INVESTIGATING INFORMATION SYSTEMS WITH MIXED-METHODS RESEARCH

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ABSTRACT

Mixed-methods research, which comprises both quantitative and qualitative components, is widely perceived as a means to resolve the inherent limitations of traditional single method designs and is thus expected to yield richer and more holistic findings. Despite such distinctive benefits and continuous advocacy from Information Systems (IS) researchers, the use of mixed-methods approach in the IS field has not been high. This paper discusses some of the key reasons that led to this low application rate of mixed-methods design in the IS field, ranging from misunderstanding the term with multiple-methods research to practical difficulties for design and implementation. Two previous IS studies are used as examples to illustrate the discussion. The paper concludes by recommending that in order to apply mixed-methods design successfully, IS researchers need to plan and consider thoroughly how the quantitative and qualitative components (i.e. from data collection to data analysis to reporting of findings) can be genuinely integrated together and supplement one another, in relation to the predefined research questions and the specific research contexts.

KEYWORDS

Mixed-Methods, Research Design, Information Systems, Quantitative, Qualitative, Triangulation.

1. INTRODUCTION

Research designs and methods adopted by Social Sciences researchers in general, and in the Information Systems (IS) field in particular, can be broadly classified into two main categories, namely quantitative and qualitative (Jick, 1979; Orlikowski and Baroudi, 1991; Mingers, 2001; Creswell, 2003; Saunders et al., 2003). However, it is widely understood and recognized that both quantitative and qualitative designs have their own advantages and limitations. For example, questionnaire survey, as a typical quantitative method, is a very efficient and economical way for collecting data from a large sample in a wide geographical area at the same time (Bryman, 2004:133-134). Nonetheless, questionnaire is arguably a less efficient method to be used in exploratory studies, which aim to investigate and explore sophisticated social contexts (Robson, 2002:234). On the other hand, interview as a typical qualitative tool is very useful and efficient in gathering and exploring in-depth human insights and perceptions on complex social phenomena (Saunders et al., 2003:246; Bryman, 2004:321). Nevertheless, as interviews can very often last more than one hour, it is very time-consuming to carry out interviews with a large group of respondents.

The realization of the inherent limitations of quantitative and qualitative approaches results in the emergence and use of an alternative research design, namely mixed-methods research. Mixed-methods research integrates and combines both quantitative and qualitative methods in one single study. This approach is deemed to be efficient in supplementing the weaknesses of single method designs and thus

leading to richer findings and higher quality research (Jick, 1979; Mingers, 2001; Creswell, 2003; Fidel, 2008). It has been used as a distinct approach in social sciences research for more than five decades (Campbell and Fiske, 1959; Jick, 1979; Rocco et al., 2003). In the IS field, a considerable number of researchers have advocated the use of mixed-methods approach since the early 1990s (Galliers, 1991; Lee, 1991; Robey, 1996; Mingers, 2001; Petter and Gallivan, 2004; Fidel, 2008). Curiously, despite strong and continuous support from IS researchers, the actual use of mixed-methods approach in IS research has not been prevalent. In particular, Mingers (2003) reviewed the IS literature between 1993 and 2000, and found that only 20% of articles published in this period of time adopted multiple research methods. In a more recent study, Fidel (2008) reviewed 465 articles published in four major journals in Library and Information Science (LIS) during 2005-2006. The study found that only 17% of these LIS articles adopted multiple methods, and only 5% could be considered as 'truly' mixed-methods research (Fidel, 2008). This low application rate of mixed-methods research in the IS field might be caused by a number of issues such as:

- there may exist some misunderstandings among IS researchers about the actual meaning of mixed-methods research (i.e. is 'mixed-methods' the same as 'multiple-methods' design?);
- IS researchers may find it difficult to decide which mixed-methods design would be suitable for a particular study (e.g. what priority or weight should be given to the quantitative and qualitative methods? In what sequence these methods should be conducted?);
- IS researchers may have difficulties in integrating and making sense of quantitative and qualitative components effectively across the entire study.

This paper provides an in-depth discussion and some practical guidelines in relation to the above issues. It aims to help IS researchers make more appropriate decisions when designing and implementing mixed-methods research, and thus leading to more rigorous and meaningful findings. We also use two previous IS studies as examples to illustrate the discussion. These two studies adopted mixed-methods designs to investigate respectively ERP post-implementation risks and knowledge leakage risks associated with the design and use of 3D modelling.

