International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 21 (2015) pp 42502-42510

Integration of Experience Feedback mechanisms to the FMECA method: a solution to improve project risk management

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Abstract
FMECA (Failure Modes, Effects and Criticality Analysis) is a recognized method of risk management that provides a formal framework to identify risks, assess their criticality and develop preventive and/or corrective actions to reduce its effects. Although frequently used in industry, it has limitations in terms of capitalization and operating experience, particularly when used in the field of project management. To overcome these difficulties, we propose to integrate the principles of Experience Feedback (EF). Indeed, the EF system designed to facilitate the capitalization of experiences and their exploitation and generate rules of good practices.

Keywords— Experience Feedback, Knowledge Management, Risk Management, FMECA, Project.

Introduction

In a particularly difficult economic context, because of the financial crisis and the increasing competition where error is not allowed; and with the increasing complexity of projects, the uncertainty and the inevitable presence of risks, risk management has become an essential step for the success of any project. Risk management is an iterative process that starts early in the project and continues throughout the life cycle of the project, a progressive and iterative approach that ensures that project objectives are met and an essential phase for the success of any project, according to Royer [1] « Experience has shown that risk management must be of critical concern to project managers, as unmanaged or unmitigated risks are one of the primary cause of project failure ».

Identifying the risks and the remedial measures prior to running the project is undoubtedly a wise way to follow [2]. To control these risks and operational forecasting requires the implementation of several activities and this iteratively throughout the project duration: analysis, reduction and risk detection and monitoring of the implementation of the identified measures are to be implemented from the beginning to the end of the project. In addition, the results of these actions must be capitalized in a common framework of reference in order to exploit the experience for future projects and therefore be part of a continuous improvement approach.

Risk management refers to strategies, methods and support tools to identify and manage the risks to an acceptable level [3]. The Failure Modes, Effects and Criticality Analysis (FMECA) method has been considered for many years as one of the most effective techniques in the risk management, and its use is widespread in the industrial world according to McDermott "This promoted applications that bridged across industries and companies" [4]. It is one of the analysis techniques recommended by international standards such as the ISO 9000 series, the standard JCAHO LD.5.2 [5] and MIL-STD-1629A standard [6] and by [7] "This is an important technique that is used to identify and eliminate known or potential failures to enhance reliability and safety of a simple product or even complex system".

The purpose of this paper is to present the findings at the base of our work and research areas proposed to improve the performance of the FMECA for the capitalization of experiences and the creation of rules of good practice. The paper is organized as follows:

We begin by presenting the process of risk management in projects. Then, we detail the principles of FMECA and some of its limitations. Then we discuss the mechanisms of experience feedback and overall architecture. Finally, before concluding, we show the interest of Experience Feedback (EF) to improve the capitalization and the operating experiences related to risks in projects.

Risk management in projects

Risk management is an iterative and progressive approach throughout the life of a project, which will ensure that the project objectives are met. According to the PMBOK (Project Management Body of Knowledge), project risk management includes the processes for conducting risk management planning, identification, analysis, responses, and monitoring and controlling [8]. The risk management planning is to decide how the project team should plan risk management activities of a project. Risk identification is to make an inventory of all the risks that may affect the success of a project and to document their characteristics. Risk analysis is the process of assessment and prioritization of risks, mainly in terms of their characteristics, such as probability, detectability (or controllability) and impact. Risk response planning is to develop procedures and methods to increase opportunities and reduce threats. The supervision and control of risks are to implement risk response plans, to track and identify the risks, to monitor residual risks, to identify the new risks and to assess the effectiveness of the risk management process throughout the project.

Fig. 1. Project Risk Management Process

A. Project risk definition

In literature, there are several definitions of the word "risk". In this article we are particularly interested in the proposed definitions in the project context:

According to the PMBOK "the project risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on the projects objectives" [8].

The project risk is defined as "combination of probability of an event occurring and its implications for project objective" of after [9].

The International Organization for Standardization defines project risk as "undesirable situation or circumstance that has both a likelihood of occurring and a potential negative consequence on a project" [10].

According to Kerzner, the project risk is defined as a « Measure of the probability and consequence of not achieving a defined project goal » [11].

