Towards a Quantitative Model to Deal with Uncertainty Management in Software Projects

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Abstract. *The evolution of thinking in project management has raised interest in areas not yet explored by researchers and practitioners of project management, including the management of uncertainties associated with risk management. The correct risk and uncertainty management in software projects can represent a competitive differential for the software development industry. Despite the increasing use of uncertainty management strategies, many projects still fail. Some recent studies show that the current techniques used to manage uncertainties organize the project's known information, but give little or no indication of the unknown information or uncertainties associated with the project. These techniques do not take into account the impact of existing dependency and interdependence relationships between the various sources of uncertainties in the project. This work will apply Action Research to develop a model with a focus on uncertainty quantification techniques. This work aims to present a model with a focus on uncertainty quantification techniques that take into account the relationships of dependencies and interdependence that exist between the sources of risks and uncertainties in software projects and as a result, contribute with the advance of state of the art in the practice of risk and uncertainty management in project software.*
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1. Problem characterization

The interest in managing uncertainty arose from the evolution of thinking about project management. For [Moura 2015], software projects can be characterized as projects that involve a high level of uncertainty, and this level of uncertainty is related to the level of innovation of these projects. The author also points out that, although risk and uncertainty management has gained much attention in recent years in academia and project management professionals, there is still considerable development potential in this field. Recent trends in project management highlight the need to address the issue of project uncertainty. In this context, uncertainty management becomes essential for risk management [Marinho et al. 2017]. It provides strategies for a manager to more efficiently

transform the unknown into the known as a way to succeed in project management [Ramasesh and Browning 2014].

[Padalkar and Gopinath 2016], in their analysis of six decades of project management research, present three main areas of research and practices that they call deterministic, exploratory, and non-deterministic. In the prevailing deterministic view, projects were measured by performance, focusing on the ”iron triangle” of cost, time, and quality. Efficiency was achieved through an optimized schedule of project activities, which were assumed to have fixed and deterministic attributes. In the exploratory view, the search was for the explanation of the project phenomenon. In the non-deterministic view, the emphasis was on the study of complexity and uncertainty in projects arguing the need for a mixture of empirical and conceptual approaches. The authors also report dissatisfaction with the results presented by the first two areas, which led to the need to rethink project management, thus bringing interest to areas considered non-deterministic, such as managing complexity and uncertainties in projects.

According to [Marinho et al. 2017], several approaches to project management do not consider the impact of uncertainty. Project managers are always faced with the need to make decisions about the future, but these decisions are made in the present, making this situation inherently uncertain. Applying uncertainty management can be a determining factor for success in software projects .Critics of the conventional form of project management argue that there has been an excessive focus on the execution and delivery of project artifacts such as the project management plan or the risk management plan. For [Chapman and Ward 2011], conventional project management techniques work best with well-defined artifacts and a relatively stable environment, but where the construction of these artifacts needs to be more fluid and uncertain, a broad perspective associated with managing uncertainty is necessary.

[Chapman and Ward 2011] demonstrate that tools such as the Risk Matrix present very simplistic definitions of risk, limited to possible adverse events, and measured by the product of the well-known equation of probability versus impact, resulting in the degree of risk exposure. Thus, for that kind of tools, the risk assessment is limited to identifying sources of uncertainty, ignoring other types of uncertainties identified by the authors, such as ambiguity, variability, and systemic uncertainty. These types of tools focus on specific sources of a low level of uncertainty, where the application of more complex models can bring better results. Works such as [McLain 2009], demonstrate that specific tools such as Gantt chart, PERT network diagrams (Program Evaluation and Review Technique) and Critical Path Method, organize the known information of the project, but give little or no indication of unknown information or uncertainties associated with the project. Furthermore, even tools like Monte Carlo Simulation do not consider the systemic relationships that exist between the various sources of risks and uncertainties that can be identified during the development of a project [Dorp and Duffey 1999]. These approaches need to recognize the various sources of uncertainty existing in projects and have the ability to model the dependency relationships between the various variables and their control/response relationships within the project [Atkinson et al. 2006].