The paper is structured as follows. The next section provides a discussion and clarification on the concept of mixed-methods research, followed by a discussion on various commonly used mixed-methods designs and their associated benefits and practical difficulties. Subsequently, the paper provides two examples (which adopted a Quan + *qual* and a Qual + *quan* approach) to illustrate how mixed-methods design can be applied in IS studies. The paper concludes with a recommendation that in order to apply mixed-methods approach effectively, IS researchers need to plan and consider thoroughly how the quantitative and qualitative components (i.e. from data collection to data analysis to findings) can be integrated together and support one another, in relation to the predefined research questions and the specific research contexts.

2. MIXED-METHODS RESEARCH

2.1 Definition of mixed-methods research

Although mixed-methods research is not a new concept, its definition has been relatively misrepresented by a number of IS researchers over time. In particular, some advocators of mixed-methods approach in the IS field, such as Gable (1994) and Mingers (2001, 2003), simply named the concept as 'multiple-methods' research in their articles. However, a further review of the literature on Social Sciences, where mixed-methods approach originated from and has been widely used, suggests that multi-methods is not equivalent to mixed-methods research, due to at least two main reasons:

- When adopting multiple-methods, researchers can select methods from just a single approach (e.g. two quantitative methods or two qualitative methods), rather than combining the use of both quantitative and qualitative methods as required in mixed-methods design (Jick, 1979; Rocco et al., 2003; Petter and Gallivan, 2004; Fidel, 2008).
- A study can be considered as a multi-methods research as far as more than one research method was employed (Petter and Gallivan, 2004). However, a mixed-methods research requires not only the use of multiple methods, but also that quantitative and qualitative approaches and findings need to be properly integrated and actually complement each other (Rocco et al., 2003; Bryman, 2007; Fidel, 2008).

Thus, for the purposes of this paper, we would adopt a more rigorous definition for mixed-methods research as proposed by Tashakkori and Creswell (2007). That is, mixed-methods research is defined as "research in which the investigator collects and analyzes data, integrates the findings, and draws inferences using both qualitative and quantitative approaches or methods in a single study or program of inquiry" (Tashakkori and Creswell, 2007). Furthermore, Fidel (2008) reinforces that 'mixing' is the core of a mixed-methods research and can occur in different stages of the study:

- In the design stage, features of all selected research methods need to be taken into consideration to establish the research design of the study.
- In the data collection stage, one approach should provide insights that improve the process of data collection of the other approach.
- In the analysis stage, data collected and results derived from both approaches need to be integrated and support each other.

These fundamental needs for integrating quantitative and qualitative elements across the entire study lead to both strengths and practical difficulties of mixed-methods research, as discussed later in this paper.

2.2 Types of mixed-methods designs

In relation to the above rigorous definition, a mixed-methods research can actually be designed very flexibly. In particular, an extensive literature review conducted by Tashakkori and Teddlie (2003) identified that, researchers in Social and Behavioral Sciences developed around fourty different mixed-methods designs that employed at least two quantitative and qualitative methods concurrently or in sequence. Nonetheless, the six (i.e. including three sequential and three concurrent) designs proposed by Creswell (2003) are some of the most commonly used ones in mixed-methods research (Ivankova et al., 2006). These six mixed-methods designs are therefore described in detail in the table below.

Table 1: Six types of mixed-methods designs (source: Creswell, 2003)

Mixed-methods design	Characteristics
Sequential designs:	
Sequential explanatory Design	This design contains two phases and is characterized by the collection and analysis of quantitative data followed by the collection and analysis of qualitative data. The priority is given to the quantitative part. The purpose of this design is to use qualitative results to further explore and explain the findings of a primarily quantitative study.
Sequential exploratory Design	This design is characterized by an initial phase of qualitative data collection and analysis. This qualitative component is then followed by a phase of quantitative data collection and analysis with the aim of increasing generalisability of the findings. The priority is given to the qualitative aspect of the study.
Sequential transformative Design	This design contains two distinct data collection phases. However, either method may be used first when collecting data, and the priority can be given to either the quantitative or the qualitative phase, or even to both if sufficient resources are available.
Concurrent designs:	
Concurrent triangulation Design	In this design, both quantitative and qualitative methods are used simultaneously in one phase, with the aim to confirm, cross-validate, or corroborate findings within a single study. Both components are considered equally important.
Concurrent nested design	This design contains one data collection phase, during which both quantitative and qualitative data are collected simultaneously. However, one method (either quantitative or qualitative) must take the predominant position, and the other method should be embedded/nested within the predominant method to address a different question or to seek information in a different level.
Concurrent transformative design	This design combines the features of both concurrent triangulation and concurrent nested designs. Specifically, it may involve a triangulation of quantitative and qualitative components that are equally important. It is then also embedded with a supplement method to further explore the issue. However, all data are collected at the same time in one data collection phase.

When there are so very different combinations to establish a mixed-methods design, it should be highlighted that one is not necessarily better than the other. In fact, the actual design that researchers should select, depends entirely on the research question and research context being investigated. In order to illustrate how a mixed-methods design can be selected and implemented in IS research, two practical examples are given in section 3.

