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A Review and Classification of the Uncertainties in Projects: The Way Forward

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Abstract

This article aims to summarize existing research on various sources of uncertainty and to classify them based on the determinants and antecedents addressed in projects. A systematic review is conducted using a total of 140 research published in peer-reviewed scientific journals during the last three decades. We classify various uncertainty based on their individual, relational, group, organizational, project-oriented, and managerial characteristics. Additionally, we uncovered a few gaps such as, how uncertainties differ based on the size of the organization, the need for exploring uncertainty from a more cross-disciplinary perspective, differentiating the concept of complexity and risk with uncertainty and the role of chaos theory, that require future study. By leveraging significant findings, this is study contributes from the perspective of theory and practice to academic, project, and industrial management discipline.

Keywords : Project Management; Uncertainty; Project Uncertainty; Systematic Reviews

Revue et classification des incertitudes dans les projets : la voie à suivre

Résumé

L'objectif de cet article est de résumer les recherches existantes sur les différentes sources d'incertitude et de les classer en fonction des déterminants et des antécédents abordés dans les projets. Une revue systématique est réalisée à partir d'un total de 140 recherches publiées dans des revues scientifiques à comité de lecture au cours des trois dernières décennies. Nous classons les différentes incertitudes en fonction de leurs caractéristiques individuelles, relationnelles, de groupe, organisationnelles, orientées vers le projet et managériales. En outre, nous avons découvert quelques lacunes telles que la manière dont les incertitudes diffèrent en fonction de la taille de l'organisation, la nécessité d'explorer l'incertitude dans une perspective plus interdisciplinaire, la différenciation des concepts de complexité et de risque avec l'incertitude et le rôle de la théorie du chaos, qui nécessitent une étude future. En s'appuyant sur des résultats significatifs, cette étude contribue, du point de vue de la théorie et de la pratique, à la discipline de la gestion universitaire, de projet et industrielle.

Mots clés : Gestion de projet; Incertitude; Incertitude du projet ; Revue systématique

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1. INTRODUCTION

Over the last three decades, a substantial quantity of literature on project management (PM) has been published (Söderlund, 2011), and the discipline has evolved into a critical business practice for many organizations, both strategically and operationally (Perminova et al. 2008). PM also entails a set of procedures, planning tools, and factors for time, scope, quality, and budget to ensure successful execution (Padalkar and Gopinath, 2016). However, project management issues are arising in part as a result of increased commercial risks (e.g. Saleh and Watson, 2017). Practitioners assert that the uncertainty effect is one of the general characteristics of projects, emerging in technical, organizational, and social contexts (Bohle et al. 2016); uncertainty is frequently viewed as a natural aspect of project life (Saunders et al. 2016).

Uncertainty is believed to occur because of a variety of ambiguous and complex causal events underpinning an organization's internal processes and external environment (Colorado, 1999; Karlsen, 2011). Additionally, it may emerge because of project delays, quality difficulties, insufficient time and resources spent during the initial pre-planning and planning phases, and an inability to cope effectively with unforeseen events that occur during the project's execution (Johansen et al. 2016).

Uncertainty is multifaceted and complex and depends on the issue at hand (Johansen et al. 2016; Wazed et al. 2009). For example, from a situational standpoint, it occurs when (1) the order or nature of things is unknown, (2) the consequences, extent, or magnitude of circumstances, conditions, or events is unpredictable, (3) credible probabilities to possible outcomes cannot be assigned (see “Knightian uncertainty,” Alvarez et al. 2018, based on Knight, 1921); and (4 (Starbuck and Milliken, 1988). Uncertainty is defined by Lindau and Lumsden (1995) as a type of disturbance and the psychological state of doubt about what current events mean or what future events are likely to occur (in Milliken 1987). Uncertainty is also linked to a lack of knowledge in terms of knowledge and information. For example, Funtowicz and Ravetz (1990) define it as a circumstance in which there is insufficient information in three dimensions. Imprecision, Unreliability is number two, and ignorance is number three. Doubt can even arise when there is an abundance of knowledge available (Van Asselt and Rotmans, 2002), and extra information does not always diminish uncertainty.

Uncertainty has been addressed in a variety of ways across disciplines and approaches (Saunders et al. 2015), and managing uncertainty is regarded as a critical component to improving performance (Perminova et al. 2008). While uncertainty is a hot topic among management scholars (Alvarez et al. 2018; Teece and Leih, 2016), it is frequently overlooked by practitioners (Martinsuo et al. 2014; De Meyer et al. 2002), and its causal factors in projects are poorly understood. Recent literature reviews on uncertainty and risk in project management (e.g., Saunders et al. 2017), managing uncertainty in projects and its gaps and trends (Zheng and Carvalho, 2016), or literature reviews to define uncertainty in projects and project management can be found (Perminova et al. 2008). However, understanding the underlying antecedents that have an impact on projects necessitates a structured approach to dealing with uncertainty. Furthermore, this can only be accomplished if scholars conduct a thorough investigation of the phenomenon.

As numerous authors emphasize, there is an imperative need for classification of uncertainty research and a better understanding of uncertainty in projects (Witt et al., 2017; Saunders et al., 2017), as well as a need for a new perspective on uncertainty; because uncertainties frequently arise during the project, it may be impossible to define them at the outset (Bohle et al. 2016). For example, the presence of uncertain information increases the risk associated with choice (Koleckzo. 2012), poses a challenge to managers (Kvalnes, 2016), and may lead to successful project outcomes. Understanding the many sources of project uncertainty and dealing with them requires managers' knowledge and skills (Korhonen et al. 2014). (Saunders et al. 2015).

