Semantic Web-based Approach for Economic Performance Indicators Based on Global Reporting Initiative (GRI) G4

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Abstract

The aim of this research is to fill the gap by developing ontology for Economic Performance Indicators based on the latest guidelines (GRI G4). The chief research question is: What is the best approach to developing an Ontological Model for the knowledge domain Economic Performance Indicators? The main objective of this research is to develop ontology for Economic Performance Indicators based on GRI G4. The methodology used in this research is a merger of several existing methodologies. The methodology adopted as a result of this applied research includes four phases: specification, conceptualization, formalization, and implementation. A requirement specification for Economic Performance Indicators ontology was created by identifying the intended scope and purpose of scenarios for each of the phases of ontology. The classes, properties, and relationships for Economic Performance Indicators based on GRI G4 were also identified. A conceptual model was formalized using UML. The implemented ontology is based on OWL language. And protégé tool to encode competency questions and subsequent SPARQL Queries. The resulting ontology was tested using instances data collected for four Australian companies listed on the Australian Securities Exchange (ASX), namely: Origin Energy Limited (ORG), Amcor Limited (AMC), Transurban Group (TCL), and BHP Billiton (BHP).

As mentioned, the ontology of content was evaluated to meet the criteria of completeness, consistency, and conciseness, and SPARQL Queries' answers were obtained establishing its utility and rationality. As a consequence, the developed ontology for Economic Performance Indicators was validated. There is clear evidence that few Australian companies have adopted either GRI or other initiatives and standards for reporting and that this position needs to be addressed. The ontology as proposed in this research could be applied to correct this concern. The four companies used to test the ontology are from different industries and sub-industry classifications and, as a result, the findings are not generalizable outside of these industries. However, the main finding of this research demonstrates that the majority of instances contained within the GRI4 Guidelines was validated suggesting that the ontology framework is effective as a standardized form of reporting.

Keywords: Economic Performance Indicators, GRI Sustainability Reporting Guidelines G4, Ontology, Stakeholders

1. Introduction

Reporting by corporations on economic, environmental and social dimensions, referred to as "Sustainability", is seen as a step towards a sustainable global economy that combines long-term profitability with social justice and environmental protection [1]. The history of sustainability reporting began at the beginning of the 20th century with employee reporting, social reporting, environmental reporting, triple bottom line reporting and sustainability reporting [2]. Some authors contend that there is currently no suitable definition for sustainability reporting [3]. Kolk and Herzig and Schaltegger claim that since the mid-1990s the number of companies reporting on sustainability has increased substantially and new forms of corporate sustainability reporting are being developed, resulting in reporting contents and formats being subject to change from year to year [4].

Several theoretical approaches that explain the motivation for sustainability reporting include: accountability theory, legitimacy theory, and political economy and stakeholder theory [5] [2]. There are several national and international bodies that promote sustainability reporting and provide guidance; these include: Global Reporting Initiative (GRI), the International Standards Organization (ISO), the World Business Council for Sustainable Development (WBCSD), AccountAbility, and the Sustainability Integrated Guidelines for Management (SIGMA) Project [2]. Christofi, Christofi, and Sisaye argued that it was important to have standardized sustainability reporting by corporations [6]. The GRI guidelines are generally accepted as "best practice" reporting and are widely used by organizations around the world as the basis for their environmental

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and social reporting [5]. The guidelines provide guidance on how to write and what to write and present principles that guide report content and report quality [7]. An ontology methodology plays an important role in the design of information systems [8]. It provides a formal specification for the concepts within a domain and the relationship between those concepts [9]. There are many existing definitions of ontology, arguments about what the definition of ontology is or ought to be [10], and debates on what is the best definition [11]. Studer, Benjamins, and Fensel define ontology as a "formal, explicit specification of a shared conceptualisation" [12]. This is one of the most comprehensive definitions from those available in the literature [13]. A new information system for sustainability reporting is required as it has become an important source of monetary and non-monetary, quantitative and qualitative information [14]. There are several studies that develop ontologies in different aspects of accounting but little ontological research exists within the accounting domain. For example, Chou, Vassar, and Lin developed an ontology concept model for profit and loss accounts and implemented it for Microsoft's NET software [15]. Teller established ontology of accounting notions to represent the entire domain knowledge based on International Financial Reporting Standards (IFRS)[16]. Chou and Chi proposed an ontological model comprising Event, Principle and Account (EPA) for accounting principles [17]. Smeureanu et al. developed ontology for Corporate Social Responsibility based on the guidelines proposed by the 'ISO 26000 Standard for Social Responsibility' [18]. Weigand and Elsas introduced a model-based auditing approach as a design artefact that includes a corresponding business modelling language [19]. Weigand, Johannesson, and Bergholtz introduced a service accounting model based on a formal ontology approach and propose some adaptations to the Resource-Event Agent (REA) model [20]. From the literature review, ontology for economic performance indicators based on GRI G4 does not exist. Thus, the aim of this research is to fill the gap by developing an ontology for economic performance indicators based on GRI G4. The Economic performance indicators focus on the financial organization's performance and impacts on the stakeholders by clarifying the flow of capital among them; it does not focus on the financial status of the organization. In addition, they focuses on economic systems at local, national, and global levels [21].

In this research, the ontologies for Economic Performance Indicators based on the Global Reporting Initiative guidelines (GRI G4) are presented. This paper is structured in the following manner. In Section 2, Research objective is described and then followed by Materials and methods in Section 3. In Section 4, Results are presented. In Section 5, ontology evaluation is described and followed by discussion in Section 6. Section 7 is a conclusion and future work.

