Risk Analysis Techniques for ERP Projects based on Seasonal Uncertainty Events

Paulo Mannini[1][a], Edmir P. V. Prado[1][b], Alexandre Grotta[1,2][c] and Leandro Z. Rezende[1][d]
[1]*IS Post-graduation Program (PPgSI), University of São Paulo (USP), São Paulo, Brazil*
[2]*IS Graduation Program, Federal Institute of Sao Paulo (IFSP), São Paulo, Brazil*

Keywords: ERP, Risk Analysis, Seasonal Uncertainty Events.

Abstract: Risk management is fundamental in order to increase Enterprise Resource Planning (ERP) project success rate in order to plan, prevent and react to risks and uncertainties. But based on the literature review, we identified a few studies relating to both seasonal uncertainty events (SUE) and ERP projects. Given this context, this research objective is to analyse the most appropriate risk assessment techniques for ERP projects based on SUE. In order to achieve this goal, we performed and Systematic Review of Literature and we applied the Delphi technique with Project Management Professionals and Enterprise Directors. According to the SLR result, we identified 16 techniques that are more suitable to deal with SUE on ERP projects. After the Delphi panels perspective, six techniques pointed out as the most suitable for these projects. In addition, we identified that not all techniques described by the literature converged with the researched context reality. These findings are very relevant for both the Academia and the Industry to scaffolding SUE on ERP projects.

1 INTRODUCTION

Enterprise Resource Planning Systems (ERP) systems are computer information systems designed to process organizational transactions and enable real-time planning, production and response to consumers (Amid *et al*., 2012). Many organizations have been implementing ERP systems via ERP projects since the 1990s. ERP systems aim to achieve enterprise uniformity between information systems and the real business towards making the organizations more competitive (Rajagopal, 2002).

Anyhow, ERP projects are a major concern to organizations (Amid *et al*., 2012). For instance, that are indications that some ERP projects might have a bad reputation of being very costly and ineffective for organizations (Motwani *et al*., 2005) including the underdevelopment countries context. Part of these claims is related to poor risk planning and control over processes in ERP projects, resulting in negative effects on the project outcomes (Tsai *et al*., 2009).

An ERP project is often complex and risky: it requires a large investment across, it takes a long time to the concluded. An ERP project also carries a high risk to the organization (Qi & Zhu 2012; Aloini *et al*., 2012): one of the top reasons is that managers do not take into account proper manners to analyze all the risks involved into an ERP project. Even further, seasonal uncertainty events (SUE) are misconceived (Schmidt *et al*., 2001) on ERP projects. One SUE example on ERP projects is the *freezing* period, a period of time when no software updates are allowed except for the emergency ones (Neubarth *et al*. 2016).

However, despite the importance of SUE in ERP projects risk analysis, there are few studies in the literature relating to seasonality and project risk management. Given this context, this research aims to answer the following research question: What are the most appropriate techniques to analyze risks in ERP projects influenced by SUE? Thus the research main objective is to analyze the most appropriate risk assessment techniques for ERP projects based on SUE. We defined two goals to achieve this objective:

[a] https://orcid.org/0000-0003-3563-4356
[b] https://orcid.org/0000-0002-3505-6122
[c] https://orcid.org/0000-0003-2549-138X
[d] https://orcid.org/0000-0002-5543-9155

Mannini, P., Prado, E., Grotta, A. and Rezende, L.
Risk Analysis Techniques for ERP Projects based on Seasonal Uncertainty Events.
DOI: 10.5220/0009420601730180
In *Proceedings of the 22nd International Conference on Enterprise Information Systems (ICEIS 2020) - Volume 1*, pages 173-180
ISBN: 978-989-758-423-7

(1) identify the techniques used for risk analysis in ERP projects via a Systematic Literature Review (SLR); (2) analyze the importance of identified techniques to SUE via the Delphi technique.

This research has the other five sections. In the next section, we present the theoretical bases used by this research. In Section 3, we present the research methodology that provides a research overview. In Section 4, we present the data collection procedures. In Section 5, we present and discuss the research results, followed by the last section: conclusion.

2 THEORETICAL BASES

This section defines the main concepts used by this research: ERP, project risk management, seasonality, and risk techniques and methods.

(1) ERP. ERP systems were originally deployed to facilitate manufacturing and business processes. Over time, they evolved to include all organization processes, such as sales, marketing, and human resources. Companies are now using ERP via web and mobile solutions in order to connect the entire value chain, including their suppliers (Rainer and Cegielski, 2012). Additionally, there is a lack of employees' knowledge regarding what an ERP system is and how to operate it (Motwani *et al*., 2005).

