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Methodology for the technical and managerial risk identification and analysis in the product design process

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Abstract: Because of product design projects are unique, they are subject to risks that if not properly managed can compromise the business. Typical risks in product design are: poor problem definition, changes in consumer needs, lack of knowledge for the activity implementation, delays in deliveries. Risk management consists of a process of identification, analysis, treatment, monitoring and control of risks. In the literature it was found that there are certain gaps in relation to the risk analysis and treatment processes. The risk analysis researches found only analyze the risk probability and their impact, without making a more complete risk analysis. The risk treatment researches found only recommend general actions to treat the risks without considering the phases and product design activities and the effect of a risk treatment action for the treatment of other risks. In this sense, this paper aims to present a methodology for the analysis and treatment of technical and managerial risks in the product design. For this, it is first made a brief review of the product development process and risk management. Then, activities and tools for the analysis and treatment process of technical and managerial risks in product design are presented. Finally, there are the conclusions.

Keywords: risks, analysis, treatment, product design.

1. Introduction

The product development process is a broad concept that includes aspects of planning and design, throughout all process activities, from market research, product design, manufacturing process design, distribution plan and maintenance until the product disposal or deactivation (BACK et al., 2008).

Figure 1 shows a reference model called Integrated Product Development Process - PRODIP, which seeks to clarify the knowledge of the product development process, in order to assist in the understanding and practice of the process. The PRODIP model shown in Figure 1 illustrates the macrofases, phases and their corresponding outputs (BACK et al., 2008).

According to Figure 1, the macro-phase of planning corresponds to the project planning phase. It encompasses the elaboration of the product project plan, which is the main phase output. The design involves the elaboration of the product design and the manufacturing plan, being decomposed into four phases, namely, informational design, conceptual design, preliminary design and detailed design. The main results of each phase are, in respective order, the design specifications, the product concept, the economic feasibility and the investment required. The macro—phase of implementation includes the implementation of the manufacturing plan for the company production plant and the project closure, and is decomposed into three phases, namely, pilot production, launch and project validation. The main outputs of each phase encompass, in respective order, the product release, the initial production and the project closure (BACK et al., 2008).

Due to the complexity and multi-disciplinary of the product design this process is subject to risks as: inappropriate definition of the design problem, changes in customer needs, lack of knowledge for the execution of the activities, delays in the delivery of results, costs being higher than envisioned, among others.

Risk management consists of a formal and systematic management process that includes the identification, analysis, treatment, monitoring and control processes of the project risks (PROJECT..., 2013). In the most literature studies it was noticed the existence of certain deficiencies related to the risk management in product design.For example, the risk analysis only considers the probability of occurrence and the risk impact. Elements such risk target probability of occurrence to be reached and relative weighting, rate of risk reduction are not considered.

With regard to the treatment of risks, it was observed that the papers recommend only general actions to deal with

