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A Go/No-Go Decision-Making Model Based on Risk and Multi-Criteria Techniques for Project Selection

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ABSTRACT

The realization of infrastructures and the deployment of processes can follow project formalism. Generally, a project goes through a design and a realization phase. Between these two phases, there is a crucial milestone: Launching the project. Making this decision is not easy at all, and constitutes a real problem-- the main reasons to this are the numerous numbers of criteria (for technical, economic, social, environmental dimensions) and risks in the sense of feared events. Criteria and risks are most of the time not considered due to lack of time (for formalization) and the difficulty to handle them. The objective of this paper is to propose a relevant approach to make the decision of launching the project or not. The proposal outlined is innovative in that it can consider indicators based on several appropriate criteria, the associated risks, and their ways of management. The fact of considering several criteria and risks increases the probability of making the good decision.

KEYWORDS

Criteria, Decision, Multicriteria, Project, Risk, Scenario

INTRODUCTION

Nowadays, the building of most infrastructures and the deployment of most processes take the form of a project. After the design phase, the main issue is to decide whether the project can be launched or not. During this phase, the decision is either to launch the project in its actual configuration, abandon it or redefine it. According to (STANDISH GROUP, 2013)) 90% of all major projects (of more than 1 million euro) fail due to bad decision-making. Making the good decision is thus the key element for the project's success (Balachandra, 1984), (Baccarini, 1999), (Asrilhant et al., 2004). To make

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these decisions, stakeholders need a decision process, with metrics that indicate the likelihood of the project's success (Shenhar et al., 2001). Thus, a project is likely to succeed if its assessed metrics are pertinent to the context and if they suit the project objectives.

The aim of this paper is to help stakeholders at the project launch phase, by proposing an approach based on a decision process and metrics on which they can rely. So that, they can decide whether the project is qualified to be launched or not. There are few studies in the literature addressing this particular issue – which is also called the “go/ no go” question (Balachandra, 1984), (Han Seung H. & Diekmann James E., 2001), (Tang, 2019), (Vergara-Martínez et al., 2020). Most authors are more interested in the bid/no bid question (Gallagher et al., 1995), (Eldukair, 1990). (Balachandra, 1984) is interested in the decision to continue instead of that to launch. There is, however, a real need to consider this problem of go/ no go for the project launch. This decision is very often based on limited criteria – mainly the cost and the duration (Rose, 2005), (Collins & Baccarini, 2004), (Hughes et al., 2004), (Belout & Gauvreau, 2004). This method can no longer be recommended, because customers are becoming increasingly demanding. Otherwise, cost and duration alone are insufficient as criteria to characterize the project success likelihood. Other criteria that consider dimensions such as technical, environmental, social, and regulatory requirements must be integrated in the assessment. Generally speaking, ignoring these dimensions widens the gap between what was planned and what was achieved and leads to the project failure. Another reason for project failure is the occurrence of non-identified and unpredicted events (risks). Thus, to make correct decisions in the launch phase, there are two main difficulties: (a) the need to integrate several criteria (Costantino et al., 2015) and (b) the consideration of risk (Dutra et al., n.d.), (Wei et al., 2016). This position is also that of (Balachandra, 1984) that states that risk and uncertainty make decision making extremely complex. Authors such as (Zhang, 2016), (Cserhádi & Szabó, 2014) and (Yim et al., 2015) have addressed some aspect of these problems, but not all of them. For instance, (Zhang, 2016) focused only on risk while (Cserhádi & Szabó, 2014) focused on criteria and (Yim et al., 2015) analysed only the project indicators. (Mirza et al., 2013) and (P. Zhang et al., 2016) proposed a decision framework without investigating risks. (Tang, 2019) proposes a Bayesian Probability to assess the Probability of Success for Go/No-Go Decision Making. (Isihara et al., 2020) a methodology to rank of all possible Alternatives by using the PAPRIKA method.

The major drawbacks of these proposals are the lack of (1) a generic framework that can consider several types of criteria, and several risks, and (2) an aggregation model to characterize the project from the characteristics of its tasks. A multi-objective programming approach proposed by (P. Zhang et al., 2016) does not provide guarantees for the existence of the criteria, unlike our proposal which is based on aggregation functions. Finally, the evaluation of the project in a context of risk, investigated by (Fang & Marle, 2012), (Marle et al., 2013), (Mustafa & Al-Bahar, 1991) does not consider risks at the task level, as our proposal does. There is thus a real scientific need to find a framework that provides an indicator that includes several risks and criteria for the project launch issue. We make the hypothesis that the use of more and better-adapted criteria and risks may lead to an improved decision-making.

The innovation in this paper, in comparison to the shortcomings in the literature, lies in providing (a) a method for considering several criteria, risks and their treatment strategies, (b) an aggregation of these criteria from low level (on the task) to the level of the whole project, (c) indicators that include a wide range of appropriate criteria that are complementary to the cost and duration factors, (d) relevant indicators that make it possible to determine whether the project can be launched or not. Thus, it becomes possible for the stakeholders to make the right decision. This, in turn, leads to a reduction in the failure rate, saving time and money.

This paper begins with a literature review of project success analysis methodologies in risk situations. Next our proposal is presented. This consists of a description of the analytical process and a conceptual model. The latter describes the main concepts. Then the methodology to assess the risk impact on identified criteria is described, along with the aggregation procedures. Finally, some

indicators for project success likelihood are proposed. A case study of a crane construction validates these proposals. Results from this use case are also discussed. Finally, our perspectives are outlined in the conclusion.

LITERATURE REVIEW

This section is divided into two parts: the first one focuses on the methodologies to assess and decide on project launching, while the second part suggests some criteria that are particularly relevant for project management.

Methodology to Analyse Project Potential Success

There are two categories of analysis in the literature for determining from its launch, the project's potential of success. The first consists in assessing a single indicator, while the second is a simulation-based approach that can integrate several indicators that are assessed using several criteria. In the first category, most models rely on risk identification, representation, and assessment tools. Failure Mode and Effect Analysis (FMEA) is used by (Tavakolan & Mohammadi, 2015) to identify risks, their impacts and correctives actions. In situations where available information is often non-numerical, (Kangari & Riggs, 1989) propose a linguistic analysis using fuzzy-set theory. In this approach, it is possible to build a risk model by expressing risk information as words or phrases termed into linguistic variables. The fuzzy-set theory is sometime combined with other tools, such as FMEA (Tavakolan & Mohammadi, 2015). This combination is called fuzzy FMEA (Razaque et al., 2012). These methods utilize a Risk Priority Number (RPN) to determine the likelihood of project success.

The second category of method simulates risk scenarios to determine if the project will be successful or not. First, data such as Risk, Interactions (Fang & Marle, 2012), or Domain (consisting in product, process and organization) (Pointurier et al., 2014) are modelled. Then a Decision-Support System simulates all possible risk scenarios. Through Case-Based Reasoning, risk response strategies can be generated (Fan et al., 2015). On this basis, the stakeholders take the decision to launch the project or not. In the ProRisk model (Gourc et al., 2015), (Nguyen et al., 2013), (Marmier et al., 2014) and (Marmier et al., 2013) the analysis methodology is based on the generation of risk and treatment scenarios. For every scenario, the cost, the duration, the scenario occurrence probabilities and their positions give some indication of the probability of success.