Although many authors have attempted on identifying uncertainties in projects, yet it remains dispersed. For instance, Miller and Lessard (2001) classified project management uncertainties into three categories: market-related uncertainties, such as demand, competition, and the supply chain;

completion-related uncertainties, such as technical, construction, and operational; and institutional uncertainties, such as regulatory, cultural, and extra-national. Similarly, Leifer et al. (2001) classify uncertainty into four broad categories: technological, market, organizational, and resource. Pich et al. (2002) highlighted managerial techniques and classified uncertainty in projects into four categories: variance, anticipated uncertainty, unanticipated uncertainty, and chaos. Ward and Chapman (2003), on the other hand, identify five: estimation variability, estimation uncertainty, design and logistics, goals and priorities, and basic connections amongst project stakeholders. Zhu et al. (2005) classified uncertainty in projects into two categories: minor deviations and disruptions. Deviations are frequently observed as a result of wild fluctuations in task durations, specifically. Disruptions, on the other hand, are uncommon, unplanned events, such as the incidence of natural disasters or the unexpected departure of important team members. Hazir and Ulusoy (2020) distinguished between internal and external uncertainty in initiatives. Internally produced uncertainties concern systems and resources that are directly related to the project and are primarily within the organization's control. Many additional uncertainties, on the other hand, are created by variables outside the scope of the project and hence cannot be controlled by the organization. These are regarded as externally induced uncertainty. However, the comprehensive review of all uncertainties encompassing in a project is yet to be developed, and with this in mind, and to the best of our knowledge, our work attempts to repertory and categorize the various causes of uncertainty in projects through a more detailed analysis and also advance the literature on providing distinct classification compared and contributing to previously found uncertainties in projects.

This paper contributes to both academic and project and industrial managerial efforts by offering a structured analysis of the existing literature on uncertainty in projects. Although uncertainty as a term has been used interchangeably with risk, volatility, or complexity, uncertainty includes all identified risks, but the risk doesn't include uncertainty (Lechler, Edington, & Gao, 2012, p. 59). Sommer & Loch (2004, p. 1335–1336) treat complexity and “unforeseeable uncertainty” as separate constructs while noting that the use of the term “complexity” is not consistent in the PM literature. Thus to avoid ambiguity, in this study we adopt only uncertainty as the keyword to perform reviews.

More precisely, our goal is to understand the determinants and antecedents of uncertainty in projects. In doing so, we introduce the classification of uncertainty according to the various sources, whether they are internal or external to the project; and the element on which its effect is more relevant: individual, project team, or organization. As seen, our work identifies several weaknesses in current approaches to uncertainty, starting from its definition and the difference between uncertainty, risk, and complexity. Also, there are several industries, geographical areas, and types of projects that remain largely unexplored by scholars. By highlighting these shortfalls, we hope to encourage scholars to direct their efforts in specific directions. We also facilitate managers whose efforts in dealing with uncertainty can be optimized by adopting a pragmatic approach when confronted with uncertainty: our classification enables them to quickly identify the sources of the specific uncertainty that they are confronted with and better target the countermeasures.

2. METHODOLOGY

In this section, we lay out a detailed step-by-step approach to performing a systematic literature review using bibliometric methods following the suggestions of Tranfield et al. (2003) and used by Aguinis et al. (2018). The goal is to apply a structured, transparent, and reproducible methodology to analyze published knowledge through a synthesis of existing research evidence. Ultimately, the aim is to produce a new and original research output (Light and Pillemer, 1984); Cooper, 1989; David and Han, 2004; Torchia and Calabrò, 2019). According to these scholars, certain fundamental principles must be addressed to guarantee the required scientific rigor, namely:

First: ensure a transparent search: a systematic literature review requires a detailed description of all the search criteria, including the databases used,

search strings, and rationale behind the choice of keywords (Denyer and Neely, 2004).

Second: describe the process step-by-step: since the goal of a systematic literature review is to structure a certain body of knowledge, which is often fragmented and complex, the reader must be able to follow each step of the review in an easily repeatable way (Tranfield et al., 2003).

Third: follow consistently the purpose of the research: the perspective of the authors must be clearly stated, thus allowing the generation of a valuable scientific contribution. The research purpose offers guidance in establishing the criteria for selecting the articles to be included in the systematic literature review (Pittaway et al., 2004). To apply these principles and ensure the necessary scientific rigor to our review, we have followed a seven-step process, detailed hereafter, to select and analyze the content of the articles to be included in the review. As a first step, we selected Elsevier's 'Scopus' database to extract articles due to its coverage of a large collection of scientific journals. Scopus is user-friendly, time-saving, provides sorting and ranking features, and refining capabilities compared to other databases like Web of science, and Google-scholar (Harzing and Alakangas, 2017; Chadegani et al. 2013).

As a second step, a keyword protocol (see Table 1) search was performed in the Scopus database as mentioned below. To ensure we do not leave any potentially relevant articles unnoticed, a search using an asterisk was adopted. *An asterisk (*) can substitute for the absence of a character, a single character, or multiple characters, anywhere in a word e.g. uncertain, uncertainty, uncertainties*

As a third step, we decided to select only peer-reviewed journal articles. Although various categories of documents appear in Scopus (e.g, book, book chapters, conference papers, weblogs, and journal articles) we selected only articles from peer-reviewed scientific journals as suggested by Thyer (2008): when compared to venues such as books, book chapters, weblogs, and presenting papers at conferences, journal articles are of high prestige and merit within the scientific community. Moreover, journal articles are commonly considered representative of methodological rigor in systematic literature reviews (Pare *et al.* 2016).