The above text reinforces the need to search for alternative forms and tools for managing uncertainties in projects, which can also be perceived by the increased search for methods of measuring uncertainty and tools that can take into account the

impact of existing interdependence relationships between sources of uncertainties in the project. Examples of such tools are those based on probabilistic methods such as Bayesian networks, and Fuzzy Logic [Padalkar and Gopinath 2016]. According to [Khodakarami et al. 2007], as it does not take into account the impact of existing interdependence relationships between the sources of uncertainties in the project, estimates that are conditionally dependent on assumptions and conditions not explicitly mentioned are not identified. These conditions and assumptions are significant sources of uncertainty and need to be identified and addressed explicitly.

Hence, the specific problem addressed by this research is the fact that the current uncertainty management tools do not take into account the interdependence relationships that exist between the various sources of uncertainties in software projects. We understand that the development of a model with a focus on uncertainty quantification techniques that take into account the relationships of dependencies and interdependence that exist between the sources of risks and uncertainties in software projects can be of great value for the community of project managers.

Furthermore, to better contextualize the impacts of not considering interdependence relationships, authors like [Chenarani and Druzhinin 2017], report the significant impact of uncertainty on project goals, quantification, and that monitoring can be very useful and informative for project managers. Also [Hester 2012] declares the difficulty in assessing the accuracy of the expert's input. [Jakeman et al. 2010] complete that little attention has been given to quantifying epistemic uncertainty.

Therefore, based on the context presented above, the research question investigated by this work is: *What are the impacts of a model based on quantification techniques to help manage uncertainty in software projects?* To answer this research question, the main objective of this research is to propose a model for managing uncertainty in software projects based on techniques for quantifying and identifying dependency and interdependence relationships in sources of uncertainty in software projects. In order to achieve this primary objective, the following specific objectives have been outlined: (i) identify in the current literature which quantitative methods are used to manage the relationship between sources of uncertainty in software projects; (ii) instantiate the first version of the model and apply it to the industry with quantifying and identifying relationships found in the literature; (iii) evaluate the version developed as a way to identify the points for improvement for a second version of the model and its capacity to answer the research question.

2. Background

The Project Management Institute (PMI), through its well-known publication PMBOK Guide [PMI 2017], defines a project as a temporary effort to create a unique product and service of a temporary nature with a beginning, middle and end as well established.

PMI in its project language standardization effort also defines a portfolio as a collection of projects, programs, sub-portfolios, and the group managed operations to achieve strategic institution objectives and programs that are grouped into portfolios and composed of subprograms, projects or other jobs managed and coordinated to support the portfolio. Individual projects can be in or out of programs and still be part of portfolios. Project management is the application of knowledge, skills, tools, and techniques to

project activities aiming at reaching the requirements defined in the planning [PMI 2017]. Project management, as stated in the PMBOK Guide, can be achieved through the application and integration of 49 processes (in its 6th edition), logically grouped and categorized into five groups of processes: Initiation, Planning, Execution, Monitoring and Control and Closure.

According to [Atkinson et al. 2006], techniques for project management do not take into account the sources of uncertainties of a project. To [Browning and Ramasesh 2015], the level of uncertainty is related to the amount of information we have and can be classified in: knowns: when there is sufficient information for uncertainty to become a risk and we can apply the known techniques for risk management in projects; known unknowns: when the information is partially known, and there is a probability that the uncertain event occurs, and the likely impact on the project objectives can be assessed; unknown unknowns (unk-unks): when it is complete ignorance of what will occur and thus impossible any type of verification on the impacts of the occurrence of uncertainty. This last level can also be called unpredictable and highly complex.

3. Methodology

For [Merriam and Tisdell 2015], Qualitative Research is an umbrella term that covers a range of interpretative techniques which seek to describe, decode, translate, and create meaning of certain phenomena in the social world. She says that basically, qualitative researchers are interested in understanding the meaning constructed by people, that is, how people make sense of their world and their experiences in the world.

