EXPLORING THE DYAD COMMUNICATION AND KNOWLEDGE MANAGEMENT:

A STUDY INVESTIGATING THE MAIN BARRIERS IN COMPLEX PROJECT CONTEXT

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Abstract: There is a lack of research exploring dyad communication and knowledge management in the complex project context. The present study aims to narrow the identified gap by identifying the main barriers, considering both tacit and explicit knowledge. Besides, the influence of this dyad in project performance is investigated. This research explores the emergent literature on knowledge management and communication management in the complex project context by performing a mapping study. A sample of 116 articles is in-depth analyzed through a combination of bibliometric and content analysis, using an axial coding process. The results point out that the main communication barriers are environmental and different priorities among team members. The study points to the knowledge barriers, particularly the knowledge codification process and inadequate information technology. This study highlights the lack of more confirmatory research approaches, such as developing a relation between triad knowledge management, communication, and project performance. Besides, it points to the lack of studies on learning capabilities.

1. INTRODUCTION

Knowledge and communication management comprise interrelated processes and influence each other (Al Shatti et al., 2018), considering not only behavioral and aspects on knowledge sharing (Razmerita et al., 2016) but also the media of communication including both traditional and digital platforms, mainly social media (Leonardi, 2014). Both knowledge and communication are essential (Lee et al., 2015), but only a few studies explored the link between knowledge and communication (Razmerita et al., 2016).

In project management (PM) practitioner literature, there is an asymmetry between communication that is well-grounded in bodies of knowledge (Carvalho, 2014) and knowledge management (KM) that has been neglected, and the immersion in project management is still recent (Nadae & Carvalho, 2017). For instance, in the practitioners' guidelines Project Management Body of Knowledge (PMBoK), only in the 6th edition, it devoted a single process to KM (PMI, 2017).

The discussion on knowledge management in projects is more nuanced in the academic literature with various theoretical perspectives (Ali et al., 2018). As projects are considered temporary organisations, they exist within the boundary of a project-based organisation (PBO) (Pemsel and Wiewiora, 2013), and effective knowledge management is particularly essential (Bosch-Sijtsema and Henriksson, 2014).

Knowledge management becomes an important component to enforce the learning process among various projects. Some of the new projects did not move along quickly because they failed to learn from an existing successful project (Liu, Hansen, & Tu, 2020)

Projects are "an efficient means for combining knowledge and thereby optimising the value from investments (Ali et al., 2018). However, the learning mechanisms of projects and firms (memory, experience, and reflection) have opposing features (Ibert, 2004). Knowledge accumulation is more likely to occur at the organizational memory level, while projects acquire new knowledge assets (Nadae and Carvalho, 2017). If viewed from the learning perspective, every step in the project management process can serve as the basis for producing and sharing knowledge for the project team (Kotnour & Vergopia, 2005).

One of the factors vital to knowledge sharing is good communication (Jones, 2017) because "knowledge sharing involves leveraging both personal and collective knowledge, and the synergetic articulation of personal into collective knowledge may be facilitated" (Razmerita et al., 2014).

Thus, a holistic understanding of project team collaboration through communication influences knowledge acquisition, which improves project manager efficiency (Al Shatti et al., 2018). The emerging theory suggests that by learning vicariously workers can "recombine existing ideas into new ideas more effectively and proactively aggregate information perceived daily" (Leonardi, 2014).

The dyad knowledge and communication are critical antecedents of team social capital leading to team performance. (Lee et al., 2015). Particularly nowadays, in which the COVID-19 outbreak pushes several teams to remote working to prevent the virus from spreading, studying this topic has become increasingly important (Abarca et al. 2020).

Empirical evidence shows that knowledge management systems positively affect project performance (Reich et al., 2013). In addition, knowledge sharing affects project performance, which is hampered by communication and coordination difficulties (Adenfelt, 2010), and affects knowledge-based goals and outcomes, particularly dynamic capabilities and absorptive capacity of the project (Pemsel et al., 2014).

The project complexity can play an essential role in influencing the strength or nature of the relationship between communication and knowledge management. Creating, maintaining, transferring, and increasing knowledge is of paramount importance to efficiently deal with projects' complexity (Disterer, 2002). The project complexity may intensify communication role and team knowledge due to the increased need for coordination and decision-making (Marks, Mathieu, & Zaccaro, 2001). In complex projects, knowledge sharing, and media or communication management need to be effectively managed so that the knowledge acquired can be shared and communication among project stakeholders flows positively (Disterer, 2002). Communication problems often arise in complex projects (Alagba, 2014), emphasizing the importance of communication in projects beyond the use of communication processes to the use of communication skills during projects (Johannessen & Olsen, 2011).

An exciting aspect of the literature is the overlapping of barriers to communication and on KB. Furthermore, communication appears an essential barrier to KM, particularly in complex projects (Santos, Soares, Carvalho, & St-Pierre, 2016). Many of the barriers present in knowledge transfer problems come from the communication process (Fukuyama et al., 2015).

The present study aims to narrow the identified gap by exploring dyad communication and knowledge management in the complex project context.

To accomplish this objective, this paper seeks to answer the following research questions. (RQ#1) Which are the main topics and influence variables relating the knowledge and communication to the complex project context?

The study pinpoints communication and knowledge barriers for answering the second research question. (RQ#2) What are the main knowledge and communication barriers in the context of complex projects?

The third question looks at identifying future research agendas. (RQ#3) What are the most up-to-date thinking, trends, and gaps in the literature?

The research design is a comprehensive literature review research design that merged bibliometrics, network, and qualitative and quantitative content analysis.

The study led to a research framework consisting of significant variables explored in the literature that influence the dyad communication and knowledge management in the complex project context. The research also helps to raise unsolved questions and propositions that can help on future research agenda.

The paper has five sections. Following the introductory section, Section 2 presents the literature review of the key concepts, followed by Section 3, which shows the research design. In Section 4, the results and discussions are presented, applying bibliometrics and network analysis to explain the different barriers related to the dyad communication and knowledge in complex projects, followed by the content analysis to answer the research questions. Section 6 presents the conclusions.

2. LITERATURE REVIEW

2.1 Knowledge Management and Communications

Communication is considered a "process of exchange of information between sender and receiver to equalize the information on both sides" (Otter & Prims, 2002, p. 3), the meaningful exchange of information between two or more people (Park & Park, 2016) and the type of information shared in companies which can be about product, organization and process (Senescu, Aranda-Mena, & Haymaker, 2013).

Communication research provides guidance as to how people must exchange these representations by collaborating within projects, sharing of information between projects, and understanding of information generated across the entire firm or industry (Senescu & Haymaker 2009).

The communication process is influenced by several environmental factors, including location, initiator, a power relation, group size and composition, physical disposition and purpose and time (Johansen & Gillard, 2005).

Moreover, effective communication practices need to ensure that all major players are kept fully informed of any problems or difficulties and have procedures for intervening and managing these immediately should they occur and not allow them to disrupt the project (Kerzner, 2006). Communication has a positive influence on knowledge sharing between project teams (Mueller, 2012) and many models of knowledge transfer encompass communication (Ko, Kirsch, & King, 2005).

Knowledge management is the process of apprehending, dispensing and effectively using knowledge (Davenport, 1994). It also can be considered as "specific data and information in the human mind related to intelligence, experience skills, and attitude, which can be the subject of manipulation regarding navigating, combining, reflection, synthesizing or even redefining the meaning of data strings"(Otter & Prims, 2002, p. 3).