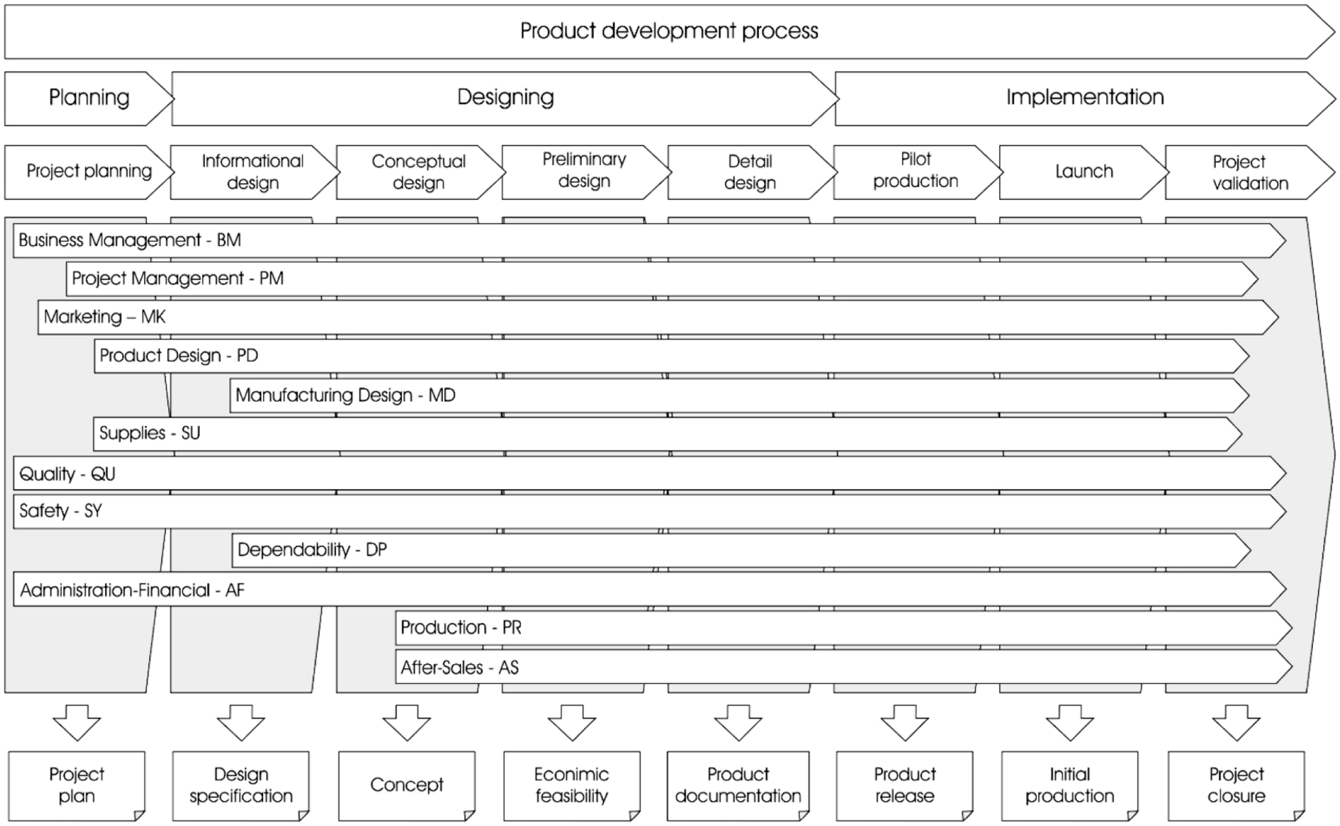

Figure 1. Graphic representation of product integrated development process model – PRODIP (BACK et al., 2008).

risks, that is, do not consider the phases and the product design activities, the type of product to be developed and neither the project team profile. In this sense, it was identified the need to propose more elements that best characterize the risks; guidelines to assist the definitions of actions to the product design risks and a method to evaluate the actions in terms of project importance.

The risks related to product design arise from the uncertainties associated with the inputs, methods, project team and outputs of these process activities. In this parper such risks are called technical risks.

The risks related to project management arise from the uncertainties associates with the scope, time, costs, communication and quality among other project management elements. These risks here are called managerial risks.

This paper aims to present a methodology for the analysis and treatment of technical and managerial risks. The present methodology seeks to better understand the project context in terms of risks in order to refine the project plan, considering an information base more precision for contingency and evaluation plans. Moreover, it is intended to add value to the project management (PM), since the other PM knowledge areas, as time and cost, are already widely known and adopted by companies. Next, a brief review on the subject of risk management is presented.

2. Risk management

A project is a temporary endeavor undertaken to create a product, service or result (PROJECT..., 2013). Because projects are unique, they are subject to risks that if not properly managed could damage the project progress.

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.

Known risks are those that have been identified and analyzed, making it possible to plan responses for those risks. Known risks that cannot be managed proactively, should be assigned a contingency reserve. Unknown risks cannot be managed proactively and therefore may be assigned a management reserve. A negative project risk that has occurred is considered an issue (PROJECT..., 2013).

