of the ontology value of whereas low AR indicates that class in GenCLOn has few attribute that belongs to the specific class but it contains more attributes that belong to many different classes. Similarly, low value of RR indicates that GenCLOn classes are connected with each other through a few basic but fundamental relationships. Though the qualitative evaluation suggests the scope and size of ontology, it does not reveal much in case if there is no reference ontology (or ontology like structure) to compare with. In such a situation, the dimensional parameters obtained from the evaluation do not indicate how “good” or “bad” ontology is. At the most these numbers give indication about a generic (shallow) or a case specific (deep) nature of the ontology but certainly do consider the quality of the ontology. Therefore, the ontology must be assessed for its quality before using it for any further use.

For the qualitative validation we have performed two types of test 1) System component validation 2) Knowledge representation validation. In the system component validation we have compared the list of concepts obtained from the cognitive map with classes available in GenCLOn. Similarly, in knowledge representation validation we have compared the relation profiles with axioms found in GenCLOn. It should be noted that we are not validating representation of only stakeholders in GenCLOn; instead this validation is for entire city logistics ontology. Thus, while validating GenCLOn using information from the cognitive map of carrier we are validating the city logistics ontology classes and its relationship that belongs to or connected to the carrier. Result from TABLE 5 asserts that 24 concepts, out of 30 identified from the cognitive map of the carrier stakeholder, are present in GenCLOn in form of ontological class. For knowledge representation validation, we can conclude that 20 relation profiles, out of 24 identified from the cognitive map of the carrier stakeholder, exist in GenCLOn. Result for other stakeholders can be interpreted in a similar manner.

TABLE 5 Qualitative Validation of GenCLOn

	System component validation			Knowledge representation validation		
	Cognitive Map	GenCLOn	%	Cognitive Map	GenCLOn	%
Carrier	30	24	80,00%	24	20	83,33%
Receiver	25	21	84,00%	23	16	69,57%
Administrator	28	22	78,57%	24	19	79,17%
Supplier	23	19	82,61%	17	12	70,59%
Total	106	86	81,13%	88	67	76,14%
Standard deviation			2,13%			5,79%

Analysis of the results shows that overall 81% of concepts and 76% of relationships identified from the cognitive maps are present in GenCLOn. At individual stakeholder level, detail related to administrator and carrier is slightly well covered for both, component and knowledge, representation levels. Nonetheless, the standard deviation for system component and knowledge representation shows that all four stakeholder types are representing the ontology mostly at equal level. Conclusively, the results of qualitative validation indicate that the city logistics ontology covers concepts and relationships of main stakeholders at a satisfactory level.

The missing concepts and relationships in the GenCLOn can be majorly attributed to the generic level of ontology. For example, specific such as "*congestion charges are not accepted by customers*" (FIGURE 4- point 10) is not found in GenCLOn and can be included while using the ontology for specific purpose (e.g. modeling city logistics activity for particular city). However, some generic relationships such as "*Rate reflects ease of access*" (FIGURE 4 - point 36) is found omitted. Such relationships are important and commonly prevail in real world practice. This indicates that GenCLOn still needs to include more classes, attributes and relationship. Nonetheless, ontology development is an on-going process and with other stakeholders from city logistics domain starts using and editing, it shall get richer in quantity and quality.

7. CONCLUSION

Ontology is a powerful way to express domain knowledge in a structured way. It is even more powerful when it can be re-used so it should be generic in nature for it can be modified by its user as per need. To utilize this powerful structural information model one need to have confidence that classes and relationships presented are accurately representing the real life practices. Confidence in using ontology can be built by evaluating and validating the ontology for its scope, structure and knowledge representation.

Anand et al. [13] introduced a generic ontology (GenCLOn) aimed to systematically as well comprehensively specify the domain of city logistics in terms of the classes and relations among each other. Extensive information and knowledge has been collected from relevant literatures as the theoretical foundation of the city logistics ontology. GenCLOn can be used as a flexible modeling framework to develop a variety of urban freight models concerning various issues of the domain. In order to use GenCLOn as a generic platform, it must be validated to assure its credibility. In this paper, quantitative evaluation and qualitative validation of generic city logistics ontology is performed. Quantitative evaluation estimates ontology parameters such as depth, breadth, inheritance richness, relationship richness and attribute richness. These parameters indicate that GenCLOn is shallow ontology and covers a wide scope of city logistics domain. For the qualitative validation we have used knowledge of city logistics domain experts (e.g. Real life stakeholders, modelers, etc.) to generate cognitive maps that represent numerous concepts identified by the stakeholders and relationship among these concepts. Information from these maps is used as reference to validate the presence of classes and its knowledge representation in GenCLOn. Qualitative validation of GenCLOn indicates that overall 81% of classes and 76% relationships existing in cognitive maps are present in GenCLOn. The results conclude that GenCLOn represents city logistics domain at acceptable level.

Nonetheless, the qualitative validation approach presented here has its limitations. The approach is time consuming since it involves collection of data, classification and finally exploring ontological properties manually.

One reason for this is the query technique available in the Protégé is not sophisticated enough to eliminate manual work. Additional techniques (e.g. plug-in) can be developed to explore the ontological properties using more sophisticated queries. However, we strongly opine that the domain expert must actively be involved in the validation to check the quality of the ontology.

The analysis of result asserts that there are still some gaps found in terms of inclusion of the common concepts of city logistics domain. Nonetheless, majority of missing classes and relations in GenCLOn are due to the fact that many points assembled in cognitive map are very specific to situation while GenCLOn is built as a generic ontology. GenCLOn is edited to include common concepts found missing during validation. Nonetheless, to create a complete generic ontology is more a direction than goal since as the domain evolves new concepts and new relationships becomes contemporary and old may become obsolete. Furthermore, we do not claim GenCLOn is fully representing the city logistics domain as the validation is done by only part of people who could use the ontology. However, with other city logistics stakeholders and experts start using and adding more generic classes will make GenCLOn more powerful in terms of content and details.

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Note

[i] Protégé is the ontology building software used for GenCLOn. Protégé is a free, open source ontology editor and knowledge base framework (http://protege.stanford.edu/)

[ii] text corpus is a large and structured set of texts electronically stored and processed

[iii] The interviews and analysis were done as a part of CFIRE project (Kawamura and Sriraj 2012). For this research, final outcome – the merged cognitive maps of stakeholders - were used

[iv] For more information go to : www.banxia.com/dexplore/

[v] OWLGrEd is a UML style graphical ontology editor for OWL (http://owlgred.lumii.lv/)