As a fourth step, considering the purpose of our project**,** *articles were selected only from the disciplines of business and management, and we excluded many others (e.g. medicine, social science, decision science, etc.).*

Table 1: Keyword Protocol used for extracting articles from Scopus

Key Word Protocol
TITLE-ABS-KEY ("Project Uncertaint*")) OR (TITLE-ABS-KEY ("Uncertaint*" AND "Project Management")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT- TO (DOCTYPE , "ar")) AND (LIMIT-TO (SUBJAREA , "BUSI")) AND (LIMIT-TO (EXACTSRCTITLE , "International Journal Of Project Management") OR LIMIT-TO (EXACTSRCTITLE , "Journal Of Construction Engineering And Management") OR LIMIT-TO (EXACTSRCTITLE , "Management Science") OR LIMIT-TO (EXACTSRCTITLE , "Journal Of Operations Management") OR LIMIT-TO (EXACTSRCTITLE , "Research Policy") OR LIMIT-TO (EXACTSRCTITLE , "Journal Of Management Information Systems") OR LIMIT-TO (EXACTSRCTITLE , "Manufacturing And Service Operations Management") OR LIMIT-TO (EXACTSRCTITLE , "Production And Operations Management") OR LIMIT-TO (EXACTSRCTITLE , "Accounting Organizations And Society") OR LIMIT-TO (EXACTSRCTITLE , "Journal Of Business Venturing") OR LIMIT-TO (EXACTSRCTITLE , "MIS Quarterly Management Information Systems") OR LIMIT-TO (EXACTSRCTITLE , "MIT Sloan Management Review") OR LIMIT-TO (EXACTSRCTITLE , "Organization Science") OR LIMIT-TO (EXACTSRCTITLE , "Strategic Management Journal"))

As a fifth step, we decided to select those journal publications that are reputed, have good citations, impact factor and rankings (Harzing, 2017), we adopted Scopus metric analysis that categorizes results into 1) CiteScore, 2) SJR (Scimago journal rank), 3) highest number of documents, 4) highest number of citation 5) SNIP (source normalized impact per paper) ranking, etc. (see table 1); from these rankings, we selected the two highly ranked journals: "International Journal of Project Management" and "Journal of Construction Engineering and Management". Second, using the suggestion of Söderlund (2011), we extended our search beyond the conventional project management journals and selected journals from the Financial Times top 50. The combination of these journals yielded us a total of 263 documents. The methodological process of our literature review is explained in Figure-1.

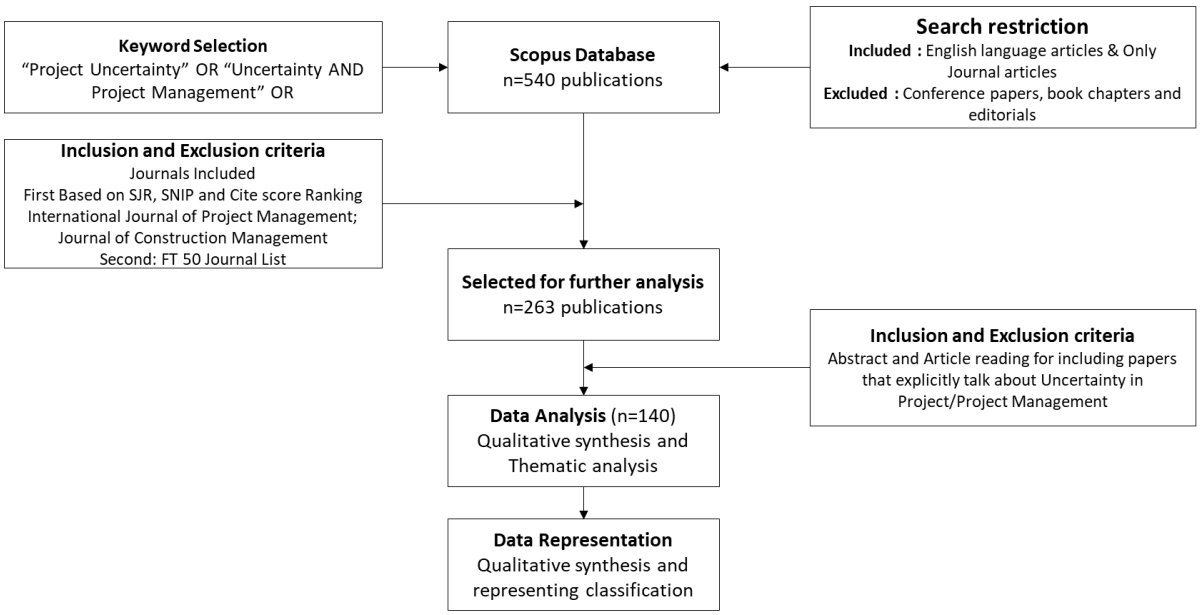

Figure 1: Methodological Process used in our study

As a sixth step, we adopted inclusion and exclusion criteria based on the following framework. Each author independently studied the abstracts of the obtained 263 articles and selected only those that address e.g. a) explicitly address the concept of uncertainty in projects, either in their title, abstracts or in the keywords b) we then read the abstracts to understand the context of uncertainty from an individual, group, organizational or others relevant perspective. After a series of readings, an inter reliability re-reading was done carefully. This resulted in 140 articles (see table 2 and table 3) as the final sample and we left other papers as they did not match our criteria.

Table 2: Journal and number of articles extracted from Scopus metrics

Name of the Journals	Numbers selected
International Journal of Project Management	79
Journal of Construction Engineering and Management	39

Table 3: Journals listed in Financial Times top 50 and number of articles extracted

Name of the Journals	Numbers selected
Accounting, Organizations and Society	1
Journal of Business Venturing	1
Journal of Operations Management	5
Management Science	7
Manufacturing and Service Operation Management	1
MIT Sloan Management Review	1
Organization Science	1
Research Policy	4
Strategic Management Journal	1

s a seventh step, the retrieved articles were subjected to review. In our reviews, we adopt a replicable, scientific, and transparent process to minimize bias and create consensus among scholars (Cooper, 1998; Tranfield et al. 2003). The process implies performing a synthesis (Mays et al. 2005), as synthesis is the core of all methodological approaches, we decided that all authors would read independently all the abstracts and code the data and classify them into different categories (e.g. context, variables, methodologies, consequences, and outcomes) according to a common classification procedure and provide meaningful interpretation through tables (Oxman 1994; Walsh and Renaud, 2017). Table matrix helps to organize the information in a logical order, the topics that are in common with authors or articles, methodological similarities, and differences, measurement tools (e.g. experiments, narrative inquiry, quantitative methods, qualitative or mixed-method, etc.), focused group (individual, dyadic or group, etc.) (Galvan, 2006).