(2) Project Risk Management. There are several definitions of risk in the literature. One of the most accepted definition is given by the Project Management Institute (PMI): considers negative risks as threats and positive risks as opportunities. For PMI, project risk management as an area of expertise that encompasses seven processes: plan risk management, identify risks, perform a qualitative risk analysis, perform a quantitative risk analysis, plan risk responses, implement risk response, and monitor risks (PMI, 2017). Another acceptable definition of risks is the deviations from expectations, caused by uncertainties that impact objectives positively or negatively (ISO 2016). Anyhow, other organizations consider the term *risk* as something negative only (OGC, 2009; IPMA, 2015). Project managers often lack knowledge about formal methods for project risk management planning (Globerson and Zwikael 2002).

(3) Seasonality and SUE. Seasonality is a periodic variation that presents a constant long-term pattern. These variations are repeated, such as annually, semi-annually or quarterly. An example of seasonality may be a sales increase during the Christmas season (Passari, 2003). Thus, SUE are those uncertainties that might have a higher probability to occur during certain periods know as seasonally (Acebes et al. 2014). However, a project risk analysis method must consider several other aspects. Thus, we consider the seasonality effects on projects according to three different types.

i. **External Environment.** For instance, the winter might be considering an external environment factor given that, for instance, the snow might affect a construction project or even the in-person meetings of an ERP project **(**Acebes *et al.* , 2014).
ii. **Products and Services.** Seasonality might affect the way people sell and acquire products or services, in which the ERP system might be prepared for those needs (Mattsson, 2010).
iii. **Processes and Operations.** ERP system *freezing* as an example of the most frequent IT seasonality, and it affects the process and company operations (Prado et al., 2017).

(4) Risk Techniques and Methods. The technique might be defined as the manner that technical details are addressed in order to achieve the desired result. The method might be defined as a systematic procedure, and an inquiry mode applied to a particular discipline. Thus, techniques are applied by humans and might utilize one or more methods towards producing the desired result (PMI, 2017).

Regarding SUE and risk analysis techniques, we can classify existing methods and their tools to fit into **four technique categories.** The qualitative risk analysis process techniques were based on (PMI, 2017) for RC. The categories DS, DP, and IP were defined based on (Stair & Reynods, 2017), as follows:

- **Risk Identification:** groups risk identification techniques. They are split into two categories: Risk Categorization (**RC**) and [Risk] Data Source (**DS**);
- **Risk Calculation:** groups how risks are calculated. It is identified by one single category, the [Risk] Data Processing (**DP**);
- **Risk Presentation:** groups how risk data is presented and shared among the project team It is identified by one single category, the [Risk] Information Presentation (**IP**).

3 RESEARCH METHODOLOGY

This section defines the research methodology and phases. In the first phase, we conducted an SLR. At the second phase, we conduct a Delphi technique, two rounds were needed. The conduction and the results of the research are described in the following sections.

3.1 Research Phases

This is an exploratory study, based on qualitative data (Creswell, 2019) applied to ERP system investigation. It aims to contribute with new findings regarding the gap in ERP projects regarding SUE. This research had **two phases** as outlined in Figure 1.

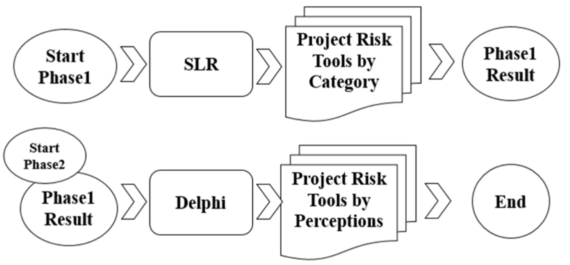

Figure 1: Research phases.

The first phase (SLR) has the objective to identify and classify the techniques used to analyze project ERP project risks according to the literature. In the second phase, were ranked these techniques according to the prism of a Delphi technique. The methodology used by these two phases is detailed at the next two subsections as follows.

3.2 Systematic Literature Review

The SLR was performed based on (Kitchenham, 2009). The data were acquired from four different search engines: Scopus, Science Direct, IEEE, and ACM, covering a state-of-art period from 2012 to 2019. The specific query strings for each search engine were created according to the following keyword: ("Project risk analysis" OR "Project Risk Assessment") AND "Project Risk Management"; (quali* OR quanti*) AND ("Risk Assessment" OR "Risk Analysis") AND project AND "Risk Management".

