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Project Risk Management for Digital Manufacturing

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Abstract. The success parameters for any projects are jeopardized by risk factors. The main barriers to effective risk management are related to the process by itself (identifying, analyzing, responding and monitoring), and with the parameters related to project risk. This paper intends to determine factors for identifying and analyzing risks in project management in automaker digital manufacturing projects. The main objective of the research is to provide a study of risk identification and classification with a list of authors that studied that subject, where the project manager can efficiently use during the project planning, regarding the next step of project risk management. The research design is desktop study, based on the process of a critical literature review with a focus on information systems and business research papers, books, case study from a manufacturer and theoretical articles, etc. Data analysis use the mechanism of triangulation for producing an assessment exercise of the digital manufacturing practices adopted by the company. The manufacturing engineering team could insert the new model into their day by day work reaching opportunities and mitigating threats/risks. The findings bring the risk structure (risk ontology) where the risks are classified in the following aspects: technical risks, people risks, organizational risks and vendors risks. Risks need to be managed from the beginning by identifying them, assessing their likelihood and possible impact, and preparing an overall action plan to deal with them.

Keywords. Digital Manufacturing, Project Management, Risk Management

Introduction

Risk can be defined as "the occurrence of an event that has consequences for, or impacts on a particular project" [1]. This definition implies a fundamental characteristic of risk, namely uncertainty. Specifically, there is a probability that the risk event may occur and can result in an impact on the business processes that may imply substantial losses.

The team under study provides to the plant, in the context of non line-up projects - projects related to the assembly means respecting the Quality-Cost-Time engagement;

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(i) design, during the development stages of new vehicles, the assembly process respecting the principles of the method driven; (ii) design and provide technical documentation of the manufacturing facilities, manufacturing facilities and process standards in these line and capacitor designs; (iii) support the factory in achieving the performance objectives; (iv) define and scale the production capacity and the factory direction scheme for performance, consistent with the volumes to be produced, the vehicle designs and the relevant flows.

Risk identification is the first step of risk management – the second step is risk analysis, and the third one is risk control. Correct risk identification assures risk management effectiveness – if risk managers do not succeed in identifying all possible losses or gains that challenge the organization, then these non-identified risks will become non-manageable [2].

What we can observe is that the risk identification executed by the practitioner (the project manager) brings some shortcomings that will make an impact in the risk analysis. In fact, maybe it is not clear what we could considere as a risk (risk identification) and how to analyze it. One of the goals of risk management is using a systematic process to make decisions about balancing between the calculated risks and the cost of mitigation [3]. On this direction, this paper proposes to find and to apply a classification of risk events, associating the list to the current studies related to risk identification and analysis. The classification could help the researcher and the practitioner to understand the actual situation and to address the risk analysis issues. In the second hand, the ranking could be a basis for a research agenda, evolving and deepening this subject.

This paper thus aims at contributing to this significant research gap by providing a study of risk identification and classification with a list of authors that studied that subject, where the project manager can efficiently use during the project planning, regarding the next step of project risk management.

1. Project Risk Management

The definition of Project Risk Management, as defined in the PMI´s Practice Standard For Project Risk Management: “Project Risk Management includes the processes concerned with conducting risk management planning, identification, analysis, responses, and monitoring and control on a project” [3]. Other definitions found in the literature agree that the whole process of project risk management is composed of risk identification, risk analysis and risk control [2]. There are some variations, where risk control is called risk response [4]. Tchankova [2] also defines risk identification as the process that reveals and determines the possible organizational risks as well as arising risk conditions. Anyway, there are four essential elements, showed in table 1 below:

Table 1. Basic elements of risk. Adapted from Tchankova [2].

Elements	Description
Source of risks	elements of the organizational environment that can bring some positive or negative outcomes
Hazard factors	condition or circumstance that increases the chance of losses or gains and their severity
Perils	Something that is close to the risk and it has negative, non profitable results. It can happen at any time and cause unknown, unpredictable loses. Peril is the cause of losses

Elements	Description
Exposures to risk	Objects are facing possible losses or gains. They will be affected if the risk event occurs

There are two important peculiarities: i) risk identification must be a continuous process and ii) continuous seeking of a new risk. The risk identification is not a one-off activity which is carried out at the beginning of the project. There are so many changes in the environment that require continuous attention for identification of new risk. An actual risk could increase its impact or probability or could decrease, or it could simply lose its importance [2]. The sources of risk can be represented depending on the environment in which they arise as follows, shown in table 2 below:

Table 2. Sources of risk. Adapted from Tchankova [2].