Project risk management includes the processes of conducting risk management planning, identification, analysis, response planning, and controlling risk on a project. The objectives of project risk management are to increase the likelihood and impact of positive events, and decrease the likelihood and impact of negative events in the project (PROJECT..., 2013; CENTRAL..., 2002).

Several models of risk management are available in the literatures which, in a general way, are quite similar. Table 1 presents some models of risk management with their constituent processes. Through these models, the risks are studied in detail, and its elements are obtained in an orderly manner over the processes.

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 (PROJECT..., 2013).

Next, there is the risk identification process. It is recommended to identify potential risks arising from interactions related to the project activities with the participation of the applicant organization and the stakeholders (ASSOCIAÇÃO..., 2006). The main output of this process is a list of existing project risks (CENTRAL..., 2002; PROJECT..., 2013).

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 (SMITH; MERRITT, 2002; PROJECT..., 2004; GRUBISIC; OGLIARI, 2007).

The next process consists of the action development to the project critical risks. The effectiveness of this process will directly determine whether the project risks will increase or decrease. Risk treatment must be appropriate to the risk severity, to be effective in terms of cost, be appropriate to be succeed, be realistic within the project context, and, especially, must be approved by the "stakeholders" (PROJECT..., 2004). Several risk strategies 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 risk characteristics (CENTRAL..., 2002; PROJECT..., 2004, 2013; SMITH; MERRITT, 2002; KERZNER, 1998; VALERIANO, 1998; VERZUH, 2000).

The RM concludes with the risk monitoring and control process that consists of monitor the risk identified evolution and the planned responses implementation. Also encompasses the residual risks monitoringf and new risk identification (PROJECT..., 2013).

Considering the article scope, it will present a methodology for the analysis and treatment of technical and management risks in the product design.

3. Methodology for the technical and managerial risk identification and analysis related to the product design process

Next, will be presented a methodology for the technical and managerial risk management to the product design. This methodology is consist of the risk analysis and treatment phases (GRUBISIC, 2009).

3.1. Technical and managerial risk analysis

The number of identified risks in product development projects can be high, given the innumerable uncertainties. Therefore, since risks have different characteristics, it is necessary to identify the project priority risks. Next, two activities are proposed for the project risk analysis.

3.1.1. Activity: characterize the risks quantitatively

The risk characterization consists of defining the calculation of the risk relative weighting, based on the risk elements, shown in Figure 2.

The first characteristic (Figure 2) which must be defined is the probability of occurrence (characteristic 1) for each technical and managerial risk identified. This value must be attributed by the people associated with the risk domains. A debate on the analyzed risk, consulting of previous projects, analysis of context and the project plan are recommended, in order to weight the opinions and establish the percentage probability of occurrence of the risk (0 to 100).

Table 1. Risk management models.

Source	Risk Management Processes					
PMI (2013)	Risk management planning	Risk identification	Qualitative risk analysis	Quantitative risk analysis	Risk treatment	Risk control
CCTA (2002)	Risk identification	Risk assessment	Risk response planning	Risk response implementation	Risk communication	
ABNT (2006)	Risk identification	Risk assessment	Risk treatment	Risk control		

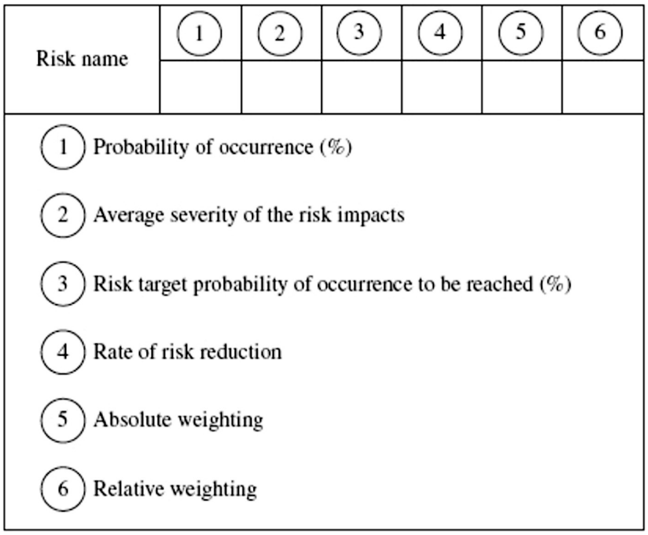

Figure 2. Elements for the calculation of the risk importance weighting (GRUBISIC, 2009).