3. FINDINGS

Based on the content analysis of the 140 articles, we identified five main axes of various antecedents and determinants related to uncertainty. 1) Individual, 2) relational, 3) organizational, 4) group, 5) project-specific, and 6) managerial. These uncertainty factors seemingly affect projects, budgets, project managers, employee performance, and overall organizational growth.

3.1 Individual specificities:

Employees, managers, subordinates, and a variety of other project participants play a larger role in the implementation phase. Certain qualities, on the other hand, may cause project uncertainty. Conscientiousness and openness to experience (Witt et al. 2017), situational behavior (Baloi and Price, 2003; You et al. 2018), individual belief system (Wong et al. 2008), norms, and cultural beliefs (Javernick-Will and Scott, 2010), trust, work ethics and values (Badenfelt, 2011), confidence, willingness, and expectation (Wong et al. 2008) are some of the dispositional and personality factors that are known to affect projects.

On the other hand, factors related to the individual role in project management and dealing with projects, such as task type (Vaziri et al. 2007), attractiveness towards the project (Gil, 2007), professional skills (Zika-Viktorsson et al. 2003), perceived view of the project (Olsson, 2007), lack of commitment (Gällstedt, 2003), and lack of motivation (Lehner, 2009), influence uncertainty. Furthermore, stress from time constraints (Leung et al. 2008), manager pressure (De Marco et al. 2016), participation (Jun et al. 2011), involvement (Gales and, Mansour-Cole, 1995), and communication all contribute to project execution uncertainty.

3.2 Relational specificities:

Numerous interactions, including project managers' behavior toward employees (Kutsch and Hall, 2005), a lack of leadership values (Wouters et al. 2009), senior executives' relationships with employees (Phua, 2007), interpersonal relationships, and conflict with other employees (Mitropoulos and Howell, 2001; Liu et al. 2011), and the leader's attitude toward the group (Tysseland 2008), have been reported to contribute to uncertainty (Pesämaa et al.. 2009). Furthermore, collaborative climate (i.e. the trust and commitment among partners) (Eriksson, & Westerberg, 2011) lack of inter-organizational collaboration (trust and control) (Kalkman and Waard, 2017), information feedback, face to face meetings, time and attention from project participants (Sakka *et al.* 2016), user participation (Jun *et al.* 2011), user involvement (Gales and, Mansour-Cole, 1995), and stakeholder's motives (Ward and Chapman, 2003).

3.3 Group specificities

From a group perspective the antecedents of uncertainty are functional diversity (Dayan *et al.* 2017), group values, norms (Wong *et al.* 2010), group cultures (Naveh 2007), lack of effective interaction (Blacud *et al*. 2009), lack of efficient cooperation (Pesamaa *et al.* 2009), lack of involvement by group members (Verworn, 2009), group and managerial conflicts (Laslo and Goldberg, 2008), lack interpersonal performance (Leung *et al.* 2008), group culture practices (van Marrewijk *et al.* 2008), lack of being active members (Olsson 2007), lack of experience (Mitchell and Nault B.R. 2007), trust and relationship issues (Wong *et al.* 2008), lack of co-operation and collaboration (Zhang et al. 2017) and lack of financial feasibility (Farrell, 1995).

3.4 Organizational specificities:

Particularly for projects in the implementation phase, uncertainty may arise from human resource issues (Zwikael and Sadeh 2007), resource constraints (Long and Ohsato, 2008), lack of schedule control (Wang and Liu 2005), lack of information (Danilovic and Sandkull, 2005), lack of clear communication (Verworn, 2009), insufficient support (Olsson 2007), time spent on transfer of information (De Treville *et al.* 2004), tasks duration, resources allocation (Vaziri et 2007), subjective judgments (Choi *et al.* 2004), decision making judgments (Kutsch and Hall 2005; Lin and Chen 2004; Hashemi *et al.* 2011), unfamiliar environments, with differing regulations, (Javernick-Will and Scott, 2010), adapting to new technology and rate of return with projects (Nobelius 2004), management styles and project infrastructures (De Meyer *et al.* 2002). Furthermore, time

pressure (Leung *et al.* 2008) dynamic social structure and procurement decisions (Tysseland 2008), project design, and cooperation (van Marrewijk *et al.* 2008) are found to influence the uncertainty in projects.
Organization structure (Laslo and Goldberg, 2008) and climate also found to create uncertainty in projects e.g. project operation environment (Laslo and Goldberg, 2008), organizational environment (Jensen *et al.* 2006; Olsson 2007), lack of organizational flexibility and capabilities (Sommer *et al.* 2009; Hawk *et al.* 2013), corporate culture (Chapman *et al.* 2006). Also, any organizational change and flexibility in projects (Olsson 2006) may create uncertainty. Furthermore, contracting issues (Wong *et al.* 2008) and customer expectation, satisfaction (Naveh, 2007) influence uncertainty. Work, capital cost, decision making (Sundararajan and Tseng, 2017), two exogenous variables - mediated power and non-mediated power of client - and three endogenous variables - client integration, contractor integration, and project performance, all play a role (Pesamaa *et al.* 2009). Also, political environment (Zayed *et al.* 2008), organizational climate and culture (Perminova *et al.* 2008), organization knowledge about cost information, financial condition and ability to bear the project cost (Xiang *et al.* 2015), delay in project payments (Kwon *et al.* 2010), price competition (Christen, 2005) budget contingency, schedule contingency, management reserve, quality issues (Bushuyev and Sochnev 1999), international transactions (bid behavior) (Han *et al.* 2005) influence uncertainty in projects.
Some authors assert that an organization's role in assessing employee contribution can also have an impact on projects, e.g. evaluation methods (Chapman and Ward, 2000) and project appraisal. Organizational maturity (Zwikael and Sadeh 2007), aggressive/passive management strategies on managing cost (Li *et al*. 2013; Hegazy and Ayed 1998), timeliness and facility value (Ford, 2002), and adequate resources and funding supply conditions (Yang and Chang 2005) can cause uncertainty in projects. market payoffs, product performance, market requirements, create uncertainties in projects (Huchzermeier and Loch, 2001).