These definitions show that in case a risk is realised, that is to say, it transforms into a proved event or a problem, the latter will have a negative impact on at least one of the quantitative objectives (cost, time, content) or qualitative objectives (motivation, involvement of crew, customer satisfaction) of the project. However, this proved event can also generate positive effects; in this case we no longer speak of risk, but rather of opportunity. In the rest of this article, risk project refers exclusively to a negative event and we propose the following definition:

"The project risk is defined as a possible event which implementation may have a negative impact on one or more objectives of the project".

B. Stakes and objectives of project risk management

It is not surprising to see projects leading to failure, or to a reconsideration of their initial objectives. Thompson and Perry [12] have attributed the failure of the projects to the absence of an effective risk management, which often leads to overlook tasks and scale down the initial objectives. Thus, risk management in projects has gradually emerged as a key success factor and a major concern for many companies, pushed according to Courtot [13] by:

- A more complex uncertain and changing economic and industrial environment, which disrupts the technical definitions and industrial scenarios. This combination of factors leads to costly, difficult to predict and even harder to anticipate or achieve adjustments.
- An increasing complexity of projects (technical, logistical, organizational), which increases the risks.
- The obligation to better control the cost, time and technical specifications of the projects due to the increasing pressure from shareholders, the media and the impact of public opinion, sharpening the competitive environment,
- The necessity to carry out projects more and more in partnership or international cooperation.

The evolution of companies towards project management instead of the operation management has put it in a fluctuating environment, where activities are temporary, irreversible (one-shot), non-repetitive, and less well known than its former operations, a new type of management that requires new business skills required for projects.

Risk management in projects aims to identify as exhaustive as possible way, from the beginning of the project, of all the risks that may affect the success of the project and to develop preventive and/or corrective measures that will eliminate these risks, reduce their occurrences or master their consequences to make them acceptable.

FMECA and risk management

A. Introduction

The objective of the FMECA method is to study, identify, prevent or reduce the risk of failure of a system, process, product or project.

Omdahl defines FMECA as « a technique used to identify, prioritize, and eliminate potential failures from the system, design or process before they reach the customer » [14].

The FMECA method is composed of four phases (see Figure 2).

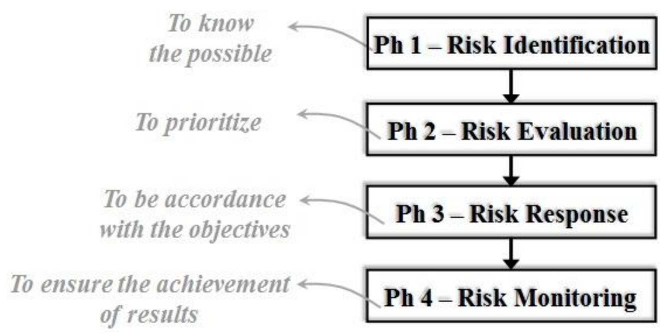

Fig. 2. FMECA Phases

i. *Phase 1-Identification*

Risk identification is to make an inventory of all the risks that may affect the success of the project and to document their characteristics.

The PMBOK provides several tools to structure and formalize the identification of risks such as: a systematic documentary analysis, Brainstorming, Delphi technique, Interviews, SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats), Ishikawa diagram or Influence diagrams. In addition, the risk profile must be considered as relevant tool [2]. This tool consists of a list of questions covering the usual uncertainty factors. It thus brings together the key questions to ask at the beginning of the project or in the early phase to identify known potential hazards.

Risk identification is a complex task because there is a wide variety of potential events that may have a negative impact on the objectives. This identification is a team work that requires the commitment of several industry experts who already work in projects similar to the current project.

ii. *Phase 2-Evaluation*

The purpose of the evaluation is to prioritize risks in order to define treatment priorities, that is to say, to identify risks for which special measures are needed.

After being identified, the method advocates a calculation for each risk, of the criticality that is denoted C (1) from the product of three indices:

- The probability of risk occurrence, denoted P, which represents the probability or frequency of occurrence (onset, appearance),
- Detectability or controllability of risk, denoted D, which is the ability to detect the risk from its appearance,
- The severity of consequences, denoted S, which represents the negative effects caused by the appearance of risk.

$$C = P \times D \times S \qquad (1)$$

The evaluation scales of each criterion are generally from 1 to 4 or 1 to 5 or 1 to 10 if the FMECA requires more precision, but it is often more practical to choose the rating 1 to 5.

It should be noted that there are other more complete comprehensive methods to assess the risks in projects, such as the method of BOCR [15].