The main shortcoming of these two categories of analysis lies in their limitation relative to the criteria. For the first category, the list is fixed, and the method does not allow any new criteria to be added. For the second one, the approaches focus mainly on cost and duration. Therefore, the particularities of the project cannot be considered. Existing criteria and their nature are described and clarified in the next review section.

Categories of Project Criteria

(Chan et al., 2002) sorts criteria into three categories: the scope, the organization and the set of (Quality, Time, Cost). The scope demarcates the project boundary, and the organization refers to the resources. (Dutra et al., n.d.), (Chan et al., 2002), (Dey, 1999) and (Turner, 2008) also propose other classifications, but these are not generic enough to be applied to all domains. We therefore propose the following classification. According to our reading of (Asrilhant et al., 2006), (Müller & Turner, 2007), (Z. Hatush & Skitmore, 1997), (Z. A. Hatush, 1996), (Crawford et al., 2005), (Atkinson, 1999), (Westerveld, 2003), (Hussein & Klakegg, 2014), (Carù et al., 2004) criteria can be grouped into four categories in the field of Project Management: Contractor Selection Criteria (CSC), Project Success Factors (PSF), Project Manager Criteria (PMC) and criteria related to Task qualification (TC).

Contractor Selection Criteria refers to the characteristics of the organization in charge of the implementation. These are central elements for the decision-making process (Z. Hatush & Skitmore, 1997), (Z. A. Hatush, 1996). Contractor Selection Criteria consists of Past failure, Financial status,

Financial stability, Credit rating, Experience, Ability, Management personnel, Management knowledge, Past performance, Bank arrangement, Project Management organization, Plant and equipment, Information system (Maintainability, Reliability, Validity).

Project Success Factors are independent variables that increase the likelihood of success for the project. They are discussed in (Crawford et al., 2005) and (Müller & Turner, 2007). Traditionally, the Iron Triangle of Time, Cost and Quality forms the most widely used Project Success Factors. But some authors, believe that other criteria can be added (Atkinson, 1999), (Westerveld, 2003), (Hussein & Klakegg, 2014). (Bregar, 2014) proposes criteria to deals the complexity. Project Success Factors now consists of Time, Cost, Quality, Complexity, Performance, Maturity, Sector (private, public), Application, Lifecycle (feasibility, design, execution, close-out, commissioning), Contract type (fixed price, re-measurement or alliance), Application area (construction, IT), Strategic importance, Supplier satisfaction, and Team satisfaction. Project Success Factors are used before the implementation phase. The same criteria can be used after the end of the project. In this situation, they are named in the literature as Project Success Criteria instead of Project Success Factors (Müller & Turner, 2007).

Project Manager Criteria refer to the attributes of the Project Manager. Their importance is highlighted in (Müller & Turner, 2007), (Lee-Kelley & Leong, 2003), (Dolfi & Andrews, 2007), (An et al., 2019). Most Project Manager Criteria come from demographic data, but some of these criteria are measured by using psychometric tests (Müller & Turner, 2007). Project Manager Criteria consist of Age, Nationality, Competence, Emotional intelligence, Management focus, Intellect, Job title, Certification, Education, Gender, Culture (single culture, host culture or expatriate). Project Manager Criteria are not often used because they can be contrary to international diversity laws.

Task Criteria characterizes project tasks. It is like Project Success Factors and Project Success Criteria, but it characterizes the task instead of the project.

The proposal made in this paper is about the qualification of the project face to risk scenarios. It complements approaches dealing with a singular risk. In the literature, several approaches have been proposed (Furlan et al., 2020), (Mostafazadeh et al., 2017), (Chatterjee et al., 2018). Our contribution in relation to these proposals is the qualification of risk scenarios by success indicators which allow decision making.

This study was carried out within the framework of a project set up by the French National Research Agency. This project involves 3 academic institutions working with 4 industrial companies. Based on this set of criteria, we conducted interviews with three experts of the AES company (www.ae-service.fr), the Team Manager, the Sales Manager, and the Business Manager. The following criteria were retained: Delay, Cost, Quality, Scope, Number of deliverables, Number of required competences and resource type, safety, similarity, novelty, ecological impact, corporate image, geographical coverage, feedback possibility, technical complexity, organizational complexity, environment changing, communication, robustness of implementation, criticality, vulnerability, and maturity.

The characterization of a project by a large set of criteria allows a better assessment of risk indicators, an evaluation and comparison of its variants, the analysis of possible scenarios, and the determination of the likelihood of success or failure. To handle large numbers of criteria and risks, a new methodology is required. To this end, the next section presents our proposal.

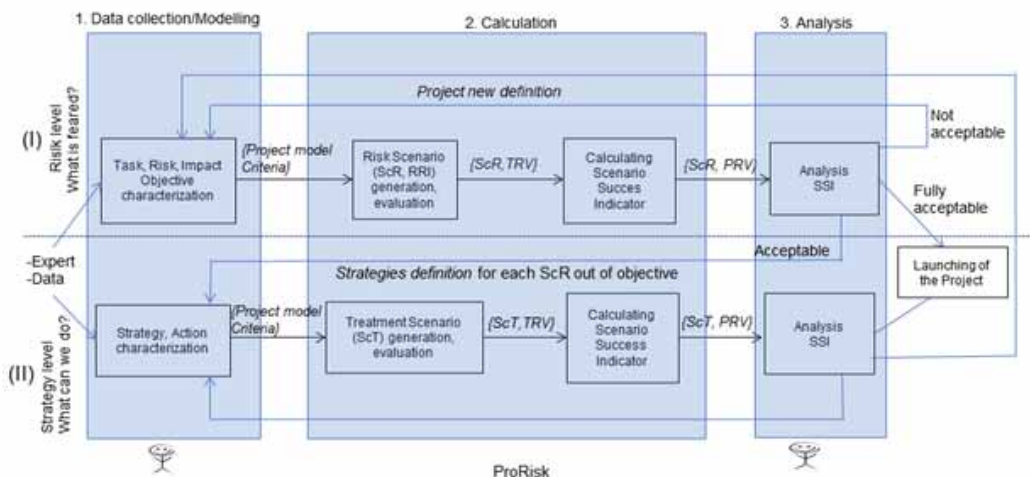
PROPOSAL

This section describes our proposal to handle the problem of deciding on the project launch in a situation involving risk, while considering several criteria. We propose a process that can be followed by stakeholders to determine if they can launch the project or not. The proposal provides relevant indicators that evaluate the success likelihood in a risk situation. This proposition complete proposal such as that of (Taufik, 2018) composed of Assumption Exploration, assumption selection, assumption testing and take a decision. Figure 1 shows the overall process. It consists of 3 steps that may be iterative: Data collection and modelling, Calculation, and an Analysis for decision-making. Every step

has two levels: risk level and strategy level. The term Risk refers to any disturbing event. According to several authors (Marle et al., 2013), (Marmier et al., 2013), (Nguyen et al., 2013), (Chapman & Ward, 2011), and project management guidelines (ISO/TMBG, 2020), risk can be defined as a potential event, which has occurrence characteristics (potentiality to occur) and consequence characteristics on the project objectives (impacts if the event occurs). The concept of risk's impact is composed of several dimensions. For each main dimension of project objectives (ie. delay, cost, quality, ...), we can define a risk's impact dimension associated. At the risk level, only risks and their impacts are considered. The strategy level also considers the identified strategies to manage risks.

