Guidelines for a risk management methodology for product design

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Abstract: In view of the innumerable uncertainties involved in the product development process (PDP), it is essential to study the risks that can obstruct the course of the PDP. This study is even more relevant in the product design process, since it is here that the most important decisions involving the product conception are made and the greater part of product life cycle costs are defined. In this regard, guidelines for the conception of a risk management methodology for the product design process are presented here based on a bibliographical review and a critical analysis. Using these procedures, guidelines are defined to underpin the proposed methodology, considering not only the technical risks involved in the various phases of the product design process but also the management risks of the project. Based on this methodology, undesirable results can be avoided, the product design process can be improved, and the areas of expertise (integration, scope, time, cost, quality, human resources, communications and procurement) of project management can be defined. This paper concludes with a partial and general conceptual vision of the methodology to be developed.
Keywords: risk management, product development, design process

1. Introduction

Due to the growing demand for innovative products, the product development team is facing many new and complex situations that bring with themselves a lot of uncertainties. It is known that these uncertainties consist of a group of unknown events related to the future, which can include favorable or unfavorable events. The events that originate favorable results are called opportunities and the events that originate unfavorable results are called risks (PINTO, 1998). This paper addresses unfavorable events specifically in relation to the product design process, since risks are an inherent characteristic of product innovation and this is obtained mainly along this process.

Such a complex situation highlights the importance for managing risks through a risk management process, that according to the PMI (2000) it is defined as a formal and systematic method of management that includes identifying, analyzing and responding to the risks of the project during its life cycle, in order to achieve certain objectives. KERZNER (1998) affirms that an appropriate risk management (RM) implies the controlling of possible future events, proactively and not reactively.

However, according to SMITH & MERRITT (2002) few product development projects implement risk management appropriately. Also, FERREIRA & OGLIARI (2004) found through a case study, carried out in a large company, that the project team identifies the eventual risks that can become apparent during the PDP in a quite informal and intuitive way and without the use of appropriate tools.

Also, RAZ & MICHAEL (1999) found in a study carried out on eighty four companies that develop software and high technology products, that the tools and techniques used by these companies in the risk identification are practically the same, regardless of whether the risk management process is carried out in a complete way or not. According to the authors it is relatively easy to identify the risks of a project in an informal way, but it is necessary to have a structured risk management process that uses methods, tools and techniques appropriate for more complicated tasks such as the analysis, response and control of design risks.

In this context, this paper presents guidelines for the conception of a risk management methodology for the product design process. For such end, firstly, a wide bibliographical review is presented on the models and methodologies already developed to deal with this matter, followed by a critical analysis of them, in order to identify gaps, needs and critical points. Using these procedures, guidelines that will be used in the proposal of the methodology that considers the technical risks of the product design process activities and the managerial risks are defined. To conclude, a partial and general conceptual vision of the methodology to be developed is presented.

2. Bibliographical review

Several definitions of risks can be found in the literature, but as defined by VALERIANO (1998) a risk is essentially the possibility of occurrence of an undesirable result, as a consequence of any event. In a complementary way, KERZNER (1998) defines risk not only as a measure of the probability of the occurrence but also as the consequences of not achieving an objective.

Thus, the project risks are characterized basically by three elements as shown in the first definition in Table 1. In this table it is possible to visualize this simplified definition of a risk, which is adopted by most of the authors, as well as other wider definitions.

The complete definition of a risk is obtained during its management process and in this regard, several models of risk management are available in the literatures which, in a general way, are quite similar. Table 2 presents some models of risk management with their constituent processes.

Although the model presented by VERZUH (2000) has less process than the others, more than one subject is considered inside

Table 1. Risk definitions according to different authors.

Authors	Risk elements	Observations
1)KERZNER (1998), PMI(2000), VALERIANO (1998)	Risk = F (event, probability, impact)	Definition used by most of the authors
2) KERZNER (1998)	Risk = F (hazard, safeguard)	A hazard that can be overcome by the knowledge of its existence and through safeguards that can be taken to overcome it.
3) KUMAMOTO & HENLEY (1996)	Risk = {(probability, outcomes, significance or utility, causal scenario, population affected)}	The outcome element is equal to the impact in the first definition. Other elements of the risk profile are: significance (amount of loss in the design in relation to the risk impacts) or utility (the opposite of significance); causal scenario that studies the causes of the results and the population affected by the risk.
4) SMITH & MERRITT (2002)	Risk = {(event, causes of the event, probability of the event, impact, causes of the impact, probability of the impact, total loss)}	Causes of the impact besides the risk itself, other causes can exist, probability of the impact to occur given the risk. The total loss is equal to the significance in the previous definition.