2. Research objective

The main objective of this research is to develop ontology for Economic Performance Indicators based on GRI G4, and this will be achieved through the following sub-objectives:

- Identifying the classes, data properties, object properties for Economic Performance Indicators based on GRI G4.
- Transforming a conceptual model into a formalized model by using the Unified Modelling Language (UML) to represent ontology for Economic Performance Indicators.
- Implementing ontology by using OWL language and Protégé tools to encode the competency questions. Subsequent SPARQL Queries will be created after implementing all classes, data properties, object properties identified within GRI G4 for Economic Performance Indicators. Data instances will be collected online for four Australian companies listed with the ASX, including Origin Energy Limited, BHP Billiton, Amcor Limited, and Transurban Group.
- Evaluating the developed ontology for Economic Performance Indicators by a process of verification and validation. Schema Metrics and Knowledgebase Metrics will be used to verify the ontology. To validate the ontology, the answers to SPARQL Queries are extracted and the ontology for an Economic Performance Indicators is validated.

3. Materials and methods

3.1 Background

3.1.1 Ontology

There are many existing definitions of ontology, arguments about what the definition of ontology is or ought to be [10], and debates regarding the best definition [11]. Studer, Benjamins, and Fensel definition of ontology as "a formal, explicit specification of a shared conceptualisation" is one of the most comprehensive definitions available [12]. They define the terms: Explicit, Formal, and Shared as follows:

- Explicit: all elements of ontology are obviously defined.
- Formal: refers to the fact that the ontology should be machine readable, which excludes natural language.
- Shared: refers to consensual knowledge agreed on to be accepted by a group of people.

The definition introduced by Studer, Benjamins, and Fensel [12] is one of the most comprehensive forms available in the literature [13]. This research is based on this definition. The main uses of ontology are to share common understanding of terms for specific domain in the real world between people and computers, and to reuse it; if it is not reused, it provides limited benefits.

It should be noted that Ontological Engineering (OE) refers to any activities involved in the ontology building process and also include lifecycle, principles and methodologies used for its construction [13]. The main methodologies and methods used to build ontologies from scratch. These methodologies are related to its lifecycle. The lifecycle as a development process consists of different activities to design and evaluate ontologies. Until the mid-1990s this process was an “art rather an engineering activity” [13].

Scholars agree that concepts, relations, instances and axioms are the main components or basic and typical elements of ontology. Because of different ontology languages, the exact specification of these elements may vary according to the underlying knowledge model [22] [23]. Concepts are also known as classes of objects. Classes have been defined as “abstract or concrete, elementary or composite, real or fictitious”; in short, a concept can refer to just about anything including speech, actions or activities, strategies or plans, or cognitive processes, to name a few [23]. Relations represent a “type of association between concepts of the domain” [13]. Binary relationships refer to the relational links involving two concepts; roles describe binary relations between concepts; inverse relationships refer to binary relation links between two concepts in the opposite direction. There are three types of relationships: association relationship, inheritance relationship, and composition relationship are used in this reseach. Properties are also known as slots or roles or attributes of classes. Properties represent relationships that describe various features and attributes of the concept [24]. Object properties and datatype properties are two main types of properties. Object properties are relationships between two individuals and they use “vocabulary” and “semantic” to describe this relationship. Instances are also known as individuals. Instances represent “real-world individuals” or are used to represent elements or individuals in ontology [25]. Horridge stated that individuals, are also known as instances or “objects” in the interested domain. Individuals can be defined as being “instances of classes”[26]. Axioms refer to constraints used on values for classes or instances; the properties of relations are types of axioms and they include more general rules [24] [27].

3.1.2 Global Reporting Initiative

A comprehensive Sustainability Reporting Framework that is the most widely used around the world has been established and improved by the Global Reporting Initiative or GRI. The GRI is a leading organization in the sustainability field. The GRI Sustainability Report is a report issued by organizations (private, public, or non-profit) that reports their economic, environmental and social impacts, and the performance of their activities, products and services. Such reporting takes a Triple Bottom Line (TBL) approach. GRI considers an organization’s impacts and performance not only on in terms of its local economy but also in terms of its sustainable global impact. Many organizations, regardless of their type, size, sector or location, voluntarily use the GRI Framework to measure and report on their performance according to specific principles and indicators. This framework is a reporting system which includes the Reporting Guidelines, “the core document” or the “cornerstone” of this framework providing guidance on how organizations can disclose their sustainability performance and increase accountability [28] in addition to Sector Guidance and other resources. G4 is the latest version of GRI’s Sustainability Reporting Guidelines released in May 2013 after several previous versions of the Guidelines: the first version in 2000; the second generation (G2) in 2002; and the third generation (G3) in 2006. In 2011, the GRI updated and published the G3.1. [29]. Global Reporting Initiative, the Global Reporting Initiative logo, Sustainability Reporting Guidelines, and GRI are trademarks of the Global Reporting Initiative [30]-[33]. GRI includes sustainability reporting that principally applies to environmental issues as well as economic and social impacts. However, in Australia, GRI guidelines are for voluntary use by business firms for reporting on the three aforementioned dimensions of their activities, products, and services [32].

3.2 Conceptual framework

The scenario is illustrated in Figure 1. In a real-world use scenario of Sustainability Reporting, small, medium or large enterprises engage in this reporting process by following Sustainability Reporting Guidelines. Because of a lack of a standard application for the report generation, ontology is used to solve this problem by generating an Ontological Model for Sustainability Reporting including Economic Performance Indicators. This enables organizational sharing, communicating and reusing this Model for Economic Performance Indicators. The components of ontology are elicited from Sustainability Report that based on GRI G4 and they involved in ontology development process and resulted ontological model. The Ontology Development Process Model includes four phases: specification, conceptualization, formalization, and implementation [24] [34] [35] [36]. Through these steps, the purpose and the scope of the ontology are defined, the conceptual model is identified and formalized, and the formalized model is encoded. Then, to verify and validate the model, an outcome of this process is to create and assess an ontological model for Economic Performance Indicators based on GRI G4.