Given the wide variety of risks, it is necessary to establish a reliable evaluation referential (assessment referential) to quantitatively classify the risks in order of importance. For this, the method FMECA advocates criticality calculation (see equation 1) based on the value assignment of three indices P, D and S. In addition, in project management, it is necessary to identify tasks affected by the occurrence of each risk and to integrate into the assessment of the severity, the consequences engendered out of:

- The other project tasks: simple performance gaps of a task on the criteria cost, time or content, can create significant losses and conflicts in other parts of the project,
- Or the other projects conducted by the company: in the same way, these differences can cause problems in other projects, such as the unavailability of critical resources.

To support of their studies, actors may use a risk matrix. This tool brings together in a single document (see Table 1), the values assigned to the three indices and tasks affected by each risk.

Table I. Risks matrix

Risk	**P**	**D**	**S**	**C**	**Tasks affected**
Machine breakdown	3	2	5	**30**	Fabrication

iii. *Phase 3-Response*

To respond to an identified risk is to choose the strategy to be implemented to guard against this risk.

There exist typically six types of strategies that can be considered:

- ✓ Risk Acceptance: this strategy consists in saying that no specific action is taken to protect against this risk.
- ✓ Risk avoidance: this strategy consists in reviewing the project in terms of objectives to achieve or deployed technical solutions or tasks organization, and affected resources... so, it is either by eliminating the risk or protecting the project objectives and making them immune to the occurrence of the risk.
- ✓ Risk prevention: this strategy consists in finding solutions or ways to get the probability of risk below an acceptable threshold.
- ✓ Risk reduction: this strategy consists in finding solutions or ways to reduce the impact of the risk.
- ✓ Risk surveillance: this strategy aims to identify the warning signs or trigger events to quickly detect the occurrence of a risk.
- ✓ Risk Transfer: this last strategy consists in finding a third party willing to take over the consequences of the occurrence of the risk. This third party then becomes the response plans owner to respond to risks. Through this, the risk is not eliminated, but the consequences are managed by someone else in return for financial compensation.

It should be noted that the implementation of preventive and/or corrective actions in response to risk is often required in projects. However, one must ensure that the impact of these actions on the project objectives (cost, time, content) is lower than the consequences arising from the occurrence of the risk.

After the risk assessment, the criticalities are compared to thresholds to identify risks that are not acceptable. For the latter, the type of strategy and response plans should be identified in order to reduce the criticality to an acceptable level. If it turns out that no relevant action can reduce the risk to an acceptable level, it becomes necessary to take transfer actions.

As noted in Phase 1, "Identification", to prioritize risks, their position in the organization of the project and the margins available in the loops must be considered. Indeed, the risk analysis should not be simply carried out on the tasks separately, but on the "loops" constituting the project, that is

to say, on the sets of tasks with dependencies and sharing the same marge. The objective is to assess, from risks affecting the tasks constituting the same loop, the probability that it will become the critical path. Following this assessment, the actions to return to a probability of becoming acceptable criticism must be defined. Thus, focusing the analysis on the critical path tasks is an illusion.
Figure 3 below illustrates the Main phases of FMECA.

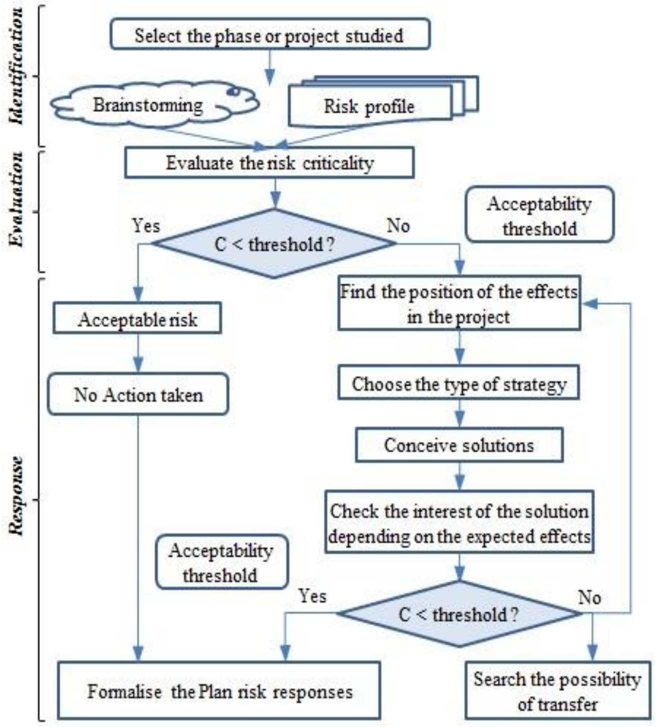

Fig. 3. Main phases of FMECA

iv. *Phase 4-Monitoring*

This last phase of risk management has several objectives. We must on one hand ensure the implementation of actions:

- ✓ Preventive in order to trait some critical risks before they occur,
- ✓ Monitoring triggers and warning signs to detect the occurrence of a risk earlier,
- ✓ Corrective to initiate the response plan developed to treat a stated risk, while guarding against new risks and, thus, define new preventive actions.

On the other hand, we must ensure that they permit to eradicate or reduce the effects of the considered risk. To each deployment of actions, it will be necessary to update the reference plan of the project (planning, budget allocation, resource allocation) and reserve funds dedicated to risk management [2].

B. *Limitations of FMECA*

As mentioned above, in order to enroll in a spirit of continuous improvement, it is necessary to capitalize the past experiences in order to learn and to derive lessons and rules of conduct to reproduce good practices (success factors, Actions, methods and techniques whose effectiveness has been found in previous projects) and to avoid pitfalls (failure factors, actions, methods and techniques disruptive or inefficient found in previous project). These lessons and rules of conduct present the expertise and knowledge of the company to integrate into its referential. Although the FMECA method is widely used in many fields, it has limitations in terms of capitalization, in particular in the projects. The main causes of these limitations are:

- ✓ The existence of multiple formats to capitalize risks: the risk matrix, the risk profile, the Ishikawa diagram, the cause tree, the minutes of meeting ... which lead to a sparse capitalization and to a difficult treatment of the recorded information,
- ✓ the heaviness of the FMECA method: the process is structured and accompanied by several documents to fill, which can hinder the involvement of certain actors,
- ✓ the periods of risk capitalization: often, the risks are only analyzed in the beginning and at the end of the project, and in a summary manner. Indeed, early in the project, the actors have difficulty perceiving the limits of the project and the importance of this analysis. During the project, it is not their priority. Developments should advance. At the end, they go directly to another project without taking time to make a synthesis and, in the case where a synthesis is carried out, it remains in memory as significant events,
- ✓ reporting of risks and their characteristics in the risk matrix is not conducive to the generation of rules: the modes of reporting risks and/or implemented actions do not allow to build knowledge,
- ✓ At last, the lack of sharing and reuse of past experience: from the creation of project-specific team, there is no natural capitalization, as in a service where the actors are always the same and where databases are clearly identified and localized.

To overcome these difficulties of risk capitalization, we propose the use of experience feedback mechanisms to collect necessary and sufficient information to generate relevant rules, while limiting the input constraints. This idea is not new and the principles of experience feedback are often advocated to overcome the difficulties of capitalization as in [16], [17], [18] and [19]. However, the means and methods to be implemented to deploy a dedicated experience feedback system remain not specified.
In the following pages of this paper we are bringing some responses.

Experience feedback system

Experience feedback belongs to the scientific field of Knowledge Management. It is an approach used to valorise knowledge or the immaterial patrimony of the company for which the company has already invested. According to [20] "This approach allows to study an event proved, or a past situation in order to learn lessons". "Experience Management" in reference to Knowledge Management, introduces the concept of knowledge management-related experience or

"Lesson Learned" and "Experience Feedback» are different terms to describe the experience feedback approaches.
However, regardless of the term used, it is the experience and its management that are at the heart of all the considered work.

A. State of the art

Learning from self experiences and those of others in terms of risk is a common and essential practice for the survival and development of any industry (business). According to [21] this method of learning is an essential tool because the industry has neither the time and the resources nor the will to experience an incident before taking corrective or preventive measures. Being conscious of the importance of experiential learning for the success of their projects, companies have started to integrate in their business processes tools to capitalize, analyze, reuse experience and transform it into knowledge in order to increase the performance of their projects.
The identification of risks of previous projects in practice is done from several sources: The memory of the person (intuition, tacit knowledge ...), the documentation of previous projects (the risk register, the matrix risk, the risk profile of the reports), databases or database experience / knowledge.
In the examined documentation, the capitalization and exploitation of previous risks in practice is done via several sources: The memory of the person (intuition, tacit knowledge ...), documentation of previous projects (the risk register, check-list, the risk matrix, risk profile, the reports ...), the statistical databases or database experience/knowledge.
These sources are fed and handled by two different approaches:
Statistical approaches: a set of risk-related data are capitalized (frequency of occurrence, causes, consequences, actions, ...) without associating a captured risk to its context which leads to a very limited reuse (statistical reuse) and does not allows the creation of knowledge and learning from experience [22], [23] and [24].
Cognitive approaches: the captured risk is documented, associated to its context, analyzed and formalized which makes it possible to represent and capitalize all we can withdraw from experience, this approach allows to reinforce the creation of knowledge and learning [25], [26] and [27].