2.3 Strengths of mixed-methods design

Mixed-methods research is particularly useful and suitable for research projects where no single approach can fully explain or explore the phenomenon being investigated, especially when this phenomenon is complex and multifaceted (Fidel, 2008). Moreover, the combination of the use of quantitative and qualitative methods in a single study can help researchers to supplement the limitations of each single method, as well as to achieve triangulation (Creswell, 2003; Fidel, 2008).

The term 'triangulation' is broadly defined by Denzin (quoted by Jick, 1979) as "the combination of methodologies in the study of the same phenomenon". In practice, the concept of triangulation can often be applied in four ways (Denzin, 1978; Jick, 1979; Patton, 1999):

- Method triangulation: multiple methods are used to collect different sets of data to study the same concept/phenomenon;
- Triangulation of sources: use the same method to collect data from different samples or data sources at different times, locations and/or contexts;
- Analyst triangulation: multiple techniques are used to analyze and interpret the same set of data from different dimensions;
- Theory/perspective triangulation: multiple theories or perspectives are used to interpret the data.

It is evident that, when multiple approaches are used to collect data in mixed-methods research, method triangulation would be achieved. According to Jick (1979) and Creswell (2003:15-16), method triangulation can provide researchers with a range of benefits:

- It allows researchers to be more confident on their results;
- It helps to neutralize or cancel the biases that may exist in single method approach;
- It stimulates the creation of new ways to combine different approaches, strategies and methods to answer a specific research question;
- It helps to uncover the unique or deviant dimension of a sophisticated phenomenon which might be overlooked by using a single method, and thus amplify the richness of the research findings.

Overall, in contrast with single method approach, mixed-methods research can allow researchers to explore and investigate sophisticated issues more holistically and widely (Fidel, 2008). This approach is thus deemed to be particularly suitable to study IS issues, which are always multi-dimensional and involve a wide range of socio-political, socio-technical, regional, cultural, and organizational factors.

2.4 Practical difficulties of mixed-methods design

Despite the above crucial benefits, mixed-methods research is however not easy to design and implement in actual practices (Ivankova et al., 2006; Fidel, 2008). In fact, while mixed-methods research opens a variety of opportunities and possibilities for research design, it also raises a wide range of questions and issues that need to be considered cautiously by researchers.

Specifically, at the design stage, researchers need to decide carefully about, e.g. which quantitative and qualitative methods should be combined in the study, in what order (e.g. sequentially or concurrently) and priority (e.g. equally important or one predominates the other) these methods can be used, and what objectives each component should attempt to achieve (Fidel, 2008; Ivankova et al., 2006; Creswell et al., 2003). It is evident that this complex set of decisions needs to be made in response to the predefined research questions and research context. Inappropriate decisions made at the early stage will not just affect the rigorousness and reliability of the mixed-methods research design, but will also impact the richness and significance of the subsequent research findings.

Moreover, researcher's attitudes and ability to implement the research design represent some further key challenges for adopting mixed-methods approach (Fidel, 2008). In fact, it is clear that quantitative and

qualitative approaches are very different in terms of underlying epistemologies, data collection procedures, nature of data collected, and data analysis techniques. As a result, it will be difficult for inexperienced researchers (e.g. PhD students) to mix these different approaches in one single study. On the other hand, senior researchers who have a traditional preference in using one approach (i.e. either quantitative or qualitative approach) may very often find it difficult to accept, and in fact may also not be equipped with adequate skills, to use the other (Fidel, 2008; Bryman, 2007). The situation can become particularly complicated when a mixed-methods study is undertaken by a team of researchers and each of them has a very strong stance on their own single approach and considers other approaches as secondary (Patton, 2002; Bryman, 2007; Fidel, 2008).

Consequently, these practical issues and difficulties can hinder efficient integration of quantitative and qualitative findings in mixed-methods research (Bryman, 2007). In particular, Bryman (2007) highlights that in many mixed-methods studies, quantitative and qualitative results may either not be genuinely integrated or be integrated to only a limited degree. The reasons for this may be related to a wide set of barriers, e.g. inefficient research design, methodological preferences and skills of researchers, and even publication tendency (i.e. only accept quantitative or qualitative findings) of some journals (Bryman, 2007). In such circumstance, the quantitative and qualitative components may neither be related nor complemented with each other. As a result, the mixed-methods design may not result in more holistic and significant findings than a single method approach, and in fact will also lose its essential meaning and original value.