Knowledge sharing can be the exchange of expertise, experiences, information and the verbal communication between the floating support worker and the adult social services for the effective delivery of floating support services (Egbu, Wood, & Egbu, 2010)

In the organizational context, it is important to highlight the types of knowledge proposed by Polanyi (1966): explicit knowledge and tacit knowledge. Explicit knowledge is the knowledge that can be encoded and stored in different media. Tacit

knowledge is the knowledge that comes from the experience, internalized by understanding and practice (Oliva, 2014). What is more, to turn tacit knowledge into explicit, those involved often talk using various communication channels in the company (Liyanage et al., 2009; Park & Park, 2016; Li et al., 2018).

Alonso et al. (2013) indicate that since knowledge is transmitted mainly through human relations, any noise generates distortions in information, creating barriers to communication and making it difficult to store and share knowledge, thus creating barriers to the management of knowledge. Therefore, it can be stated that many of the barriers present in knowledge transfer are also in the communication process (Fukuyama et al., 2015) and the opposite can also occur.

Considering the challenges to implementing knowledge management, the biggest impediment to knowledge management success is a lack of understanding. A focus on communicating with the constituent knowledge workers, administrators, and support staff as well as systems owners and senior management is essential (O'Sullivan, 2007)

In the literature on knowledge transfer, most researchers have recognized communication as an essential influence (Ren, Deng, & Liang, 2018) As knowledge sharing is undoubtedly a form of communication, this variable can be expected to be of significant influence here (Van Den Hooff & Ridder, 2004)

Communication refers to the interaction between individuals, including through oral conversations or body language to exchange ideas. And the communication between a project manager and their assistants has been viewed as a central component of project leadership (Yang, Kuria, & Gu, 2020). For knowledge to be shared, people need to communicate effectively to accomplish their project tasks.

Many authors, see **Table 1**, study the difficulty of sharing knowledge and organizational communication. The communication barriers are presented in this table, as well as the knowledge management barriers. It is noted that some considered barriers of knowledge management are also considered barriers by some authors as barriers of communication management.

	Barriers	Knowledge Management	Communication Management
PEOPLE	Conflicts	-	Carvalho and Rabechini (2015)
	Lack of feedback	-	Carvalho and Rabechini (2015)
	Emotional distractions	-	Johansen and Gillard (2005)
	Personally type/characteriscs/appearance	Riege (2005)	Johansen and Gillard (2005)
	Psychological distractions	-	Johansen and Gillard (2005)
	Physiological distractions	-	Johansen and Gillard (2005)
	Comunication and coordination	-	Bano, Zowghi and Sarkissian (2016)
	Trust	Santos et al. (2016)	Carvalho (2013); Fox (2001); Larkey (1996); Mackenzie (2010); Kurland e Pelled (2000)
	Semantics or Words	-	Carvalho (2013); Gillard (2005); Debrabander and Edstrom (1997); Debrabander and Thiers (1984); Robey and Markus (1984); Kirsch et al. (2002); Mackeen et al. (1994); Debrabander and Souder (1988); Yang et al. (2008); Weick and Roberts (1993); Johansen and Gillard (2005)
	Lack of motivation and/or initiative	KPMG (1998),Chua (2004), Zyngier (2002), Riege (2005), Santos et al. (2016)	-
	lack of senior management support	KPMG (1998), Singh and Kant (2008)	-
	The sharing of one's own knowledge	KPMG (1998), Singh and Kant (2008)	-
ORGANIZATIONAL	Culture and Cultural heritage	KPMG (1998), Ang and Massingham (2007), Carneiro (2001), Chase (1997), Chua (2004), DDC Group (1997), Mason and Pauleen (2003), Riege (2005), Sensky (2002)	Johansen and Gillard (2005) Carvalho and Rabechini (2015)
	Geographic Distributions of the team	-	Bano, Zowghi and Sarkissian (2016)
	Integrated systems	-	Bano, Zowghi and Sarkissian (2016)
	Structutre, Processes and channels	Chong and Choi (2007); Riege (2005); Santos et al. (2016)	Carvalho and Rabechini (2015) Bano, Zowghi and Sarkissian (2016)
	Communication structures	KPMG (1998), Singh and Kant (2008)	Bano, Zowghi and Sarkissian (2016)
	Priority	-	Carvalho (2013); Gillard (2005); Debrabander and Edstrom (1997); Debrabander and Thiers (1984); Robey and Markus (1984); Wang et al. (2005); Mackeen et al. (1994); Bostrom (1989); Gupta et al. (1985);
	Environment	Santos et al. (2016)	Carvalho (2013); Johansen and Gillard (2005); Yates and Orlikowski (1992); Gillard (2005); Fox (2001); PMI (2008)
	Lack or unclear of methodology or strategy	KPMG (1998), Singh and Kant (2008), Chong and Choi (2007)	-
	Knowledge complexity lack of awareness about KM	Fraunhofer Stuttgart 8 Jager and Straub (1999), DDC Group (1997), KPMG (1998), Singh and Kant (2008), Mason and Pauleen (2003), Santos et al. (2016)	-
	Lack of top management commitment	KPMG (1998), Chua (2004), Brand (1998), Jager (1999), Wong and Aspinwall (2004), Zyngier (2002)	-
	Staff retirement and/or staff defection	KPMG (1998), Ang and Massingham (2007),	-
	Lack of ownership of problem	KPMG (1998), Riege (2005), Chase (1997), Sensky (2002)	-
	Lack of incentives, funding, time and/or resource	Singh and Shankar (2006), KPMG (1998), Singh and Kant (2008), Sensky (2002), Santos et al. (2016), Chua (2004), Riege (2005), Zyngier (2002)	-
TECHNOLOGICAL	Information censorship	-	Carvalho and Rabechini (2015)
	Learning curve of information systems	Santos et al. (2016)	-
	Technological infrastructure	KPMG (1998), Bullinger, Worner and Prieto (1997), Chong and Choi (2005), Chua (2004), Ang and Massingham (2007), DDC Group (1997), Santos et al. (2016), Mason and Pauleen (2003), Riege (2005), Wong and Aspinwall (2004)	-

Table 1. Knowledge management and Communication management barrier

2.1.1 Knowledge Management (KM): Absorptive capacity, dynamic capabilities and lessons learning

Knowledge is a key resource to organizations as it is the foundation for executing tasks and learning (Guvernator IV & Landaeta, 2020) and the ability of a firm to recognize, acquire and commercialize external knowledge, is known as its absorptive capacity. Research has found that absorptive capacity closely relates to knowledge management processes, such as acquisition, creation, utilization and sharing (Sun, 2010).

According to Cohen and Levinthal (1990), absorptive capacity relates to external information, and it is influenced by knowledge sources and prior knowledge. Prior knowledge regards basic skills and shared languages and enables an organization to recognize, assimilate and apply new information, contributing to innovation, flexibility, and organizational performances (Mariano & Walter, 2015). Absorptive capacity enables firms to internalize external knowledge to innovation (Wang, Guo, & Yin, 2017).

From the perspective of organizational learning, absorptive capacity is built on existing knowledge and previous learning experience, and then sequentially shapes a firm's innovative activities in the future (Cohen & Levinthal, 1990; Macher & Boerner, 2005; Yap, Abdul-Rahman, & Chen, 2017).

However, absorptive capacity "depends on the organization's ability to share knowledge and communicate internally" (Lane, Koka, & Pathak, 2006). The concept of absorptive capacity is framed in terms of dynamic capability and a review of the relevant literature is proposed by (Noblet, Simon, & Parent, 2011).