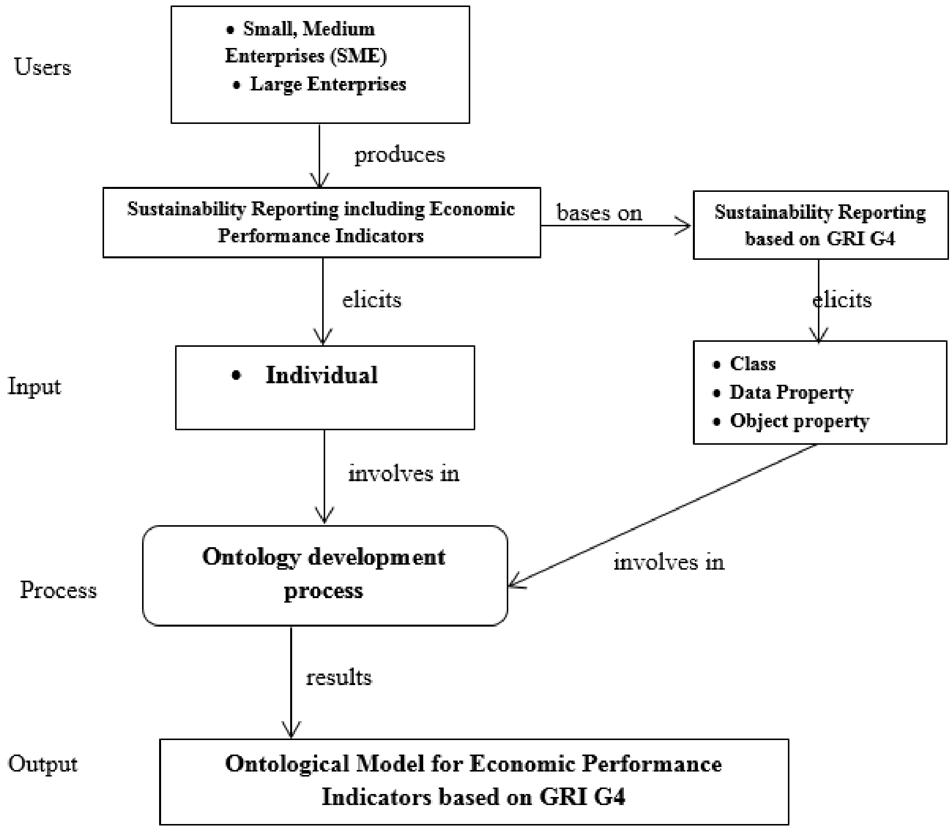

Figure 1 Conceptual framework

Figure 2 shows the contained tasks in each phase. In the specification phase, the motivation scenarios and competency questions need to be described. In the conceptualization phase, the conceptual models need to be defined. In the formalization phase, the conceptual models are required to be formalized. In the implementation phase, the ontology will be built by encoding [24] [34]-[38]. The following subsections will explain each phase.

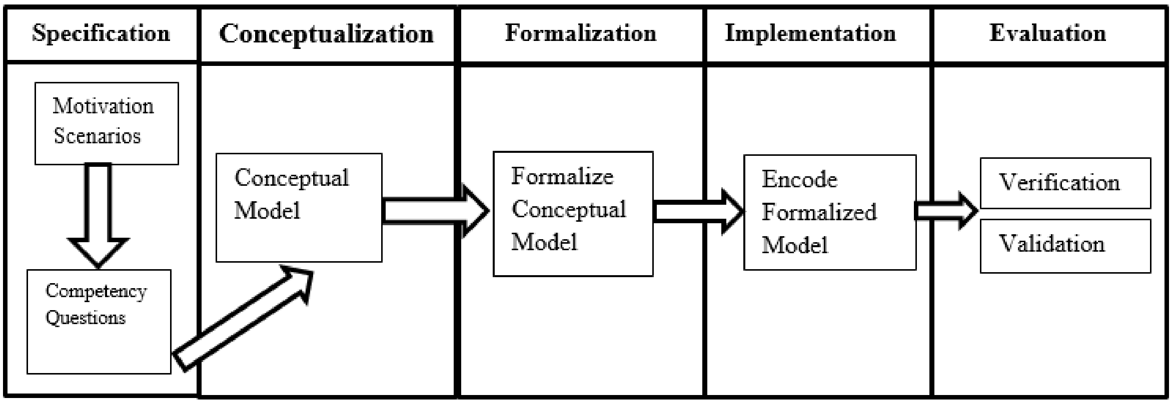

Figure 2 Tasks in each phase of the Economic Performance Indicator ontology development

3.2.1 Specification phase

The first development phase of ontology is the specification phase; this activity is ontology description (usually in natural language). The aim of this phase is to 'state why the ontology is being built, what is intended uses are, who the users are, and which requirements the ontology should fulfil' [39]. The first requirement is to describe the motivating scenario and present solutions to the problems arising in the scenario [40] as stated above. Uschold and Gruninger [36] and Uschold [37] identify the purpose and scope of ontology. Fernández-López, Gómez- Pérez, and Juristo [41] and Lopez et al. [35] show a brief example of ontology requirements specification document in the chemicals domain. The following information should be included in the specification phase. A detailed ontology requirements specification document (ORSD) is required in this phase as proposed by (Uschold 1996) [37]. The specifications of the Sustainability Reporting ontology are defined as follows:

Domain: Sustainability Reporting based on GRI Guidelines G4.

Purpose: Developing a Sustainability Reporting ontology-based knowledge base for software to automatically create GRI reports for the following reasons:

1) Enabling knowledge sharing among people, organizations, and software systems [24] [36] [42] [43] [44].

2) Reusing knowledge. The proposed ontology can be reused by organizations and can also be updated to adapt to new generations of GRI.

End users: Engaged stakeholder groups, for example, civil society, customers, employees, other workers and their trade unions, local communities, shareholders and providers of capital, and suppliers.

Level of formality of the implemented ontology: Semi-formal. This is the level of formality that will be used to codify the terms and their meanings in a language somewhere between natural language and a rigorous formal language [41]. Uschold and Gruninger [36] classify the level of formality into: highly informal, semi-informal, semi-formal or rigorously formal ontologies.

Scope: All components of Economic Performance Indicators defined according to GRI Guidelines G4.

Sources of knowledge:

1) Interviews with the experts in GRI Sustainability Reporting Guidelines because the ontologists and the GRI reporters are different jobs. However, in this research the ontology is used as a tool to design Economic Performance Indicators according to GRI G4. So, the reporters are the professionals experienced in the content of GRI reporting and the ontologists will structure the information of GRI G4 into: classes, properties, relationships, axioms and individual. Then Protégé is used to implement this ontology development process.