The protocol for **quality criteria** was based on (Kitchenham, 2009) and is described as follow:

(1) Exclusion Criteria: i) duplicated articles; ii) articles whose access were not free; iii) articles that did not deal with project risk management; iv) articles that did not address qualitative and/or quantitative aspects of risk analysis; v) articles that did not provide details techniques details or characteristics;

(2) Inclusion Criteria: studies that had techniques for assessment and/or application in risk analysis projects. We then read the articles to collect the information according to the details given in the next subsection.

3.3 Delphi Technique

According to Skulmoski *et al*. (2007) and Skinner *et al*. (2015) Delphi technique is an appropriate technique for acquiring expert recommendations when addressing a research problem in the IT field. It is suitable for ranking technology issues of new IT product development projects, like the one proposed in this research.

According to Dalkey and Helmer (1963), the Delphi technique uses a group of experts, is based on pre-established criteria, uses multiple rounds of questioning with these experts, through questionnaire or interview, and is applied individually to avoid direct confrontation between them. Skinner *et al.* (2015) state that there is no limitation on the number of experts but should include people with knowledge and experience in the subject being evaluated.

The Delphi technique has been used for risk management in IT projects, mainly to prioritize the risk factors involved in these projects (Huang *et al*., 2004; Schmidt *et al*., 2001; Nakatsu & Iacovou, 2009). This technique is especially suitable for studies in which the objective is to improve understanding of problems, opportunities or solutions (Skulmoski *et al*., 2007).

The need or not for a new Delphi panel round is assessed by the *Kendall coefficient of concordance* (W) and the statistical significance of this coefficient and defined by the following formula (Siegel *et al*., 2006):

$$W = \frac{12S}{m^2 n(n^2-1) - m\sum_{j=1}^{m} Tj}$$

Variable S represents the sum of the standard deviations of all elements. Variable m represents the number of panel members. Variable n represents the number of elements evaluated in the panel. Thus, variable Tj $=\sum_{i=1}^{gj}(ti^3 - ti)$, where *ti* is the number of ranks in the *ith* grouping and *gj* is the number of draw groups in the *jth* ordering set.

4 DATA COLLECTION

This section describes how both SLR (phase 1) and Delphi (phase 2) data were collected and aggregated. The results of this section are presented in the next section (Results and Discussion).

4.1 SLR Data Collection

The SLR data was collected from the select articles according to the four steps highlighted in dark-gray in

Figure 1. In summary, the four steps are detailed as follows: **First:** we read the titles and abstracts to verify if they met the defined criteria; **Second:** we read the full paper text in order to verify the adequacy of the article to the research objectives; **Third:** we applied the quality criteria; **Fourth:** we collect all the relevant information from the remaining 42 articles.

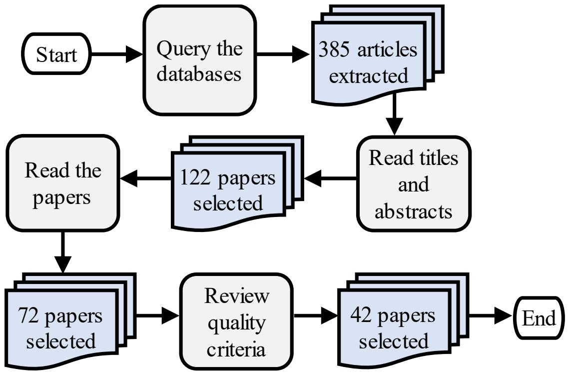

Figure 2: SLR Process.

4.2 Delphi Data Collection

This subsection first describes the participants' profile, followed by the Delphi technique details. This section also details the Delphi first and second rounds.

4.2.1 Panelists Profile

The selection of Project Management Professionals and Enterprise Directors to compose the Delphi panel was based on two criteria: professional knowledge of the topic of research at the academic or the professional level. All participants were from the same country. Below are the minimum criteria considered.

• Degree in the areas of Engineering or Information Systems. In addition to undergraduate Information Systems, all undergraduate engineering was accepted, as the complexity of IT techniques and methods exhibits typical characteristics of engineering activities.

• Experience in project management. Selected professionals must have at least five years of experience in public or private organizations; or at least three years of experience in public or private organizations and with postgraduate in project management.

The reason for adopting these criteria is because professionals with technical background and project management experience have the appropriate profile to address project risk management issues. After selecting the professionals who met the minimum criteria of knowledge and experience, two groups of experts were defined:

• System analysts, project managers, and project leaders, hereinafter referred to as Project Professionals (PP).