Sources of risk	Definition
Physical environment	A vital source of risk. Natural disasters like earthquakes, storms, flooding, landslides, can lead to severe losses
Social environment	The changes in people´s values, human behavior and state of social structures are another sources of risk. Civil unrest, social riots, and strikes. The level of worker skills and loyalty to the organization are related to the success of the project
Political environment	The ruling party can affect organizations in different ways by cutting aid to some industry branches or protecting some branch, by implementing strict rules about he environment, etc
Operational environment	Operational activities of the organization create risk and uncertainty: unfavorable working conditions, the formal procedures for hiring or firing employees, the manufacturing process
Economical environment	The economic environment usually is hardly influenced by the political environment in a single country, but the globalization of the market creates a market that is greater than a single market and needs to be considered separately
Legal environment	The legal environment creates risk and uncertainty in business by the disparity of current or new laws to the environment. Also creates opportunities by stablishing the society and, due to that, organizations know the restrictions in their work
Cognitive environment	The risk managers' ability to reveal, understand and assess risk is not perfect. The difference between perception and reality for different people is an important source of risk for an organization. The questions of how to assess the effect of the uncertainty on the organization and how to understand whether the perception of risk is real are considered

These concepts regarding risk management are expanded and studied by several authors:

Takashi Shimizu, Young Won Park, Paul Hong [5] wrote "the majority of firms define the scope of product risk management in terms of product quality management, project management, and quality management; firms that have risk managers include the entire supply chain in the scope of risk management; and firms reexamine the systematic risk management processes through actual major accidents (direct learning) or other firms' risk outcomes (indirect learning)", bringing the subject to the company´s vision. The technical issues are related to the people aspects. The use of the calculus of investment to manage the project as a whole is the main idea of the work

from Seyfert, Rosenberg & [6]. This idea contrasts with managing only costs and revenues during the manufacturing phase of a project, adding dimensions from the company and the vendors. An approach to asset management to minimize risks in the most cost-effective way is presented by Ujjwal R. Bharadwaj, Vadim V. Silberschmidt & John B. Wintle [7], the risk-based methodology presented a cost-effective way to minimise life-cycle costs in the management of assets while maintaining reliability or availability targets, and operating within safety and environmental regulation. Rao Tummala & Tobias Schoenherr [8] wrote "supply chain risks can be managed more effectively when applying a structured approach that can be divided into the phases of risk identification, risk measurement, and risk assessment; risk evaluation, and risk mitigation and contingency plans; and risk control and monitoring via data management systems. Specific techniques for conducting this process are suggested". Ammar Ahmed, Berman Kayis & Sataporn Amornsawadwatana [9] advocate that a more risk-focused approach is likely to result in an integration of several of techniques, resulting in increased effectiveness of project management. An extended model is presented by Muhammad Usman Tariq [10] combining the previous risk management methodologies with Six Sigma methodologies, to achieve both improvement and minimization of risks simultaneously. Jacques G. Richardson [11] brings that the uncertainty and hesitation in the conception of plans and strategy and to assess new results in risk management. Young H. Park [12] discusses risk and performance management processes during the product development period. Anna Burduk & Edward Chlebus [13] proposed a method of risk evaluation, it may be helpful to determine the risk level in the chosen production line and eventually for the whole enterprise manufacturing systems. Catherine P. Killen & Robert A. Hunt [14] wrote: "the research compares service and manufacturing environments; future challenges are likely to result from the increasing blurring of the boundaries between service and manufacturing industries."

The ISO 31000 brings that the external context (external environment in which the organization seeks to achieve its objectives) can include risks as: the cultural, social, political, legal, regulatory, financial, technological, economic, natural and competitive environment, whether international, national, regional or local; key drivers and trends having impact on the objectives of the organization; and relationships with, and perceptions and values of external stakeholders [15].

Also, ISO 31000 brings that the internal context (internal environment in which the organization seeks to achieve its objectives) can include: governance, organizational structure, roles and accountabilities; policies, objectives, and the strategies that are in place to achieve them; the capabilities, understood in terms of resources and knowledge (e.g. capital, time, people, processes, systems and technologies); information systems, information flows and decision-making processes (both formal and informal); relationships with, and perceptions and values of, internal stakeholders; the organization's culture; standards, guidelines and models adopted by the organization; and form and extent of contractual relationships [15].