3.5 Project specificities

Includes the antecedent's influencing uncertainty at the different stages of projects, for instance, type and nature of the project, project management approaches, project planning, project selection (Thiry, 2002; Howell *et al.* 2010; Shenhar, 2001; Chapman *et al.* 1985; Dean 1986; Ghapanchi *et al*. 2012). Factors such as project risk (Acebes et al, 2014, 2015) project duration, size, estimation (Lee *et al.* 2009; Moussa *et al.* 2007; Chapman 2006; Arashpour *et al.* 2016; Barraza, 2011; Caron *et al.* 2016), project portfolio (Martinsuo *et al.* 2014; Petit, 2012), project operational goals (Tatikonda and Montoya-Weiss, 2001), project design (Ramasesh and Browning, 2014), project delays and overlaps, (Mitchell and Nault 2007; Dehghan, and Ruwnapura, 2014). Characteristics such as information technology (Bardhan *et al.* 2007), project knowledge (Ahern *et al.* 2014; Laine *et al.* 2016; Dikmen *et al.* 2012), profit (Gopal *et al.* 2003), rate of return (Nobelius, 2004), project cost, (Elkjaer, 2000; Farshchian *et al.* 2018), over-head cost (Goh and Hall, 2013) project budget (Günhan and Arditi, 2007), disruptions (Schatteman, 2008; Aaltonen, 2011), rescheduling cost (Bordley *et al.* 2019; Xiang *et al.* 2012), accounting information (Van Der Velde *et al.* 2002), performance and decision environment (e.g., criteria weights, total budget) overlapping strategies, workforce control policies, and schedule adjustments (Pena-Mora and Park, 2001), development schedules (Nightingale, 2000).
Furthermore, organizational process factors such as product development capabilities, operational/market performance in product development projects (Tatikonda and Montoya-Weiss 2001; Turner and Simister 2001), project duration overrun, loss of key project personnel, absence of recognition and allowance (Chapman, 1998), lack of client

satisfaction, lack of precision in finishing projects (Brodetskai *et al.* 2013), lack integration between the organization and its projects (Vuorinen *et al.* 2018) quality deficiencies (Arashpour et al. 2016), cost estimating procedures (Diekmann and Featherman, 1998), project situations (Laufer and Cohenca, 1990; Chapman *et al.* 1985), project schedule and man-hour variance (Laufer, 1991) and role of project manager and their performance (Turner and Müller, 2003). Uncertainties may also arise from the type of contracting and subcontracting agreements (Cardenas et al. 2017 and Choudhry *et al.* 2012), control modes, and control mechanisms fairness, and culture integration mechanisms.

Further, Dawson and Dawson (1995) and Pillai and Tiwari (1995), suggested that network structure in the project activity can cause uncertainty; also, the complexity of the methods involved and the lack of easy to use tools (Dawson and Dawson, 1998), project resources (Padilla and Carr 1991), project initiation, postponements to avoid unfavorable restoration conditions, (Hwang *et al.* 2016), probability estimation (Moret and Einstein, 2012) lack of information, ambiguity, characteristics of project parties, tradeoffs between trust and control mechanisms, (Atkinson *et al.* 2006), lack of project contingency (Dey *et al.* 1996) effectiveness and efficiency, create uncertainties in the project.

3.6 Managerial specificities

Managerial specificities among the uncertainty effects on projects are reported in management practices such as management control systems (Davila, 2000), manager skills (Baqerin *et al.* 2016), managerial flexibility (Koppenjan *et al.* 2011), managerial decisions (Sauser *et al.* 2009; Santiago *et al.* 2005). Furthermore, technological, organizational, and social contexts (Böhle, *et al.* 2016), socio-technical environments, sense of balancing competing demands, and provided evidence of learning, acting mindfully, avoiding over-rigid processes, and upholding constructive tensions, conceptual slack and close interdisciplinary working (Saunders *et al.* 2016), variable compensation, organizational structure (Davila, 2003), co-ordination between clients and consultants (Scott and Harris, 2004), political behavior (Svejvig and Andersen, 2015), incentive provision and decisions (Liu *et al.* 2018) exogenous technological change, failure to search strategy (Chandrasekaran *et al.* 2016), influence uncertainty in projects.

