Ontology Driven Feedforward Risk Management

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Abstract. Organizations are increasingly relying on projects to support their activities. With this increase, the management of these projects is becoming critical. New methods, tools and frameworks appear in order to improve the success rate of these projects. However, being complex endeavours, projects face numerous challenges that have to be addressed with proper risk management. Various risk management frameworks have been developed in order to support project managers in their task of identifying and controlling risk. Although these frameworks are effective in reducing the impact of risk, they are slow to implement. In order to more productively address these risks, we have developed an ontology to support feedforward risk management. This ontology can be implemented in project management software to provide project managers with a multi-level approach of the risks associated with their projects. The scope and breadth of the risks identified by the software will be closely related to the project data collected in the system, reducing the need for a lengthy setup. Moreover, using data collected by the project management software, the system will be able to proactively raise management awareness towards potential upcoming issues.

Keywords: Risk management · Ontology · Feedforward · OWL

1 Introduction

During the last few decades, the flattening of organizational hierarchies, the weakening of firms' boundaries in favour of networks of collaborations and the restructuring of competition between firms within and across industries has caused a large increase in project-based work [1]. Even though project management methods and tools have seen an important development over the same period, successful project execution is still a challenge for organizations. Consulting firms such as the Standish Group regularly publish alarming reports about projects success rates [2]. While the figures produced in these reports are questionable [3], studies by researchers also show that project success is still hard to achieve [4].

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Projects are complex endeavours involving multiple actors, compressed schedules, ambitious goals, limited budget and frequently changing requirements and are therefore affected by several sources of uncertainties such as market payoff, project budget, product performance, market requirements and project schedule [5].

In this context, risk management is a critical element for successful project management. Project risks can be defined as any undesired event that may cause delays, excessive spending, unsatisfactory project results, safety or environmental hazards and total failure [6]. In order to prevent problems and deal with uncertainties, risk management techniques have been developed for project management. However, such techniques are still seldom used, as many managers still do not fully understand their value or know how to apply them in the context of project management [7].

In order to manage these risks effectively, practitioners need effective means of detecting and monitoring potential risk factors. An ontology supporting risk management and integrated to project management and ERP systems could potentially enable proactive risk management.

In this paper, we address the following research question: how can an ontology be designed and be used in project management software in order to improve preventive risk management?

This research is being carried out in collaboration with an external software company and aims to provide practitioners with an integrated tool for identifying, assessing and monitoring project risks.

2 State of the Art

First, we present the literature review for project risk management, which is the application domain of our ontology. In order to frame the concepts composing the ontology, we built a typology of project risks. This typology defines a hierarchy of ideal types of projects which have different risk profiles and are believed to ask for different approaches in terms of risk monitoring and management. Each of the resulting ideal types represents a unique combination of the organizational attributes that are believed to determine the relevant outcome(s) [8].

One important aspect of every typology is the objectives underlying its development. In our case, this objective is the identification of project types requiring different approaches in terms of risk management. With this in mind, we reviewed and combined characteristics of existing typologies of project risks from different domains in order to build our own.

2.1 Existing Typologies for Project Risk Management

A risk breakdown structure is a hierarchical structure of risk sources that is used to aid the understanding of the risks faced by a project [9]. Hillson [9] proposed a risk breakdown structure for generic projects based on the work of the Risk Management Specific Interest Group of the Project Management Institute [10]. Shown in Table 1, this risk breakdown structure comprises the general risks faced by any kind of project.

Table 1. Risk breakdown structure for generic projects [9]

Top level	Risk family	Risk factors
Project risk	Management	Corporate
		Customer & stakeholder
	External	Natural environment
		Cultural
		Economic
	Technology	Requirements
		Performance
		Application

A "risk factor" is a source of risk from the internal or external environment of the project. These factors influence the occurrence of adverse events in risk assessment and are used as independent variables. The works of Barki et al. provide us with a comprehensive review of risk factors and variables for project management that are presented in Table 2 [11, 12]. We will use these risk factors and underlying variables as the attributes characterizing the ideal types in our typology.