2. Research Design

This study is divided into four steps: (i) Literature review for searching the steps of risk management (with interest in risk identification - regarding the Non-Product-Range Projects); (ii) Document research and interviews with the specialists responsible for the

risk assessment on one specific project at the automotive company; (iii) Analysis of results; (iv) Set of risk events listed and classified.

In the first step, it was conducted a literature review on academic journals to guarantee the most relevant information regarding the specific topic, with the following criteria: a) It must be a scientific article published in the peer-reviewed journal; b) Contain the keywords determined; c) Articles published from the year 2000. The Literature Review Protocol showed in Table 3, together with the Boolean operators adopted and the reference databases used for searching.

Table 3. Literature Review Protocol.

Search Terms	("Project management" OR "project planning") AND ("risk") AND ("industry 4.0" OR "digital manufacturing")
Boolean Operator	AND, OR
Database	Science Direct, Emerald
Language	English
Publication Type	Paper from journals

The literature review was based on the search procedure in which the research methodology uses an iterative and incremental procedure where the relevant articles were searched, checked and reviewed by relevance until the complete review is completed.

The second step contains the document research and interviews with the specialist responsible for the risk assessment on one specific project at the automotive company (table 4). The documented research is based on a spreadsheet used to register the information regarding risk identifying, and the decisions held about risk (estimation, actions, and control).

Table 4. Different types of documents collected and analyzed.

Types of documents	**Information captured and examined**	**Significance**
Risk assessment practice (spreadsheet)	The different risk types The way the risks are identified The way the risks are analyzed The way the risks are controlled	It was relevant to understand the different risk types and the practices used by the company that we are studying. Relationships between the practice and the literature review will lead to building the ontology model
Interview	The sensibility of the specialist	There are no lessons learned process working, so, it is a way to know more about what happened before
Procedures	Details	Internal reference to the company

Following the development of the proposed analysis, at the third step, we stablished the relationships between the information regarding the risk types defined within the automotive company identified by the practitioner and the factors appointed by the literature review, supporting the relationship with the authors that studied the subject.

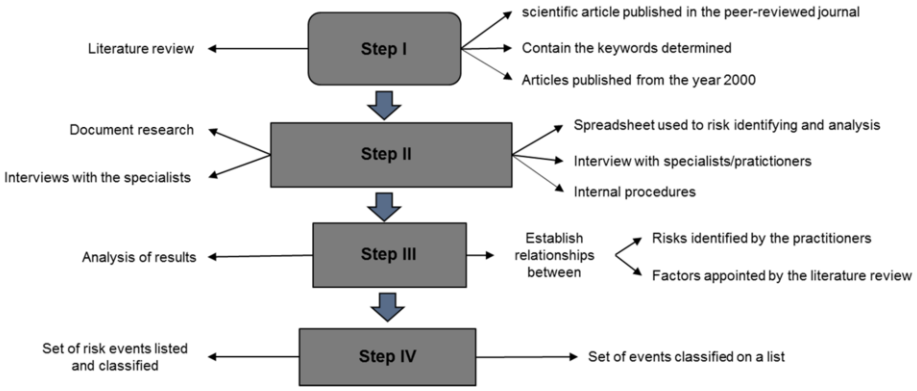

Figure 1. Research Protocol.

The fourth step shows the set of events classified on a list that can be applied in risk management practice. Ontology is a tool that has been commonly used in computer sciences and programming and is increasingly adopted by social sciences researchers to highlight and share key concepts and ideas in their study. There are three reasons why an ontology is worth developing in research studies [16]:

- An ontology allows researchers to highlight and share common and novel concepts in their subject domain more easily and efficiently.
- Other researchers can reuse the domain knowledge presented in the ontology and make further extension and development.
- Concepts and assumptions made in the ontology can be easily changed and extended by changes of the researcher's knowledge about the subject domain.

3. The Project Risk Management Structure for Non-Product-Range Projects

It must be clear that the project management team illustrated at this work is responsible for a specific part of an automaker digital manufacturing projects (the Non-Product-Range Projects). They work with the product design done, and their projects are concerned to prepare the industrial plant (with means and process), allowing the manufacturing process takes place, delivering the new product (or new versions of an existing product).