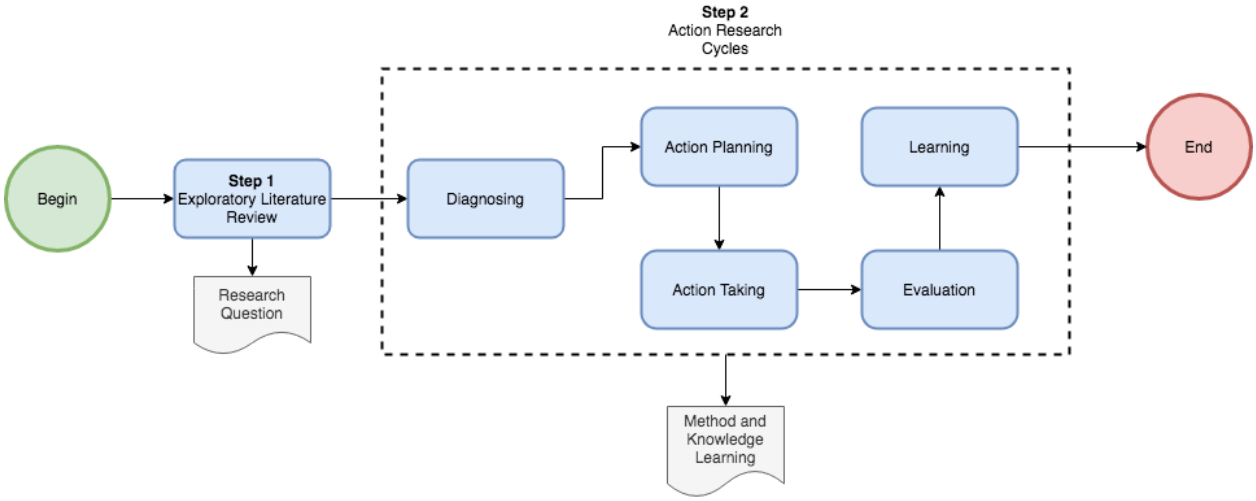
The philosophical roots called Constructivism assumes that reality is socially constructed. There is no single, observable reality. To this kind of researchers, there are multiple realities, or interpretations, of a single event. For this research, the adequate philosophical position is the Constructivist thought since it defends that knowledge must be based on the inductive as a primary mode of analysis and constant comparative methods. The inductive method stance and strives to derive meaning from the data. Findings founded in this kind of method approach derived from the data in a qualitative study and are showed in the form of themes, categories, typologies, concepts, tentative hypotheses, and even theory about a particular aspect of practice [Merriam and Tisdell 2015].

3.1. Research Design

When starting a research effort, you need some idea of what you want to do and a plan that will get you to reach your research goals. This plan or research design is the logical plan for getting from here to where, where the initial set of questions to be answered is, and there are some set of conclusions (answers) about these questions [Yin 2013].

This research consists of two significant steps. In the first step, an exploratory literature review was carried out, consisting of a broad review of concepts related to uncertainty management in software projects. An exploratory literature review was conducted using search engines such as Google, Elsevier ScienceDirect, Scopus, IEEExplore and ACM Digital Library, and Springer Link for being the engines used in [Marinho et al. 2015b] 's work to create their uncertainty management approach. Two search blocks were performed as the first free text search block conducted on the above

Figure 1. Research Steps



Source: Author

engines with the search criteria for peer-reviewed journals. The result of this research was analyzed and made a snowballing search back which brought us more articles for the search.The final result of the research indicates a gap in Software Engineering field that was the lack of approaches to take into account the impact of existing dependency and interdependence relationships between the various sources of uncertainties in project management.

3.2. Action Research

This work use as process research an Action Research (AR). The AR processes use the model described in [Staron 2020] derived from the authors' experience in conducting different studies of AR in Software Engineering. In each cycle, we have the **Diagnosing** phase, which deals with the exploration of the research problem and certifies that it can be feasible. The **Action Planning** phase deals with the planning of the actions to be performed during the action research. In this phase, we will identify what will be done, when it will be done, how it will be done, and how the research actions will be carried out to solve the problem identified in the previous cycle. The next phase, **Action Taking**, deals with conducting action research. In this phase, there will be an intervention in the organization object of study of action research to evaluate the consequences and effects of this intervention. The next phase deals with the **Evaluation** of impacts, reduction of bias in the researcher's observations, and the effects of the intervention on the research object. Finally, we have the **Learning** phase considered one of the most important in the cycle, as it helps to raise the organization's skills in dealing with the problem initially identified. In this phase, methods are used to increase the learning process in the organization.

As an evaluation method, AR cycles can use qualitative analysis made with the results of the transcription of semi-structured interviews and observations made by the researcher. The method for evaluating action research cycles within the scope of the qualitative analysis used for this research is Thematic Analysis, which is the method for identifying, analyzing, and reporting patterns (themes) within data. The evaluation of the founded or new model is planned by the evaluation of the number of new uncertainties arise in the project and the number that represents the amount of uncertainty present in

the project. So this is the stop criteria. It is hoped that the result of the AR cycles, together with the results of the analyzes and research in the literature, can help in the creation of the model proposed by this research and consequently help to answer the research question asked in the introductory section.