For the second characteristic, the project team must allocate one value to the severity of each impact of the identified risks, according to the following scale: 0.1/0.3/0.5/0.7/0.9. In qualitative terms, the values correspond, respectively, to the following: very low, low, medium, high and very high (PROJECT..., 2004).

Considering that generally risks involve more than one impact, the average severity (arithmetic mean) of the impact of each risk needs to be calculated (characteristic 2), Figure 2. These average values must then be classified according to the Table 2 (PROJECT..., 2004).

Next, the risk target probability of occurrence to be reached must be defined (characteristic 3). This characteristic involves defining the risk tolerance, that is, the maximum value that the project team can accept for the risk probability of occurrence. For example, let's imagine that the probability of occurrence of the risk "Project delay of 30 days" was defined as 90%. However, the maximum acceptable delay for the project is one week. In this case, the risk probability of occurrence defined initially must be reduced to a much lower value, for example, 10%. To reach this probability, the level of effort in terms of action for the risk treatment will be considerable (GRUBISIC, 2009).

Ideally, all risks should have probabilities of occurrence close to zero, in which case the project would be executed in an environment predominated by certainties. Some risks can be reduced to zero through actions that eliminate them but, unfortunately, not all risks can be managed by this type of action.

In this regard, the project team must define the target probability of occurrence to be reached within the interval

Table 2. Scale for the average severity of the impacts (PROJECT..., 2004).

Interval	Severity of the total impact
[0.1;0.3)	Very low
[0.3;0.5)	Low
[0.5;0.7)	Medium
[0.7;0.9)	High
≥ 0.9	Very high

of 0 to 100. Values close to zero mean that the project team desires that the risk is eliminated, in these cases the project manager must not economize efforts to eliminate such risks. Values approaching 1 mean that the risk matters little to the project, it is a negligible risk, in the project team's opinion.

For the definition of this characteristic value the project team should take into account the project importance for the company and its goals. In addition, the average severity of the risk impact can strongly influence the value of the risk target probability of occurrence to be reached. For example, risks with high average severity of the risk impact tend to be less tolerated by the team, as the damage that may cause to the project.

Based on the definition of risk probability of occurrence and the target probability of occurrence to be reached, it is possible to calculate the rate of risk reduction (characteristic 4) which is the division of the former by the latter. The rate of risk reduction indicates the degree to which its probability of occurrence has to be reduced in order to reach an acceptable level, that is, it indicates how much the project team members have to work to reduce the risk.

Finally, based on the four risk characteristics defined previously, the absolute weighting (characteristic 5) and the relative weighting (characteristic 6) for each risk are calculated. The risk absolute weighting is obtained by the multiplication of the average severity of its impact by its rate of reduction. For the calculation of each risk relative weighting (pi), it is necessary to divide the risk absolute weighting by the sum of all technical and managerial risk absolute weightings (GRUBISIC, 2009).

Table 3 presentes a hypothetical example of calculating of the risk importance weighting to technical and managerial risks. The last column of Table 3 shows the risk relative weighting.

3.1.2. Activity: Conclude the list of project priority risks

After the calculation of each risk relative weighting, the values are ranked to show the order of importance, as shown in Table 4. A list of the technical and managerial risks by priority order is obtained.

Table 3. Hypothetical example of the risk importance weighting calculation (GRUBISIC, 2009).