2) GRI Sustainability Reporting Guidelines G4: Reporting Principles and Standard Disclosures [21] and GRI Sustainability Reporting Guidelines G4: Implementation Manual [33].

The second requirement is to create 'competency questions' 'CQ' as the technique for establishing the ontology requirements [40]. Competency questions are queries written in natural language and the ontology to be built should be able to answer all questions raised by stakeholders and can be used to verify the correctness of the ontology with the ontology requirements identified (scope of the ontology) [39]. The main concepts and their properties, relations and formal axioms of the ontology are used to extract these questions and answers [45]. In this research, competency questions are created for data instances found in four Australian companies to implement ontology as can be seen two examples in this research.

3.2.2 Conceptualizations phase

The second step in the ontology lifecycle is conceptualization. The output of the first phase will be transformed into a conceptual model by means of conceptualization [46]. The aim of this activity is to structure the domain knowledge in a conceptual model in terms of the domain vocabulary identified in the ontology specification activity [41]. Weber [47] defines 'Conceptual modelling' as an 'activity undertaken during information systems development to build a representation of selected semantics about some real-world domain'. According to Noy and McGuinness [24], the requirements for the conceptualization phase are:

1. Identify terminologies for Economic Performance Indicators in the GRI G4 Guidelines; and
2. Identify the classes, their properties, and the relationships between them as defined in GRI G4 Guidelines and create instances from actual sustainability report.

3.2.3 Formalization phase

The formalization phase is the core of an ontology development process. It involves transforming a conceptual model into a formalized model or semi-computable model [22] [46] [25]. Colomb [48] explained that a formal ontology is an "advanced knowledge representation system". Guebitz, Schnedl, and Khinast [49] stated that creating a neutral ontology formulation, independent of implementation languages is the goal of this phase. There are different levels of the transformative process in relation to the conceptual model ranging from semi-formal to rigorously formal. The greater the formality, the greater is the amount of automation required to support ontology [37]. It depends on the implementation requirements of the ontology. Guebitz, Schnedl, and Khinast [49] presented the object-oriented modelling language as an appropriate formalism to represent ontology by using the Unified Modelling Language (UML). Thus, for the development of the sustainability report ontology, the formalization requires a notation system to formalize the sustainability report ontology conceptual model.

To create a formal ontology, all main structural components and their constraints must be explicitly described [49]. The object oriented modelling language can be used for ontology modelling. Cranefield and Purvis [50] suggested that UML as a static modelling notation can be used to model the "formal semantics" of ontologies.

In this research, three types of relationships are identified between classes, which are: Association relationship, Inheritance relationship, and Composition relationship.

3.2.4 Implementation phase

This activity builds computable models in a formal language or representation of conceptual models by using an ontology language [46]. To implement computable models, there are tools used in different ontology languages as ontology editors. There are several languages: XML, RDF, OIL, DAML+OIL, OWL, CARIN, FLogic, Jess, and Prolog [25]. The requirements of the implementation phase are:

1. A formal language that can be used to encode the ontology; and
2. A tool that supports the ontology development activities.

In this research, Web Ontology Language OWL is used as a standard and broadly acceptable ontology language, which provides classes, data properties, object properties and individuals [51]. Protégé Onto Edit (protégé.standford.edu) is used as a tool to represent ontology in a machine readable format. Ontologies are stored as Semantic Web documents (W3C OWL Working Group)[1]. The full ontology coding is available at http://www.semanticweb.org/14174782/ontologies/2014/6/csr#.

3.2.5 Evaluation phase

Evaluation is a 'technical judgment of the content of the ontology with respect to a frame of which can be requirements specifications, competency questions or the real world during each phase and between phases of their lifecycle to guarantee to end users the consistency, completeness and conciseness of the ontologies definitions, documentations, and software' [52] – [55]. Ontology evaluation includes:

Ontology verification and
Ontology validation

[1] http://www.w3.org/TR/2012/REC-ow12-overview-20121211

In this research, all classes, data properties, object properties identified for Economic Performance Indicators according to GRI G4. All instances data as identified from actual sustainability report for 4 Australian companies. Most definitions of classes can be found in [33].

4. Results and discussion

There are four Aspects as classes within the 'Economic Category' class – the 'Economic Performance Aspect' class, the 'Market Presence Aspect' class, the 'Indirect Economic Impact Aspect' class, and the 'Procurement Practice Aspect' class. The following subsection explains the ontology for each Aspect class.

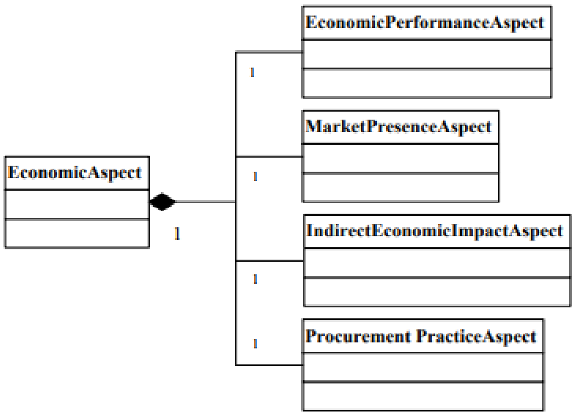

Figure 3 Ontology formalization for 'Economic Aspect' class

4.1 Ontology for Economic Aspect class

This is the first aspect which addresses the "direct value generated" [3] of the organization's activities and immediate consequences of monetary flows to stakeholders. There is a generic DMA and four indicators related to this indicator class as shown in Figure 4. In the following subsections, the ontologies for the four indicators of the class 'Economic Performance Aspect' are presented.

