Assessment of Operational Risks Associated to New Product Development

An Application using a Bayesian Networks Method

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Abstract: This work presents an application of a method for assessing the operational risks associated to the development of new products, aiming to address the uncertainties of technical and managerial risks. The method has been developed using the Design Research approach, which enabled the development of a set of artifacts linked through six steps, where the main artifact is a Bayesian Network model. The performance evaluation of the application was carried out by a tentative application in a new product being developed at a design center of a global company, where the main focus was to assess the risks associated with reliability failures. This research, besides contributing with a proposal of an application to support the new product risk management, indicates potential enhancements to the decision making process, and to the knowledge management in project environments.

1 INTRODUCTION

During the design of new products risks can be classified in technical and managerial (Grubisic, 2009). The technical risks include the risks associated with particular activities during the development process, but also consider other activities of product development, such as the setting of validation tests and quality evaluation of suppliers. The managerial risks are derived from some more specific elements of the project, such as cost, time, communication and scope, i.e. the variables related to project management.

In discussing strategies for dealing with the risks associated with new product development, Chen, et al. (2007) highlight the need for these to be thoroughly and systematically analyzed. Considering also the fact that in the business environment the risks, in general, have increased the product developments, managerial risks have become a very important element of project management. According to Carbone and Tippett (2004), failures in implementing the risk management process can cause many undesirable effects therefore this topic has been increasingly important for success in business management.

Considering the context of the growing level of risks it is necessary to use methods and tools to adequately deal with these uncertainties. However in several cases only the use of classic methods such as the tools for risk analysis in project management has been proven to be not enough to deal with the complexity of the research object. Furthermore, although it is usually accepted the idea that many subjective factors, e.g. experience of the project team contributes to the product risks, the classical models for risk assessment do not consider the subjective information (Neil, Fenton and Nielsen, 2000).

2 LITERATURE REVIEW

The definition of risk is one of the most controversial issues in the projects risk management community (Chapman, 2011). Modarres (1993) explains that it can be seen both qualitatively and quantitatively when constructing the definition of risk. Qualitatively when it is exposed to danger and so there is a possibility of loss or damage. Zio (2007), on the other hand, explains the first intuitive observation comes from the fact there is a risk in case there is a potential source of harm or danger. The author also emphasize the presence of a danger alone is not sufficient to set the risk condition - there is an uncertainty factor in the transformation of a

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potential risk in using a real risk of danger.

Although the well-known risk analysis techniques, e.g. FMEA (Failure Mode and Effect Analysis), PHA (Preliminary Hazard Analysis) and BDA (Block Diagram Analysis) are more detailed than the simple identification of hazards, they require a greater effort of the organization to implement them. Nevertheless all are also considered to be qualitative tools even indicating levels of risk and none allows systemic and a more dynamic risk analysis. Certain tools have been developed to help close these mentioned gaps such as the Markov chain modeling and dynamic event trees.

Considering the Risk Management as an element of Project Management, Project Management Institute (PMI, 2004) recommends some activities such as the step in preparation for the identification of hazards, called Risk Breakdown Structure (RBS). The goal is to guide the definition of risk categories with the team.

A Bayesian network (BN) $\mathcal{N} = (\chi, \mathcal{G}, \mathcal{P})$ consists of an acyclic graph $\mathcal{G} = (V, E)$ with nodes $V = \{v1, \ldots vn\}$ and E directed links, a set of discrete random variables, χ, represented by the nodes of $\mathcal{G}$ and a set of conditional probability distributions, P, having a distribution $\mathcal{P}(X_v \mid X_{PA(v)})$ for each random variable X_v and χ (Jensen and Nielsen, 2007). A BN is a probability distribution over a set of random variables, χ of the problem domain (Kjaerulff and Madsen, 2008). The set of probability distributions, $\mathcal{P}$, specifies a multiplication factor of χ probability distribution, as can be seen in equation (1).

$$P(\chi) = \prod_{v \in V} P(X_v \mid X_{pa(v)}) \tag{1}$$

Hamada et al. (2008) present an important consequence of the subjective probability utilized by Bayesian inference, is that it allows incorporating the use of information beyond what is classically obtained from experimental data. The authors also emphasize the use of relevant information constitutes a useful and powerful component of the Bayesian approach. Several sources of information or knowledge can be incorporated as computational analysis, general industry data, results of previous tests of the product, data from similar products and expert opinion.

Khodakarami (2009) describes the construction of a BN occurs in three stages. The first phase is the identification of important variables and their possible states. The identification of the variables of a problem is not always an easy task, and require some practice (Kjaerulff and Madsen, 2008). The second phase is called the elicitation of the model structure. It comprehends the identification of relationships between the variables and the representation of these relationships through a graph. The third phase for the construction of BN is called elicitation of numerical parameters of the model.