Nº	Risks	Elements for the calculation of the risk importance weighting					
		1	2	3	4	5	6
1	Customers/users express their needs in terms of solutions and not in their needs.	0.6	0.9	0.1	6	5.4	0.615
2	Design specifications that does not meet the market needs.	0.7	0.4	0.4	1.75	0.7	0.079
3	Product representation in terms of solution and not in terms of its functionality.	0.2	0.3	0.1	2.0	0.6	0.068
4	Not meeting the product scope.	0.5	0.2	0.1	5	1	0.113
5	Delaying the project.	0.6	0.9	0.5	1.2	1.08	0.123

Table 4. Risk priority order of the example considered (GRUBISIC, 2009).

Risk priority order	Risk initial order	Risks in priority order
R1	1	Customers/users express their needs in terms of solutions and not in their needs.
R2	5	Delaying the project.
R3	4	Not meeting the product scope.
R4	2	Design specifications that does not meet the market needs.
R5	3	Product representation in terms of solution and not in terms of its functionality.

3.2. Technical and managerial risk treatment

The risk treatment phase consists of the definition of specific actions associated with the following strategies: prevent, mitigate, transfer or accept the project risks. This phase comprises some activities, which are detailed below.

3.2.1. Activity: Defining actions for the risk treatment

This activity seeks to guide the project team in the definition of actions for the treatment of the technical risks that most affect the Project and for the treatment of the risk of scope, time, cost and quality.

The present activity also requires abstract thinking and creativity from the project team for the identification of actions for the risk treatment. Based on the literature, some guidelines in order to aid the identification of actions for the risk treatment are proposed.

Guideline 1:

Define the action strategy to be adopted as avoidance, mitigation, transfer or simply accepting the risk. The rate of risk reduction, defined in section 3.1.1, must be considered since it indicates the effort necessary to reduce the risk to acceptable levels.

Guideline 2:

Analyze the element "cause" of the risk. For that, it can be used the tool cause and effect diagram. The project manager and the person responsible for the risk must consider specific actions directed toward the causes. These actions can be of a managerial and/or technical nature.

Also known as Herringbone diagrams and Ishikawa diagram, the cause and effect diagrams consist of an effective method to find the problem root (PROJECT..., 2013).

The project team must identify the main reasons that make the risk exists, that is, its main causes. The origin of the major causes, i.e., its root causes, also must be identified. Thus, the project team will get detailed information that will serve as subsidies for the risk treatment.

Figure 3 shows an example of identifying the causes of the risk "product representation in terms of the solution and not in terms of its functionality" of the activity "Establish the functional structure of the product," conceptual design.

Guideline 3:

Identify alternative actions that do not require too many resources. Bear in mind that simple actions can reduce or even eliminate the risks.

For example, actions that encourage communication among project team members may be sufficient for the treatment of certain risks.

Guideline 4:

Identify actions based on the best practices of product development in order to improve this process and avoid potential technical risks.

Guideline 5:

Identify actions based on the best practices of project management in order to improve the projects and avoid the potential managerial risks.

Guideline 6:

Involve the sponsors, clients/customers and suppliers in the identification and definition of actions for the risks.

Guideline 7:

Search historical information on past or similar projects and experiences that can aid in the risk treatment phase.

Table 5 gives examples of actions for the risk "product representation in terms of the solution and not in terms of its functionality," defined from the previously presented guidelines. Besides these, other actions can be defined by the project team. In a company, the greater the understanding