For Eisenhardt and Martin (2000) dynamic capability corresponds to the existence of identifiable and specific routines that are fundamental to activities such as knowledge creation and acquisition, or the capacity to develop strategic alliances or partnerships. Dynamic capabilities can draw on various clearly identifiable processes, activities or methods that address specific needs that could, for example, be met by the development of new knowledge or, conversely, by discontinuing certain practices that have essentially become irrelevant. We believe it should be possible to apply the knowledge learned from the study of dynamic capability to knowledge transfer (Noblet et al., 2011)

As well as absorptive capacity and dynamic capabilities, lessons learned are a key element of knowledge management (Garon, 2006). One key of knowledge management is ensuring that information can be shared, discussed, and learned. A valid knowledge management should provide real-time formal and informal communication expediently for individual, the project team, and various kinds of relevant personnel. (Cai, Chen, Zheng, & Miao, 2011). Projects completed should be reviewed and lessons learned, documented, and incorporated in the next project to avoid repetition of mistakes (Dogbegah, Owusu-Manu, & Omoteso, 2011). Lessons learned are a key element of knowledge management (Garon, 2006).

2.2 Project Complexity

A project can also be a complex work system in which human elements, organizations, procedures, and techniques are integrated (Ruuska & Vartiainen, 2003). Then project management is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements (PMI, 2017).

All projects exhibit the attributes of interconnectedness, hierarchy, communication, control, and emergence - attributes that are generally useful in describing all kinds of projects. This means that managing complex projects requires the ability to observe them from many different perspectives (Koskinen, 2013)

Project complexity is the property of a project that makes it difficult to understand, predict, and maintain its overall behavior even when there is reasonably complete information about the project system (Vidal & Marle, 2008).

Complexity in a project management context is a matter of observation and ambiguity: that is, whether an individual sees a situation as complex depends on how he or she observes it (Koskinen, 2013). Project management in complex projects, therefore, requires upfront attention and reflection by project management on uncertainty and the complexity of the project through the entire life span of an offshore wind park (Brink, 2017).

Different project complexity classifications are presented in the literature and they are summarized in **Table 2**.

These dimensions are relative to the interpretation of each author, some consider the number of stakeholders involved, investment in the project and cultural factors, but also others consider the skills of the project team as shown in **Table 2**.

3. RESEARCH METHODS

The research method combines quantitative and qualitative strategies, including bibliometric analysis, content analysis and a systematic literature review. Owing to the great number of academic publications, bibliometric studies are being more accepted and bibliometrics is being recognized as a systematic and relevant approach (Ikpaahhindii, 1985; Neely, 2005).

The content analysis allows an in-depth understanding of the research constructs and their relationship (Duriau et al., 2007). The procedures were organized at each stage of the research protocol

Dimensions	Authors (year)
Causal connections	Homer-Dixon (2000)
Cognitive complexity	Girmscheid and Brockmann (2008)
Contractual and Financial	Carvalho, Patah and Bido (2015)
Cultural	Girmscheid and Brockmann (2008); He et al. (2015)
Diversity of skills	Santos et al. (2016)
Dynamic	Geraldi, Maylor, and Williams (2011)
Environmental	He et al. (2015)
Information	He et al. (2015)
Interdependence	Homer-Dixon (2000); Vidal and Marle, (2008); Vidal, Marle, and Bocquet (2011)
Intra-organizational and Organizational	Baccarini (1996); Kim and Wilemon (2003); Kim and Wilemon (2003); He et al. (2015); Carvalho, Patah and Bido (2015)
Market complexity	Kim and Wilemon (2003)
Non-linear behavior	Homer-Dixon (2000)
Operation and development	Kim and Wilemon (2003); Girmscheid and Brockmann (2008)
Pace or Rhythm	Shenhar (2001); Geraldi, Maylor, and Williams (2011)
Scope and context	Shenhar (2001); Vidal and Marle, (2008); Vidal, Marle, and Bocquet (2011); He et al. (2015)
Size and multiplicity	Homer-Dixon (2000); International Project Management Association (2006); Vidal and Marle, (2008); Santos et al. (2016)

Table 2. Dimensions of Project Complexity

proposed by Littell, Corcoran and Pillai (2008), following three steps: data collection, data analysis and synthesis. It merges bibliometrics and content analysis because these methods are complementary (Carvalho et al., 2013).

Aligned with the research objectives of mapping the literature on the themes, a systematic literature review (SLR) approach was selected to answer the three research questions (RQs) as highlighted in the introduction section. A systematic review "provide[s] collective insights through theoretical synthesis" (Tranfield, Denyer, & Smart, 2003). Also, reviews articles bring together accumulated research knowledge to articulate/critique (Davidson & Barret, 2018),

A systematic review is defined as a type of review that follows a strict methodology to enable rationality, transparency, and replicability for selecting and evaluating scientific publications. (Khan, Mittal, West, & Wuest, 2018). The whole research flow is presented in **Figure 1**.

3.1 Sampling process

Data were obtained from the scientific databases, ISI Web of Knowledge, Web of Science Core Collection and Scopus by late October 2018. The ISI Web of Science has high relevance in the academic field, as well as differential data treatment options (Franco, Hirama, & Carvalho, 2018). Moreover, the Scopus database is considered the largest database of abstracts and citations in the peer-reviewed literature: scientific periodicals, books, and congress proceedings (Scopus, 2018). The overlap between sources of publications considered in the Web of Science and Scopus is not large, and consequently these sources can be used in combination to provide a wider view of the subject (Geraldi, Maylor, & Williams, 2011).

In addition, both databases provide compatible metadata for bibliometric analysis software, carrying the articles 'respective abstracts, references, citation indexes, authors, institutions, and countries, among others (Carvalho, Fleury, & Lopes, 2013).

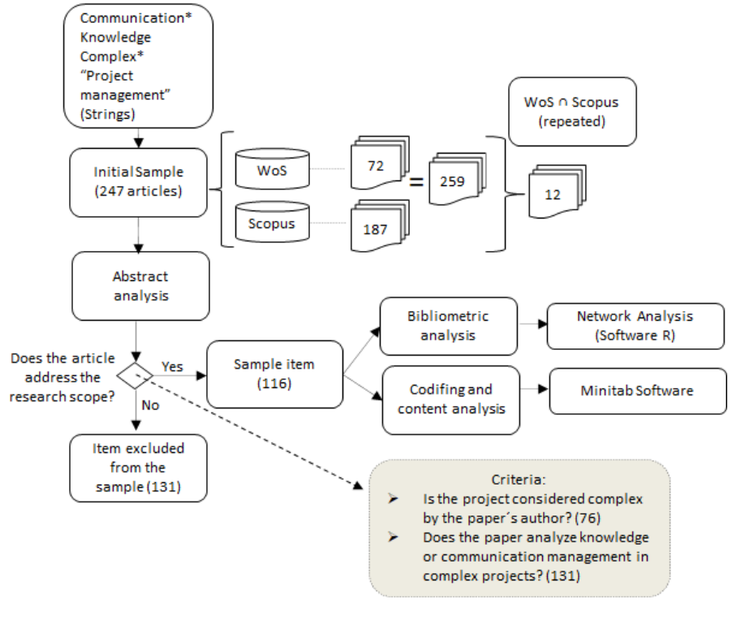

Table 2. Dimensions of Project Complexity

The search string used was communication AND knowledge AND complex* AND "project management", applied as a "topic" in the Web of Science and in Scopus. The same search string was applied for "article title, abstract and keyword", resulting in 72 articles in the ISI Web of Science (WoS) and 187 articles in Scopus. Within this number, 12 articles were duplicated (found on both databases). The only filter applied was "type of documents", choosing only "articles", "reviews" and "articles in press" (the last one only in the Scopus database) because of the robustness of the pairwise review process (Takey & Carvalho, 2016).