Table 2. Risk factors [11]

Top level	Risk factors
Project risk	Technological risk
	Project size
	Deliverable complexity
	Organizational environment
	Project complexity
	Exogenous conditions
	External agents characteristics

2.2 Ontology

In information systems (IS), ontologies are used to describe concepts and their relationships in a given domain. Their importance in the IS community is being recognized in a multiplicity of research fields and applications areas, including knowledge engineering, database design and integration and information retrieval and extraction [13]. Ontologies support the description of the entities and their interrelationships in order to structure the knowledge of a particular domain of discourse. They can be used to build a 'web of data' understandable by machines to support the Semantic Web [14], identify similarities between concepts [15] or to model a specific domain of knowledge [16]. The second property of ontologies is that they support various operations such as merging, translation, alignment, refinement of concepts, extension, specialization and inheritance.

Facing the task of ontology creation, researchers put efforts in fully or at least partially automating the generation process [16]. Ontology learning is associated with techniques supporting the extraction of content from structured or semi-structured data [17]. This presupposes the existence of data sources covering the domain of interest. In cases where this data is not available or is only partially available, a traditional way of ontology creation is recommended.

3 Ontology Driven Risk Management

3.1 Developing the Ontology

In order to support the creation of a risk management framework, we decided to create an ontology representing the domain of risk management. The idea behind the creation of an ontology is to be able to represent the whole domain, but also to be able to use ontological properties such as inferences.

To support our work, we chose to use the Methontology framework, "a methodology to build ontologies from scratch" [18]. It follows a multi-step process: specification, conceptualization, formalization, integration and implementation, along with maintenance, knowledge acquisition, documentation and evaluation.

Specification. The first step consists of establishing the purpose and scope of the ontology. In our case, the ontology will be used in enterprise risk management software, integrated in a complete enterprise resource planning (ERP) solution. Our ontology can therefore be categorized as a systems engineering one [1, 2]. End users for the risk management system and the underlying ontology will be managers and top-level executives, who will use it for preventive risk management. Automatic data collection from the ERP and self-reporting from the employees will be used to populate the system and produce the risk management indicators. The resulting scope encompasses the concepts of risk management and project management presented in the literature review above.

Based on the purpose of the ontology, we moved to define the level of formality. Uschold and Gruninger [19] classify the level of formality on a continuum from highly informal to rigorously formal, based on the language used to specify the ontology. In our case, given that the ultimate goal of the ontology is to be integrated in some sort of computerized tools, we agreed on using a semi-formal ontology. Such ontologies combine informal descriptions in plain English with some sort of formalisms to describe the concepts and relationships.

As recommended by Uschold and Gruninger [19] we followed a middle-out approach to identify the main terms for our ontology. Based on interviews of experienced project management practitioners, we identified the primary concepts of the ontology. We then confronted these initial terms to existing typologies of risks and depending on the project's need, we further specialized and generalized those terms, to make sure that the concepts were defined at an adequate level of granularity to satisfy the purpose of our ontology [18]. During this refinement process, we used intermediate classification trees of the risk-related concepts, to check the conciseness and completeness of the ontology.

Knowledge Acquisition. To have a broad understanding of the domain and to cover all of its aspects, we started by brainstorming, in order to identify potentially relevant terms. During this process, we identified more than 120 terms related to risk management and grouped them by affinity reaching 12 classes of risks. Six interviews with professionals of the fields were conducted in order to extend the list of terms and to improve our understanding of the relationship between risk management concepts. The second part of the knowledge acquisition phase consisted of an extensive literature review in order to identify risk management frameworks, risks definitions and existing categorizations of risks. Using these elements, we were able to refine our terms, formalize their relationships and agree on a classification.