• Project professionals who work or have worked on projects, but held an executive position, hereinafter referred to as the board of directors (BD).

The selected experts were generically referred to as “panelists” in subsequent steps of the Delphi technique.

4.2.2 Delphi Technique Details

The questions sent to the experts were grouped into the four categories identified in the SLR (RC, DS, DP, and IP). We use online surveys through the eSurveysPro platform. Some parts of the questionnaires were customized for each participant to facilitate the collection of personal data and to provide participants with their choices in previous rounds.

Panelists' opinions were collected through questions about the level of importance of risk analysis techniques in SUE. The questions used a five-point Likert scale: 1-very low; 2-low; 3-medium; 4-high; and 5-very high. The following criteria were used to finalize the panel rounds:

• The value of the coefficient of concordance W equal to or greater than 0.5, determining a high convergence between opinions (Schmidt, 1997).

• The chi-square value ($\chi 2$) greater than 43.82. According to Siegel *et al.* (2006), chi-square values for samples with 19 degrees of freedom, have p-value of less than 0.001. In Fisher's significance scale (Morettin & Bussab, 2017) p-value less than 0.001 represents a very strong statistical significance of W.

In summary, there were **two rounds** until the criteria for completing the research rounds were met.

The first round of the Delphi panel allowed participants to interact and suggest adjustments to instrument questions.

The suggestions were analyzed by the researchers before making any changes. In the first round, researchers were also allowed to clarify questions for participants about the research or the applied questionnaire.

The second round used the outcome of the first one, providing participants with the first choices and allowing them to review their previous responses to achieve convergence between the group. In this way, participants received feedback from the first round keeping their anonymity.

4.2.3 Delphi First Round

The panelists were contacted via email or Linkedin platform. We explained the purpose of the survey and provided the access link to the questionnaire.

The questionnaire was custom made, changing only the names of the participants. It allowed panelists' contributions to refining the questions of the questionnaire. All contributions received were reviewed and necessary adjustments made.

The first round was applied in March 2019 to 34 professionals. After a period of one month, it was decided to close the first round of the panel with the participation of 18 panelists, 14 from the PP group and four panelists from the BD group.

The opinions collected resulted in values of W = 0.29 and chi-square = 99.18, which indicates a low degree of convergence of opinions among the panelists. Thus, it was necessary to carry out a new round with the objective of increasing the degree of convergence.

4.2.4 Delphi Second Round

The second round of the Delphi panel consisted of the same questions evaluated in the first round and sent to the 18 participants in the first round, allowing them to review their answers. The responses were collected in May 2019 and were attended by 12 panelists from the PP group and four from the BD group. Opinions collected in the second round resulted in values of W = 0.52, which indicates a high degree of convergence of opinions among the participating panelists in (Schmidt, 1997).

The calculated value for chi-square was 158.08, which indicates that W has high significance. Based on these values, the results of the second round met the panel's completion criteria, with W value having high convergence and high significance.

5 RESULTS AND DISCUSSION

This section presents the SLR results, the Experts Group Analysis, and the Delphi results. It also presents the consolidated result. Then we discuss the results and their limitations.

5.1 SLR Results

As SLR result, we identified 16 different risk management techniques in project management, according to the categories defined at the research method section: Risk Category (RC), Data Source (DS), Data Processing (DP) and Information Presentation (IP). The median rank considers the most/least cited risk analysis techniques in the literature as detailed in Table 1 as follows.

Table 1: SLR risk analysis techniques.

Technique Category	X	Technique short name	Technique Description Risk Identification: risks are identified by…	*f.*
RC Risk category	⇧	**T01 - Risk source**	The sources where risks might come from (their sources)	13
	⇩	T02 - Project area	The project area where risks might come from	5
		T03 - Project phase	Each project phase where risks might come from	3
DS Data Source	⇧	**T04 - Experts opinion**	Taking into account subject matter (experts) opinion or vision	31
	⇩	T05 - Historical database	Investigating and utilizing risk historical data of past projects or company knowledge	11
		T06 - Stakeholders opinion	Taking into account stokeholds opinion or vision	1
			Risk Calculation: risks are calculated via…	
DP Data Processing	⇧	**T07 - Risk probability and impact analysis**	The probability of a certain risk might occur times the impact it might cause if it happens	21
	⇧	**T08 - Modeling and Simulation**	Computer to model and simulate risk and their impacts	15
	⇩	T09 - Multicriteria decision making analysis	Merging several criteria to analyze and decide	12
		T10 - Fuzzy Logic	Using the fuzzy logic to predict risks and their consequences	10
		T11 - Risk interdependence analysis	Analyzing the interdependence among risks	7
			Risk Presentation: risks are presented as…	
IP Information Presentation	⇧	**T12 - Prioritized list of risks**	A simple list of risks group by their prioritization	18
	⇧	**T13 - Tables**	A table showing the risks	13
	⇩	T14 - Charts	A chart, like pareto or pie charts	10
		T15 - Project relationship management	A visual representation of risks and the project management	8
		T16 - Impact and probability matrix	A matrix that relates each impact with their probability	6