The initial sample analyzed was composed of 247 articles (WoSΩScopus and WoSυScopus), which were then imported to Mendeley software (Butros & Taylor, 2010) for the first screening based on the analysis of the titles and abstracts.

Then, we excluded 131 papers that all agreed did not meet the criteria for inclusion, which were to fit the research scope of communication or knowledge management in complex projects. When the consensus was not achieved among authors, the full paper was analyzed and discussed. Next, the snowball sampling technique was employed to identify the most relevant references that were not retrieved in the initial sample, considering the most cited studies that fit the research scope, using the same screening process. A final selected sample of 116 articles resulted from this process.

3.2 Data analysis

To manage the sample, Mendeley software (Butros & Taylor, 2010) was used, and the Microsoft Access database allowed the metadata generated by Sitkis software to perform further analysis. To answer the three research questions (RQs), three methods were used in the SLR, as shown **Table 3**.

First, to answer RQ#1, bibliometrics and network analysis were applied. Three types of social networks were designed: evolution of publications per year, keywords, and authors' outliers. The network analysis (similarity analysis) was carried out using the following software IRAMUTEQ (Routine Interface for Multidimensional Analysis of Texts and Questionnaires).

IRAMUTEQ is a free program that is anchored in software R and allows for the processing and statistical analysis of produced texts. It was developed by (Marchand & Ratinaud, 2012) in the French language, but currently has complete tutorials in other languages. IRAMUTEQ allows the following types of analysis: group specificity search, descending hierarchical rank, similarity analysis and word cloud (Adas, Moimaz, & Amaral, 1983).

In IRAMUTEQ, a similarity analysis shows a graph representing the link between words in the textual corpus. From this analysis, it is possible to infer the structure of text construction and the themes of relative importance, from the co-occurrence between words (Salviati, 2017).

#	Research Question	Method	Software
1	Which are the main topics relating the knowledge and communication to complex project context?	Bibliometrics and Network analysis	Minitab, Excel, Iramuteq
2	What are the main knowledge and communication barriers in complex projects?	Semantic analysis Content analysis	Sitikis, Access, Ucinet, Netdraw, Minitab
3	What are the most up-to-date thinking, trends and gaps in the literature?		

Table 3. Research questions and methods

It assists the researcher in identifying the structure of the database (corpus), distinguishing the common parts and the specificities, as well as allowing them to be verified according to the existing descriptive variables.

The graph makes it possible to identify the co-occurrences between the words, and its result brings indications of the connection between the words, helping to determine the structure of the representation (Marchand & Ratinaud, 2012).

Furthermore, applying additional software, such as Minitab 17 (Minitab, 2014), was used as the distribution of articles per year and the analysis of outliers. Outlier is considered an atypically large or small observation that may have disproportionate effects on the statistical results of a sample, such as the average, which may result in misinterpretation (Minitab, 2017).

The content analysis was used to answer RQ#2 and RQ#3, based on an in-depth analysis of the core papers (Mayring, 2014; Seuring & Müller, 2008; Tranfield et al., 2003).

In addition, the coding scheme was used to classify the works according to the codes presented in Table 4. Each code was taken from studies by different authors and then a content analysis was performed manually in parallel with the coding, by a careful reading of each article.

The content analysis research protocol combines the recommendations of Tranfield et al., (2003) and Duriau et al., (2007) in the following steps: (i) planning the review (research questions, search strategy and coding), (ii) conducting the review (frequency counts and cross-tabulations), and (iii) reporting and disseminating (interpretation of results).

After reading the 116 articles and their coding, core-periphery analysis was performed. Core-periphery structures are highly centralized. In a core-periphery structure, the entire network is centered on a single group: the core (Borgatti & Everett, 1999). High-status actors (those with a high number of connections) are connected to each other, forming a cohesive core (Duque, 2017).

Core-periphery analysis involves two assumptions that are absent in community structure: (i) high-degree actors are connected to each other; and (ii) the entire network is centered on a single subgroup, the core (Duque, 2017). With the core-periphery structure of the articles, the networks were presented showing the relationship between the codes.

For qualitative content analysis, the axial coding process, starting with codes derived from the literature, as summarized in Section 2, with additional emerging codes added as the article's content analysis progressed (Saldaña, 2013). The initial codes explore the surveyed papers' methodological perspective with three groups of codes applied: the unit of analysis (Senescu et al., 2013), research method, and research approach (Franco et al., 2018). Two groups grounded the initial related to communication-related codes, the type of communication (Senescu et al., 2013), and communication barriers (Carvalho, 2014), which incorporated other codes during the saturation process. Three KM groups of theoretical codes initiate the analysis of knowledge management goals and outcomes (Pemsel et al., 2014), type of knowledge (Nonaka & Takeuchi, 1997), and knowledge management barriers (Santos et al., 2016). Finally, two groups of codes related to project complexity and project sector were practically only resulted from the emerging codes added during the content analysis process. The coding cycles provide the basis for inferences (Miles et al., 2014), resulting in the whole coding schema presented in Section 4.

4. RESULTS AND DISCUSSION

4.1 Bibliometric Analysis

The review cover almost a thirty-year period, starting with the first article is from 1992, with a quantitative approach, examining the transfer of tacit and explicit knowledge in an IT group, published by (Agarwal & Tanniru, 1992). Table 4 deployed the articles on 8 years period, exploring the evolution on the variables related to project complexity in projects and barriers.

To analyze the most outstanding authors in the sample, we plotted outliers based on the number of citations of each article in the sample. For Figueira (1998), an outlier is characterized by its relation to the remaining observations (data) that are part of the sample. The distance between the outlier and these observations is fundamental for its correct characterization. Outliers are also known as abnormal, contaminating, strange, extreme, or aberrant observations. **Figure 2** presents the outlier authors obtained through the Minitab software.

The most cited articles (see Figure 2), using the outlier's criteria (≥ 30 citations), are from International Journal of Medical Informatics and International Journal of Project Management.

4.2 Network Analysis

Analyzing the keywords of the 116 articles, they have 4.727 words occurrences that correspond to the total number of words contained in the corpus; it differs if the corpus is lemmatized or not because when it is lemmatized it does not include word variations. Of this total, 1,147 words correspond to the number of shapes present in the corpus (active and supplementary words). The number of words that appear only once throughout the corpus corresponds to 517 (10.94% of occurrences and 50.84% of forms), and the average occurrence per text corresponds to 40.75, indicating a similarity between the use of keywords by the authors.

4.2 The Content Analysis

The careful reading and interpretation of all the 116 papers result in the coding schema detail in this section. The quantitative content analysis explores the code frequencies and the key topic identified in the literature. The detail classification of all articles on the coding schema is presented in Appendix A.

First, we explored the methodological perspective of the surveyed articles, as shown in Table 5. It pinpoints towards the emergent and exploratory characteristic of the literature surveyed, once most of the articles are qualitative (75%), applying theoretical-conceptual (34%), or case study (27%) research design. Only 10% of the sample uses quantitative and confirmatory research design.