The non-range-projects is how we call the projects outside the product range; as follows:

- It is up to the central services to optimize the use of existing systems at the Automobile Branch.
- Investment projects that include the re-use of existing equipment must be submitted to the relevant central services for approval.
- If the existing equipment has an effective resale value on the market (ordinary machine, IT equipment, etc.), this value must be considered in the investments.
- If the existing equipment has no market resale value and if there is no more useful purpose for it in another entity of the Automobile Branch than that proposed, the existing equipment is not valued in the economic study.

- Costs for recovery, rehabilitation, packaging, transport, re-installation, etc. of this equipment must be included in investments.

The risk analysis can be held in three phases: 1) identification, where the potential risks affecting a project are identified; 2) estimation, where these risks are assessed; and 3) Analysis and evaluation, where the acceptability of the risk is determined and the actions to be taken are evaluated [17] – this is not the focus here.

The focus here in this work is how to help the practitioner at the risk identification, so, we can find a classification from the work from Mobey & Parker [17], who classifies the risks in three types: 1) technical risks, 2) people risks and 3) organisational risks. There are two current projects during the research period, during the interviews, both project managers pointed the vendors as a risk source. This way, the authors would like to make an excerpt from the organisational risks (brought from the Mobey & Parker classification) and add one more category called vendors risks.

The document research and interviews with the specialists responsible for the risk assessment on the project at the automotive company lead to the following classification of main risks from non-range-projects – regarding the industrialization process – as related with the literature found capable of helping the practitioner to identify the risks better.

The ISO 31000 [15] brings that the risk management is tailored and it must be aligned with the organization's external and internal context and risk profile. Defining risk criteria – as ISO 31000 - "*The organization should define criteria to be used to evaluate the significance of risk. The criteria should reflect the organization's values, objectives, and resources. Some criteria can be imposed by, or derived from, legal and regulatory requirements and other requirements to which the organization subscribes*". When defining risk criteria, factors to be considered should include the nature and types of causes and consequences that can occur and how they will be measured [15];

- how likelihood will be defined;
- the timeframe(s) of the likelihood and/or consequence(s);
- how the level of risk is to be determined;
- the views of stakeholders;
- the level at which risk becomes acceptable or tolerable; and
- whether combinations of multiple risks should be taken into account and, if so, how and which combinations should be considered.

Table 5 shows the classification of the risks in four types: 1) technical risks, 2) people risks and 3) organizational risks and 4) vendor risks. This classification was based at ISO 31000 prescription [15] together with the classification based on the work from Mobey & Parker [17], who classifies the risks in three types: 1) technical risks, 2) people risks and 3) organisational risks, the authors would like to add one more category: vendors risks – that is aligned with the significance of risk given by the organization. For each one, there is a group of references that could be applied by the practitioner to deepen the knowledge about the risk under assessment.

Table 5. Classification of risks and papers related.

Technical Risks (TR)	Fail in Methodes especification of the Equipment purchasing	[8];[5]
	Fail in competition process of the Equipment purchasing	[8];[5]
	Fail in purchese order	[8];[5]
	Error found at the mechanical design at the phase of Studies Technical Agreement	[7];[9];[13]
	Error found at the electrical/automation design at the phase of Studies Technical Agreement	[7];[9];[13]
	Error found at documentationat the phase of Studies Technical Agreement	[7];[9];[13]
	The phase of Studies Technical Agreement is not validated	[9];[13]
	Delay at end of Commissioning Technical Approval due to fail in infrastructure	[7];[9];[13]
	Delay at end of Commissioning Technical Approval due to equipment Installation	[7];[9];[13]
	Delay at end of Commissioning Technical Approval due to Facility Training	[7]
	Delay at end of Commissioning Technical Approval due to Equipment Functional Validation	[7]
	Delay at end of Commissioning Technical Approval due to Documentation	[7]
	Delay at Technical Agreement of Setting in Production due to Documentation	[7]
People Risks (PR)	Fail in Methodes especification of the Equipment purchasing	[8];[5]
	Fail in competition process of the Equipment purchasing	[8];[5]
	Fail in purchese order	[8];[5]
	Delay at end of Commissioning Technical Approval Meeting	[8]
	Delay at Technical Agreement of Setting in Production due to Manufacturing Team validation	[7]
	Delay at Technical Agreement of Setting in Production due to Documentation	[7]
	Delay at Technical Agreement of Setting in Production due to Regulatory compliance of the production / Performance Obtainement Certificate	[7];[11]
Organisational Risks (OR)	Fail in competition process of the Equipment purchasing	[5];[6];[14]
	Error found at the mechanical design at the phase of Studies Technical Agreement	[7];[10];[14]
	Error found at the electrical/automation design at the phase of Studies Technical Agreement	[7];[10];[14]
	Error found at documentationat the phase of Studies Technical Agreement	[7];[10];[14]
	The phase of Studies Technical Agreement is not validated	[9];[10];[12]; [14]
	Delay at end of Commissioning Technical Approval due to fail in infrastructure	[7];[10];[12]; [14]
	Delay at end of Commissioning Technical Approval due to equipment Installation	[7];[10];[12]; [14]
	Delay at end of Commissioning Technical Approval due to Facility Training	[7];[10];[12]; [14]
	Delay at end of Commissioning Technical Approval due to Equipment Functional Validation	[7];[10];[12]; [14]
	Delay at end of Commissioning Technical Approval due to Documentation	[7];[10];[12]; [14]

