An Ontology for Project-Based Organization Design: the Star Model Case

Edison Atencio and Mauro Mancini
Department of Management, Economics and Industrial Engineering
Politecnico di Milano
Via Lambruschini 4b, Bovisa, 20156 Milan, Italy

Department of Industrial Engineering
Pontificia Universidad Católica de Valparaíso
Av. Brasil 2241, 2340000, Valparaíso, Chile

Mauro Mancini
Department of Management, Economics and Industrial Engineering
Politecnico di Milano
Via Lambruschini 4b, Bovisa, 20156 Milan, Italy

Guillermo Bustos
Department of Industrial Engineering
Pontificia Universidad Católica de Valparaíso
Av. Brasil 2241, 2340000, Valparaíso, Chile

Abstract

Star Model (SM) is a framework used for designing Project-Based Organizations (PBO) with a wide acceptance. Some researchers have chosen the SM considering its completeness, holistic perspective and the interdependence between its five components: Strategy, Process, Behaviour, Human Resources and Structure. For SM use and implementation, this framework is available as a text guideline. If the size and complexity of the designing and analyzing organization increases, this activity could be manual and difficult. Ontologies are a means for describing domain models and provide computational inference useful for the analysis of these models. This paper proposes an ontology of the SM for PBO designing, describing its components and relationships in a high level of abstraction. The resulting model seeks to be helpful for understanding and managing the complexity of the designed organization and a tool for business analysis—the above considering the automatic analysis possibilities available through the computational inference of ontologies.

Keywords
Star Model, Project-Based Organizations (PBO), organization design, organizational project management, project management, ontologies, business analysis.

Introduction
Society is substantially *projectified,* and 40% of the economy is project-based (Miterev et al. 2017), and companies use projects to develop new products and achieve key capabilities (Pellegrinelli et al. 2015). In this context, a group of organizations obtains their income by developing projects. These organizations are known as Project-Based Organizations (PBO) (Di Vincenzo and Mascia 2012). The study of PBO has increased in the last years, and one of the main concerns is the PBO design (Miterev et al. 2017a). There are wide alternatives for organizational design; however, these tools focus on individual choices, such as people, structure, and processes (Miterev et al. 2017). The

SM proposed by Galbraith (Galbraith 2007) is a framework for organizational design and is currently adapted for PBO design (Miterev et al. 2017). This framework gained adherence because it has a complete viewpoint of designing dimensions – five in total: strategy, process, behaviour, human resources, structure and strategy. Also, SM deploys these dimensions in an interrelated way (Miterev et al. 2017). The application of SM could be based on a text guideline, and its application could be a difficult task in practice.

On the other hand, the concepts displayed in a text guideline could be heterogeneous, dispersed and complex, and the accuracy recovery of the information could be difficult, too (Labrada 2014). Using computational tools could simplify the designing, analysis, and reduction manually for PBO business modelling and analysis. In this context, ontologies emerge as an alternative for overcoming these concerns. Ontologies are a collection of key concepts and their interrelationships, giving an abstract view of an application domain. Ontologies allow converting the information in knowledge through structures that reference the data, using metadata, under a common standardized schema on some domain of knowledge domain (Xing et al. 2008). Ontologies have been applied in the project management domain in specific topics, such as human resources (Zaouga et al. 2019) and risk management (Tereso et al. 2019), as well as practical issues such as solving the complexity in project controlling (Hai et al. 2011).
The ontology model proposed in this research seeks to be a management tool for organizational designers and project managers contributing with a systemic view of the PBOs.
This paper is structured as follows: Section two includes a background regarding project management, PBOs and the use of ontologies. The research method used in this article is described in section three. The results and discussion are developed in section four. Finally, section five contains the conclusions obtained through this research. An appendix is included with a link to the constructed ontology.

1. Background

1.1 Project Management and Project-Based Organizations

Project Management (PM) has been, during the last two decades, one of the current transformations of organizations (Midler 2019), generating a growing adherence to this discipline (Too and Weaver 2014). PM studies have been mainly focused on the project (Miterev et al. 2017). However, the look has been broadening the relationship of projects with the organization and the tendency of organizations to manage their operation in the form of projects (Midler 2019). Moreover, the concern has also focused on effective management of the individual project and the systems, processes, structures, and capabilities that support the projects in an organizational context (Drouin and Besner 2014).