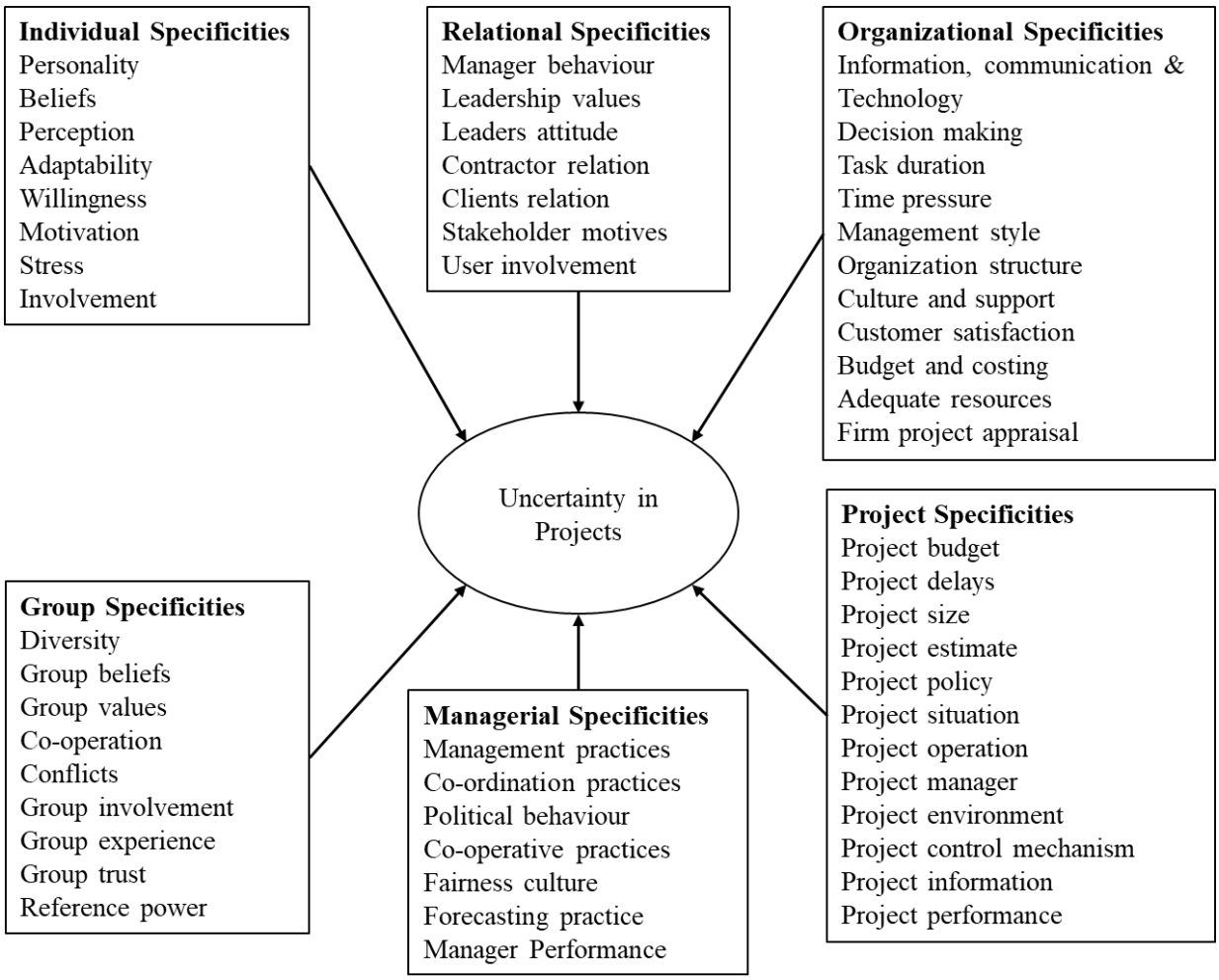

Figure 2 Summary of the key classification of sources of uncertainty in projects.

Figure 2 allows us to develop a classification for the various sources of uncertainty in projects. This is composed of six categories since uncertainty can originate from an individual, group, managerial, organizational, relationship, and project specificities. We reported certain factors in multiple categories since different scholars relate the same factor to different sources.

4. DISCUSSION AND NEW PERSPECTIVES

The findings of this research contribute to the field of project management and for project managers in two ways: firstly, our findings help scholars in advancing and better understanding the sources of uncertainty by classifying them into six separate categories, dealing with these issues individually can provide better opportunities for future research; secondly, the antecedents and determinants presented here can support project managers, practitioners and researchers in developing solutions applicable to specific projects.

The classified uncertainties will be able to foresee and define occurrences to assist stakeholders and project managers in developing contingency plans typically the degree of uncertainty for a specific project (e.g. oil and gas context, hydroelectric power, nuclear, geothermal, etc.). This study demonstrates that the degree of uncertainty associated with the classification has a direct effect on the project's success when stakeholders, firms, and project staff are involved. The work contributes insights into how to better manage industrial projects within the context of uncertainty, as industrial projects are part of

execution by many big firms such as Total, Alstom, etc. Thus, the findings from this study will help industrial project managers (who are involved in design, construction, planning, execution, etc.) to be aware of and respond to uncertainty factors classified in this study. The study implications are the developed framework, which can be used as a guideline to better plan the responses to uncertainties in industrial projects.

In addition to incorporating the aforementioned taxonomy for sources of uncertainty, our literature review helps us to recognize some additional primary findings important to discipline study and help shape future research:

Dealing with uncertainty is an inherent part of project management: an adequate strategy is required to improve project performance, particularly in large projects. Nevertheless, most literature focuses on heavy engineering and construction industries; however, from the reviews, we found that the discipline of uncertainty resides mainly in massive or mega projects (Daniel and Daniel, 2018); in particular, we found various studies on oil and gas, public and government building projects, nuclear projects, defense, and rail projects. Therefore, the impact of uncertainty as a function of the project's size is missing evidence. Future research should therefore study how uncertainty varies by organization size and project size (e.g. small projects, medium projects, and mega projects).

There is a steady growth of uncertainty literature in several disciplines: the literature on uncertainty has been growing over the last two decades (see figure 3). For instance, increased awareness of uncertainty and risk management appeared in literature particularly given the backdrop of sensational financial collapses of major corporate and banking institutions (Harvett, 2013). Statistics obtained from the Scopus database indicate that the number of articles published around uncertainty in project literature has doubled since 2010 (see figure 3). This also confirms that the topic of uncertainty started to emerge as a new sub-topic of project management.