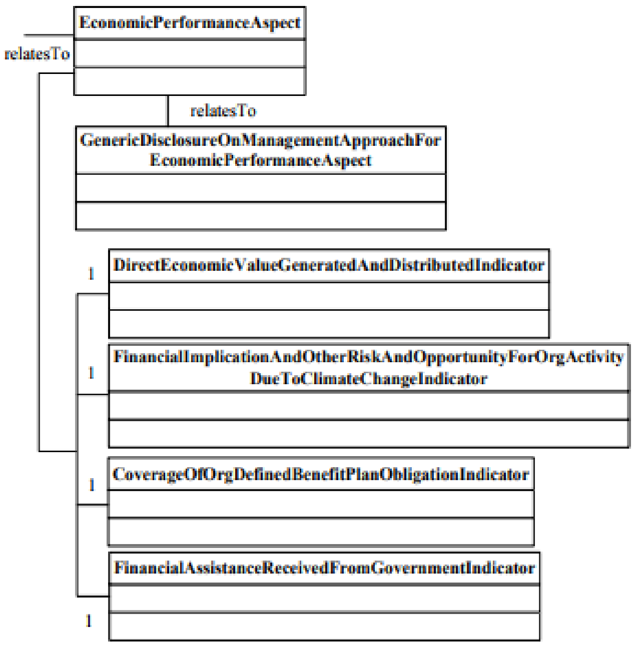

Figure 4 Ontology formalization for 'Economic Performance Aspect' class

4.1.1 Ontology for 'Direct Economic Value Generated and Distributed Indicator' class/ EC1

This indicator class concerns the economic value generated and distributed (EVG&D) (Figure 5). The concept that is related to this indicator is 'Economic Value Retained' class. The class 'Organization' retains

'Economic Value Retained'. This class is obtained from the 'Direct Economic Value Generated' class and 'Economic Value Distributed' class. The class 'Organization' generates the 'Direct Economic Value Generated' class. In addition, the class 'Organization' distributes 'Economic Value Distributed' class. The class 'Direct Economic Value Generated' is generated from 'Revenue' class. The class 'Economic Value Distributed' is distributed to: 'Operation Cost' class; 'Employee Wage and Benefit' class; 'Payment To providers of Capital' class; 'Payment To Government' class; and 'Community Investment' class [33].

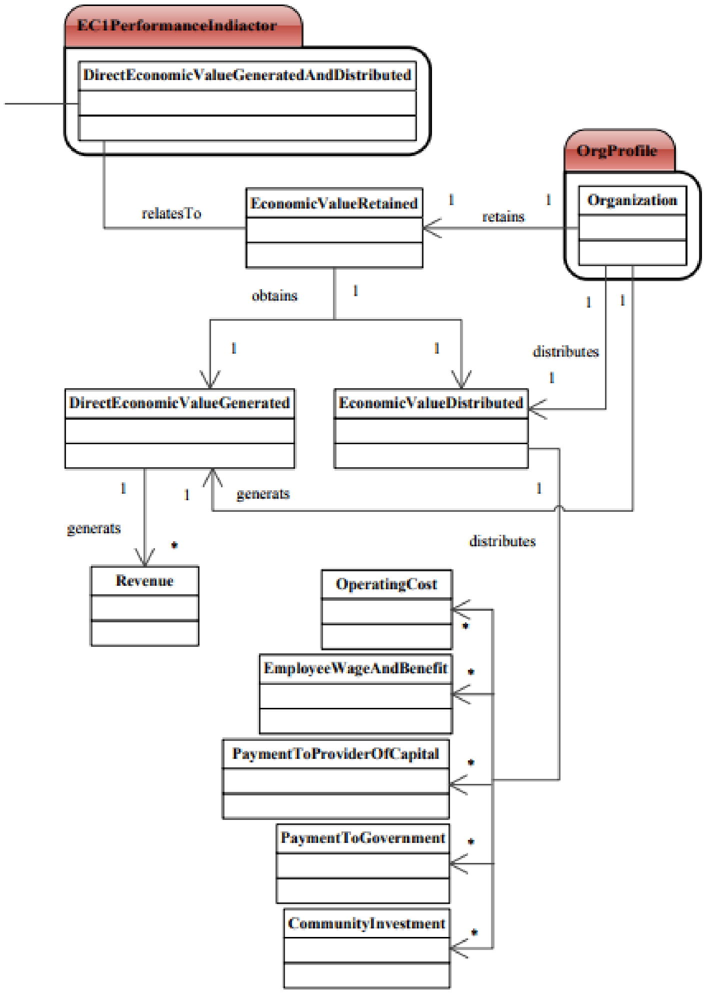

Figure 5 Ontology formalization for 'Direct Economic Value Generated And Distributed Indicator' class

4.1.2 Ontology for 'Financial Implication And Other Risk And Opportunity For Org Activity Due To Climate Change Indicator' class/ EC2

This indicator centres on how climate change affects economic performance. It is required to identify 'Climate Change Risk' class and 'Climate Change Opportunity' class that posed by 'Climate Change' class. The class 'Climate Change Risk' categorizes risk according to 'Physical Risk' class, 'Regular Risk' class, and 'Other Risk' class. The class 'Climate Change Opportunity' categorizes opportunity according to 'Physical Opportunity' class, 'Regular Opportunity' class and 'Other Opportunity' class [33].

4.1.3 Ontology for 'Coverage Of Org Defined Benefit Plan Obligation Indicator' class/ EC3

This indicator class focuses on structure of retirement plan offered to employee. The concept that is related to this indicator is 'Structure Of Retirement Plan Offered To Employee' class whether is based on 'Defined Benefit Plan' class; 'Defined Contribution Plan' class; and 'Other Type Of Retirement Benefit' class. For class 'Defined Benefit Plan' whether is funded by 'Org General Resource' class or by the class 'Separate Fund' which is used to pay to 'Pension Liability' class which is kind of 'Liability' class. For class 'Defined Contribution Plan' is required to report 'Percentage Of Salary' class and 'Level Of Participation' class. The

'Percentage Of Salary' class which is contributed by employee and employer as 'Contribution Of Employee' class and 'Contribution Of Employer' class. For the class 'Other Type Of Retirement Benefit' is specified where not fully covered by general resource and separate fund. In addition, the class 'Jurisdiction Regarding Calculation Plan Coverage' is required to identify calculations used to determine plan coverage [33].