The concept of permanent organization can be found recurrently in the literature (Nilsson Vestola et al. 2021), a company where one or more projects occur. The temporary organization corresponds to the team that directly manages the project, to the eaves of the permanent organization (Artto 2013; Pemsel and Wiewiora 2013). There are also organizations intensive in realizing projects where the management of temporary organizations and projects constitute their main processes. These organizations are known as PBOs (Miterev et al. 2017). (Turner and Miterev 2019) recognize three types of PBO: the contractor type, which carries out projects for an external client (Example: a construction company); the back-office type, which serves business units within the same parent organization (example: the project division of a mining company) and; the third type, the organization that supports projects to achieve its core processes (Example: the area of project development of new models in a car brand).

The requirements and goals of project development in this type of organization suppose a complexity must be managed (Mikkelsen and Venable, 2020). Complexity in projects has been categorized in different dimensions (Bakhshi et al. 2016), for instance, technical (where the concerns are technological and professional practices); human complexity, where formal and informal relationships meet, as aspects of leadership. Finally, the political category, whose object is negotiations and stakeholders (Falcao and Meyre 2020). Faced with this complexity, using models and computational tools sources as an alternative for understanding and managing it (Lankhorst 2009) is also useful for analyzing changes and aligning with organizational objectives (Niemi and Pekkola 2020).

1.2 Ontologies

In the context of computer science, ontologies are defined as an explicit and formal specification of a shared conceptualization (Studer et al. 1998) and are composed of classes and relationships (Noy and McGuinness 2017). In the context of business analysis, ontologies promote common understanding between people-companies and facilitate communication between people and applications and between applications. (Martin et al. 2013). Ontologies can enable a computerized analysis of their models and relate these models to others at a high level of abstraction. One of the uses of ontologies is the integration of concepts between models. The integration of ontologies can be achieved through the following approaches (Bakhshandeh et al. 2013):

- *Ontology mapping* is building a new ontology by searching for common concepts between two (or more) concepts belonging to two (or more) different ontologies.
- *Ontology alignment* corresponds to constructing a new ontology by identifying correspondences between all the concepts of two ontologies, which are considered equivalent.
- *Ontology Merging* is building a new ontology by merging several ontologies into one, obtaining a more general ontology.

The process of formulating ontologies considers different steps for their construction. For instance, METHONTOLOGY is a guideline that establishes seven steps for developing an ontology: specification, conceptualization, formalization, integration, implementation, evaluation and documentation (Fernández et al. 1997). The evaluation stage determines the quality and usability of the ontology and could be addressed with different strategies (Fernández et al. 1997). An alternative is verifying the correct containing into an ontology through queries using, for instance, using SPARQL tool (Osenberg et al. 2015) available in ontologies editors, such as Protégé[1] and NeOn Toolkit[2]. The evaluation concerns are, for example, the rules or axioms in an ontology (For instance, a herbivorous is an animal) (Uysal andKarakaya 2017). Another evaluation mechanism is that the ontology contains the identifiable concepts and relationships in the process of a business process (Cubillos C. 2010). For instance, elements such as Project manager and schedule should appear in a monitoring process.

In the PM domain, there are also ontological applications for describing, for example, a PM framework, such as PMBOK, PRINCE and DIN69901 (Abels et al. 2006; Fitsilis et al. 2014), as well as specific domains, such as human resource management, risk, PM (Project Management Information Systems - PMIS) information systems and project monitoring processes (Hai et al. 2011; Srisungnoen and Vatanawood, 2018; Zaouga et al. 2019).

3. Research Method

This research was developed using the METHONTOLOGY (Fernández et al. 1997) guideline for creating ontologies with the following activities:

Table 1. Research method.

Step N°	Activity	Output
1	Specification	• The purpose of the ontology e.g. intended users, and scenarios • Level of formality: highly formal, semi-informal, semi-formal or rigorously formal. • Scope, with the terms represented and granularity.
2	Knowledge acquisition	• The data extraction uses, for instance, experts and, books.
3	Conceptualization	• Structure of the domain knowledge. • Glosary of terms.
4	Integration	• Definitions aligned with other ontologies.
5	Implementation	• The ontology model developed in a software tool.
6	Evaluation	• Validation of correctly language modelling • Validation of domain modelled
7	Documentation	• The code of the ontology, papers, etc.

[1] https://protege.stanford.edu/
[2] http://neon-toolkit.org/wiki/Main_Page.html

4. Results and Discussion

The results and discussion are developed in this section following the structure described in the research method (Section 3).