Legend: **X**= Comparing with the median; ⇧ = Above; ⇩ = below; ***f.*** = Citation frequency;

Table 2: Risk analysis techniques ranking after Delphi panels.

Techniques	Level of importance	Ranking			Ranking differences between groups		
		All groups	PP	BD			
		(A)	(B)	(C)	(AxB)	(AxC)	(BxC)
T07 - Risk probability and impact analysis	Very high	1	1	3	0	2	2
T12 - Prioritized list of risks		2	2	2	0	0	0
T16 - Impact and probability matrix		3	3	5	0	2	2
T03 - Risk categorization by project phase	High	4	4	1	0	3	3
T05 - Historical database		5	7	4	2	1	3
T11 - Risk interdependence analysis		6	6	6	0	0	0
T02 - Risk categorization by project area		7	5	9	2	2	4
T14 - Charts	Medium	8	8	8	0	0	0
T13 - Tables		9	10	10	1	1	0
T04 - Experts opinion		10	9	11	1	1	2
T06 - Stakeholders opinion	Low	11	11	12	0	1	1
T01 - Risk categorization by source		12	14	7	2	5	7
T15 - Project relationship management		13	12	15	1	2	3
T08 - Modeling and Simulation	Very low	14	13	13	1	1	0
T09 - Multicriteria decision making analysis		15	16	14	1	1	2
T10 - Fuzzy Logic		16	15	16	1	0	1

5.2 Experts Group Analysis

The most suitable techniques for risk analysis in SUE are those classified as very high or high importance and they are presented in table 2 (T07, T12, T16, T03, T05, T11 and T02). There was a very strong similarity between the results of the PP and BD groups, and with the total number of panelists. Techniques ranked with importance high and very high are the same for all groups with only one exception in the BD group. This group assigns more importance to T01 than to T02

Only five classifications, out of 16 made by the PP and BD groups, had a gap greater than two. Most of these techniques (T01, T02 and T03) belong to the RC category. This shows that the biggest difference in the assessment made by these two groups is related to risk categorization techniques.

Professionals that held an executive position (BD) ranked the techniques that categorize risk by source and project phase more importantly than techniques that categorize risk by project area. It is plausible to conclude that the major importance assigned by these professionals to phase risk categorization techniques is that they do not perform activities directly related to risk mitigation. They manage the project outcomes and therefore have a different view of the activities.

5.3 Delphi Results

The outcome of the second round of the Delphi panel consisted of 16 panelists, resulted in the scores shown in table 2. The scores are presented by panelists group (PP and BD) in order to compare the answers of these two groups. The techniques ranking was based on the five-point Likert scale used by panelists to answer the questions.

5.4 Consolidated Results

Table 3 presents the techniques classified by citation frequency in the literature and by the importance given by the experts. The groups' analysis is presented below. Risk Categorization (RC).

Table 3: Consolidate literature review vs. experts' review.

TC	Techniques	LR*	ER*
RC	T01 - Risk categorization by source	<u>#6</u>	#12
	T02 - Risk categorization by project area	#14	<u>#7</u>
	T03 - Risk categorization by project phase	#15	<u>#4</u>
DS	T04 - Experts opinion	<u>#1</u>	#10
	T05 - Historical database	<u>#8</u>	<u>#5</u>
	T06 - Stakeholders opinion	#16	#11
DP	T07 - Risk probability and impact analysis	<u>#2</u>	<u>#1</u>
	T08 - Modeling and Simulation	<u>#4</u>	#14
	T09 - Multicriteria decision making analysis	<u>#7</u>	#15
	T10 - Fuzzy Logic	#10	#16
	T11 - Risk interdependence analysis	#12	<u>#6</u>
IP	T12 - Prioritized list of risks	<u>#3</u>	<u>#2</u>
	T13 - Tables	<u>#5</u>	#9
	T14 - Charts	#9	<u>#8</u>
	T15 - Project relationship management	#11	#13
	T16 - Impact and probability matrix	#13	<u>#3</u>

Legend: * = underlined scores are above the median; TC = Technique category; LR = Literature Ranking; ER = Experts Ranking

Technique T03 was rated by experts as the most important among risk categorization techniques, although it is the least mentioned in the literature.