The first step in this literature review was to identify the key areas of risk-related activities within projects. The distinguishing criterion was that the relevant risks are different from one sector to another. To do this, a bottom-up approach was used to ensure the reliability of the sources. This approach consisted of identifying the major risks within the projects. Afterwards, we distinguished business sectors, based on these risks.

The second phase of this literature review involved grouping the main risks for each sector of activity in the form of risk breakdown structures. Bourdeau et al. [12] reviewed the project management literature and identified general risk factors and their underlying variables which we used as attributes to characterize the ideal types in our typology. Finally, a risk framework by business area was designed using the same process, this time incorporating the main risks identified in each sector.

At a finer level of granularity, individual risk variables from the literature were listed and integrated in the risk management framework. For these individual risk variables, indicators were extracted from relevant literature. This general catalogue of risk variables and related indicators will be used by project managers to select the specific risks associated with their projects. As each project has its specificities, different risks will need to be monitored through different sets of indicators.

The flexibility of our ontology, linking multi-level risks to indicators in a per project configurable manner, will allow for preventive risk management of projects with individual risk profiles.

Conceptualization. Following the knowledge acquisition phase, we moved on to the conceptualization of the ontology. The goal of this phase is "to structure the domain knowledge in a conceptual model that describes the problem and its solution in terms of the domain vocabulary identified in the ontology specification activity" [18]. Following the methodology of Fernández-López et al. [18], we build a glossary of terms structured as a two-dimensional table organized according to high level risk factors and economic activity domains. This allowed for identifying recurring concepts, synonyms, instance candidates, verbs and typical properties for the risk management domain. We described all the concepts in our typology using a data dictionary. This dictionary consists of tables specifying the attributes for the classes of our ontology. Table 3 shows an excerpt of the data dictionary for the "indicator" and "risk variable" classes.

Integration. It is highly recommended to integrate existing ontologies during the process of creating a new ontology [18]. In this project, we chose to not follow this recommendation. There are two main reasons for doing so. First, there are no ontologies

Table 3. Data dictionary example for class attributes

Class	Attributes
Indicator	Name, Definition, Hierarchy, Measures, Frequency, Data, source, Target
Risk variable	Name, Definition, Domain, Type

covering a substantial part of our domain of interest. This would imply combining multiple ontologies having different degrees of specification into our ontology. Second, and more importantly, the goal of the project is to create an integrated framework of risk management, which implies a highly integrated definition of the concepts of the domain. Therefore, we chose to base our definitions on the literature for sound proofness, but to work on each definition by ourselves in order to guarantee the consistency of the whole ontology.

Implementation. The next step was to implement the ontology in a formal language. There are many languages supporting the codification of ontologies such as Ontolingua, LOOM, OCML, OIL, DAML + OIL and OWL. Based on the comprehensive work of Corcho et al. [20] to compare the main methodologies, tools and languages for building ontologies, we decided to use Protégé and OWL to codify our ontology. This choice was made based on our previous experience with Protégé as a tool for building and supporting ontologies. OWL was elected due its compatibility with the RDF Schema, without the limitations of RDF's expressive power [21]. OWL files and a database of instances were provided to our implementation partner to support the integration of the ontology in their project management software and ERP systems. The simplified ontology is depicted in Fig. 1.