B. Definition

In the literature, there are several definitions of Experience Feedback. These definitions vary essentially by industry considered, with a wealth in the area of risk activities (power plants, air transport ...). Indeed, the events in this area can have catastrophic consequences and it is important to implement predispositions to eliminate the occurrence of such events or to mitigate their impact. Experience feedback is considered with a vision of "operating safety" [28].
According to Weber [29], the process of experience feedback corresponds to the following definition: «Lessons learned (LL) processes are knowledge management (KM) solutions for sharing and reusing knowledge gained through experience (i.e. lessons) among an organization's members ».
According to the U.S Department of Energy [30] «A lessons learned is a good work practice or innovative approach that is captured and shared to promote repeat application. Lessons learned may also be an adverse work practice or experience that is captured and shared to avoid recurrence ».
Bergmann defines experience feedback as follows: « Experience Management is a knowledge management initiative which objective is to convey experiential knowledge or lessons learned applicable to an operational, tactical, or strategic level such that, when reused, this knowledge positively impacts on the results of the organization » [31].
As part of our work, we used the following definition of experience feedback:
"The experience feedback is a structured process of capitalization and exploitation of knowledge resulting from the analysis of positive and/or negative events. It implements a set of human and technological resources that must be organized to reduce the repetition of errors and to promote certain good practices "[28].
The general approach taken to generate knowledge from experiences, based on an architecture composed of three processes (see Figure 4), themselves centered around a common database called "Base EF". This database consists of two databases including "contextualized" experiences and knowledge.
The capitalization phase corresponds to the non-intrusive collection of information characterizing an experience. The treatment phase aims to generalize certain capitalized information and transform it into knowledge. Finally, the exploitation phase consists of the making available of the recorded information and the generated knowledge.
It is interesting to note that man is present at both ends of the chain of information in the experience feedback. As a producer, he supplies the information systems with elements to be processed, to be stored and disseminated, and as a consumer, using this information in a decision process.
For more information on experience feedback system we invite the reader to refer to [32], [31] or [33].
In the following pages of this paper, we propose to detail these three processes constituting an experience feedback system. We then present the interests of an EF System learn under FMECA method for managing risk in projects and enroll in a spirit of continuous improvement.

Fig. 4. Experience feedback process

C. Capitalization Process

The Capitalization process consists in identifying, formalizing and storing information related to the identification and treatment of risks into the data base EF. For project risk management, we distinguish three levels to build experience:

- *Context:* This level corresponds to the description of the risk, with its three characteristics (P, D, S) and criticality (C), but also its position in the project (place of appearance) and affected tasks. It should be noted that the same risk may impact multiple tasks with different criticalities.

- *Analysis:* This level contains the synthesis of risk analysis. Then we find information relating to: the search of root causes, evaluation of the effects on the system, the considered acceptability thresholds, their classification and their position in the project. As we previously reported, the risks are divided into three groups:
  - ✓ Acceptable risks: no special measures will be taken to reduce the criticality. However, these risks will remain under supervision to ensure that advances in the project have not changed the criticality or that risk assessment is correct.
  - ✓ Unacceptable modifiable risks: actions may be engaged to reduce their criticality to an acceptable level. These actions can be protective, preventive or of cancellation type.
  - ✓ Unacceptable unmodifiable risks: for certain risks, it is not possible to influence events or contexts leading to their high criticality. For the latter, actions of transfer must be taken and warning symptoms monitored.

Another key result to place in the analysis is the allocation of risk in the project. Indeed, we should consider the risks on the loops of the project and ensure that the impact of the risk on each loop is acceptable. To help actors to conduct these studies, there are tools like the free software Project Risk Management or PERT probabilistic method [8].