1. Specification

The purpose of the ontology is to generalize the knowledge of the Star Model guideline for an organization's design for facilitating access to its content. Moreover, it is expected to be a tool for organizational designers to develop designing processes through models safeguarding the coherence and standardization of the concepts and the existing relationships. The above is expected to understand the complexity of designs and be a managing tool.
Regarding the model's granularity (level of details), the ontology was constructed using the literal concepts described in the guideline. Implicit relationships or concepts from an interpretation are not included in the scope and are proposed for future studies.

2. Knowledge acquisition

The data extraction was done by reading the Star Model guideline and mapping first in a Kumu.io © system map editor, as shown in Figure 1. This tool was chosen considering its friendly and fast mapping process and the exporting alternatives in formats such as .csv and .xls. This possibility allows using this map to develop other analyses such as Network Analysis to measure the level of connection of the concepts, analyzing as a network.

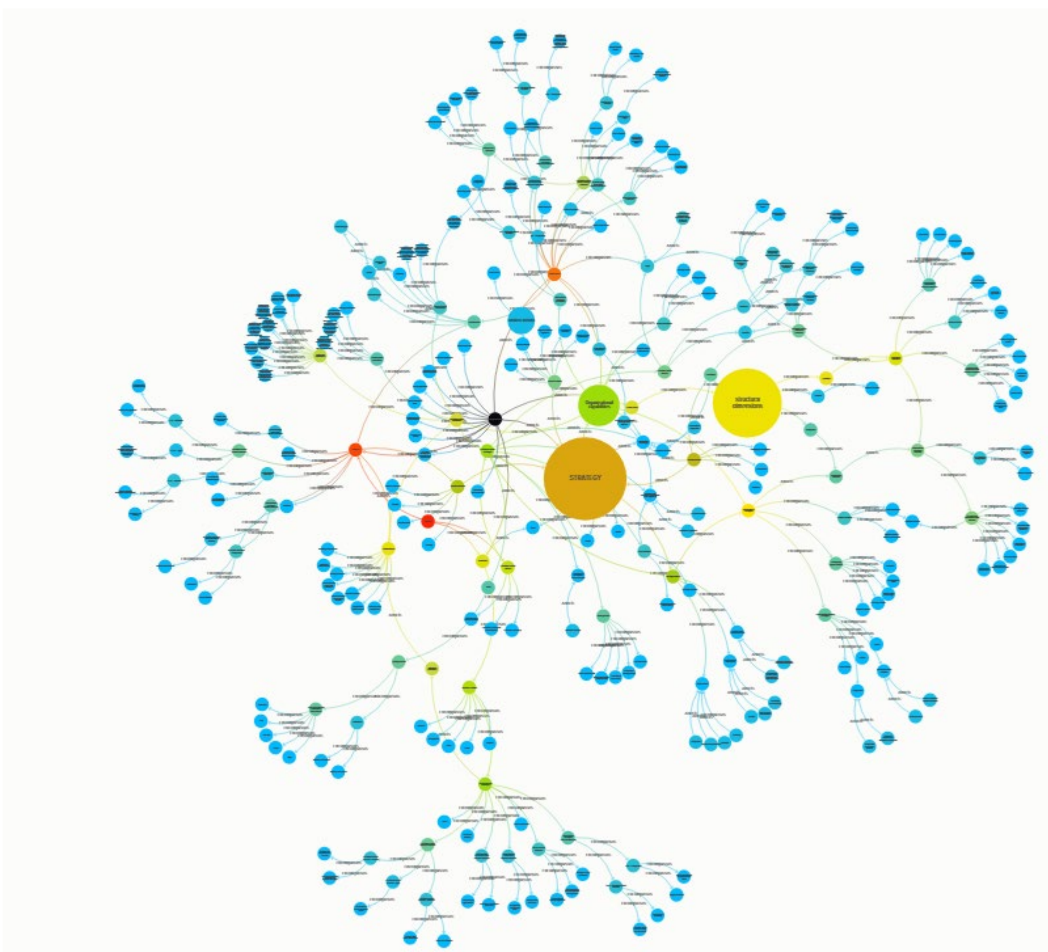

Figure 1. System map obtained using Kumu.io.

3. Conceptualization

The obtained map can be exported to a data table, obtaining the list of concepts to start constructing the glossary of terms and the relationships, as shown in Figure 2.

Filter...