The first step consists in characterizing the Tasks, Risks, their Impacts, and the project's Objectives using several Criteria. Based on expertise and/or data, an analyst performs this characterization. It leads, in the second step, to a model of the project including risks. From this model, the Risk Scenarios (ScR) are generated and evaluated. A risk scenario characterizes the set of risks that occur during the realization of the project. Indeed, during a project execution, generally, only a subset of the identified risks is encountered. This sub-set can take the form of an empty sub-assembly, in the ideal case where no risk arises, until all of the risks appear in the pessimistic case. As argued in (Marmier et al., 2013), in a project presenting n risks the number of possible subset is 2^n . So, to correctly analyze the possible impacts of risks on project objectives we have to evaluate 2^n risks scenarios. In this work, we modeled a risk scenario as a combination of occurrence/ none occurrence of the risks identified. Then a Risk Resulting Impact (RRI) is assessed for every generated risk scenario that affects a task. The value of the Risk Resulting Impact is aggregated to the task to obtain a Task Resulting Value (TRV). At the end, the Task Resulting Value of all tasks are aggregated from tasks to the project level to obtain a Project Resulting Value (PRV). Project Resulting Value is a set of aggregated criteria that characterize the project for every risk scenario. Based on the Project Resulting Value and the objectives, a Scenario Success Indicator (SSI) is assessed for every pairing of (risk scenario, type of criterion). After this, a Scenario Success Indicator is assessed for every risk scenario for all criteria. From the Scenario Success Indicator, the step of analysis classifies the project into one of these three categories: Fully Acceptable, Acceptable, and Not Acceptable. Fully Acceptable means that the project, in its actual configuration, meets the objectives. Thus, the project can be launched. Not Acceptable means that the objectives are not respected, and the gap is too wide. In this case the project must be redefined and characterized again - or abandoned. Acceptable refers to a situation where the project does not fulfil the objectives, but some risk management strategies could be used to drop it into the objectives

Figure 1. Project launch: Decision-making process



domain. In such a situation, preventive and corrective strategies for risk handling are characterized. From the new project model, including the management of risks, Treatment Scenarios (ScT) are computed for every risk scenario. A new Scenario Success Indicator is assessed, and the analysis categorizes the project and makes the decision to abandon, launch, redefine or characterize the project once again. Data collection/Modeling (1) and the Analysis (3) are performed by a stakeholder with the help of our built- in tool. The calculation (2) is totally performed by the tool.

Data Collection Modelling

Data is collected for six concepts, presented in Figure 2: Project (P), Task (T), Risk (R), Impact (I), Strategy (St) and Action (A).

A project consists of many Tasks. During task realization, Risks can occur. Risk is used in the sense of an undesirable event characterized by an occurrence probability which impacts on the project objectives (Marmier et al., 2014). A Risk affects one or many task criteria depending on the value of its Impact. Strategy aims to manage risk. It can reduce the impact of risks as well as the probability of their occurrence. Strategies can be preventive, corrective or a mixture of preventive and corrective if the risk occurs despite a preventive strategy. Strategy consists of a series of Actions. An action can add new tasks to the project, remove or modify existing ones. The first innovation in the paper is to characterize each concept by several criteria representing a relevant dimension: Technical, Economic, Ecological, Social, Regulatory etc. The second innovation lies in performing an analysis by including the objective on the identified criteria. Therefore, an objective for every criterion is defined according to four values: a minimum unacceptable (MINU), a minimum acceptable (MINA), a maximum acceptable (MAXA) and a maximum unacceptable (MAXU), as shown in Figure 3.

Interval 1, between the maximum acceptable and the minimum acceptable, is the acceptable zone (Fully Acceptable situation for the considered criterion). While the value of a criterion is in

Figure 2. Necessary concepts for the decision making

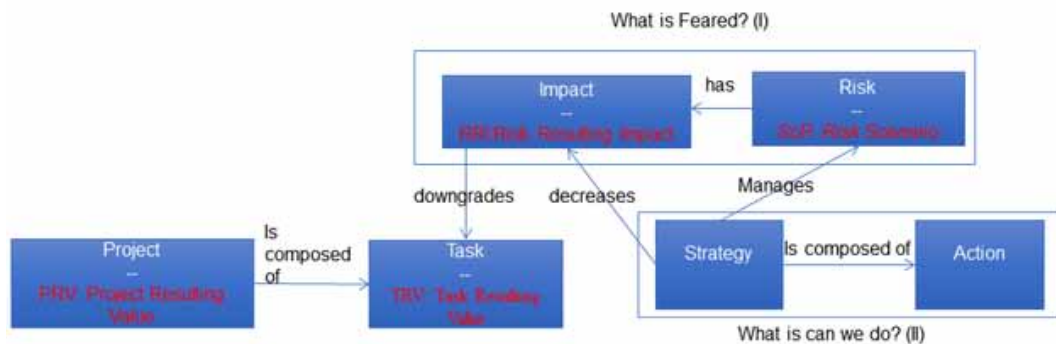
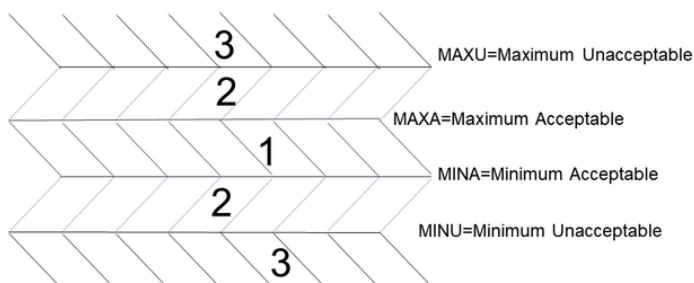


Figure 3. Values of the objective for a criterion



this zone, it is not deemed to be compromising for the project's success. Intervals 3, after maximum unacceptable and minimum unacceptable, are the unacceptable zones (Not Acceptable situation for the considered criterion). If the value of a criterion is greater than the maximum unacceptable or lower than the minimum acceptable, then this criterion puts the project in the Not Acceptable situation. In intervals 2, the objective could be accepted under some conditions (Acceptable situation). In these intervals the project is not so bad that it must be abandoned, but not good enough to be launched either.