- *Solutions:* this last level is initiated following the risk analysis and their position in the project. It consists of actions taken to address the risks. These actions are classified according to the typology presented in Phase 3-Response (see 3.1). It should be noted that this level Solutions is continuously supplied during the course of the project:
  - ✓ At the beginning of the project, the actors provide information indicating the actions engaged before the appearance of risk (preventive measures) and those planned that should be implemented after the appearance of risk (substitution plan),
  - ✓ during the project, following the detection of a risk, the actions engaged are reported in a database. It should be noted that the action must also be evaluated in terms of obtained performance to keep track of its interest. These actions are in their majority corrective actions corresponding to substitution plans but we must also consider preventive measures put in place to deal with new and potentially critical risks,
  - ✓ at the end of the project, the synthesis of the engaged actions and the obtained performance is performed. Similarly, an analysis between the projected risks with their assessment and the operational risks with their assessment is established in order to ensure the validation of the initial analysis and to capitalize on verified information.

The capitalization process can be illustrated by the diagram of Figure 5 taken from [20].
To gain efficiency and effectiveness, the capitalization phase of the context, of the analysis and of the solutions must be supported by a computer tool. In fact, order to limit the impact on the actors and to make the capitalization non-intrusive, it is necessary to propose a computer tool providing a working support containing the methods and tools used in the analyzes.

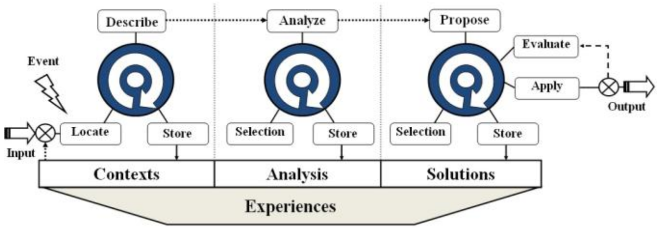

Fig. 5. Capitalization Process

D. *Treatment Process*

The role of the treatment process is to generalize certain information from recorded experiences. The goal is not just to make of an event, a lesson. Indeed, it is also to draw lessons from the combination of several experiences. Therefore, when the capitalization has resulted in a set of experiences sufficiently rich and relevant, it is necessary to generate generic knowledge, that is to say, knowledge constructed as:

- ✓ Questions to ask at the beginning of the project to guard against certain risks: risk profile,
- ✓ list of potential risks with the identification of impacted tasks: risk matrix,
- ✓ good practices or alternative plans: preventive or corrective solutions that have been proven effective,
- ✓ pitfalls: solutions or actions that have shown their inability to eliminate the risk.

Thus, following this treatment process, all documents allowing the characterization of risks are updated and integrated into the base EF to be used for construction but also (see Exploitation Process) for the control of future projects. The elaboration of knowledge is a form of generalization and consolidation of a set of experiences. This construction involves several domain experts who, based on information recorded progressively in the course of a project, will define the rules (procedures) in order to avoid the appearance of certain disruptive events and generalize good practices. The treatment is a formal process whose key tasks are the analysis, interpretation, synthesis of information and knowledge formalization.
The treatment process can be illustrated by the diagram in Figure 6 adapted from [34].
In this way, the generalization of the experiences is a way to understand the origin of errors and good practices and draw lessons, in order to enroll in a spirit of continuous improvement.

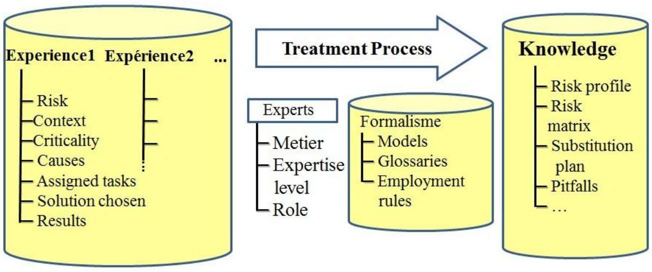

Fig. 6. Principle of knowledge creation

E. Exploitation process

This process is the most important to get an efficient EF system. In fact, it is for the purpose of permitting an easy exploitation of the relevant information that all relevant Experience Feedback system is deploying. It is therefore necessary to develop an information system that allows actors to easily access relevant information, in line with the current case, while controlling access rights.

There are two main operating methods:

- ✓ The Pull mode: the actor has access to the entire database of EF and researches by himself what he esteems appropriate to resolve the current case,
- ✓ The Push mode: the information directly related to the current cases that are automatically distributed to actors when they log on the EF basis.