The use of Bayesian networks for risk analysis has the potential to have several positive aspects, such as the representation of subjective knowledge, the dynamic update of the model and the representation of causal variables. However, while there are some challenges in the construction and analysis of models, some of them have been at least partly solved by various researchers and software developers in the last decade. Some studies have explicit evidence of a significative ROI (Return on Investment) in commercial applications of Bayesian networks, as mentioned by Fenton and Neil (2007) as well as Pourret, Naim and Marcot (2008),

3 METHODOLOGY

By looking at different research methodologies to develop a method to be used by product development professionals the paradigm of Design Research (DR), also known as Design Science, was considered appropriate to the research question, the general purpose and nature of this work. Design Research defines as a process of using knowledge to design useful devices and then use various rigorous methods to analyze whether a particular artifact is effective or not (Manson, 2006).

The design cycles consist of the following sub processes (Takeda, et al., 1990): awareness of the problem (to identify a problem by comparing the object under examination with the specifications), conceptualization (to suggest key concepts needed to solve the problem), development (to construct candidate solutions from key concepts using various types of knowledge for Design), Evaluation (evaluating candidate solutions in various ways such as computing structured), simulation or evaluation of the costs and Conclusion (deciding which solution to adopt, modify the descriptions of the object).

4 RISK ASSESSMENT METHOD

The initial step in designing the application was to develop a list of general requirements, such as: it should enable analysis of the risks associated with the operation with qualitative and quantitative perspectives (COSO, 2004), it should provide tools for easy computational implementation (Grubisic, 2009), it should provide a systematic way of transmitting knowledge facilitating the learning process of the method users (Grubisic, 2009). From the list of requirements, the theoretical framework and research methodology, the application was developed starting with the creation of the model in Bayesian Networks. A sequence of steps has been developed and four artifacts required for instantiation of the model and use the results in the context of risk management.

At the first method step (Planning), the method objectives need to be aligned to company's senior management. An explanation of the key concepts related to the method, emphasizing the potential of the model built on Bayesian networks as well as the constraints need to be presented and well understood. Once the objectives are aligned with the organization's senior management, a team must be built to support the method implementation.

The second method step is the BN Model Construction. The BN model and its implementation in a software is a mandatory step since the intelligence related to the calculation of risk levels is derived from the implemented model together with the software algorithms and the model constructs elicitation.

The elicitation of numerical parameters is the third method step in which greater effort and time is required, since knowledge of the company experts must be transferred for each construct to the CPTs (Conditional Probability Tables). Besides extracting the knowledge of experts, this step provides the collection of data from previous projects. It is very important that all experts are adequately prepared for elicitation, especially by training on the meaning of each construct.

During the last step of the method is carried out the risk assessment itself. At this time, experts must make inferences based on the artifact BNS and then must lay the evidence collected from the artifact in each phase of the project. Once launched, the experts should receive information from the most important risk levels to support the decision making process. The method should allow the simulation of different scenarios to be assessed how the risk can be modified depending on the actions taken.

Once each phase of the project is completed, the final risk must be recorded for subsequent monitoring, which will allow to be evaluated to what degree has varied over the projects. The last activity by the method used should be performed once the project is completed.

5 CASE STUDY

The application was evaluated in a company of the electronics industry. In the implementation team there were three experts with experience in executing several projects in the company. The implementation took two weeks for the Planning step, five to the elicitation, and two weeks for prioritization and the Risk Assessment itself.

The model was constructed as described in the previous section. In the final version 21 variables and 4 main areas (Supply Management, Product Design, Project Management and Reliability Engineering) were considered. The final model can be seen at Figure 1.

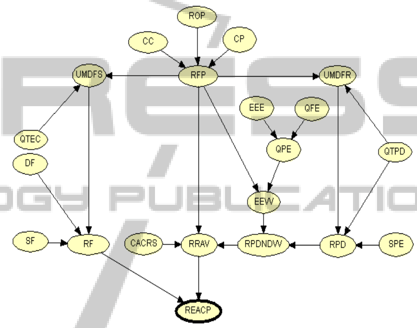

Figure 1: Developed Model.

Once the RB was elicited in the software, the next activity was the adaptation from the collection of evidence of recent projects completed by the organization, as the experts considered the number of cases collected as significant.

Started from the adaptation of cases, evidences were collected from eight projects previously run by the organization, representing about 70% of recent projects carried out over a period of five years. To implement the process of adaptation by lot, it was created a list of evidence in a compatible format.