Calculation and Aggregation Procedure

This section presents the aggregation procedure used to assess a success indicator. The third innovation in this approach is to begin by low-level information (values of criteria and impacts on tasks) then move to a higher level (the project level by assessing the Project Resulting Value for every risk scenario). For this purpose, let us consider a set of tasks \vec{T} , and Risks \vec{R} . A single task T, and Risk R are characterized by a set of criteria type \vec{C} . To manage Risks, sets of corrective and preventive strategies are available. \vec{C} , \vec{T} , \vec{R} , are vectors composed of several elements. A risk R has a set of impacts \vec{I} (one for every criteria). For $r = |\vec{R}|$ risks, $2r$ risks scenarios are generated from our built-in tool. A risk scenario could be composed of a single risk, several risks, or the situation where there is no risk (None). In the following part of this section, the proposal is described for one criterion. For risk scenarios composed of several risks, and impacting a single Task, their resulting impact corresponds to the Resulting Risk Impact (RRI). In the literature, the impact of a risk scenario composed of several risks is handled by summing their impacts. However, the "sum of value" model is not suitable to characterize all situations. For instance, both fire and flood can cause delays in a project. Their impact can be determined separately from a model or through data/expertise. But the simultaneous occurrence of fire and flood leads to a resulting impact different from that of the sum of fire and flood. For this reason, the Resulting Risk Impact (\overrightarrow{RRI}) of Risk Scenario (ScR), is calculated as follows:

$$\overrightarrow{RRI} = \text{MRRI}(\vec{I}) \tag{1}$$

where MRRI is a model. \overrightarrow{RRI} is a set of aggregated criteria that characterize every risk scenario.

At its occurrence, a risk scenario modifies the initial value of a Task criterion \vec{C} . The modified criterion value is named the Task Resulting Value (\overrightarrow{TRV}). It is assessed by:

$$\overrightarrow{TRV} = \text{MTRV}(\overrightarrow{RRI}, \vec{C}) \tag{2}$$

where MTRV is a model. \overrightarrow{TRV} is a set of aggregated criteria that characterize every task for a given risk scenario.

To characterize the project from its tasks, the evaluation is aggregated at the project level through the Project Resulting Value - \overrightarrow{PRV} . In a general way, the \overrightarrow{PRV} of the set of criteria \vec{C} for the project is:

$$\overrightarrow{PRV} = \text{MPRV}(\overrightarrow{TRV}) \tag{3}$$

where MPRV is a model. \overrightarrow{PRV} is set of aggregated criteria that characterize the project for every risk scenario.

Figure 4 summarizes the aggregation procedure. From the set of Risk \vec{R} , Risk Scenarios are generated. From every Risk Scenario ScR, an aggregation model MRRI allows assessment of a Risk Resulting Impact - RRI. From the Risk Resulting Impact and the value of a Task, a model MTRV allows a Task Resulting Value (TRV) to be evaluated. Finally, a model MPRV aggregates all the TRV to obtain a Project Resulting Value - PRV. All this calculation is for a single criterion.

The fourth innovation in this proposal is the use of generic models complementary to the standard ones. The models MRRI, MTRV, MPRV, can take the form of the average, the median, the sum or any other model according to the context.

The results of the calculation phase are summarized in Table 1 for all criteria.

In this table every risk scenario has an occurrence probability and a Project Resulting Value for every type of criterion. s is the number of risk scenarios and c the number of criteria. From this table, we calculate a Scenario Success Indicator (SSI) associated to every pairing of risk scenario i and criterion j according to the following formula:

$$SSI(ScR_i, j) = \begin{cases} 1 & \text{if } PRV_{ij} \in [MINA_j, MAXA_j] \\ 0 & \text{if } PRV_{ij} \geq MAXU_j \text{ or } PRV_{ij} \leq MINU_j \\ 1 - \frac{PRV_{ij} - MAXA_j}{MAXU_j - MAXA_j} & \text{if } MAXA_j \leq PRV_{ij} < MAXU_j \\ 1 - \frac{MINA_j - PRV_{ij}}{MINA_j - MINU_j} & \text{if } MINU_j \leq PRV_{ij} < MINA_j \end{cases} \quad (4)$$

Figure 4. Aggregation procedure from a task to the project

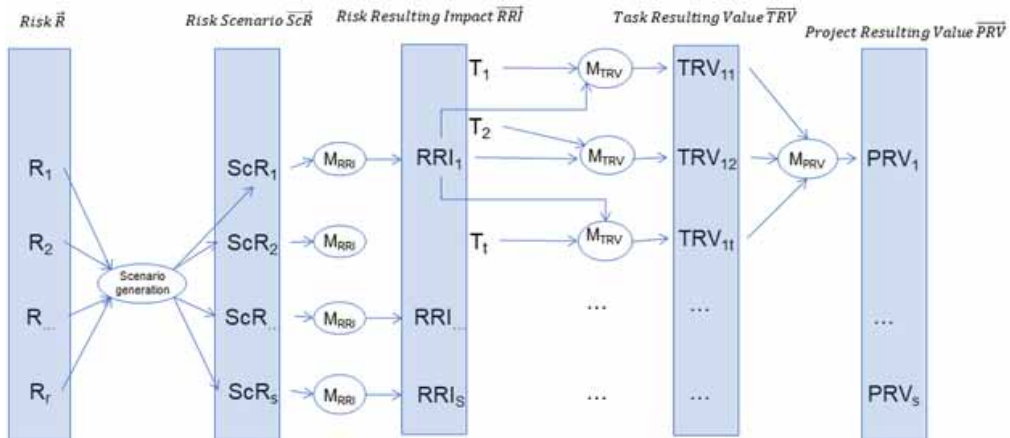


Table 1. Summary of calculation

Risk Scenario	Probability	Criteria			
		C1	C2	...	Cc
ScR1	P1	PRV11	PRV12		PRV1c
ScR2	P2	PRV21	PRV22		PRV2c
...					
ScRs	Ps	PRVs1	PRVs2		PRVsc

In equation (4) the value of $MINU_j$, $MINA_j$, $MAXA_j$, $MAXU_j$ are given for a criterion j . PRV_{ij} is the Project Resulting value for the risk scenario i and the criterion j . The global Scenario Success Indicator for all criteria depends on its occurrence probability P . It is assessed as shown below.

$$SSI(ScRi) = \begin{cases} 1 & \text{if } \forall j, PRV_{ij} \in [MINA_j, MAXA_j] \\ (1 - P_i) \times \prod_j SSI(ScR_{ij}) & \text{else} \end{cases} \quad (5)$$

According to equation (5), the value of a Scenario Success Indicator is necessarily between 0 and 1. 1 is the best value and 0 the worst.