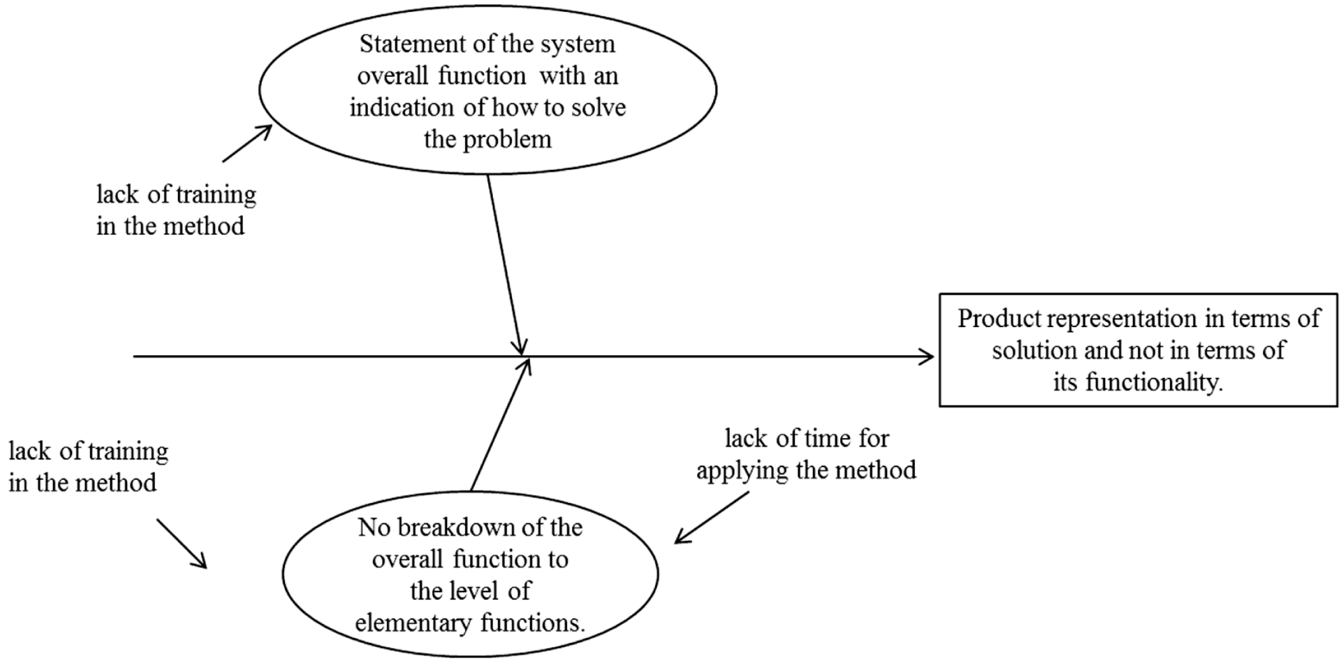

Figure 3. Example of application of the Diagram of Cause and Effect (GRUBISIC, 2009).

Table 5. Examples of actions for a risk (GRUBISIC, 2009).

Risk	Actions
Product representation in terms of solution and not in terms of its functionality	Offer training on design methodology, mainly on functional synthesis methods for the project team Based on the cause and effect diagram of this risk, as shown in Figure 3, such action could eliminate the two main causes: Statement of the system overall function indicating how to solve the problem and no breakdown of the overall function to the level of elementary functions. This happen because the two main causes have common roots causes.
	According to the Figure 4 it is recommended to allocate more time for the activity of unfolding of the global function.
	Considering the best product development practices, it is recommended to express the functions in terms of technical verbs in the global function decomposition activity, for example: transform, transmit, guide, mixing, interrupt, turn on, among others. The use of standards containing typical functions of technical systems it is recommended.

of the product development process and the context of the project, more appropriate actions for the risk treatment can be identified.

The identified actions must be registered to be evaluated in the next activity. For this, it is proposed the Table 6. The first three columns are allocated to the risk identification, the third to the identified action number and the last to record the action.

3.2.2. Activity: Prioritize the risk treatment actions

Although previously identified actions must be implemented, it is proposed to prioritize them. Thus the actions with the greatest positive effect on the risk treatment are highlighted and implemented first.

Table 6. Form for registration of the risk actions (GRUBISIC, 2009).

Nº	Risk	Nº	Action
R_1		1.1	
		1.2	
		1.n	
R_2		2.1	
		2.2	
		2.n	
R_3		3.1	
		3.2	
		3.n	
R_n		n.1	
		n.2	
		n.n	

By analogy to the first matrix of the QFD method, the "house of quality", it is proposed the use of a matrix for the priority actions for the risk treatment. The degree of importance of each action is defined by analyzing the relationship of the actions with all risks. Table 7 shows the structure of the matriz.