In projects, the first operation (in Pull or Push mode) is to use the EF database information to achieve the risk identification phase (see 3.1) to, from risk profiles, build a list of the potential risks in the current project. The purpose of having coupled EF system to FMECA is that actors not only can easily access the past analysis but also access their accuracy by comparing the forecast to the actual analysis. In addition, they can recover the risks "contextualized", that is to say, the context, the substitution plan deployed and the obtained results.

The second operation concerns the response phase (see 3.1). When searching for actions to implement in order to deal with a potentially critical risk, stakeholders can rely on past solutions and their performance. In addition, following the process of treatment, they will have the rules of good practices and updated pitfalls at their disposal. To improve the search and comparison of past cases to current actions, it will be possible to integrate the principles of case-based reasoning (CBR) in order to assess the similarity.

The third operation is to use the database information EF for the Monitoring phase (see 3.1). Again, the rules of good practices, pitfalls and past experience will be of valuable help for:

- ✓ Identifying appropriate actions to the risk and the project context. It should be noted that in projects, it is frequent that an action taken locally to respond quickly to a reported risk, leads to conflicts and constraints for the following tasks or phases. The use of an EF database information is a barrier to these frequent changes.
- ✓ Implementing in optimal conditions the chosen actions by collecting tips and available settings in the EF database.

Therefore, as we have just shown in this section, the use of experience feedback mechanisms to improve the capitalization of risks in forecast or operational is more relevant. The diagram in Figure 7 is used to illustrate the assembling of these two methods, showing with a double arrow, the exchange of information with the EF base.

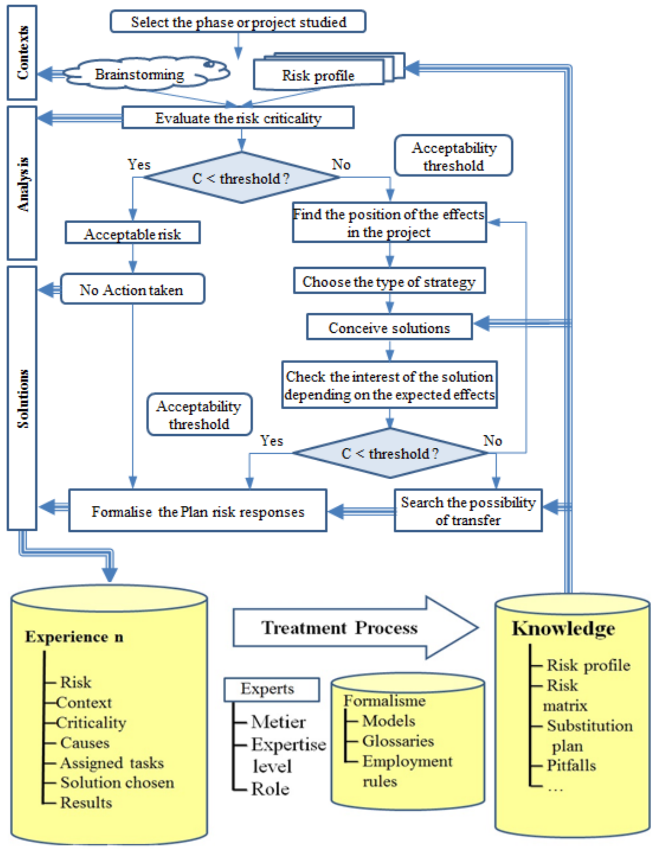

Fig.7. Coupling FMECA/EF

Conclusion

Our overall work aims, on the one hand, to provide a formal framework of representation of risks in projects as Experience: risk, context, analysis, solutions and results.

The entity "Experience" permits to overcome the difficulties of capitalization and reuse of information and knowledge that experts keep handling in in their process of project risk management. In addition, experience feedback systems permit to assist the experts by providing them with past experiences and by avoiding generating new risks causing many conflicts in projects.

On the other hand, we aim to develop a computer tool to support a dedicated to project FMECA study, with a backed system of experience feedback.

On the other hand, we aim to develop a computer tool to support a FMECA study dedicated to projects, with a backed system of experience feedback.

The interest of such a computer application is to provide actors with a formal framework with a simplified input (dropdown list, previous actions …) to enable them to improve efficiency, while capitalizing in a non-intrusive manner and transparent way the key information permitting to characterize future experiments.

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