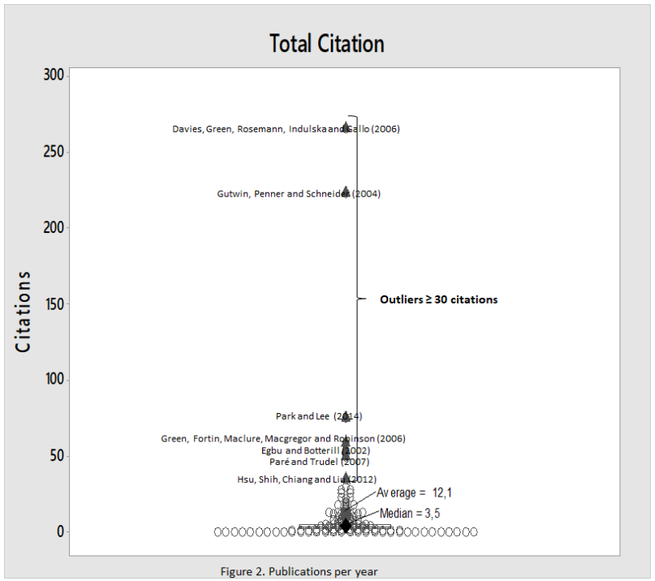

Figure 2. Most Cited articles

	Code	Description	n	%
Research Method	RM_1	Modelling	9	8%
	RM_2	Theoretical-conceptual	36	34%
	RM_3	Literature Review	8	8%
	RM_4	Simulation	1	1%
	RM_5	Survey	12	11%
	RM_6	Case Study	29	27%
	RM_7	Action research	0	0%
	RM_8	Interview (Focus Group)	14	13%
	RM_9	Observation	7	7%
	RM_10	Experimental	2	2%
Research Approach	RA_1	Qualitative	80	75%
	RA_2	Quantitative	11	10%
	RA_3	Multi-Methods	13	12%
Unit of Analysis	UA_1	Product	36	34%
	UA_2	Organization	38	36%
	UA_3	Process	46	43%

Table 5. Coding Scheme: methodological perspective

	Code	Description	n	%
Project Sector	PA_1	Information Technology (IT)	42	40%
	PA_2	Mechanic	1	1%
	PA_3	Construction	19	18%
	PA_4	Manufacturing	5	5%
	PA_5	Oil and Gas	6	6%
	PA_6	Engineering	8	8%
	PA_7	Automotive	2	2%
	PA_8	Eletronic	2	2%
	PA_9	School	4	4%
	PA_10	Bank/Financial	3	3%
	PA_11	Health/Hospital	8	8%
	PA_12	Biotechnology	1	1%
	PA_13	Nuclear	1	1%
	PA_14	Pharma	1	1%
	PA_15	NPD	6	6%
	PA_16	Logistic Provider	1	1%

Table 6. Coding Scheme: project sector

Note: Relative percentages compared to 116 articles in content analysis.

Second, the project type of sector most frequent in the sample is IT project (40%), followed by construction projects (18%), as shown in **Table 6**. These two sectors are frequent in other studies in PM field.

The coding schema on project complexity perspective results on four sub-code Size (PC1), Variety (PC2), and Interdependence (PC3), as shown in **Table 7**. Most of the articles use a combination of these variables to describe project complexity, being the most frequent PC1 with 72%.

The coding schema related to communication resulted in seven codes, clustered in two groups as shown in **Table 8**. Considering the Type of Communication, three types emerged Collaborating (TC_1), Sharing (TC_2) and Understanding (TC_3), with a prominence of TC2 with 94% of the sample exploring communication sharing. Considering the Communication Barriers, four emerged Trust (CB_1), Priorities (CB_2), Semantics (CB_3), and Environment (CB_4), and CB4 stood out among them with 92%.

The coding schema related to knowledge resulted in 13 codes, clustered in three groups, as shown in Table 9. The first cluster is knowledge Management outputs, deployed in dynamic capabilities (KM_1), absorptive capacity (KM _2), and lessons learned (KM 3), in which the most frequent was KM3 with 37%. Both types of knowledge, tacit (KM_4) and explicit (KM_5), were commonly approached together with a slight prominence of explicit knowledge in 92% of the sample. Finally, eight knowledge management barriers emerged as shown in **Table 9**, particularly the Codification process (KMB_1) and Inadequate information technology absorptive capacity (KMB_2), mentioned in 89% and 61%, respectively.

	Code	Description	n	%
Project complexity	PC_1	Size	76	72%
	PC_2	Variety	66	62%
	PC_3	Interdependence	60	57%

Table7. Coding Scheme: project complexity

	Code	Description	n	%
Type of Communication	TC_1	Collaborating	43	41%
	TC_2	Sharing	100	94%
	TC_3	Understanding	22	21%
Communication Barriers	CB_1	Trust	22	21%
	CB_2	Priorities	54	51%
	CB_3	Semantics	35	33%
	CB_4	Environment	98	92%

Table8. Coding Scheme: communication related codes

	Code	Description	n	%
Knowledge Management Outputs	KM_1	Absortive Capacity	10	9%
	KM_2	Dynamic Capabilities	7	7%
	KM_3	Lessons Learned	37	35%
Type of Knowledge	KM_4	Tacit KM	83	78%
	KM_5	Explict KM	97	92%
Knowledge Management Barriers	KMB_1	Codification process	94	89%
	KMB_2	Inadequate information technology	65	61%
	KMB_3	Lack of initiative and strategy by the workers	47	44%
	KMB_4	Lack of time and resources	33	31%
	KMB_5	Learning curve of information systems	4	4%
	KMB_6	Competitive environment	16	15%
	KMB_7	Lack of trust	13	12%
	KMB_8	Unawareness of other people' s work	7	7%

Table 9. Coding Scheme: knowledge related codes

	1992 - 2000	2001 - 2009	2010 - 2018
Project Complexity	Size	Size Variety	Size Variety Interdependence
Communication Barriers	Environment	Environment Priorities	Environment Priorities
Knowledge Management Barriers	Codification process Inadequate information technology Lack of initiative and strategy by the workers	Codification process Inadequate information technology Lack of initiative and strategy by the workers	Codification process Inadequate information technology

Table 10. Coding schema evolution by period

For understanding the evolution of the coding schema over the decades, **Table 10** deployed three eight years period of analysis.

About the project complexity, it is noted that in the first period the studies classified the projects as complex by the size, considering the number of stakeholders. Over time the classifications will differ, considering the number of stakeholders (size dimension), variety of information system, geographic location of the stakeholders and variety of interests of the stakeholders (variety dimension). In the last period the papers include at least these two dimensions and included the interdependencies, which consider dependencies with the environment, availability of resources, interdependence between sites, companies, team cooperation and communication, interdependence of objectives and others as proposed by Vidal, Marle & Bocquet (2011).

Regarding communication and knowledge management barriers, over the years, the concern with barriers is repeated. The environmental factors such as noise, physical discomfort, visual distractions, interruptions, and others (Carvalho, 2008), remain the main communication barrier studied over the years. Moreover, the codification process and inadequate information technology difficulties appear to be the most common knowledge management barriers.

The codification process was considered by (Santos et al., 2016) as the major barrier pointing to knowledge sharing in complex projects, which is related to the following difficulties: transferring the knowledge in one's head to paper or digital in an appropriate format; incapacity to structure and to share the knowledge in a different format besides the official documents of the project; participants consider that knowledge has different levels and that some levels cannot be codified; documents and initiatives to share knowledge are not appropriate and/or easily understandable, because participants do not know how to conduct a proper approach to knowledge sharing; and most of the knowledge is in the key participants' heads.

The second barrier, mainly pointing to knowledge, was inadequate information technology and concerned the following aspects: tools available to share knowledge are very time consuming and not user friendly, so people are reluctant to use them; different solutions or tools are used; absence of easy communication with other tools and assurance that people really understand the meaning (ambiguity); and knowledge sharing systems are mainly process-oriented and do not support a more "fuzzy" content (Santos et al., 2016).