The first two columns are allocated, respectively, to record the project risk number and their relative weight. The following columns are dedicated, to define the action importance degree for each risk.

Initially, for each action, the existence of a relationship with each priority risk is verified. For this, the project team must reflect on whether the implementation of one action can eliminate, mitigate, transfer or accept (actively) the risk.

Table 7. Matrix for the prioritizing of the actions for the risk treatment (GRUBISIC, 2009).

Risks	Relative weighting	Actions				
		1.1	1.2	1.3	2.1	n.n
R_1	p_1	Gr1.1 (R1)	Gr1.2 (R1)	Gr1.3 (R1)	Gr2.1(R1)	Grn.n (R1)
R_2	p_2	Gr1.1 (R2)	Gr1.2 (R2)	Gr1.3 (R2)	Gr2.1(R2)	Grn.n (R2)
R_3	p_3	Gr1.1 (R3)	Gr1.2 (R3)	Gr1.3 (R3)	Gr2.1(R3)	Grn.n (R3)
R_4	p_4	Gr1.1 (R4)	Gr1.2 (R4)	Gr1.3 (R4)	Gr2.1(R4)	Grn.n (R4)
...	...	...	...	...	...	...
R_i	p_i	Gr1.1(Ri)	Gr2.1 (Ri)	Gr1.3 (Ri)	Gr2.1(Ri)	Grn.n (Ri)
TOTAL:		∑pi. Gr1.i	∑pi. Gr1.n	∑pi. Gr1.n	∑pi.Gr2.i	∑pi. Grn.n

Table 8. Scale for definition of the importance degree of the actions (GRUBISIC, 2009).

Action degree of importance (Gr)	Values for relationship between the action and risk
Null	0
Low	1
Medium	3
Strong	5

If so, there is a relationship between the action and the risk in question. In these cases, the intensity (Gr) of this relationship must be defined according to the scale proposed in Table 8. The results of this analysis are registered in the column of each action.

Finally, in the last line of the matrix, Table 7, the sum of the products of the relative weighting of each risk multiplied by the degree of importance of the relationship between each action and the risk is calculated. The result obtained will correspond to the order of priority of each action in the project, indicating the implementation order.

Table 9 gives an example of a form for the registering of actions for the treatment of three risks and the application of the matrix (Table 7).

The values of the relative weightings of the three risks and the degree of importance of the actions of these risks were obtained from the Tables 4 and 8, respectively.

Through the procedures presented for the calculation of the importance degree of the risk actions, it is possible to conclude, from Table 10, that action 1.1 is the most relevant for the considered scenario, that is, this action must be implemented first. Subsequently, actions 2.1, 3.1, 1.2 and 2.2 are applied, as shown in Table 10.

3.2.3. Activity: Register the prioritized actions of the risks

This activity consists of registering the actions defined and evaluated in activities 3.2.1 and 3.2.2, in order to complement the project documentation.

In addition, it is recommended that these actions are detailed in terms of the implementation date and their responsible.

This information will aid in the risk treatment implementation on the most appropriate time by the person in direct contact with the risk.

For this, a structure for the action plan for the risk treatment is proposed in Table 11.

The first blank field serves to register the risk number, the second one to register the action, defined in the Table 6. The third blank field is to register the person responsible for the action implementation. The last field in Table 11 is for the definition of the implementation date of the action, that

Table 9. Example of actions for technical and managerial risks.

Nº	Risk	Nº	Action
R_1	Customers/users express their needs in terms of solutions.	1.1	Improve the questionnaires to be applied in the research with clients/users, in order to encourage the expression of their needs in terms of problems/desires and not solutions.
		1.2	Involve more product customers/users in the activities that require information from them through fortnightly meetings.
R_4	Product representation in terms of solution and not in terms of its functionality.	2.1	Provide training on design methodology, especially on the method of synthesis functional to the product development team.
		2.2	Give more time to the unfolding activity of global function.
R_2	Delaying the project.	3.1	Encourage communication between the areas involved in the product development process through fortnightly meetings.