	From	To	Label
1	Matrix manager	Integrative roles	Affects
2	Teams	Networks	Affects
3	Relationships	Networks	Encompasses
4	Business model	Business portfolio	Encompasses
5	Driving factors	Global coordination	Encompasses
6	Level of integration of products and services	Low	Encompasses
7	Customer relationship management process	Relationships customers profitability and segments	Encompasses
8	IG People concerns - Geographic	Expatriates	Encompasses
9	Centralization-Decentralization structure concerns	Internal markets	Encompasses
10	Design principles	REWARDS	Affects
11	Customer-centric structures - Intensive	Define front-back structure	Encompasses
12	STRUCTURE	Structural dimensions	Encompasses
13	Matrix rewards concerns	Joint objectives and performance management	Encompasses

Figure 2. List of concepts and relationships exported with Kumu.io ©.

The list of terms obtained is composed of 292 concepts and 325 relationships. Two different relationships are identified, the relation of class and sub-class between concepts (labelled as "encompasses" in Kumu.io©) and relationships describing the influence of a concept over other concepts (labelled as "affects" in Kumu.io©).

4. Implementation

The model obtained in Kumu.io© could be used as an ontology. However, the possibilities of making queries or processing other relationships are limited. For this reason, the Protégé ontology editor was used. The metrics of the obtained model are shown in Figure 3.

Ontology metrics:

Metrics	
Axiom	689
Logical axiom count	396
Declaration axioms count	293
Class count	292
Object property count	1
Data property count	0
Individual count	0
Annotation Property count	0
Class axioms	
SubClassOf	262
EquivalentClasses	54
DisjointClasses	0
GCI count	0
Hidden GCI Count	21

Figure 3. Metrics of the obtained ontology.

The count corresponds to the 292 concepts modelled, and the object property count is the "affects" relationship modelled. Regarding Figure 4, this property generates 270 connections.

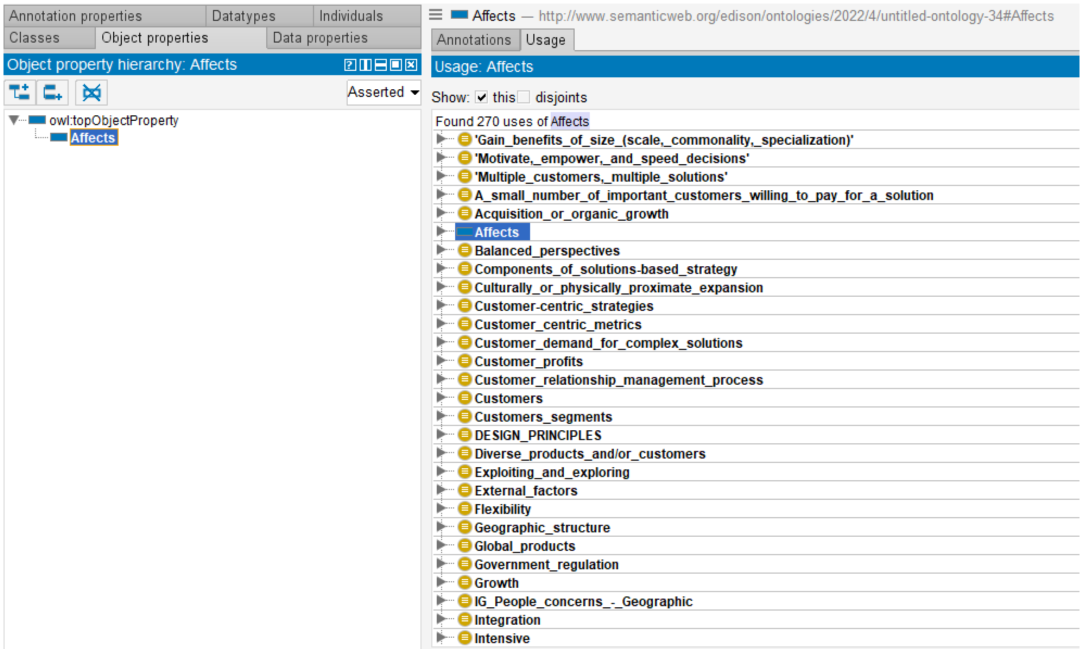

Figure 4. "Affects" property applied to the ontology.

The "encompasses" relationship in the ontology are represented by the class-subclass relationship as a cascade, as shown in Figure 5 and Figure 6.