About the unit of analysis, the fact that the communication theme, more precisely the communication process has stood out in the sample is because the communication process can influence the transfer of knowledge, either explicit or tacit. The communication process can also be a barrier to knowledge transfer between the project team (Al Nahyan, Sohal, Hawas, & Fildes, 2019; Mueller, 2012; Park & Park, 2016; Ren et al., 2018; Van Den Hooff & Ridder, 2004).

The size dimension classifies most complex projects and often studies in the IT and construction sectors. About communication management, the main unit of analysis of the articles is on communication sharing, and the most studied barrier is environmental, and it is possible to see that most of the articles studied the codification process as the leading knowledge management barrier.

It is verified by the analysis of the codes that more articles are linked to the theoretical-conceptual methodology and to the case study. This demonstrates that empirical or field analysis is required for the subjects of this study, since from them it is possible to seek the practical verification of something and thus anchor and prove in the experience plane what is presented conceptually. In relation to the approach, the most found are the qualitative ones, which highlights that the subjects discussed are recent in the literature and still need to be well understood by the research of the perceptions and understanding about the general nature of a question, opening space for interpretations.

About the unit of analysis, the fact that the communication theme, more precisely the communication process has stood out in the sample is because the communication process can influence the transfer of knowledge, either explicit or tacit. The communication process can also be a barrier to knowledge transfer between the project team (Al Nahyan, Sohal, Hawas, & Fildes, 2019; Mueller, 2012;

Park & Park, 2016; Ren et al., 2018; Van Den Hooff & Ridder, 2004).

The quantitative content analysis helps to explore the first research question proposed, RQ#1 Which are the main topics relating knowledge and communication to the complex project context?

The cross-analysis of the 116-article coding allowed for the identification of the core themes in the literature, that are highlighted as core class membership codes: Project Complexity (PC), Type of Communication (TC), Communication Barriers (CB), Knowledge Management (KM), Knowledge Management Barriers (KMB), with a core/periphery fit of 0.9233 is shown in **Figure 4**.

Note: Analysis performed in UCINET software with cross-tabulation data.

Core/Periphery fit (correlation) = 0,9233

Core/Periphery Class Memberships:

Core:	PC_1 PC_2 PC_3 TC_2 CB_4 KM_4 KM_5 KMB_1 KMB_2
Periphery:	UA_1 UA_2 UA_3 TC_1 TC_3 CB_1 CB_2 CB_3 KM_1 KM_2 KM_3 KMB_3 KMB_4 KMB_5 KMB_6 KMB_7 KMB_8

		20 KMB	8 TC_	6 PC_	4 PC_	5 PC_	18 KM_	13 CB_	17 KM_	19 KMB	3 UA_	2 UA_	9 TC_	10 CB_	14 KM_	15 KM_	16 KM_	11 CB_	12 CB_	1 UA_	7 TC_	21 KMB	22 KMB	23 KMB	24 KMB	25 KMB	26 KMB
20	KMB_2	65	63	37	44	42	64	62	55	58	31	25	13	16	7	3	26	33	22	21	25	39	30	4	14	12	7
8	TC_2	63	100	59	72	64	94	94	80	90	44	37	21	22	9	6	36	51	34	35	39	46	32	4	15	13	7
6	PC_3	37	59	60	43	35	56	57	51	55	29	24	14	13	7	4	16	32	19	19	27	28	19	1	9	5	2
4	PC_1	44	72	43	76	50	71	74	62	69	34	28	20	15	7	5	30	39	27	27	35	35	25	4	13	11	6
5	PC_2	42	64	35	50	66	60	62	52	59	26	29	12	14	5	5	23	32	21	22	28	31	22	1	12	10	5
18	KM_5	64	94	56	71	60	97	92	81	88	44	34	21	22	9	5	35	50	34	34	40	46	32	4	16	13	7
13	CB_4	62	94	57	74	62	92	98	79	90	42	36	22	19	10	6	35	52	33	36	41	47	32	4	15	11	7
17	KM_4	55	80	51	62	52	81	79	83	74	40	33	18	20	9	5	32	42	25	25	33	40	25	4	15	13	5
19	KMB_1	58	90	55	69	59	88	90	74	94	41	35	20	19	10	7	31	52	35	33	39	43	31	4	15	10	7
3	UA_3	31	44	29	34	26	44	42	40	41	46	7	12	17	4	2	13	24	15	6	19	18	13	2	5	7	4
2	UA_2	25	37	24	28	29	34	36	33	35	7	38	6	6	3	4	18	22	11	6	16	23	19	1	11	6	1
9	TC_3	13	21	14	20	12	21	22	18	20	12	6	22	8	2	1	9	17	12	6	14	10	8	2	3	6	5
10	CB_1	16	22	13	15	14	22	19	20	19	17	6	8	22	1		9	15	10	3	11	13	7	1	5	7	2
14	KM_1	7	9	7	7	5	9	10	9	10	4	3	2	1	10	5	2	6	5	6	6	6	3		1	1	1
15	KM_2	3	6	4	5	5	5	6	5	7	2	4	1		5	7	2	6	3	4	3	2	2		1	1	1
16	KM_3	26	36	16	30	23	35	35	32	31	13	18	9	9	2	2	37	22	9	15	14	21	16	1	9	9	2
11	CB_2	33	51	32	39	32	50	52	42	52	24	22	17	15	6	6	22	54	20	18	29	27	19	3	12	9	6
12	CB_3	22	34	19	27	21	34	33	25	35	15	11	12	10	5	3	9	20	35	16	18	17	11	3	7	3	4
1	UA_1	21	35	19	27	22	34	36	25	33	6	6	6	3	6	4	15	18	16	36	16	14	7	1	5	1	2
7	TC_1	25	39	27	35	28	40	41	33	39	19	16	14	11	6	3	14	29	18	16	43	24	12	1	10	4	4
21	KMB_3	39	46	28	35	31	46	47	40	43	18	23	10	13	6	2	21	27	17	14	24	47	30	4	14	9	6
22	KMB_4	30	32	19	25	22	32	32	25	31	13	19	8	7	3	2	16	19	11	7	12	30	33	4	13	9	6
23	KMB_5	4	4	1	4	1	4	4	4	4	2	1	2	1			1	3	3	1	1	4	4	4	3	3	3
24	KMB_6	14	15	9	13	12	16	15	15	15	5	11	3	5	1	1	9	12	7	5	10	14	13	3	16	6	4
25	KMB_7	12	13	5	11	10	13	11	13	10	7	6	6	7	1	1	9	9	3	1	4	9	9	3	6	13	5
26	KMB_8	7	7	2	6	5	7	7	5	7	4	1	5	2	1	1	2	6	4	2	4	6	6	3	4	5	7

Figure 4. Core-periphery analysis

4.3 Cross-codes Analysis

In this section we explored the research questions (RQ#2 and RQ#3) proposed, based on the in-depth qualitative analysis of the surveyed articles looking for insights for further research.

The RQ#2 shed light on the main knowledge and communication barriers in the context of complex projects.

Figure 5 analyzes the relations between (b) type of communication, communication barriers, knowledge management, and knowledge management barriers. We can see a strong relationship (about 81% of papers) between sharing (TC2) and environment (CB4) as a communication barrier, explicit knowledge (KM5) and tacit knowledge (KM4) moreover, with the knowledge barrier known as the codification process (KMB1).

Tacit knowledge (KM4) and explicit knowledge (KM5) are strongly correlated with the codification process (KMB1) and inadequate information technology (KMB2) barriers in more than 50 % of articles.

The process of knowledge codification leads organizations to focus people primarily on documentation, using information technology to efficiently use knowledge (Venkitachalam and Ambrosini, 2017).