4. Current state of the work

In the context of this AR, the project team consists of software developers, database administrators, and infra architects. All team members are involved in the research. The team uses sprint-oriented agile development for product development. They need to understand how to measure the uncertainty to manage better the uncertainty associated with the project. The team needs to quantify the amount of uncertainty in the project. They need to find or develop a new approach to quantify uncertainty in a software project.

The AR is currently at the end of its first cycle. In this cycle, we find in the literature evidence of the use of techniques such as Bayesian Networks [Padalkar and Gopinath 2016][Khodakarami et al. 2007][Khodakarami and Abdi 2014] to deal with the management of uncertainty and its dependence and interdependence relationships of the various sources of uncertainties existing in software projects. At the end of this first cycle, sufficient scientific knowledge is expected, from exploratory literature research and interviews and observations made by the researcher, to support the construction of a model focusing on a viable solution for managing uncertainty in software projects.

A first semi-structured interview was also conducted with one of the project's developers. This interview is based on the protocol used by [Taipalus et al. 2020] with some of the following questions "How, in your experience, uncertainty affects software development work?", "How can we cope with uncertainty in software development?", and at the end of interview we ask if "Is there anything you would like to add, to any of the topics?". The interview was transcribed, and the results are being analyzed using the Atlas.ti software for qualitative analysis of the data produced. We called this first cycle the learning cycle. Two more interviews with key project participants are planned at the end of the second cycle of action research. It is expected to produce a first version of the model to apply it and analyze its effects in the third cycle of action research.

It is expected to conduct at least three cycles of AR, the first being the learning cycle, a second cycle to produce a pilot version of the model, and a third cycle for evaluating the version produced in the previous cycle.

5. Expected contributions

As contribution, the development of a model with a focus on uncertainty quantification techniques that take into account the relationships of dependencies and interdependence that exist between the sources of uncertainties and risks in software projects can be of great value for the community of project managers. It is also known that the scientific knowledge generated in the different cycles of action research can also generate contributions to the community of practitioners and researchers in project management. It is understood that the construction of this model can help both researchers in the area of risk and uncertainty management and practitioners of risk and uncertainty management in software projects, since their results aim at contributing with regard to the state of the art

of research, without leaving aside the practical look of the management of uncertainties in software projects.

6. Comparison with related work

[Marinho et al. 2017] defines an approach to uncertainty management and describes strategies that allow team members to formalize and manage uncertainty in software projects. Marinhos's approach revealed five methods and 18 practices for reducing uncertainties in the software project. The action research used by the authors applied some of these methods and practices to investigate whether they contributed to better uncertainty management [Marinho et al. 2015a]. The first practices identified by Marinho in his approach is the characterization of projects as a way to minimize the probability of failures. He reports that it is essential to check already in the early stages if uncertainty associated with the project exists in its aims and solutions, and adopting a management model that is suitable for the project type, as well as Stakeholder analysis should be conducted to determine project objectives better and define success criteria. In identifying sources of uncertainty, he reports that specific uncertainties may not always be apparent and warns of 4 sources of uncertainty that may influence project success.

Project managers must ask what is unknown or unclear in a project among these four sources and adopt strategies to analyze the project more closely. Early Signal Detection can be done verbally, non-verbally, and in writing such as through an indicator in the project status report. This step of the Marinho's process built a table for identifying early signs. By recognizing early signs of uncertainty, corrective actions can be taken; however, it is necessary to establish a culture of mindfulness and to check the early signs table to do this successfully. Once an early signal is identified, it is necessary to make sense of it by interpreting the signal so that appropriate uncertainty responses can be applied at the end of the process. Following the process of identifying early signal awareness, we have traditional risk management widely disseminated by guides such as PMBOK [PMI 2017].

However, this approach does does not clearly address the problem of the need to identify the pending and interdependent relationships that exist between the various sources of uncertainties in project management. Despite recommending in the "Mapping the knowledge of sources of uncertainties" phase the need to answer the question: "How well understood are connections, relationships and dependencies between uncertainty sources?", but without presenting a tool to assist in the search for these relationships.