Table 10. Example of prioritizing of actions for the risk treatment.

Risks	Risk relative weighting	Actions				
		1.1	1.2	2.1	2.2	3.1
R1	0.44	5	5	3	0	3
R4	0.074	3	3	5	5	3
R2	0.39	5	1	5	0	5
TOTAL:		4.372	2.812	3.64	0.37	3.492

Table 11. Structure of action plan for the risk treatment.

Nº	Action	Responsible	Implementation date

is, the moment at which the action must be implemented in the project. For this, the project manager must check in the project plan the date allocated to the activity. For example, the action "Improve the questionnaires to be applied in the market research with clients/users, in order to encourage the expression of the needs in terms of problems/desires and not solutions" must be implemented at the date of the activity "preparation of the questionnaire for field research".

Some actions, however, may be continuous, for example, conducting fortnightly meetings meetings to improve the communication. In such cases, it is recommended to set the meeting dates for this purpose.

The information obtained in this activity will complement the project documentation. Thus, the project manager must update the project plan with the results of the risk treatment in order to improve the estimates of the time, resources and costs.

3.2.4. Activity: Implement the action plan for the technical and managerial risk treatment

This activity consists of implementing the actions planned for the risk treatment.

For this, based on the literature, some guidelines in order to aid the project manager in this process is proposed.

1. Integrate the actions for the risk treatment into the project plan. Thus, the project plan will be update in terms of the risks of scope, time, cost and quality.
2. The person responsible for the risk and the project manager are responsible for the implementation of the action for the risk treatment. Moreover, they are directly responsible for the risk control. The people indirectly responsible for the risk control are the other project members involved with the risks.
3. Define the frequency with which the risks will be controlled based on their estimated date of occurrence and relative weighting and the probability of occurrence of the managerial risk of scope, time, cost quality given the probability of the other risks.
4. In the dates of control, the characteristics of the priority risks must be revised, as well as the results of the implemented actions. The documentation of the project plan be updated.
5. Verify whether the scope, schedule, budget and the project quality have been affected by any risk throughout the project. If so, the project manager must take action to improve the project.
6. After each risk control, the project manager must share the updated information with the project team.

Based on the above guidelines, the implementation of the actions for the risk treatment will be carried out in a pro-active way, that is, before the risk becomes a problem. The implementation of these actions will improve the chances for the project to be executed and concluded as planned.

4. Final considerations

This article has as the main objective to present a risk management methodology for the product design process, considering the technical and managerial risks, in order to improve the project plan in terms of activities, cost, time estimates and quality.

For this purpose, activities and tools have been proposed to the analysis and treatment of technical and managerial risks.

For the risk analysis process is defined elements that characterize the risks, beyond the probability of occurrence and their impact, allowing the prioritization of project technical and managerial risks. Every effort for the analysis and treatment of technical and managerial risks must be done to achieve results consistent with the project reality.

Note that the value of the probablity of ocurrence and the severity of the risk impacts, depend heavily on the knowledge, experience and discussions among the project team members. If these assessments are dubious, it can compromise the other activities of risk analysis, as this is a basic activity for the others.

As the risk treatment approaches in the literature are very general, it has been proposed in this paper guidelines to define actions for the technical and managerial risks involving the project team.

Moreover, with the actions prioritization it is possible to identify and prioritize those that have an effect on a greater number of risks. Thus, optimizing the action implementation result for the risk treatment are optimized.

In this way, the activities and the methods of the risk treatment phase seek to stimulate the project team to identify actions for the technical and managerial risks according to the following strategies: prevent, mitigate, transfer or accept.

Finally, the methods suggested in the proposed activities as forms, guidelines, matrices, graphs and tables are relatively simple to be applied by companies, through text editor or spreadsheet.

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