Table 2. Models of risk management.

Authors	Risk Management Process					
KERZNER (1998)	Risk identification	Risk quantification	Risk response	Risk control/ Lessons learned		
PINTO (1998)	Risk identification	Assessment and quantification	Response development	Documentation and control		
PMI (2000)	Risk management planning	Risk identification	Risk qualification	Risk quantification	Risk response development	Risk monitoring and control
VALERIANO (1998)	Planning of risk management	Risk evaluation	Option evaluation	Risk treatment System		
VERZUH (2000)	Risk identification	Risk response development	Risk control			
SMITH AND MERRITT (2002)	Identify risks	Analyse risks	Prioritize and map risks	Resolve risks	Monitor risks	

a single process, since the risk response development process also addresses the risk quantification.

In this paper the risk management processes will be described briefly, given that the aim is to focus on the review of risk management studies related to product development projects. For this description the model proposed by the PMI (2000) was chosen since it includes all of the processes of the other models.

According to the PMI (2000) risk management begins with its planning which consists of deciding how to approach and to plan the risk management activities. At this point, the project team should decide which RM model will be used, analyze the RM training needed along with the necessity for acquisition and/or development of tools, and other resources.

Next, the process of identifying and describing the events that can produce adverse effects on the project (PMI, 2000) begins. Several techniques can be applied, such as: brainstorming; interviews; Delphi technique; Nominal group technique; *SWOT* (strenght, weakness, opportunities and threats); cause and effect diagrams and risk classification according to their sources.

Qualitative analysis serves as an initial study of the risks, and the risks that present more serious characteristics should be subsequently analyzed in full detail through the process known as quantitative risk analysis. Here, the occurrence probability and the impacts generated by the risks are examined in more detail through tools such as the decision tree, the Monte Carlo technique and Bayesian networks.

The next process consists of the development of a response to the critical risks of the project. The effectiveness of this process will directly determine whether the project risks will increase or decrease. Several strategies of risk response can be adopted such as: avoidance, mitigation, transfer or simply accepting the risk. The basis for the selection of a strategy will depend on the characteristics of the risk.

After these processes, the risk evolution should be monitored during the project, as well as the appearance of new risks, in order to assure the execution of the risk plans. Tools and techniques such as project risk response audits, periodic project risk revisions, analysis of the value gained from the work carried out, performance assessment and additional risk response planning can be adopted to monitor and control the risks.

In the context of the PDP, some studies on risk management have already been developed, such as the approach proposed by COPPENDALE (1995), which is quite similar to previously presented models, but is applied to the PDP. Such an approach comprises three stages: identification and evaluation of the risk occurrence probability and development of RM plan. In the first stage, the author proposes a brainstorming meeting involving all of the personnel involved in the PDP, because many risks derive from areas that are not immediately responsible for the product development. At the end of this stage a long list of potential project risks is compiled and organized into categories such as: external, project management, commercial, manufacturing, marketing and technical. In the second stage, the author proposes the use of the risk probability/impact classification matrix in which the probabilities and impacts are classified on a scale of 0 to 10. In the last stage the author describes some actions that can be taken to reduce the risk occurrence probability and impacts, like: imposing rigorous contract conditions and obtaining a second opinion on areas that involve critical technologies.

Based on the fact that the PDP should consider concepts such as concurrent engineering, KRISHNAN (1996) proposes a structure to manage the existent risks in two phases of this process, which will be executed simultaneously. For this, the structure is based on two concepts: evolution and sensitivity. The evolution is defined as fast when the information becomes close to its final form rapidly, in the initial phase, so that it can be transfer to the beginning of the following phase. In turn, the sensitivity is a measurement of the reworking time taken in the second phase to accommodate changes which occurred in the first phase. For each evolution and sensitivity combination the author proposes a kind of phase overlapping, for example, iterative overlapping, which should occur when the evolution of the initial phase is slow and the sensitivity of the following phase is low, because in this case the information of the initial phase can be processed by the following phase without many significant risks in terms of reworking.