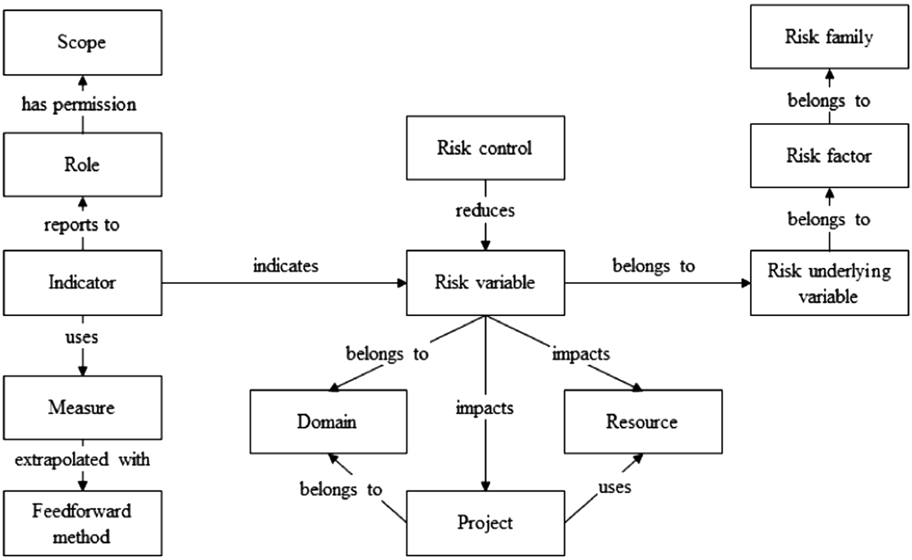

Fig. 1. Ontology for project risk monitoring and feedforward control

Evaluation. This phase consists of carrying out a technical judgement of the ontology and its implementation with respect to a frame of reference [18]. In our case the reference will be the scope and purpose of the ontology. The verification of the technical correctness of the ontology was done during its modelling in Protégé. The validation of the ontology has been possible through the configuration of a third-party decision dashboard tool that uses data from the instances to present project managers with the risk management indicators as defined in our ontology.

3.2 Application

The ontology can be implemented in a risk management module for a project management system. To support the goal of increasing project success in the long run, the ontology brings three key advantages to the risk management module.

First, the ontology allows for integration of human-related risks. The risk management module will collect and analyse data that provides information about influential contributors of project performance such as employee engagement, team members motivation state, team interrelationships, stakeholders commitment and political changes. Human-related risks will be managed at the individual, group and organizational levels.

Second, the ontology allows for automatic data collection of the vast majority of indicators. Meaningful human-related data will be collected throughout project lifecycle. Data gathering processes will rely mostly on automated collection procedures of digital data. This is a major advantage as it can be performed with no direct involvement of managers or team members, who can focus on their activities. When needed, self-reported personal data will complement data collected automatically. To motivate people to hand over personal data, proper incentives have to be defined and implemented.

Third, the ontology will support the use of preventive controls. Human-related indicators will be combined with more traditional indicators to generate alerts that will work as early warning signals. The software solution will favour feedforward controls (as opposed to feedback controls) in order to prevent risks from arising, rather than dealing with damage when observed.

4 Discussion

Most of the available approaches to dealing with risk are model-based. Modelling syntaxes vary from simple diagrams to very complex mathematical formulas. We propose an alternative approach to risk management that leverages the power of ontological conceptualization. Supported by the ontology, the risk identification, which takes place at the heart of the project management software, can be effectively presented in a multi-level project management dashboard. Compared to a classical approach, this will foster an ex-ante treatment (feedforward controls) of risks as opposed to an ex-post one (feedback controls). Detective controls come after the action (feedback) when preventive controls come before the action and are designed to prevent major problems from ever occurring [22]. This approach is expected to support project managers in effectively reducing the impact of risk by taking appropriate preventive measures.

The ontology is currently implemented and data is being collected through the ERP system, in order to assess the ontology's effectiveness in detecting risks and allowing for better risk control. The evaluation of its actual effectiveness will be the subject of further research.

5 Conclusion

Effective project management is a complex activity in which risk management plays a critical role [5]. In this paper, we have presented an ontology for risk management, based on the existing literature about project risk management and interviews of project management professionals. This ontology has been built according to the Methontology technique [18] and is integrated into the risk management module of an ERP system, forming together a new tool that provides project managers with a multi-level approach to the risks associated with their projects. Thanks to the extensive risk catalogue instantiated in the ontology, it will allow for better identification, definition, monitoring and control of the multiple risk variables that can impact a project.

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