4.1.4 Ontology for 'Financial Assistance Received From Government Indicator' class/ EC4

This indicator concerns the financial support received from government. The 'Financial Assistance' class is related to this indicator. The class 'Organization' receives 'Financial Assistance' class. It is received from the class 'Government' which is part of 'Stakeholder Group Engaged By Org' class. It is received in 'Reporting Period' class. The data properties can be found in [33].

4.2 Ontology for 'Market Presence Aspect' class

This is the second Aspect that focusses on "entry-level wage by gender compared to local minimum wage" [3]. This Aspect comprises generic DMA and two indicators as following.

4.2.1 Ontology for 'Ratio Of Standard Entry Level Wage By Gender Compared To Local Minimum Wage At Significant Locations Of Operation Indicator' class/EC5

This indicator concentrates on entry level wage by gender compared to local minimum wage. The classes that are related to this indicator are: 'Local Minimum Wage'; 'Entry Level Wage'; and 'Ratio Of Standard Entry Level Wage' class which are presented at 'Location Of Operation'. The fourth class is 'Salaried Employment' which is offered by the class 'Organization' [33].

4.2.2 Ontology for 'Proportion Of Senior Management Hired From Local Community At Significant Location Of Operation Indicator' class/ EC6

This indicator concentrates on percentage of senior management at significant locations of operation that hired from the local community. So, the concept of 'Proportion Of Senior Management' class is related to this indicator class. It is required to report the 'Percentage Of Senior Management' class that is hired at 'Location Of Operation' class which is hired from 'Local Community' class [33].

4.3 Ontology for 'Indirect Economic Impact Aspect' class

This is the third Aspect that emphasizes "impact of infrastructure investments" in relation to local communities and regional economies [3]. There are generic and specific DMA classes and two indicators:

4.3.1 Ontology for 'Development and Impact of Infrastructure Investment and Service Supported Indicator' class/ EC7

This indicator focuses on significant infrestructure investment in terms of its development and impact or service supported. The concept related to this indictor is the 'Infrastructure Investment and Service Supported' class that has an impact on 'Community and Local Economy' class [33].

4.3.2 Ontology for 'Significant Indirect Economic Impact Including Extent Of Impact Indicator' class / EC8

The additional impacts that are generated by an organization through the economy in terms of financial flow are included in this indicator. It has indirect impacts as a participant or agent in socio-economic change, and in developing economies in terms of local communities and regional economies [33]. So, this indicator has significant positive and negative indirect economic impacts on 'Local Community and Regional Economy' class.

4.4 Ontology for 'Procurement Practice Aspect' class

This is the final aspect, the essence of which is "spending on local suppliers" [3]. There are generic and specific DMA classes associated with this aspect and only one indicator which is the Ontology for 'Proportion Of Spending On Local Supplier At Significant Location Of Operation indicator' class/ EC9. This indicator concentrates on ratio of local spending at significant locations of operation. The concept that relates to this indicator is 'Percentage of Procurement Budget Spent On Local Supplier' which is used for the class 'Location of Operation' [33].

In implementation phase, Web Ontology Language (OWL) is used as a standard and broadly acceptable ontology language which defines classes, data properties, object properties, and individuals. Protégé_5.0_beta (protégé.standford.edu) is used as a tool to create ontologies. Ontologies are stored as Semantic Web documents

(W3C OWL Working Group)[2]. The full ontology coding is available at http://www.semanticweb.org/14174782/ontologies/2014/6/csr#.

In addition, only the following language elements are used: Owl:Ontology, owl:Class, owl: ObjectProperty, owl:DatatypeProperty, rdfs:subClassOf, rdf:datatype, rdfs:domain, and rdf:range [56].

Therefore, all classes' object properties, and data properties identified and formalized are created in Protégé_5.0_beta. The instances of classes are referenced from the four Australian companies mentioned before. According to the scope and purpose of ontology for a Economic Performance Indicators specified in phase 1, stakeholders need information about an Economic Performance Indicators disclosures, and therefore they raise questions. Competency questions are prepared as a standard technique in ontology engineering methodologies [36]. Grüninger and M.S.Fox [57] proposed competency questions as a methodology for evaluating ontologies. The query language is required to encode the competency questions appropriately [58].

4.5 Competency questions and SPARQL queries for 'Economic Performance indicator' class

In this section, questions in natural language are detailed and covered all the instances in the ontology. All these questions are correct and complete. They are then transformed to SPARQL queries for inquiring the 'Economic Performance indicator'' class as shown for example in Table 1 and Table 2.

Table 1 Competency questions and SPARQL query for 'Direct Economic Value Generated' class

CQ60: What is the total value of direct economic value generated, by region, basis, and measurement unit currency for this company?
SPARQL query SELECT ?subject ?object WHERE { ?subject csr:directEconomicValueGeneratedBasis ?object } csr:regionNameForDirectEconomicValueGenerated ?object } csr:totalValueOfDirectEconomicValueGenerated ?object } csr:totalValueOfDirectEconomicValueGeneratedByRegion ?object } csr:measurementUnitCurrency ?object }

Table 2 Competency questions and SPARQL query for 'Revenue' class

CQ61: What is the total value of revenue by region, basis, and measurement unit currency for this company?
SPARQL query SELECT ?subject ?object WHERE { ?subject csr:revenueName csr:revenueandOtherIncomeBasis ?object } csr:regionNameForRevenueandOtherIncome ?object } csr:totalValueOfRevenueandOtherIncome ?object } csr:totalValueOfRevenueandOtherIncomeByRegion ?object } csr:measurementUnitCurrency ?object }

5. Ontology evaluation

Weller [22] considered the evaluation of ontology as an additional process. It incorporates verification and validation. It refers to "judging the quality of the content of the ontology" [22] [54]. To evaluate the ontology, there are many approaches based on the level of evaluation [59] and relevant criteria identified [54]. It is performed differently depending on the methodologies used to build ontology [54]. Grüninger and Fox [40] propose to evaluate ontology by identifying a set of competency questions. These questions need to be formalized in a query language to encode the competency questions using an appropriate tool [58]. The form of questions is used in this evaluation.