If the organization decides to implement a dominant coding process for tacit or explicit knowledge, adequate IT support is essential for knowledge management (Razmerita, Kirchner, & Nielsen, 2016; Venkitachalam & Ambrosini, 2017)

Therefore, information technology is important to support KM in an organization, especially when employees are involved in the process of coding, storing, reusing and transferring knowledge of the work routine throughout the organization (Hansen et al., 1999; Venkitachalam & Willmott, 2015).

With inadequate IT support, organizations face impediments to knowledge capture and storage, such as lessons learned from previous projects, product development, employee knowledge and work-related best practices (Patriotta, 2004). Lack of adequate IT to support coding and transfer will result in loss of knowledge and reinvention costs for the organization (Patriotta, 2004).

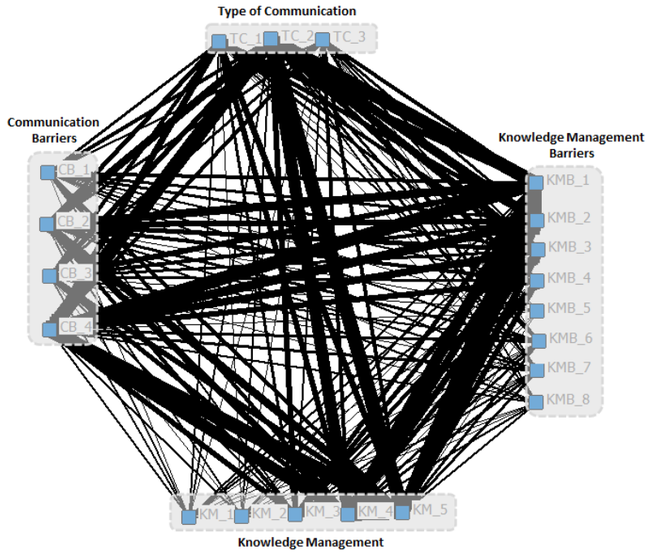

Figure 5. Relation between KM and communication barriers

There needs to be a link between KM and IT to promote the knowledge coding process and should be considered a strategic part of the organization. The problem with inadequate information technology is the lack of communication, or communication tools, between a team to develop a KM coding process that assists the KM coding process and is related to the organizational environment (Choi & Lee 2002; Ruck; Albers & Reiß, 2017)

According to this, the link between environment (CB4), tacit knowledge (KM4), explicit knowledge (KM5), codification process (KMB1), inadequate IT (KMB2) and communication sharing (TC2) is stressed in Figure 6.

In the literature on knowledge transfer, most researchers have recognized communication as an essential influence (Ren et al., 2018). The knowledge sharing is undeniably a form of communication so this variable can be expected to be of significant influence (Van Den Hooff & Ridder, 2004), because to turn tacit knowledge into explicit, those often involved talk (Li et al., 2018), through various communication channels (Liyanage et al., 2009).

The process of knowledge codification is causally related to the organizational environment, the environment in which knowledge communication will be carried out between individuals. Communication tools will contribute to this, and information technologies developed for this purpose will assist in this process of knowledge sharing (Ruck, Albers, & Reiß, 2017; Soto-Acosta, Popa, & Martinez-Conesa, 2018; Venkitachalam & Ambrosini, 2017). Inadequate communication processes and tools, problems with the organizational environment (people involved in the process, culture, among other environmental barriers) impact the process of coding knowledge, whether tacit or explicit (Omotayo &

Babalola, 2016; Ruck et al., 2017; Venkitachalam & Ambrosini, 2017)

It is noteworthy that lessons learned (KM3) also stand out in over 22% of articles when they find that the difficulty in the codification process (KMB1) and inadequate information technology (KMB2) make the lessons learned process difficult. When considering KM coding strategy, organizations often rely on IT applications to capture, store and reuse different aspects of organizational knowledge in different ways, such as best practices, lessons learned, plans, procedures and guidelines (Venkitachalam & Ambrosini, 2017).

The knowledge coding process and inadequate IT make it difficult to share knowledge and lessons learned. Project participants need to transfer their knowledge and need media for knowledge transfer, storage and sharing between project teams. Codification relies on information technology tools to connect people to reusable explicit knowledge (Javernick-Will and Levitt, 2010). For this, organizations should use tools, methods and techniques that support learning processes and have mechanisms to facilitate and promote different types of learning to support the transfer of individual learning to organizational learning (Gieskes and Broeke, 2000).

To transfer knowledge requires communication and it is necessary to avoid barriers to transmitting and storing knowledge. Thus, lessons learned are knowledge stored during all project phases, so if there are communication barriers, communication does not happen effectively, and knowledge is not transmitted or stored, making lessons learned impossible.

About lessons learned, if they are a vital element of knowledge management (Garon, 2006), valid knowledge management should provide formal real-time and informal communication expediently for the individual, the project team and various kinds of relevant personnel (Cai et al., 2011).

The sharing process can be assessed with respect to how the team learned from other project teams or vice versa (Senescu et al., 2013). The difficulties posed by the environment in which complex projects are embedded, such as excessive noise, visual discomfort, distractions, interruptions, and others can disrupt the process of sharing communication. According to Carvalho (2008), the environmental factor remains the main communication barrier studied over the years.

To go further in the discussion, we explore the role of project complexity (PC) and unit of analysis (UA) in the relation between communication barriers (CB) and knowledge barriers (KMB), as shown in **Figure 6**.

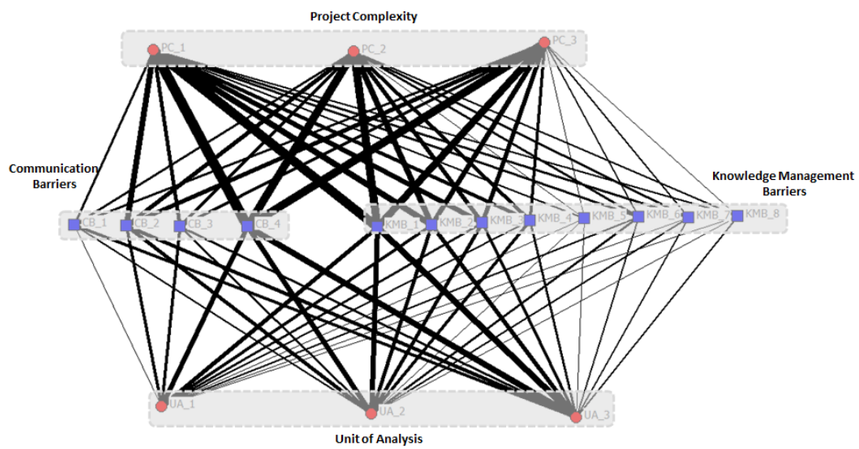

Figure 6. CB and KMB: The role of Project Complexity (PC) and Unit of analysis (UA).

Communication and knowledge barriers are also related to complex project types (more than 50% of papers), the main correlated communication barriers being environmental (CB4) and priority (CB2) and knowledge codification process (KMB1) and inadequate information technology (KMB2) which in turn relate to the unity of analysis: process (UA3). The unit of analysis refers to the type of communication, if information is about the organization, product, or the process.

There are two types of communication processes, internal and external, which result in internal and external communication barriers. In both, the most cited problems are knowledge and lack of knowledge sharing, both inside and outside (Fan, Xue, & Li, 2014; Thunberg, Rudberg, & Karrbom Gustavsson, 2017). The scope and communication priorities, development of knowledge concerning the correct use of the communication infrastructure, adequacy of a selection of communication channels and their effectiveness (Winkler, 2018) can be considered barriers of communication in organizational processes.

The environmental factor is composed of the internal or external communication process. It is important to prioritize the information and the kind of information shared with each one, which helps to reduce the failure in the projects (Thunberg et al., 2017).