Analysis and Use of the Indicators for Decision-Making

According to the values of the Scenario Success Indicators, the decision on the project launch is determined as follows:

The project is in a Fully Acceptable situation if the values of all scenario success indicators are 1 (one). In this situation the project can be launched.

$$\forall i, SSI(ScRi) = 1 \quad (6)$$

The project in a Not Acceptable situation if the values of all scenario success indicators are 0 (zero). In this situation the project needs to be abandoned or defined again.

$$\forall i, SSI(ScRi) = 0 \quad (7)$$

If some risk scenarios exist for which $SSI(ScRi) \in]0, 1[$, the project is in an Acceptable situation. In this situation, the project is not so bad that it must be abandoned, but not good enough to be launched either. Then, some strategies must be redefined. The bottom part of the process in Figure 1 is followed and new Scenario Success Indicators are assessed. To avoid infinite loop (in the case where the project is in Acceptable situation again and again), the new value of the Success Indicator is compared to a threshold \widehat{SSI}_t . The threshold is the minimum acceptable value of the Success Indicator after the incorporation of strategies. Then, the project can be launched if $\exists i / SSI(ScRi) \geq \widehat{SSI}_t$.

The next section presents the case study we have used to validate our proposal.

CASE STUDY

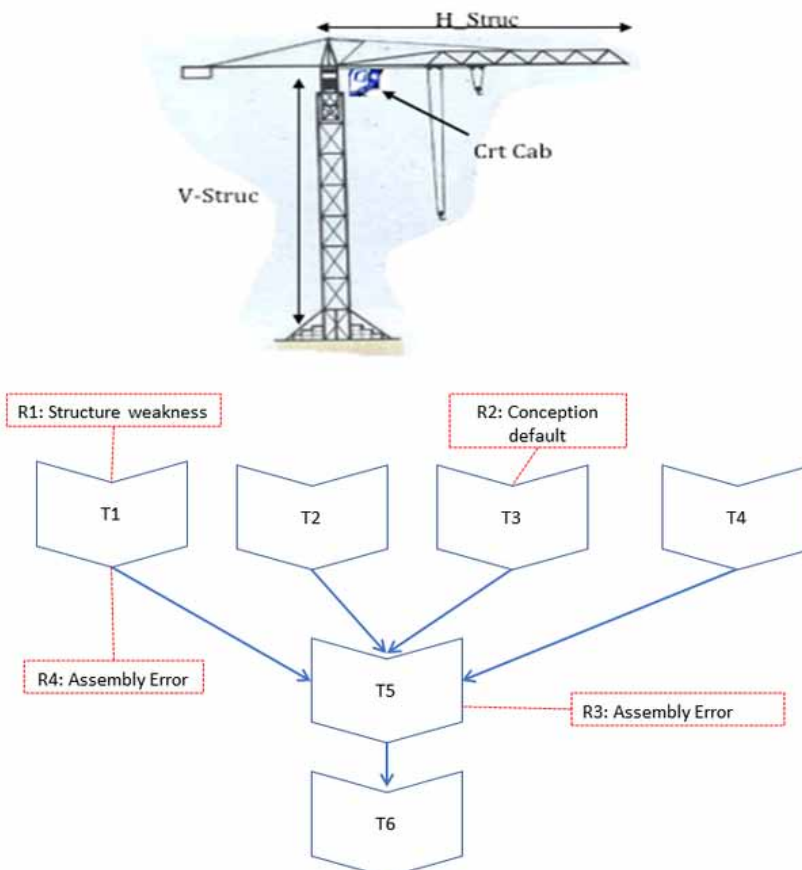
The case study is based on the activities of one of the partners of the project, a specialist in crane building. We have a long-standing partnership with this crane builder, which has led to two research projects. Several meetings and interviews were conducted to build the use case. The structure of the activities under study has been used many times by the partner. As every crane-building project is specific, the data and the objectives are different from one project to another. For reasons of confidentiality, we have used realistic data to illustrate and validate our proposals instead of the actual data. The next three sections describe the process followed according to our proposal.

Data Collection and Modelling

The launch issue in this case study concerns a project to build a crane, as can be seen in Figure 5.

The crane is composed of a horizontal and vertical structure (H-Struc and V-Struc), a control cabin (Crt Cab) and a source engine. The building project contains six tasks named from T1 to T6. T1 (Manufacturing Horizontal Structure), T2 (Manufacturing Vertical Structure), T3 (Source Engine Conception), T4 (Manufacturing Control System), T5 (Assemble Crane), T6 (Transport and Delivery). The task T1, T2, T3 and T4 can be carried out at the same time. The task T5 can only be done after T1, T2, T3 and T4. The task T6 can be done only after T5. Several criteria characterize the project. But in this case study, for pedagogical reasons and the needs of the demonstration, only four of them have been retained to evaluate the project: the duration (C1), the cost (C2), the technical complexity (C3) and the safety level (C4). The analysis process is the same with a higher number of criteria. For criteria C1 and C2, the estimated values are expressed in the dedicated units: weeks for criterion -C1 and k€ for criterion C2. For example, for task T1, criterion C1 indicates that the duration of this task is 11 weeks. For the two other criteria, the values are between 1 and 14, where 1 is the best value and 14 the worst. Specific metrics were developed by the company to assess these criteria. These metrics express the meaning of each of them to ensure that all the team members assess a specific situation in the same way. The criteria can be composed and have sub-criteria. We assume that there is business knowledge allowing to aggregate the compound criteria into a single criterion value.

Figure 5. Use Case: Analysis of a crane building project



The project risk management process identified four risks. During task T1, two risks could occur: structural weakness (R1) and an assembly error (R4). For the task devoted to conception and realization of the source engine T3, a risk concerns a possible defect in the waterproofing system (R2). The assembly of the crane is susceptible to an incorrect alignment of the structures (risk R3), causing an unacceptable sweepback and crane instability for task T5. The impact is assessed for every criterion. **Erreur ! Source du renvoi introuvable.** and **Erreur ! Source du renvoi introuvable.** present the characteristics of Tasks and Risks. We assume that the risks are independent.

Objectives formulated by the client and the crane builder are expressed according to the four selected criteria in Table 4. It shows, for every criterion, the value of maximum unacceptable (MAXU), maximum acceptable (MAXA), minimum acceptable (MINA) and minimum unacceptable (MINU).

The objectives fixed for project duration are explained by the fact that the client would not accept reception of the crane too early because the infrastructures for receiving the crane would not be available before this date. Therefore, an early reception could generate supplementary costs. The minimum acceptable value of the cost criteria is a quality guarantee, as most customers would not accept a low-cost product. The maximum acceptable value is the maximum cost the client can accept. The minimum acceptable value for complexity is dictated by the fact that only high-tech tools are available for this project. So, tasks must have some degree of complexity to justify the use of such tools.