[2] http://www.w3.org/TR/2012/REC-ow12-overview-20121211/

Ontology evaluation includes technical evaluation. The core of technical evaluation is the evaluation of the definitions that consider different aspects of ontology in terms of vocabulary, structure, content, syntax, semantic and representation that satisfy the criteria of completeness, consistency, and conciseness of definitions [58][54]. To assess specific features of ontology, technical evaluation methods are required.

Verification is the process whereby the correctness of ontology is ascertained. The process involves the creation of an ontology whose definitions adequately meets its requirements and competency questions, and function correctly in the real world [52] – [55]. Ontology verification is quite distinct from ontology validation. Ontology verification ensures that the ontology was created correctly, whereas ontology validation determines whether the right ontology was created [58]. It deals with the problem of the three Cs: (consistency, completeness, and conciseness) [55] [53] [52]. Gómez-Pérez [55] defines the three Cs as follows:

Consistency refers to definitions in the ontology that are semantically consistent;

Completeness refers to the extension, degree, amount of or coverage of the information about the real world in the ontology;

Conciseness refers to the usefulness and precision of all the information gathered in the ontology.

It requires a common understanding between the domain knowledge experts and ontology engineering experts. For this purpose, SPARQL queries are used to extract answers for the competency questions after SPARQL queries are created as shown in Table 1 and Table 2. The extracted answers for the competency questions as shown in Figure 6 and Figure 7 are the correct answers that confirm that the reported data are instantiated and correctly describe all relationships between the data. Therefore, the developed ontology for the Economic Performance Indicators is valid.

SPARQL query's answer to CQ60(a-e)
a-Direct economic value generated basis: accruals basis. b- Region name for direct economic value generated: Africa and Other, Australia and Asia, Europe, North America, South America. c-Total value of direct economic value generated: 68083. d1- Total value of direct economic value generated by Africa and Other region: 5007. d2- Total value of direct economic value generated by Australia and Asia region: 40917. d3- Total value of direct economic value generated by Europe region: 172. d4- Total value of direct economic value generated by North America region: 9468. d5- Total value of direct economic value generated by South America region: 12519. e- Measurement unit of currency: $ US million.

subject	object
bhpDirectEconomicValueGeneratedBasis	"Accruals basis."^^<http://www.w3.org/2001/XMLSchema#string>

subject	object
bhpRegionNameForDirectEconomicValueGenerated	"Africa and Other, Australia and Asia, Europe, North America, South America."^^<http://www.w3.org/2001/XMLSchema#string>

subject	object
bhpTotalValueOfDirectEconomicValueGenerated	"68083"^^<http://www.w3.org/2001/XMLSchema#decimal>

subject	object
bhpTotalValueOfDirectEconomicValueGeneratedByAfricaAndOtherRegion	"5007"^^<http://www.w3.org/2001/XMLSchema#decimal>
bhpTotalValueOfDirectEconomicValueGeneratedByAustraliaAndAsiaRegion	"40917."^^<http://www.w3.org/2001/XMLSchema#decimal>
bhpTotalValueOfDirectEconomicValueGeneratedByEuropeRegion	"172."^^<http://www.w3.org/2001/XMLSchema#decimal>
bhpTotalValueOfDirectEconomicValueGeneratedByNorthAmericaRegion	"9468."^^<http://www.w3.org/2001/XMLSchema#decimal>
bhpTotalValueOfDirectEconomicValueGeneratedBySouthAmericaRegion	"12519."^^<http://www.w3.org/2001/XMLSchema#decimal>

subject	object
bhpMeasurementUnitCurrency	"$ US million."^^<http://www.w3.org/2001/XMLSchema#string>

Figure 6 SPARQL query result for CQ60 in Table 1 related to 'Direct Economic Value Generated' class

SPARQL query's answer to CQ61(a-f)
a-Revenue name: Revenue and other income. b- Revenue and other income basis: accruals basis. c- Region name for revenue and other income: Africa and Other, Australia and Asia, Europe, North America, South America. d- Total value of Revenue and other income: 68083. e1-Total value of Revenue and other income by Africa and Other region: 5007. e2- Total value of Revenue and other income by Australia and Asia region: 40917. e3- Total value of Revenue and other income by Europe region: 172. e4- Total value of Revenue and other income by North America region: 9468. e5- Total value of Revenue and other income by South America region: 12519. f- Measurement unit of currency: $ US million.

subject	object
bhpRevenueName	"Revenue and other income."^^<http://www.w3.org/2001/XMLSchema#string>

subject	object
bhpRevenueAndOtherIncomeBasis	"Accurals basis."^^<http://www.w3.org/2001/XMLSchema#string>

subject	object
bhpRegionNameForRevenueAndOtherIncome	"Africa and Other, Australia and Asia, Europe, North America, South America."^^<http://www.w3.org/2001/XMLSchema#string>

subject	object
bhpTotalValueOfRevenueAndOtherIncome	"68083"^^<http://www.w3.org/2001/XMLSchema#decimal>

subject	object
bhpTotalValueOfRevenueAndOtherIncomeByAfricaAndOtherRegion	"5007"^^<http://www.w3.org/2001/XMLSchema#decimal>
bhpTotalValueOfRevenueAndOtherIncomeByAustraliaAndAsiaRegion	"40917"^^<http://www.w3.org/2001/XMLSchema#decimal>
bhpTotalValueOfRevenueAndOtherIncomeByEuropeRegion	"172"^^<http://www.w3.org/2001/XMLSchema#decimal>
bhpTotalValueOfRevenueAndOtherIncomeByNorthAmericaRegion	"9468"^^<http://www.w3.org/2001/XMLSchema#decimal>
bhpTotalValueOfRevenueAndOtherIncomeBySouthAmericaRegion	"12519"^^<http://www.w3.org/2001/XMLSchema#decimal>

subject	object
bhpMeasurementUnitCurrency	"$ US million."^^<http://www.w3.org/2001/XMLSchema#string>

Figure 7 SPARQL query result for CQ61 in Table 2 related to 'Revenue' class

Moreover, Schema Metrics and Knowledgebase Metrics were the means used to verify the ontology for this research, [60] [61]. These metrics include:
Relationship Richness (RR)
Attribute Richness (AR)
Inheritance Richness (IR)
Class Richness (CR)
Average Population (P)

According to Table 3, the total number of classes, data properties, object properties, instances, sub-classes, and non-empty classes of Economic Aspects are 64, 193, 59, 173, 0, and 29 respectively. Therefore, the RR is 1.00 because the number of SC is 0. Each class on average has data properties of 3.02. In addition, the CR is 0.45. Besides, each class has an average instance of 2.70 which shows the richness of instances in particular for EC1, EC2, EC9, EC3, EC7, and EC6.