Barriers to communication can be easily detected in the organizational environment, where problems with the centralization of information and issues related to dubious interpretations are apparent (Carvalho, 2013).

Project stakeholders have specific objectives that may conflict. In complex projects, this barrier may be more evident because of the number of stakeholders involved.

Analyzing this relationship between the project's complexity and the communication and knowledge barriers, the literature shows that creating, maintaining, transferring and increasing knowledge is of paramount importance to efficiently deal with the complexity of projects (Disterer, 2002). The complexity of the projects may intensify the role of communication and team knowledge due to the increased need for coordination and decision-making (Marks et al., 2001).

Complex projects are characterized by their size, variety, interdependence of stakeholders and especially project teams, which can often have a different language, culture and behavior and be located in different regions affecting communication and the transmission of project information (Casey, 2010).

Complex projects involve social interactions among different participants that enable knowledge sharing (Santos, Soares, & Carvalho, 2012), and there may be communication problems (Alagba, 2014). Johannessen and Olsen (2011) emphasize the importance of communication in projects, particularly those that are large and complex. They argue that companies must move from the use of communication processes to the use of communication skills during projects, and these skills can help the knowledge transfer.

According to Rabechini Jr., Carvalho, and Laurindo (2002), to achieve effective communication, a process of communication management system is required, which at the most comprehensive stage is called knowledge management. Alonso et al. (2013) indicate that since knowledge is transmitted primarily through human relations, any noise generates distortions in information, creating barriers to communication and making it difficult to store and share knowledge, thus creating barriers to knowledge management.

Moreover, according to Santos et al., (2016) in complex projects, one of the communication barriers is KM. Knowledge management and communication management comprise interrelated processes because to share knowledge it is necessary to create adequate communication medias for this. What is more, the communication management among project stakeholders is required to know project complexity phases (Senaratne & Sexton, 2009; Whyte et al., 2016, Eriksson, Larsson & Pesamaa, 2017).

It is possible to notice that the dimensions of project complexity considered in this analysis (size, variety, and interdependence) correlate with the knowledge and communication barriers. These dimensions show that project complexity, as well as traditional projects, face communication and knowledge difficulties. Moreover, these problems may intensify because of the complexity of the projects, the number of stakeholders involved, different teams, the variety of information systems, the geographic location of the stakeholders and the variety of their interests, the availability of people, material and any resources due to sharing, dependencies between schedules, dependencies with the environment, dynamic and evolving team structure, interconnectivity and feedback loops in task and project networks, interdependence between actors, interdependence between sites, departments and companies, and interdependence of information systems. These are among other characteristics of project complexity that impact on the communication process and consequently the knowledge transfer.

By presenting these characteristics, project complexity presents communication problems, especially environmental barriers (CB4) and priority (CB2), because the environments are diverse and difficult to control because of the number of stakeholders involved. Even so, because there are many involved and interdependent, the difficulty of prioritizing communication and establishing an effective process becomes more difficult for complex projects.

It is noteworthy that the two barriers, highlighted in this codification, are also mentioned by Santos et al., (2016) that indicated that the two most cited barriers to knowledge management in complex projects were KMB1 and KMB2. It is also emphasized, that information and communication technology is currently considered one of the enablers for the effective implementation of KM (Mazorodze & Buckey, 2019).

This discussion suggests that the following proposition should be considered in any future research agenda:

- **P1:** Project complexity influences knowledge management barriers and communication barriers.
- **P2:** The unit of analysis influences knowledge management barriers and communication barriers.
- **P3:** The type of communication influences knowledge management.

To explore the RQ #3 What are the most up-to-date thinking, trends, and gaps in the literature? (**see Table 11**). It is possible to indicate that the authors are including communication in the knowledge management process and giving greater emphasis to the difficulties of knowledge management, with communication being a process to facilitate knowledge sharing.

Moreover, based on the results obtained by the content analysis and codification, it was observed that a significant number of the studies are focused on the communication process as a form of knowledge transfer in complex projects. This is because some authors also emphasize that communication is a barrier to knowledge management. There is a decrease in the studies on communication management and an increase about knowledge management.

It is still possible to realize that a significant gap is the lack of studies on dynamic capabilities and absorptive capacity in the complex project context and the lack of quantitative reviews, comparisons and difficulties faced in complex international projects.

5. CONCLUSIONS

This article presents an in-depth analysis of 116 articles dealing with the triad of knowledge management, communication, and project complexity. Three main contributions to the literature stood out in relation to the proposed research question. First, it was possible to identify not only the influence of communication on knowledge management but also the moderating role of project complexity and the unit of analysis. Second, the type of communication can influence not only the communication barriers but also knowledge management and knowledge management barriers. Furthermore, communication barriers influence knowledge management.

Third, dynamic capabilities, absorptive capacity and lessons learned as moderators of knowledge management do not influence communication or knowledge management barriers.

It is also highlighted that the project complexity does not influence the type of communication just as the project areas do not influence the communication or knowledge barriers in the complexity project context. Moreover, the research method and research approaches do not influence the triad.

An important implication for practice for companies is related to the need for providing an environment that fosters the communication process, which has a strong influence on knowledge sharing, and the learning process. What is more, when communication flows, the knowledge-sharing behavior among project teams can help with lessons learned and mitigate barriers to knowledge management, considering the type of project complexity.

Research Gap	Potential Research Questions	Theories/Concepts that can be applied
1. Develop a relation between triad knowledge management, communication and project complexity including		
Lessons learned	What are the collective processes of lessons learned in complex projects?	KM process (Cohen and Levinthal, 1990; Lane et al., 2006; Garon, 2006; Sun, 2010; Cai et al., 2011; Dogbegah et al., 2011; Venkitachalam and Ambrosini, 2017)
	What is the role of communication in the process of lessons learned?	
	How can the communication process help the lessons learned?	Organizational learning (Cohen and Levinthal, 1990; Gieskes and Broeke, 2000; Macher and Boerner, 2005; Yap et al., 2017)
	How can lessons learned help knowledge barriers in projects?	
Dynamic capabilities	How can dynamic capability and absorptive capacity help lower barriers to knowledge management?	
	How can the communication process help the dynamic capability in organizations?	Knowledge transfer (Eisenhardt and Martin, 2000; Noblet et al., 2011)
	What are the main communication processes that support dynamic capacity?	
Absorptive capacity	How can absorptive capacity assist the project team?	
	How can absorptive capacity help external communication?	Absorptive capacity (Cohen and Levinthal, 1990; Macher and Boemer, 2005; Yap et al., 2017)
	How can absorptive capacity help knowledge management processes?	Knowledge sharing (Polanyi, 1966; Disterer, 2002; Van Den Hooff and Ridder, 2004; O'Sullivan, 2007;

Table 11. Research gaps

This research has limitations related to the use of search engines and the methodological choices concerning the search string, filters and databases selected. The content analysis, despite being performed by a group of three researchers, may generate an interpretation bias. However, the systematic multimethod approach applied (bibliometric, network analysis and content analysis) helps to mitigate these limitations.

This exploratory research highlights that this theme brings new inspiration and challenges for future analysis. This study points out the lack of more confirmatory research approaches, such as developing a relationship between triad knowledge management, communication and project complexity including lessons learned, dynamic capabilities and absorptive capacity. It also directs increased attention to the type of communication and the project complexity area. Based on this, future potential research questions are shown in **Table 11**.

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EXPLORING THE DYAD COMMUNICATION AND KNOWLEDGE MANAGEMENT:

A STUDY INVESTIGATING THE MAIN BARRIERS IN COMPLEX PROJECT CONTEXT