However, considering risk management in SUE, categorization by phase is important, probably due to it allows better management of seasonal project uncertainties.

Data source (DS). Technique T05 (historical database) was rated above the median both in the frequency of literature citation and in the degree of importance given by the experts. This result is in line with the work of Acebes *et al*. (2014) who used this technique for risk analysis in SUE. Another finding was a divergence in classification between techniques T04 (Expert Opinion) and T06 (Stakeholder Opinion). While the literature cites more the former, the experts assigned more importance to the latter. In addition, for Delphi panel experts the two techniques have very close importance rankings. Therefore, it is advisable to evaluate the cost-benefit ratio of technique T04, because it involves the cost of an expert opinion whereas technique T06 has a similar level of importance, with a lower cost.

Data process (DP). Technique T07 (Risk probability and impact analysis) was the most cited data processing technique in the literature and considered the most important by experts. This shows that the risk exposure measure by probability and impact is widely accepted by experts and the literature. On the other hand, the T10 technique (Fuzzy Logic) is not among the most important according to experts. We identified that this result was due to the lack of knowledge of six panelists about the T10 technique applied to project risk analysis.

Information presented (IP). Reports showing a list of prioritized risks were highlighted by experts as the most important and were the most cited in the literature. This is evidenced by the T12 technique (Prioritized list of risks) that was above the median in experts' opinion and literature citations. On the other hand, there is a difference between experts and the literature: the former prefers information in charts and matrices and the latter on tables.

In summary, the consolidate results point out the most relevant techniques to deal with SUE among those techniques found in the literature and also among those ones pointed out by experts.

5.5 Research Limitations

The most relevant limitations of this research are related to the data collection and analysis process. Qualitative data collection might be subject to human bias, given they involve human judgment on collecting and classifying them (Kitchenham, 2009). In order to avoid bias, we carefully planned and followed the research methodology according to the scientific procedures as much as possible. Additionally, the results might be limited to the Delphi participants' vision and contexts only.

6 CONCLUSIONS

ERP systems are a fundamental part of present-day Enterprise technological infrastructure. Anyhow, implementing and maintaining these information systems is not an easy deal, which, most of the time, is delivered by ERP projects.

Seasonality brings several additional risks that are misconceived in ERP such as the seasonal uncertainty events (SUE) (Schmidt *et al*., 2001). Given this gap, the main objective of this research was to identify and analyse the most appropriate techniques to analyze risks in ERP projects influenced by SUE. We defined two goals to achieve this objective: (1) identify the techniques used for risk analysis in ERP projects via a Systematic Literature Review; and (2) analyze the importance of identified techniques to SUE via the Delphi technique.

We identified that, according to the literature, from 2012 to 2019, there were cited 16 techniques that have been used to address SUE on ERP projects. The most relevant ones were, for risk identification: risk identification by source (T01) and Experts opinion (T04). For risk calculation: risk probability and impact analysis (T07) and modeling and simulation (T08). And finally, in order to present the risks to the team and stakeholders, prioritized list of risks (T12) and Tables (T13).

We then presented these finds to participants into two sessions of Delphi. After their perspective, the results were for instance that the most used by ERP project techniques are: Risk probability and impact analysis (T07), Prioritized list of risks (T12), and impact and probability matrix (T16). On the other side, the rare techniques were: Modeling and Simulation (T08), Multicriteria decision making analysis (T09) and Fuzzy Logic (T10).

The main research question was: what are the most appropriate techniques to analyze risks in ERP projects influenced by SUE? Based on these two finds, we might state that at least 16 techniques are actual reported regarding ERP projects. On the other hand, there were a few techniques such as T07 and T12 in which both literature review and industry converged. Given these finds, we can conclude that there is space in order to match the scientific researches and academic world with the enterprises' reality regarding SUE and ERP projects.

The contribution of this work to identify and summarize all the techniques that related SUE and ERP projects, thus helping both Industry and Academic fields to identify, apply and training their staff and stakeholders on these techniques. As future researches, to expand to order contexts and countries. Other identified gap is related to the low usage of certain techniques, whenever we consider the Academic or the Industry areas.

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