Table 3 Schema Metrics and Knowledgebase Metrics for Economic (EC) Aspects

Definition of class	Class (C)	Data property (att)	Object property (P)	Instance (I)	Number of Sub-class (SC)	C`	RR	AR	IR	CR	Average Population (P)
EC Category	1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
EC Aspect	4.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Economic Performance Aspect	5.00	6.00	3.00	0.00	0.00	0.00	1.00	1.2	0.00	0.00	0.00
EC1	9.00	54.00	8.00	89.00	0.00	9.00	1.00	6.00	0.00	1.00	9.89
EC2	9.00	60.00	5.00	60.00	0.00	9.00	1.00	6.67	0.00	1.00	6.67
EC3	13.00	23.00	9.00	18.00	0.00	5.00	1.00	1.77	0.00	0.38	1.38
EC4	2.00	4.00	6.00	0.00	0.00	0.00	1.00	2.00	0.00	0.00	0.00
Market Presence Aspect	3.00	6.00	3.00	0.00	0.00	0.00	1.00	2.00	0.00	0.00	0.00
EC5	5.00	5.00	6.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
EC6	2.00	4.00	4.00	1.00	0.00	2.00	1.00	2.00	0.00	1.00	0.50
Indirect Economic Impact	4.00	10.00	3.00	0.00	0.00	0.00	1.00	2.50	0.00	0.00	0.00
EC7	2.00	5.00	3.00	2.00	0.00	2.00	1.00	2.50	0.00	1.00	1.00
EC8	1.00	2.00	2.00	0.00	0.00	0.00	1.00	2.00	0.00	0.00	0.00
Procurement Practice	3.00	11.00	2.00	0.00	0.00	0.00	1.00	3.67	0.00	0.00	0.00
EC9	1.00	3.00	3.00	3.00	0.00	2.00	1.00	3.00	0.00	2.00	3.00
Total	**64.00**	**193.00**	**59.00**	**173.00**	**0.00**	**29.00**	**1.00**	**3.02**	**0.00**	**0.45**	**2.70**

6. Discussion

In this paper, the implemented ontology using OWL language and the Protégé tool is validated through the competency questions written in SPARQL Queries as shown in Table 1 and Table 2. Instances data were collected online for four Australian companies listed within the ASX for FY 2014; these are ORG, AMC, TCL, and BHP. The evaluation ontology of content to meet the 3Cs criteria of completeness, consistency, and conciseness was verified and the answers to the SPARQL Queries were obtained. These answers show that the reported data are instantiated and correctly describe all relationships between the data. Hence, the developed ontology for 'Economic Performance Indicator' is valid. Thus, the fourth objective of this research, which is to develop ontology for 'Economic Performance Indicator' class, was achieved. The main contribution of the research is that it provides a formal framework for concepts, properties, and relationships for 'Economic Performance Indicator' class based on GRI G4 guidelines. The framework facilitates knowledge-sharing among stakeholders and computer software through a shared and common understanding of terms and vocabulary for 'Economic Performance Indicator' class. It also helps to store knowledge in a repository which can be automatically renewed to be compatible with the new generation of GRI.

The majority of instances relating to economic indicators' data instances was extracted from BHP, in particular for EC1, EC2, and EC9 (full disclosures), EC3 and EC6 (partial disclosures). This company is unique in terms of the quantity and quality of information disclosed. Whereas, the ORG data instances disclosure for EC7 was found to be optimal. There was a dearth of disclosure for EC4, EC5, and EC8 by any company in the sample. The valid answers are appeared. The summary of Schema Metrics and Knowledgebase Metrics for 'Economic Performance Indicator' class in terms of total number of classes, data properties, object properties, instances, number of sub-classes and non-empty classes were 64, 193, 59, 173, 0, and 29 respectively. Therefore, the RR is 1.00 because the number of SC is 0. Each class on average has data properties of 3.02. In addition, the CR is 0.45. Besides, each class has an average instance of 2.70 which shows the richness of instances in particular for EC1, EC2, EC9, EC3, EC7, and EC6. The content of the ontology was thereby validated. SPARQL queries were used to extract answers for the competency questions and correctly describe all relationships between the data within the inclusive set. Therefore, the developed ontology for the Economic Performance Indicator is active.

7. Conclusion and future work

This paper is aimed at formally modelling the real world of Economic Performance Indicators within Sustainability Reporting. Ontology has provided a shared and common understanding of terms and vocabulary that can be communicated among stakeholders in an organization, and computer software to facilitate the sharing and reutilization of knowledge. The methodology adopted included four phases: specification, conceptualization, formalization, and implementation. A requirement specification for Economic Performance Indicators ontology was created by identifying the intended scope and the purpose to address the various ontology scenarios. The classes, properties, and relationships for Economic Performance Indicators based on the GRI G4 were identified. A conceptual model was transformed into a formalized model using UML to represent the ontology formalization for 'Economic Performance Indicator' class. However, using SPARQL to access information in the ontology is sometimes too complicated for end users who have little knowledge of the language. Therefore, in the future work, we plan to develop an application that can support end users to effectively access and manage knowledge captured in the Ontology for Economic Performance Indicators Based on Global Reporting Initiative (GRI) G4.In addition, an inference and logic reasoning ability will be applied for this research in the future.

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