Figure 5. Classes and sub-classes modelled.

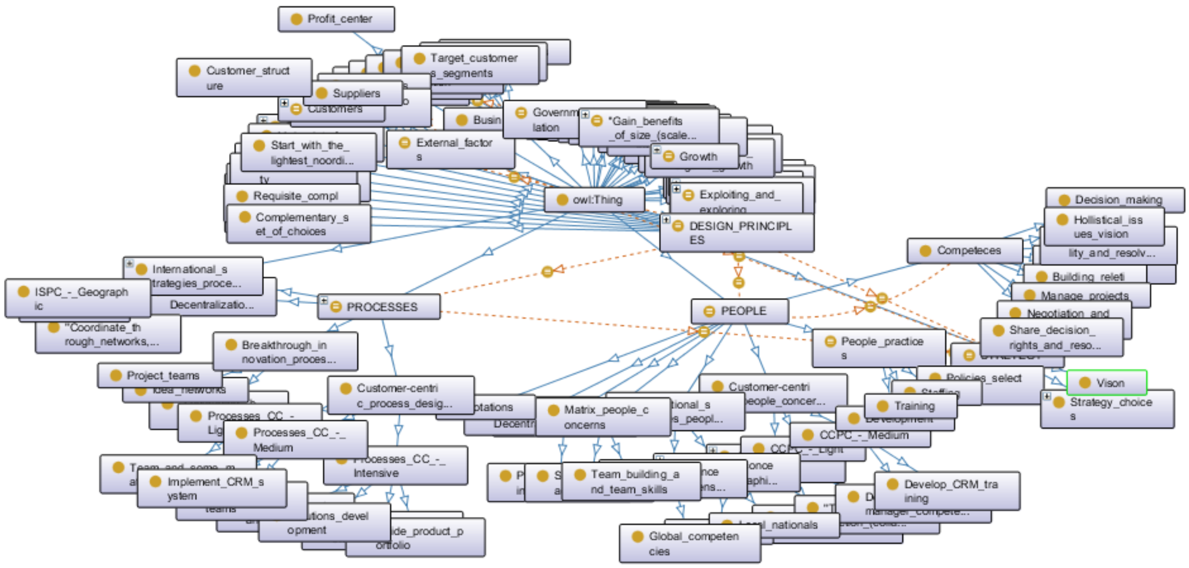

Figure 6. Graphic view of the ontology obtained.

Evaluation

The evaluation of ontologies considers the technical judgment of the ontologies, their software environment, and documentation regarding the frame of reference (Fernández et al., 1997). The evaluation was conducted from two perspectives. (1) the correctly use of modelling language and (2) the consistency regarding the used framework (Star Model).

For the first (1) evaluation, the Oops! Ontology Pitfalls Scanner was used. This tool was developed by Villalon et al. (Poveda-Villalón et al., 2014) and allowed to find the ontology model's error (and its levels) through a .rdf file exported from Protégé as an input. Also, a second evaluation of the ontology was carried out through the Protégé debugger tool. The report of the evaluation process is shown in Figure 7 and Figure 8.

Evaluation results

It is obvious that not all the pitfalls are equally important; their impact in the ontology will depend on multiple factors. For this reason, each pitfall has an importance level attached indicating how important it is. We have identified three levels:

- **Critical** : It is crucial to correct the pitfall. Otherwise, it could affect the ontology consistency, reasoning, applicability, etc.
- **Important** : Though not critical for ontology function, it is important to correct this type of pitfall.
- **Minor** : It is not really a problem, but by correcting it we will make the ontology nicer.

[Expand All] | [Collapse All]

Results for P04: Creating unconnected ontology elements.	3 cases | Minor
Results for P07: Merging different concepts in the same class.	38 cases | Minor
Results for P08: Missing annotations.	293 cases | Minor
Results for P10: Missing disjointness.	ontology* | Important
Results for P13: Inverse relationships not explicitly declared.	1 case | Minor
Results for P19: Defining multiple domains or ranges in properties.	1 case | Critical
Results for P22: Using different naming conventions in the ontology.	ontology* | Minor
Results for P24: Using recursive definitions.	2 cases | Important
Results for P30: Equivalent classes not explicitly declared.	1 case | Important
Results for P41: No license declared.	ontology* | Important

Figure 7. Evaluation results of ontology model using OOPS! Scanner.