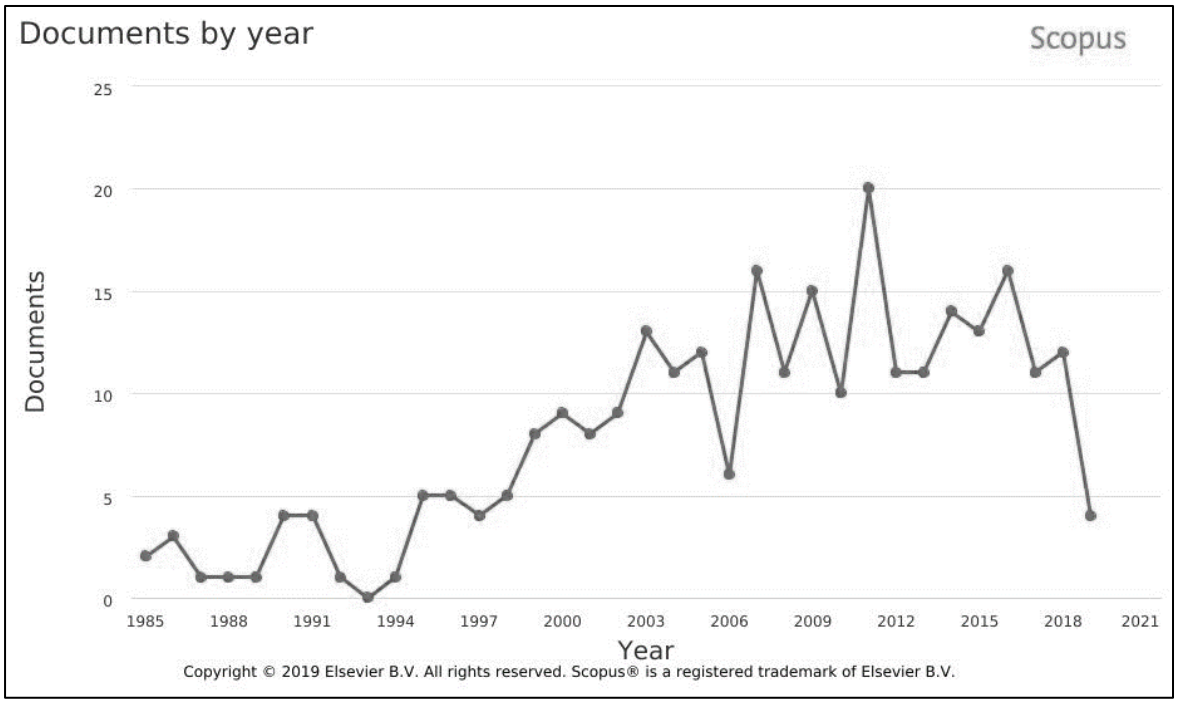

Fig 3: The growth of documents on the topic of uncertainty in projects

Further analysis of the obtained dataset shows how most of the literature focuses on engineering, business, and management disciplines (see figure 4); this high concentration in specific domains may have introduced a bias on the efforts done by scholars to understand the sources of uncertainty. Nevertheless, the growing interest of researchers from other disciplines like computer science suggests that managing technological and software projects is also increasingly threatened by uncertainty. Therefore, our research calls for more cross-disciplinary studies.

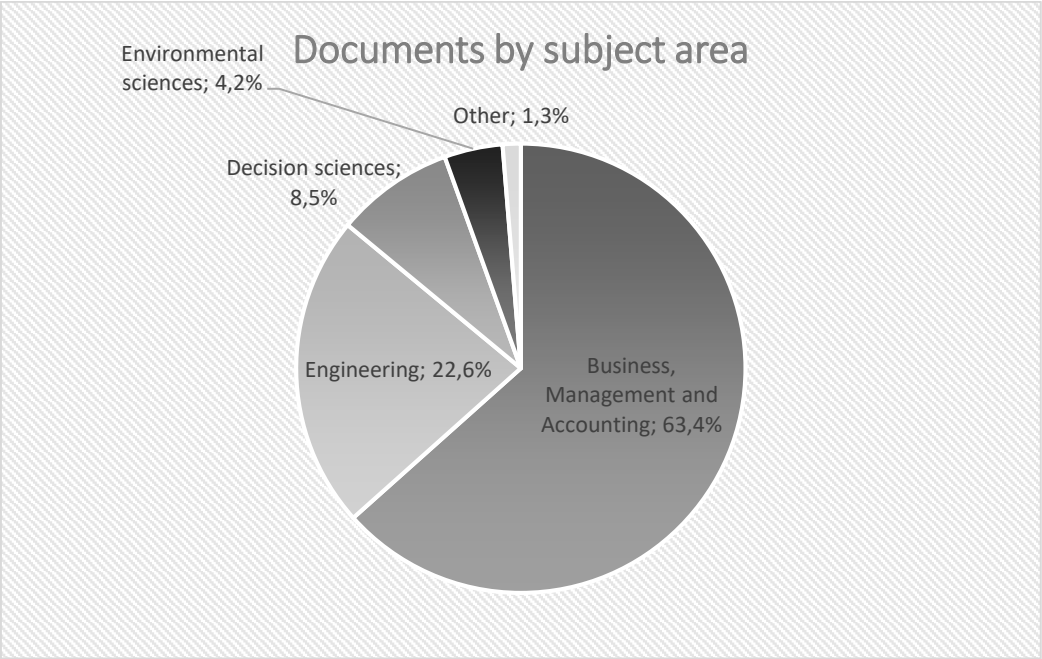

Figure 4: The multidisciplinary literature about uncertainty in projects

Finally, from our datasets, it emerges that the biggest contributors to the uncertainty literature are authors from the US and the UK (see figure 5). Therefore, we cannot exclude a bias in the findings of research activities due to this geographic concentration. Consequently, we call for more international studies.