Table 2. Task parameters

Code	Task Name	C1	C2	C3	C4
T1	Manufacturing Horizontal Structure	11	7	3	9
T2	Manufacturing Vertical Structure	10	7	3	9
T3	Source Engine Conception	40	8	6	4
T4	Manufacturing Control System	9	4	9	8
T5	Assemble Crane	7	3	9	9
T6	Transport and Delivery	4	0.6	1	1

Table 3. Risks parameters

Risk Code	Risk Name	Risk Proba	Impact				
			Impacted Task	C1	C2	C3	C4
R1	Structural weakness	0.15	T1	9	6.5	3.5	0.55
R2	Conception defect	0.05	T3	40	7.2	7	0
R3	Assembly error	0.05	T5	15	0.38	1.75	1.5
R4	Assembly error	0.2	T1	4.3	4	6.1	4

Table 4. Objectives

	C1	C2	C3	C4
MAXU	120	45	10	11
MAXA	67	30	6	7
MINA	63	25	5	6
MINU	30	15	3	3

The values of safety for every task are recorded in the safety procedures. We followed our proposal and incorporated these data in our built-in tool. Below the different phases of our proposal are shown.

Calculation and Aggregation Procedure

The scenario generation process leads to 16 project scenarios: 15 risk scenarios and the risk-free scenarios (None). For the calculation of the Risk Resulting Impacts, only task T1 has two risks that could affect it (R1 and R4). A sum was chosen by the company as an aggregation model. The RRI of the risk scenario R1R4 is then:

$$\overline{RRI(R1R4)} = \begin{cases} 13.3 = 9 + 4,3 \\ 10.5 = 6.5 + 4 \\ 9.6 = 3.5 + 6.1 \\ 4.55 = 0.55 + 4 \end{cases}$$

The values of the vector $\overline{RRI(R1R4)}$ correspond to the four criteria. This means that an occurrence of R1 and R4 at the same time would give their combined impact as 13.3 weeks on the duration, 10.5 K€ on the cost, 9.6 on the complexity and 4.55 on the safety level. The impact of risk scenarios on tasks is assessed through the Task Resulting Value (TRV). For task T1, the TRV of R1R4 is calculated by using the sum as an aggregation model.

$$\overline{TRV(R1R4, T1)} = \begin{cases} 24.3 = 13.3 + 11 \\ 17.5 = 10.5 + 7 \\ 12.6 = 9.6 + 3 \\ 13.55 = 4.55 + 9 \end{cases}$$

The values of the vector $\overline{TRV(R1R4, T1)}$ mean that at the occurrence of R1 and R4, the task T1 will last 24.3 weeks, cost 17.5K€, induce a complexity of 12.6 and a safety level of 13.55. For every risk scenario, the TRV is aggregated at the project level. For this purpose, we use in equation (3) the PERT model for the duration, a sum for the cost, and a mean for the technical complexity and the safety level to obtain the Project Resulting Value (PRV), to assess the success indicators for every couple (Risk Scenario, Criteria) and provide a Success Indicator for every Risk Scenario. These values are shown in Table 5.

Analysis and Use of the Indicators for Decision-Making

When no risk occurs, the value of the duration, the cost, the technical complexity, and the safety level, represented for the project by the Project Resulting Value are respectively, PRV1=65, PRV2=28.6, PRV3 = 5.08 and PRV4 = 6.66. These values meet the overall objective. This situation is consequently reflected by the values of the success indicator that is equal to 1 for all criteria. Based on this result, it can be observed that the project is performing consistently well. Considering the probability of the NONE scenario (0.5079), the project has a fifty-fifty chance of success. However, the interest of this proposal is to go deeper into the situation and to consider the risk scenarios before the decision is made.

When risks are considered separately (ScR2 for risk R1, ScR10 for risk R2, ScR14 for risk R3 and ScR16 for risk R4), the success indicators are respectively, 0.3763, 0.3025, 1 and 0.3678. Among these four risks only risk R3 is not compromising for the project. This analysis demonstrates

Table 5. Project Resulting Criteria

Code Risk Scenario	Name	Proba	C1		C2		C3		C4		SSI
			PRV1	SSI1	PRV2	SSI2	PRV3	SSI3	PRV4	SSI4	
ScR1	NONE	0.5079	65	1	28.6	1	5.083	1	6.666	1	1
ScR2	R1	0.1040	51	0.6363	35.1	0.66	5.666	1	6.758	1	0.3763
ScR3	R1R2	0.0078	91	0.5471	42.3	0.18	6.833	0.7916	6.758	1	0.0773
ScR4	R1R2R3	0.0004	106	0.2641	42.68	0.1546	7.125	0.7187	7.008	0.997	0.0292
ScR5	R1R2R3R4	0.0002	106	0.2641	46.68	0	8.141	0.4645	7.675	0.831	0
ScR6	R1R2R4	0.0033	91	0.5471	46.3	0	7.85	0.5375	7.425	0.8937	0
ScR7	R1R3	0.0066	66	1	35.48	0.6346	5.958	1	7.008	0.997	0.6291
ScR8	R1R3R4	0.0028	66	1	39.48	0.368	6.975	0.7562	7.675	0.831	0.2306
ScR9	R1R4	0.0445	51	0.6363	39.1	0.3933	6.683	0.8291	7.425	0.893	0.1772
ScR10	R2	0.0382	91	0.5471	35.8	0.6133	6.25	0.9375	6.666	1	0.3025
ScR11	R2R3	0.0024	106	0.2641	36.18	0.588	6.541	0.8645	6.916	1	0.1339
ScR12	R2R3R4	0.0010	106	0.2641	40.18	0.3213	7.558	0.6104	7.583	0.8541	0.0442
ScR13	R2R4	0.0163	91	0.5471	39.8	0.3466	7.266	0.6833	7.333	0.9166	0.1168
ScR14	R3	0.0324	66	1	28.98	1	5.375	1	6.916	1	1
ScR15	R3R4	0.0138	66	1	32.98	0.8013	6.391	0.9020	7.583	0.8541	0.6088
ScR16	R4	0.2176	51	0.6363	32.6	0.8266	6.1	0.975	7.333	0.9166	0.3678

in a very easy way a postulate assumed by most of the authors in the literature (Cervone, 2006): The risk occurrence could compromise fulfilment of the project objective and consequently its launch.