BROWNING & EPPINGER (2002) analyzed the impact of different forms (architectures) of activity sequencing in the PDP, in relation to the risks of cost and schedule. The authors used the DSM (Design Structure Matrix), that enables a visualization of the order in which the activities are sequenced and their dependence relationships. Five different activity sequencing arrangements for a vehicle design are shown and simulations based on the Monte Carlo technique are carried out to produce cost and duration distributions of the vehicle design process in order to define the of cost and schedule risk levels that each architecture offers in the product design.

HULETT (1996) uses the critical path method to identify the risks of delays and the Monte Carlo technique for their quantification. For illustration, the author considers two design activities and defines the optimistic, realistic and pessimistic time periods for the completion of each activity. Then, based on a normal distribution, the author develops a series of simulations using the Monte Carlo technique to obtain the probability distribution calculation for the deadline of the activities. With this distribution it is possible to determine on which dates it is more probable that the project will finish within the previously defined interval and thus improve the project plan.

ZHU & DESHMUKH (2003) developed a decision support system that models uncertainties in the initial phases of product design project, more specifically for the process of the product life cycle analysis. They applied Bayesian networks for the evaluation of the decisions to be taken regarding the life cycle of a product: an oil-drilling platform. The phases of the product life cycle analysis are: design, production, distribution, maintenance, disposal and recycling. Each phase has solution alternatives and their selection is based on reducing the environmental impact caused by the product, through a Bayesian network in which utility values of the *n* possible combinations of solution alternatives for the phases are calculated.

WANG (2002) proposed a methodology based on fuzzy logic to solve precision problems in the schedule estimates for PDP activities. An algorithm was developed for the construction of the activity schedule with a minimum possibility for delay and the start time of each activity is defined by the optimization of the degree of satisfaction in relation to all the time restrictions.

DEYST (2002) considers the PDP as an estimate problem and develops a mathematical model that aims to provide a quantitative method to evaluate the project plan in order to minimize the risks associated with estimates. For such, the author uses concepts such as variance and probability density function, among others.

3. Critical analysis of the bibliographical review

Although KUMAMOTO & HENLEY (1996) and SMITH & MERRITT (2002) have proposed apparently complete definitions of risk, these are not adopted by most authors in the project risk management area. This is because in early attempts to gain an understanding of the word risk, the initial definitions appeared to be very complex, discouraging their use by project teams. However, such definitions should be obtained during the risk management process, mainly in the risk analysis stage, because this stage has the objective of studying the risk causes, the probabilities of the impact occurrence and the extent to which the population is affected by the risks. In the case of a product development project the population may include a project team member and the final consumers of the product.

In a general way, the PMI (2000) model seems to be the most complete although, as with the others, it was shown to be poor in tools. However, all models were found to be very useful guides for a first study on risk management. Of the models, only SMITH & MERRITT (2002) dedicated their research to product development projects, through examples, because these demand specific treatment for the particular characteristics present such as: a high uncertainty degree, innovation, complexity, multidisciplinary teams, concurrent engineering, product life cycle, among others. However, the structures of the other models, that were shown to be quite similar, can be used and adapted to this end, as demonstrated by COPPENDALE (1995).

The structures proposed by the PMI (2000) and VALERIANO (1998) are very interesting, mainly, because they approach the theme of risk management planning. This is an important theme in terms of the risk management of product development projects, since before beginning an RM process it is advisable to firstly structure and organize the planning of essential areas of the project management such as scope, time and cost.

It was found that in the risk identification phase each author uses only one technique. However, this approach is not considered here to be the most effective because with only one technique it is not possible to identify the several risks that express themselves in different ways.

On the other hand, in the qualitative analysis phase the approaches were found to be appropriate, because they allow a preliminary study on the risk characteristics. In the quantitative analysis stage, most studies adopt the Monte Carlo technique which is considered efficient when the aim is to evaluate the probability distribution of a single variable, that is, a variable which is being considered separately without the others. This can be complimented with the use of the Bayesian networks that take into consideration the cause and effect relationship among variables allowing the identification of the causes and impacts of the risks, as well as their quantification. Along with the Bayesian networks used by ZHU & DESHMUKH (2003), the studies presented by WANG (2002) and DEYST (2002) are very interesting because they deal with the precision of the estimates of the design activities duration.