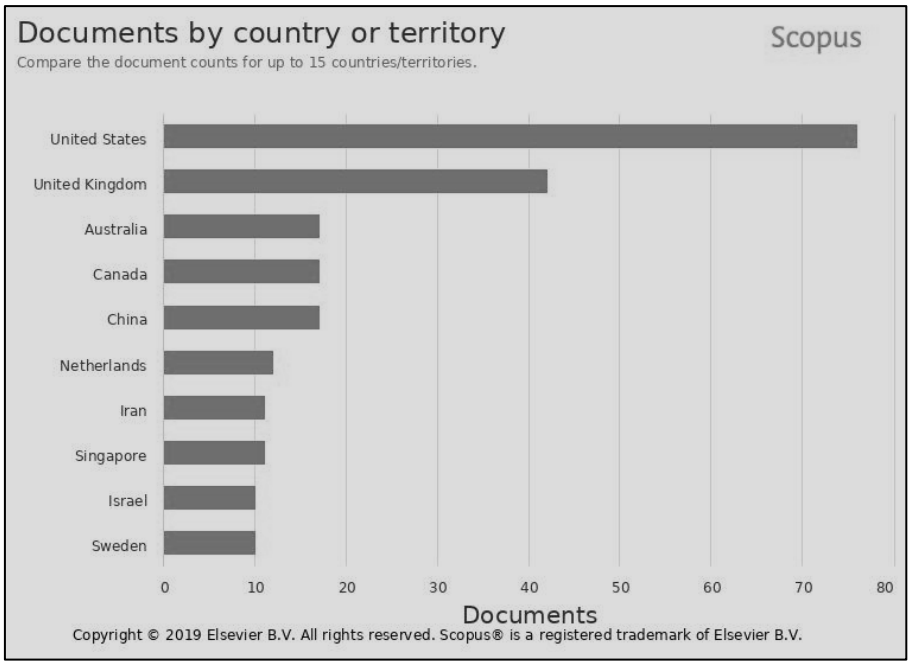

Fig 5: The Major continents contributing to uncertainty literature

***There is a need for better differentiating between the concepts of risk, uncertainty, and complexity*:** uncertainty is often closely associated, and even sometimes interchangeably used, with risk and complexity (Sommer *et al.* 2009; Turner and Cochrane, 1993; Williams, 2005; Bos-de Vos *et al.* 2019). Daniel and Daniel (2018) state that "degrees of uncertainty and complexity is embedded [in projects], uncertainty being a characteristic of the management subsystem, and complexity being a characteristic of the project management system". Moreover, confusing risk and uncertainty, implies that both are treated alike (Perminova *et al.* 2008). The confusion is potentially harmful since it tends to focus attention on planning and operational control, at the expense of strategic issues (Atkinson *et al.* 2006).

We argue that more clarity should be adopted by researchers in using the different terms; in particular, risk should be adopted to describe an event or condition that has a quantifiable probability of occurring, and that, if it occurs, has a positive or negative effect on a project objective (Ward and Chapman, 2003); complexity for situations in which systems are complex, i.e. the interactions between different components are hard to model and evolve (San-Cristobal, 2017); finally, uncertainty should be reserved to those situations in which credible probabilities to possible outcomes cannot be assigned as certain events cannot be predicted (Alvarez *et al.* 2018, based on Knight, 1921). Our call for clarity in the terminology is supported by several scholars who report confusion in the use of different terms (Padalkar and Gopinath, 2016).

***Chaos theory may help to deal with uncertainty*:** De Meyer *et al.* (2002) asserted that "project managers can't predict the future, but accurately gauging the degree of uncertainty inherent in their projects can help them quickly adapt to it", such a recommendation is derived from drawing a parallel between uncertainty and chaos theory (Geraldi, 2008). Since its introduction during the 20th century, chaos theory has concentrated on studying systems that are highly sensitive to initial conditions: very little changes in the initial conditions produce considerably different results as illustrated by the famous butterfly effect, according to which "the flap of a butterfly's wings in Brazil may set off a tornado in Texas" (Lorenz, 1972). We endorse the line of thought that promotes the analogy with chaos theory to offer new insights in developing strategies to cope with uncertainty (Werndl, 2009; Thietart *et al.* 1985; Nychka *et al.* 1992) and we call for further research in this specific field.

5. LIMITATIONS AND FUTURE RESEARCH

This article contains few restrictions for further research. To begin, we limited our search to a subset of peer-reviewed journals, which may have excluded several articles. For instance, future research can examine the outcomes of this work focusing on project management-related journals such as Project Management Journal, International Journal of Management Projects in Business, IEEE transaction on Engineering and Management, etc. Second, while we justify our use of Scopus as a database, future research may benefit from studying data from other databases such as Google Scholar, Web of Science, and EBSCO. Due to the remarkable increase in the number of publications and journals, the study may examine the literature using bibliometric or scientometric approaches. Third, our study excludes conference papers and book chapters, which may have harmed generalizability.

6. CONCLUSION

In this paper, we presented a comprehensive review of the sources of uncertainties in projects and introduced a taxonomy based on individual, relational, group, organizational, project, and managerial specificities. When encountering uncertainties, the project manager faces many dilemmas (Zwikael, and Sadeh, 2007), identifying the appropriate source or sources of uncertainty among the six introduced in this article, may help the project manager to better cope with the unknown that may occur during various phases of projects. Our study confirms the increasingly central role that scholars studying project management attribute to uncertainty in projects: the number of article published in peer-reviewed journals kept growing steadily over the last years; also, academics point to the necessity for companies involved in projects to elaborate strategies to deal with

uncertainty when it happens; another finding is that the literature studied shows that the terminology about uncertainty, risk and complexity lacks clarity and we invite scholars to adopt common definitions: we argue that risk should be used to describe an event or condition that may impact the outcome of the project and that has a quantifiable probability of occurring; complexity for situations in which the interactions between different components of a system are hard to model and evolve over time; finally, uncertainty should be reserved to those situations in which credible probabilities to possible outcomes cannot be assigned as certain events cannot be predicted.

Through this paper, we also open new avenues for future research; indeed, we have identified several gaps in existing literature, the most important of which are: the absence of studies investigating the impact of uncertainty as a function of firm and project size: most literature deals with large or mega projects only, leaving mid to small size projects uninvestigated; also, a large majority of articles treats of with oil and gas, construction, nuclear, defence and rail projects, hence the need to extend the area of investigation to other industrial sectors; there is an intense geographical concentration of authors writing on project uncertainty from Anglo-Saxon countries: we encourage scholars from other parts of the world to conduct local investigations of uncertainty in projects; finally, we highlight some interesting opportunities that may emerge from adopting tools and methods of chaos theory to cope with uncertainty in projects: we consider that further research in this field may prove very beneficial to support practitioners facing the challenges of uncertainty in projects.

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