	Delay at end of Commissioning Technical Approval Meeting	[7];[10];[12];[14]
	Delay at end of Regulatory compliance of the production / Performance Obtainement Certificate (Technical Agreement of Setting in Production)	[5];[9];[10];[11];[12];[14]
Vendors Risks (VR)	Fail in Methodes especification of the Equipment purchasing	[5];[8]
	Fail in competition process of the Equipment purchasing	[5];[8]
	Fail in purchese order	[5];[8]
	Delay at technical agreement for delivery - buying	[5];[8]
	Delay at technical agreement for delivery - Assembly	[7]
	Delay at technical agreement for delivery - Try-out	[5];[7]
	Delay at technical agreement for delivery - Authorization to deliver and to go on the production site.	[5]

- Technical risks: Takashi Shimizu, Young Won Park, Paul Hong [5]; Ujjwal R. Bharadwaj, Vadim V. Silberschmidt, John B. Wintle [7]; Rao Tummala, Tobias Schoenherr [8]; Ammar Ahmed, Berman Kayis, Sataporn Amornsawadwatana [9]; Anna Burduk, Edward Chlebus [13]
- People risks: Takashi Shimizu, Young Won Park, Paul Hong [5]; Ujjwal R. Bharadwaj, Vadim V. Silberschmidt, John B. Wintle [7]; Rao Tummala, Tobias Schoenherr [8]; Jacques G. Richardson [11]
- Organisational risks: Takashi Shimizu, Young Won Park, Paul Hong [5]; W. Seyfert, D. Rosenberg, E. Stack [6]; Ujjwal R. Bharadwaj, Vadim V. Silberschmidt, John B. Wintle [7]; Ammar Ahmed, Berman Kayis, Sataporn Amornsawadwatana [9]; Muhammad Usman Tariq [10]; Jacques G. Richardson [11]; Young H. Park [12]; Catherine P. Killen, Robert A. Hunt [14]
- Vendor risks: Takashi Shimizu, Young Won Park, Paul Hong [5]; W. Seyfert, D. Rosenberg, E. Stack [6]; Ujjwal R. Bharadwaj, Vadim V. Silberschmidt, John B. Wintle [7]; Rao Tummala, Tobias Schoenherr [8]

4. Conclusions

As a result of this work, the researchers identified and proposed a comprehensive set of 20 risk events that may occur during the project planning of an industrial plant (with means and process), allowing the manufacturing process takes place. The observation also showed that this work is useful in a culture where the focus is resolving technical problems rather than systematically considering project risk management.
The PMI´s Practice Standard For Project Risk Management [3] recommends the using of risk management: "*Project Risk Management is not an optional activity: it is essential to successful project management. It should be applied to all projects and hence be included in project plans and operational documents. In this way, it becomes an integral part of every aspect of managing the project*". This work may help to assist the organization to integrate risk management into its overall management system.

The ISO 31000 [15] brings that the risk management is tailored and it must be aligned with the organization's external and internal context and risk profile.
The main idea of this work was to help to identify the risks and bring the theory necessary to the practitioner to understand the risk identified. It is clear that with an appropriated risk identifying the process, the following step is to develop the right risk management strategy. The whole strategy could be compromised if the risk identification is not meaningful, by another hand, the success of the project can be assured with appropriate risk management.

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