At the work of [Ramasesh and Browning 2014], the authors presented a theoretical framework that proposes factors and relationships that increase the level of uncertainties (unknown unknowns) in projects. The factors are addressed by the authors through a literature review. As the framework is used and specific areas of uncertainty are determined, a project manager needs approaches to attack them and transform unknown unknowns into known unknowns to apply the known risk management techniques currently in the literature. At this work we can identify the presentation of six main factors related to project and behavior problems that may increase the probability of project uncertainty: complexity, complicatedness, dynamism, equivocality, mindlessness and project pathologies.

Although this conceptual framework indicates the concern with identifying ex-

isting relationships between sources of uncertainty, it does not present any quantitative technique to help the process of measuring these relationships. Besides, the authors introduced a conceptual framework without giving something structured that could be used in practice for managing project uncertainties.

References

Atkinson, R., Crawford, L., and Ward, S. (2006). Fundamental uncertainties in projects and the scope of project management. *International Journal of Project Management*, 24(8):687 – 698. Rethinking Project Management.

Browning, T. and Ramasesh, R. (2015). Reducing unwelcome surprises in project management. 56:53–62.

Chapman, C. and Ward, S. (2011). *How to manage project opportunity and risk*.

Chenarani, A. and Druzhinin, E. (2017). A quantitative measure for evaluating project uncertainty under variation and risk effects. *Engineering, Technology & Applied Science Research*, 7(5):2083–2088.

Dorp, J. V. and Duffey, M. (1999). Statistical dependence in risk analysis for project networks using monte carlo methods. *International Journal of Production Economics*, 58(1):17 – 29.

Hester, P. (2012). Epistemic uncertainty analysis: an approach using expert judgment and evidential credibility. *Journal of Quality and Reliability Engineering*, 2012.

Jakeman, J., Eldred, M., and Xiu, D. (2010). Numerical approach for quantification of epistemic uncertainty. *Journal of Computational Physics*, 229(12):4648–4663.

Khodakarami, V. and Abdi, A. (2014). Project cost risk analysis: A bayesian networks approach for modeling dependencies between cost items. *International Journal of Project Management*, 32(7):1233 – 1245.

Khodakarami, V., Fenton, N., and Neil, M. (2007). Project scheduling: Improved approach to incorporate uncertainty using bayesian networks. *Project Management Journal*, 38:39–49.

Marinho, M., Lima, T., Sampaio, S., and de Moura, H. P. (2015a). Uncertainty management in software projects - an action research. In *Proceedings of the XVIII IberoAmerican Conference on Software Engineering, CIbSE 2015, Lima, Peru, Apr 22-24, 2015.*, page 323.

Marinho, M., Sampaio, S., Luna, A., Lima, T., and Moura, H. (2015b). Dealing with uncertainties in software project management. In *2015 IEEE International Conference on Computer and Information Technology; Ubiquitous Computing and Communications; Dependable, Autonomic and Secure Computing; Pervasive Intelligence and Computing*, pages 889–894. IEEE.

Marinho, M. L., Sampaio, S., and Moura, H. (2017). Managing uncertainty in software projects. *Innovations in Systems and Software Engineering*, 14.

McLain, D. (2009). Quantifying project characteristics related to uncertainty. *Project Management Journal*, 40(4):60–73.

Merriam, S. and Tisdell, E. (2015). *Qualitative Research: A Guide to Design and Implementation*. The Jossey-Bass higher and adult education series. Wiley.

Moura, H. (2015). Software project framework. *Federal Univerity of Pernambuco, Recife, Pernambuco, Tech. Rep., 2011*.

Padalkar, M. and Gopinath, S. (2016). Six decades of project management research: Thematic trends and future opportunities. *International Journal of Project Management*, 34:1305–1321.

PMI, P. M. I. (2017). *A Guide to the Project Management Body of Knowledge (PMBOK® Guide) — Sixth Edition and Agile Practice Guide (ENGLISH)*. Project Management Institute.

Ramasesh, R. V. and Browning, T. R. (2014). A conceptual framework for tackling knowable unknown unknowns in project management. *Journal of Operations Management*, 32(4):190 – 204.

Staron, M. (2020). *Action Research as Research Methodology in Software Engineering*, pages 15–36. Springer International Publishing, Cham.

Taipalus, T., Seppänen, V., and Pirhonen, M. (2020). Uncertainty in information system development: Causes, effects, and coping mechanisms. *Journal of Systems and Software*, 168:110655.

Yin, R. (2013). *Case Study Research: Design and Methods*. SAGE Publications.