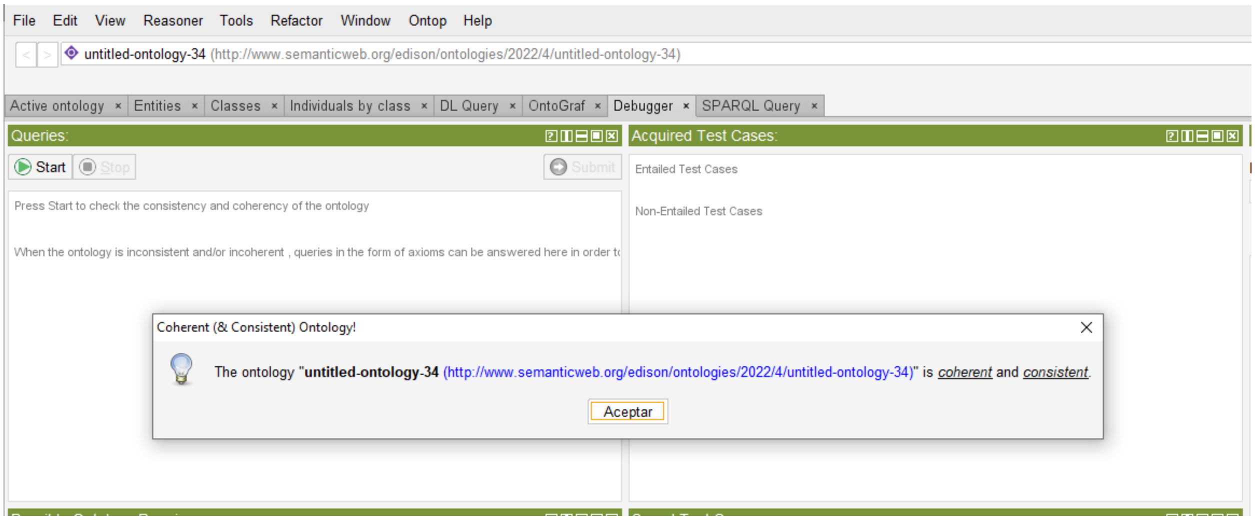

Figure 8. Evaluation results of the ontology model using Protégé debugger.

As shown in the figures above, the model's issues are mainly classified in a minor level of critically. Only the critic issue (P19) was corrected. The Protégé debugger shows that the ontology is coherent and consistent. The following step is addressed with these results, evaluating the domain modelled and analyzing their content.

Regarding the second (2) perspective of evaluation, some statements declared in the Star Model text were verified in the model, using the Ontograf tool of Protégé for graphic visualization of the concepts and relationships:

- *"The idea of alignment is fundamental to the Star Model".* This statement could be verified through the interrelation between the five components of the Star Model, as shown in Figure 9. In this case, the components as a class are connected directly through the "affects" relationship (yellow arrow) and components as a bridge, for instance, the design principles and goals.
-

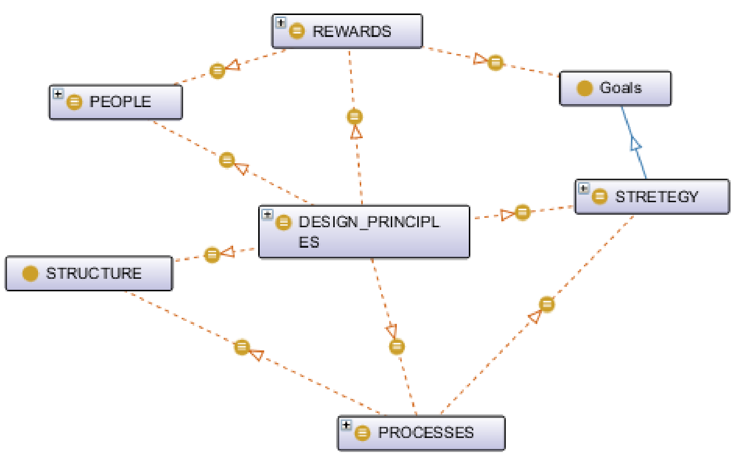

Figure 9. Interrelation between Star Models' components.

- *"Each component of the organization, represented by a point on the model, should work to support the strategy. The more that the structure, processes, rewards and people practices reinforce the desired actions and behaviours, the better able the organization should be to achieve its goals".* In this case, the people's practices appear as a sub-class of people's components and affect the strategy, as shown in Figure 10.