In this study it was observed that the studies that deal with risk management of product development projects are more about risks related to delay and costs and they don't consider the risks of the other knowledge areas presented by the PMI (2000): scope, quality, integration, human resources, communications and procurement. Also, they analyze the risks of isolated activities and don't consider the cause and effect relationships between the project activities.

To conclude, a complete methodology involving all the risk management processes was not found, as that proposed by the PMI (2000): risk management planning, risk identification, risk qualification, risk quantification, risk response development and risk monitoring and control related to product development projects with techniques and practical tools.

4. Guidelines

Based on the bibliographical review and critical analysis of risk management, general and specific guidelines that will be used in the proposition of a risk management methodology for the product design process are presented.

General:

I) Guide the project team in the complete and detailed management of possible risks that can obstruct the course of the project;

II) Aid the company in the improvement of the product design process and in the best definition of the knowledge areas relating to the project management.

For the proposition of the risk management methodology for the product design process:

III) Consider the technical risks of the activities of the product design process comprising the following stages, according to the Consensual Model: design specification (the outcome of this process being the product design specifications), conceptual design (that generates a product conception that meets, in the best possible way, the requirements identified in the previous phase), embodiment design (optimizes the product layout) and the detailed design (leading to the final documentation and procedures);

IV) Consider the managerial risks of the following knowledge areas: integration, scope, time, cost, quality, human resources, communications and procurement proposed by the PMI (2000); and

V) Elaborate methods, techniques and practical tools for the planning process of risk management, identification and qualitative/quantitative analysis of the risks, risk response development and risk monitoring and control.

Based on the guidelines above, a partial and general conceptual vision of the scope of the methodology to be developed is proposed, with its principal elements and relationships.

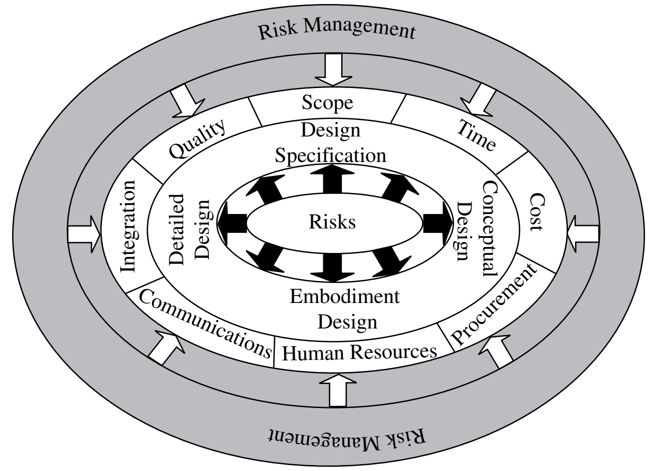

Figure 1. Conceptual vision of the elements of the risk management methodology for the product design process.

5. Final considerations

As can be observed, Figure 1 displays in a clear and extensive way the scope of the methodology to be developed. The technical risks of the product design process activities and the managerial risks of the project will be considered according to the knowledge areas of the PMI (2000). The risk management processes will be based on those proposed by the PMI (2000) which, as stated previously, is the most complete.

The gaps identified in the bibliographical review and described in the critical analysis will be used to elaborate the methodology. One of the gaps that will be investigated in-depth is the quantitative analysis of the risks, because the approaches found in the literature deal with probability and impact studies in a superficial way. With this in mind, themes like Bayesian networks will be explored, which have already been shown to be appropriate for this end according to FERREIRA & OGLIARI (2004), who demonstrated that the Bayesian networks approach cause and effect relationships between variables, which in product design relate to the relationships between the project activities, besides enabling the alignment of specialist knowledge and data sources of previous projects for the risk occurrence probability estimates and their impacts.

As can be seen, a study of this nature will represent a great contribution given the many gaps existing in this area, the growing importance of the field to a knowledge of product development and, more specifically, product design and the many changes and uncertainties that surround the innovative atmosphere of product development.

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