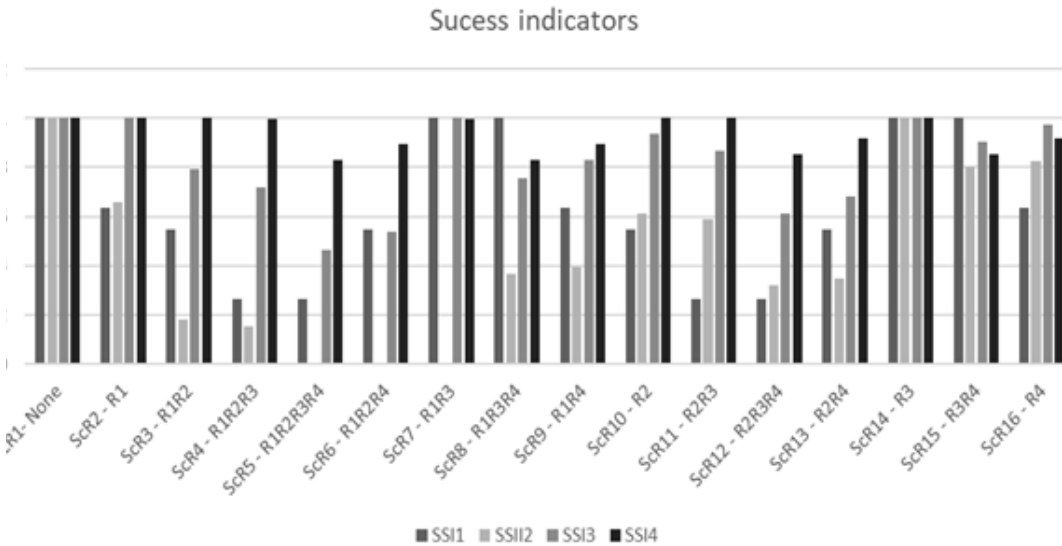
Now, let us look at the occurrence of several risks. Figure 6 shows the values of the success indicators for the four criteria (SI1 to SI4) for the 16 risk scenarios and that of the scenario SSI. It can be observed that the more risks included in the risk scenarios, the lower the success indicator is. This is also the point of view of (Bañuls et al., 2017). The average success of one risk scenario is 0.5116; that of 2 and 3 risks are respectively 0.2905 and 0.0760. The decrease in the success indicator according to the number of risks highlights, once again, the impact of the risk on the project's success.

Considering all risk scenarios, only one risk scenario (ScR14 including R3) meets the objective for all criteria. For the other 15 risk scenarios, only 4 meet the duration objective, 1 the cost objective, 3 the complexity objective and 5 the safety objective. This analysis justifies the need for an indicator on which to rely for decision-making in risk situations. This need is also pointed out by (Speriusi-Vlad, 2014) and (Waas et al., 2014)

About the criteria, ScR15, ScR17 and ScR8 are not compromising for the duration, but they are compromising for the cost. This example supports the argument supported by (Hwang & Lin, 2012) and (Yu, 2013): the inclusion of several criteria might change the analysis process and have a consequence on the decision to launch the project. These findings demonstrate our initial hypothesis: the use of more and better-adapted criteria, including risks, may lead to a different launch decision.

The values in table 4 shows that risk R4 is compromising for all criteria. In the same table one might expect that the risk scenario R3R4 would also be compromising for all criteria. This seems logical because scenario R3R4 includes R4, which compromises achievement of the project. In fact, in R3R4 the success indicator for the duration is 1, traducing the fact that this scenario fulfils the objective on this criterion. This is because the objective here has a minimum requested for every criterion. At the occurrence of R4, the resulting value is below the objective; therefore, the objectives are not likely to be fulfilled. In scenario R3R4, the resulting value of the duration is high enough to meet the objective. For this reason, the success indicator of R3R4 is better than that of R4. This

Figure 6. Calculation for risks scenarios



situation demonstrates that in some cases, a risk could become an opportunity as argued by (Chapman & Ward, 2011).

There are two scenarios, ScR5 and ScR6, for which the objectives cannot be fulfilled. For these two scenarios the success indicators are 0. According to our proposal, the project is not in a Fully acceptable situation, but in an Acceptable one. It cannot be launched in this situation because the success indicators are not equal to 1 for all scenarios. We therefore follow the process and characterize strategies and actions. **Erreur ! Source du renvoi introuvable.** shows the characteristics of the five identified strategies. Among them, there are two preventive strategies, ST1 and ST3.

The actions that make up the strategies are described in Table 7. At this time, the analysis is at the strategy level shown in Figure 1. The identified actions become additional tasks of the project.

By following our proposal, the following two tables group the assessed indicators. Table 8 and Table 9 show the values of Strategies Scenarios for the two compromising Risk Scenarios, R1R2R4 and R1R2R3R4.

Table 8 reveals that there are only two treatment scenarios that offer a chance for the project to be a success: ScT1 and ScT6. In the same way, in Table 9, only ScT16 and ScT23 offer a chance for the project to be a success. The threshold fixed by the stakeholders is 0.00001. This means that if there

Table 6. Treatment scenarios

Code	Description	Risk	Reducing impact					Type
			C1	C2	C3	C4	Probability	
ST1	Thermal treatment	R1	-6	-3.5	-2	-0.7	0.03	Preventive
ST2	Ordering new engine	R2	-22	-8	-4	-2		Corrective
ST3	Metrological measurement	R3	-4.5	-0.15	-0.8	-1	0.04	Preventive
ST4	Disassembling and reassembling	R3	-7	-0.4	-1	-1		Corrective
ST5	Disassembling and reassembling	R4	-3	-3	-5	-1		Corrective

Table 7. Actions

Code	Strategy	Action Name	Task Code	C1	C2	C3	C4	Previous task	Next task
A1	St1	Thermal treatment	Thermal treatment	5	1	10	11	T1	T5
A2	St2	Ordering new engine	Ordering new engine	14	48	4	1	T3	T5
A3	St3	Metrological checking	Metrological checking	3	0.25	11	4.4	T1, T2, T3, T4	T6
A4	St4	Disassembling	Disassembling	5	1.5	3	8	T5	Reassembling
A5	St4	Reassembling	Reassembling	7	3.5	4.3	8.4	Disassembling	T6
A6	St5	Disassembling H_Struct	Disassembling H_Struct	6	4	2.2	7.1	T1	Reassembling H_Struct
A7	St5	Reassembling H_Struct	Reassembling H_Struct	12	7	3.2	11	Disassembling H_Struct	T5

Table 8. Treatment Scenario for the risk scenario R1R2R4

Code Treatment Scenario for R1R2R4	Name	Proba	C1		C2		C3		C4		SSI
			PRV1	SSI1	PRV2	SSI2	PRV3	SSI3	PRV4	SSI4	
ScT1	R1R2R4ST1	0.0027	91	0.54	43.8	0.08	7.8714	0.53	7.8357	0.79	0.018
ScT2	R1R2R4ST1ST2	0.0027	83	0.69	83.8	0	6.8875	0.77	6.7312	1	0
ScT3	R1R2R4ST1ST2ST3	0.0027	79	0.77	83.9	0	7.3277	0.66	6.3611	1	0
ScT4	R1R2R4ST1ST2ST3ST5	0.0027	79	0.77	91.9	0	6.0318	0.99	6.7590	1	0
ScT5	R1R2R4ST1ST2ST5	0.0027	83	0.69	91.8	0	5.55	1	7.095	0.97	0
ScT6	R1R2R4ST1ST3	0.0027	87	0.62	43.9	0.07	8.2437	0.43	7.2812	0.92	0.018
ScT7	R1R2R4ST1ST3ST5	0.0027	87	0.62	51.9	0	6.635	0.84	7.535	0.86	0
ScT8	R1R2R4ST1ST5	0.0027	91	0.54	51.8	0	6.1666	0.93	7.9944	0.75	0
ScT9	R1R2R4ST2	0.0033	83	0.69	86.3	0	6.7285	0.81	6.2214	1	0
ScT10	R1R2R4ST2ST3	0.0033	79	0.77	86.4	0	7.2437	0.68	5.8687	0.95	0
ScT11	R1R2R4ST2ST3ST5	0.0033	79	0.77	94.4	0	5.835	1	6.405	1	0
ScT12	R1R2R4ST2ST5	0.0033	83	0.69	94.3	0	5.2777	1	6.7388	1	0
ScT13	R1R2R4ST3	0.0033	87	0.62	46.4	0	8.2785	0.43	6.85	1	0
ScT14	R1R2R4ST3ST5	0.0033	87	0.62	54.4	0	6.4833	0.87	7.2277	0.94	0
ScT15	R1R2R4ST5	0.0033	91	0.54	54.3	0	5.9375	1	7.7062	0.82	0

is a risk situation compromising the project (i.e. its SSI=0), and if there is a treatment scenario for this risk scenario, which has a chance of being a success superior to 0.00001, then the project can be launched. This is indeed the situation in this case study, where the probability of the four treatment scenarios is greater than 0.00001. The project can thus be launched.