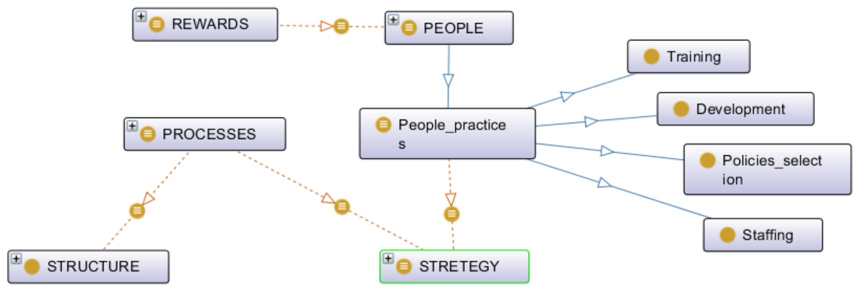

Figure 10. People practices related to the strategy.

- *"The four primary building blocks of organizational structure are function, product, geography, and customer. We also refer to these as structural dimensions"*. As shown in Figure 11, the structural dimensions are displayed in the ontology as a subclass of the main structural component. The customers' dimension appears to affect the customer structure sub-class.

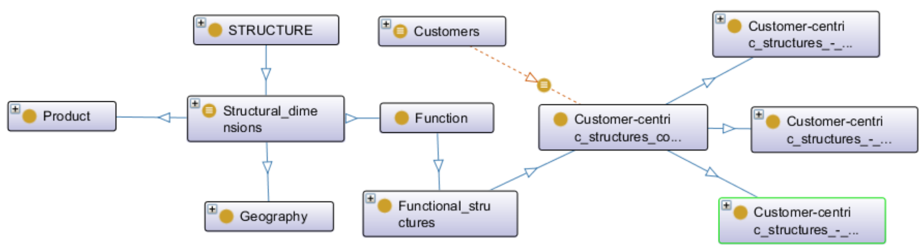

Figure 11. Structural dimensions displayed in the ontology.

Conclusions

A Star Model framework ontology for organizational designing was developed in this research. Star Model has been highlighted in the literature for encompassing the main concerns of the organizational design: strategy, structure, processes, people and rewards. These components are displayed in a guideline in a text format, and computational tools and models could be useful for facilitating the designing process and analysis. Our proposal seeks to be a designing and managing tool for the Star Model implementation. The obtained ontology was developed using the METHONTOLOGY framework and displayed in the Protégé ontology editor. The modelling language using was evaluated using the Oops! Scanner tool and the Debugger tool of Protégé. The results show that the ontology has minor issues and, in general, the ontology is correctly modelled in terms of the language. Regarding the domain modelled, some statements of the Star Model were verified into the ontology with success.

Future works can continue the modelling process, mapping other relationships that could be implicitly identifiable and with a domain's expert judgement. Also, the granularity of the ontology could be increased by identifying other subclasses. The modelling of a PBO with this ontology can be made as a practical application. Also, in a complex project environment, this ontology will be useful for establishing the projects' governance, standardizing roles, concerns, and competencies, and merging the ontology with other standards such as PMBOK or PRINCE.

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Biographies

Edison Atencio is a civil engineer and master of industrial engineering. Currently is a double degree PhD student of the School of Industrial Engineering of Pontificia Universidad Católica de Valparaíso, Chile and the Engineering Management Department of Politecnico di Milano, Italia. He has ten years of working experience managing projects in industries such as construction, banking, retail and oil & gas.

Mauro Mancini Mauro Mancini is full professor of Project and Program Management at the Department of Management, Economics and Industrial Engineering at Politecnico di Milano, he is Associate Dean for Corporate Education of the POLIMI Graduate School of Management of the Politecnico di Milano and Director of an international Master in Project Management and other Master programs. Author of more than 100 international publications in Project Management, Industrial Plants Management, Project Management, Building Information Modelling and Megaprojects, he is involved in national and international research and consultant projects in multiple industrial sectors.

Guillermo Bustos is professor at the School of Industrial Engineering of Pontificia Universidad Católica de Valparaíso, Chile and teaches several courses in the areas of Information Systems and Technologies for undergraduates, masters' and PhD programs

Appendix

Link to the developed ontology in .RDF format.

https://docs.google.com/document/d/19DY7O0Z9AYUBjHpK3Rpf1oO-Ukqx-xWklpOBs7_UJE4/edit?usp=sharing