After collecting some few evidences at the first phase of the development, e.g. project complexity level, the Risk Index was below the 59.7 level, being slightly higher than the value without evidence (58.9). However, the fact that the value of risk have been above the acceptable threshold for the launch of the product (52.0) indicated the organization should take action along the project that reduce this level of overall risk compared with the usual level the other variables.

A design risk assessment indicated the need for caution due to some components that were being considered for the BOM (bill of material) - due to strong pressure for lowering the overall product cost, it was defined the need to use components of lower price. Given the concerns related to components, raised at Phase 2 of the project, the construct DF was assessed at low level ("L"), although there were not very objective evidences the performance of the selected suppliers was low.

Once selected all levels of the variables for which there were evidences, the artifact SOFTRB executed the algorithm and presented the variable results. The Risk Index stood at 64.2, i.e. within the red band and above the risk threshold for phase 2. It indicated the need to take action to modify some risk levels before going on with the project, i.e. before starting the third phase.

6 CONCLUSIONS

This work evaluated a method for assessing operational risks associated with the development of new products. Through the Design Research method, five artifacts have been developed, in addition to the steps of the risk assessment method itself. The method seemed to contribute to the improvement of the process of Risk Management held during the introduction of a new product.

The main evaluated artifact was a model constructed using the Bayesian Networks approach. The model considers the judgment of company experts with some qualitative data in order to evaluate technical and managerial risks, which were linked through probability tables, generating by means of a prototype system the overall risk associated to the product launch. For the model to be used in practice and in any consumer electronics design center it was proposed a logical sequence of steps involving the use of all artifacts.

The general objective was the evaluation of the method in a first real application. Of course, the conclusion about the method feasibility in all companies require a more extensive research, involving several companies from different segments.

The limitations of this study are related to the implementation of the empirical part of it. There was only one attempt to apply the method and in a single project. This fact restricts the generalization of findings regarding the applicability of the method in other projects.

As suggestions for future work, first is the use of alternative approaches in the process of elicitation of the probability tables in order to minimize the effort required. Other possible enhancement is the inclusion of methods to enable the calculation of economic loss distributions.

REFERENCES

Carbone, T.A. and Tippett, D.D., 2004. Project risk management using the Project risk FMEA. *Engineering Management Journal,* 16(4), p.28.

Chapman, R. J., 201. Simple Tools and Techniques for Enterprise Risk Management. *2nd ed. London: J. Wiley & Sons*.

Chen, M., Chen, Y., Chen, B. and Wang, Q., 2007. Analysis on Product Technical Risk With Bayesian Belief Networks. Knowledge Enterprise: Intelligent Strategies in Product Design, Manufacturing and Management. Boston: *Springer*, p. 990-995.

Comitee of Sponsoring Oganizations of the Treadway Comission (COSO), 2004. Enterprise Risk Management- Integrated Framework. New York: *AICPA*.

Fenton, N., Neil, M., 2007. Managing Risk in the Modern World: Applications of Bayesian Networks. London: *Mathematical Society*.

Grubisic, V.V.F., 2009. Metodologia de Gerenciamento Integrado de Riscos Técnicos e Gerenciais para o Projeto de Produtos. Ph.D. *UFSC*.

Hamada, M.S., Wilson, A., Reese, C.S., Martz, H., 2008. Bayesian Reliability. New York: *Springer Science*.

Jensen, F.V. and Nielsen, T.D., 2007. Bayesian Networks and Decision Graphs. *2nd ed. New York: Springer Science.*

Khodakarami, V., 2009. Applying Bayesian Networks to model Uncertainty in Project Scheduling. Ph. D. Queen Mary, University of London.

Kjaerulff, U.B. and Madsen, A.L., 2008. Bayesian Networks and Influence Diagrams: a Guide to Construction and Analysis. New York: *Springer Science.*

Manson, N.J., 2006. Is operations research really research? *Operations Research Society of South Africa*, 22(2).

Modarres, M., 1993. What Every Engineer Should Know About Reliability and Risk Analysis. New York: *Marcel Dekker*.

Neil, M., Fenton, N. and Nielsen, L.M., 2000. *Building Large-Scale Bayesian Networks*. The Knowledge Engineering Review, 15(3): p. 257-284.

PMI (Project Management Institute), 2004. ANSI/PMI99-001-2004 A guide to the project management body of knowledge. Milton Square: *Project Management Institute*.

Pourret, O., Naim, P. and Marcot, B., 2008. Bayesian Networks: a Practical Guide to Applications. New York: *John Wiley & Sons*, 429 p.

Takeda H., Veerkamp, P., Tomiyama, T. and Yoshikawa, H. 1990. Modeling design processes. *Artificial Intelligence Magazine*, 11 (4).

Zio, E., 2007. An Introduction to the Basics of Reliability and Risk Analysis. Danver: World *Scientific Publishing.*