This case study validates the feasibility of our proposal by following the suggested process. It shows how it is possible to make the decision to launch the project or not in risk and multi-criteria situations.

CONCLUSION AND FUTURE WORKS

Making the decision to launch the project based on the cost and duration is no longer a guarantee of its success in a context of risk. The assessment of potential success must integrate a wide range of other criteria, and of course consider the management of risks. The objective of this paper has been to propose an approach to determine the likelihood of project success, to take the decision to

Table 9. Treatment Scenario for the scenario R1R2R3R4

Code Treatment Scenario for R1R2R3R4	Name	Proba	C1		C2		C3		C4		SSI
			PRV1	SSI1	PRV2	SSI2	PRV3	SSI3	PRV4	SSI4	
ScT16	R1R2R3R4ST1	0.0001	106	0.2641	44.18	0.0546	8.1214	0.46	8.05	0.73	0.005
ScT17	R1R2R3R4ST1ST2	0.0001	98	0.4150	84.18	0	7.1062	0.72	6.91	1	0
ScT18	R1R2R3R4ST1ST2ST3	0.0000	93.5	0.5	84.28	0	7.5222	0.61	6.52	1	0
ScT19	R1R2R3R4ST1ST2ST3ST5	0.0000	93.5	0.5	92.28	0	6.1909	0.95	6.89	1	0
ScT20	R1R2R3R4ST1ST2ST4	0.0001	103	0.3207	88.78	0	6.315	0.92	7.07	0.98	0
ScT21	R1R2R3R4ST1ST2ST4ST5	0.0001	110	0.1886	97.18	0	5.3791	1	7.40	0.89	0
ScT22	R1R2R3R4ST1ST2ST5	0.0001	98	0.4150	92.18	0	5.725	1	7.24	0.93	0
ScT23	R1R2R3R4ST1ST3	0.0000	101.5	0.3490	44.28	0.048	8.4625	0.38	7.46	0.88	0.0056
ScT24	R1R2R3R4ST1ST3ST5	0.0000	101.5	0.3490	52.28	0	6.81	0.79	7.68	0.82	0
ScT25	R1R2R3R4ST1ST4	0.0001	111	0.1698	48.78	0	7.0166	0.74	7.97	0.75	0
ScT26	R1R2R3R4ST1ST4ST5	0.0001	111	0.1698	56.78	0	5.7772	1	8.07	0.73	0
ScT27	R1R2R3R4ST1ST5	0.0001	106	0.2641	52.18	0	6.3611	0.90	8.16	0.70	0
ScT28	R1R2R3R4ST2	0.0002	98	0.4150	86.68	0	6.9785	0.75	6.43	1	0
ScT29	R1R2R3R4ST2ST3	0.0000	93.5	0.5	86.78	0	7.4625	0.6343	6.0562	1	0
ScT30	R1R2R3R4ST2ST3ST5	0.0000	93.5	0.5	94.78	0	6.01	0.9975	6.555	1	0
ScT31	R1R2R3R4ST2ST4	0.0002	103	0.3207	91.28	0	6.1277	0.96	6.71	1	0
ScT32	R1R2R3R4ST2ST4ST5	0.0002	103	0.3207	99.28	0	5.05	1	7.05	0.9875	0
ScT33	R1R2R3R4ST2ST5	0.0002	98	0.4150	94.68	0	5.4722	1	6.90	1	0
ScT34	R1R2R3R4ST3	0.0000	101.5	0.3490	46.78	0	8.5285	0.36	7.06	0.98	0
ScT35	R1R2R3R4ST3ST5	0.0000	101.5	0.3490	54.78	0	6.6777	0.83	7.39	0.90	0
ScT36	R1R2R3R4ST4	0.0002	111	0.1698	51.28	0	6.8937	0.77	7.68	0.82	0
ScT37	R1R2R3R4ST4ST5	0.0002	111	0.1698	59.28	0	5.555	1	7.85	0.78	0
ScT38	R1R2R3R4ST5	0.0002	106	0.2641	54.68	0	6.156	0.96	7.89	0.77	0

launch, abandon or redefine the project by relying on an innovative indicator. For this purpose, we have proposed success indicators by identifying and aggregating several criteria, risks, and strategies. The approach we have adopted is to propose a theoretical framework and apply it to a practical case study. We performed a review of criteria assessment and risk management methodologies in the field of project management. In this review, we determined several categories of criteria. We then proposed a methodology to assess risk impacts, strategies and the aggregation of criteria in all possible configurations. This approach is a way to evaluate the project from criteria defined to assess tasks. Finally, we proposed success indicators and decision procedures to determine whether the project could be a launched or not. Besides the proposal of the process, our contribution are: (1) A project evaluation model (2) During data collection/modelling, we propose a project model that includes risks (3) During characterization, we propose the integration of several criteria (4) For the scenario evaluation framework, aggregation functions are proposed. Indicators to evaluate project success complete these functions (5) Finally, a methodology to categorize scenarios is proposed in the last part.

We have observed that (a) risk occurrence may compromise fulfilment of the project objective and consequently affect its launch, (b) the more risks included in the risk scenarios, the lower the success indicator is, (c) the inclusion of several criteria might change the analysis process and have a consequence on the launch decision (d) in some cases, a risk could become an opportunity. These findings demonstrate the need for an indicator on which to rely for decision-making in risk and multi-

criteria situations. They confirm the initial hypothesis: the use of more and better-adapted criteria, including risks, may lead to a different launch decision.

As a perspective, our aim is to look at the problem of relationships inside the criteria and risks and address their dependencies. Indeed, in the risk scenario, the occurrence of one risk may influence the occurrence of another risk in the same scenario. We also plan to expand the proposal to consider compound criteria. For compound criteria, aggregation mechanisms will be useful for their consideration in our proposal. Similarly, since the criteria may influence each other, a procedure to ensure their independence must be defined. In addition, given that, cognitive load may become critical for users of our approach, we consider working on the reduction of user-perceivable complexity, as well as visualization tools allowing a cognitive exploitation of the results.

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