3. EXPERIENCES IN APPLYING MIXED-METHODS APPROACH IN IS RESEARCH

In order to provide further insights and guidance to address the above practical challenges, this paper presents two studies as examples to illustrate how mixed-methods research can be designed and implemented effectively in the IS field. These two studies respectively adopted a sequential explanatory (Quan + qual) and a sequential exploratory (Qual + quan) design, as proposed by Creswell (2003) and outlined earlier. The presentation of both studies follows a common structure, namely research aims and objectives; choice and rationale of the research design; quantitative or qualitative data collection and analysis; and finally the integration of findings.

3.1 Identification and assessment of risks associated with the post-implementation of ERP systems in China

3.1.1 Research aims and objectives

Enterprise Resource Planning (ERP) systems have nowadays been widely adopted by Chinese companies in order to improve operational efficiency and enhance core competencies. However, successful implementation of the system is not the end of the ERP journey. Very often, the system post-implementation or exploitation stage is where the real challenges will begin and more critical risks may occur.

Thus, the research project reported in this section aimed to identify, assess and explore potential risks that Chinese firms may encounter when using, maintaining and enhancing ERPs in the post-implementation phase. It also attempts to explore the causes, impacts, probability of occurrence and frequency of occurrence of identified risk events, as well as to investigate the relationships between them. The research strives to generate a set of in-depth and meaningful findings that can be used by practitioners as an important tool for risk prevention, management and control, as well as, for strategic planning and decision making.

3.1.2 Research design: QUAN + *qual* approach

At the initial stage of the study, the first temptation of the researchers was to undertake a national study of the whole of China. However, this soon proved to be virtually impossible, given the size of China and the fact that the current economic situation and context in the country are very complicated and fluid. As a consequence, after studying the national and business environment of China by conducting a Political, Economic, Social and Technological (PEST) analysis, the researchers decided to focus and base the study on

a specific set of Chinese companies, namely State-Owned Enterprises (SOEs) in the electronic and telecommunication manufacturing sector in Guangdong province in China.

When the study focused on such a specific context, the researchers considered that findings that were generalisable to this particular context would not just be essential but in fact also highly valuable and meaningful. It therefore became apparent that a deductive quantitative questionnaire based study was needed to produce generalisable statements. Moreover, due to a lack of study in ERP post-implementation in general and in the Chinese context in particular, IS and ERP literature used to ground the theoretical basis of the quantitative study were published mainly in the West. However, it was then anticipated that some findings derived from Western contexts may not be entirely applicable to the Chinese one. Therefore, the early quantitative study might yield findings that would differ from the original theory and it was considered that a follow-up qualitative study should be carried out. This second study aimed at using a process of interviews to explore any unexpected findings derived from the quantitative component.

Consequently, these considerations clearly pointed to the selection and adoption of a two-phase sequential explanatory (Quan + Qual) design for this research. In particular, a questionnaire survey was carried out as the first phase of this mixed-methods design and took the predominant position of the entire research. Subsequently, a follow-up case study component was conducted to explore further the quantitative findings and thus achieve triangulation.

3.1.3 Quantitative data collection and analysis

As part of the theory building phase of the Quan component, a desktop study, based on the process of a critical literature review, was conducted by the researchers. As a result of this extensive literature review, the researchers established a risk ontology, which consisted of 40 potential ERP risks that Chinese companies may encounter during ERP exploitation. This risk ontology was then used as the theoretical basis to construct the questionnaire.

The questionnaire was used to seek Chinese managers' perceptions of the 40 pre-defined ERP risks as well as exploring the correlations between these risks. The designed questionnaire was sent to IT managers and operational managers of 118 selected Chinese SOEs, from which 42 valid and usable responses were received and analysed. This questionnaire survey thus achieved a response rate of 35.6%.

The quantitative data collected were analysed by using a statistical software, namely SPSS (Statistical Package for the Social Science). Based on the results of data analysis, the researchers identified the top 10 ERP risks in the context of selected Chinese SOEs and also explored a set of statistically significant correlations between these risks. On the other hand, it was also identified that the results related to certain risk items were very different from original expectation. Consequently, the researchers decided to seek further explanation and verification of these questionnaire findings through the follow-up case study.

3.1.4 Qualitative data collection and analysis

At the end of the questionnaire, respondents were asked whether or not they would be willing to participate in the multi-case study stage to discuss further ERP-related risks and issues in their companies. Two volunteer companies were thus identified to participate in the second phase of the study. As discussed above, this follow-up qualitative component aimed to validate the most significant findings of the survey, as well as to explore further any unexpected results derived from the first stage.

In order to achieve these exploratory purposes, semi-structured interview was used as the data collection method in the case-study component. The interview instrument was designed based on a set of refined and selected questionnaire findings (i.e. top 10 risks, correlations between risks, and unexpected outcomes related to certain risks). Consequently, 25 semi-structured interviews were carried out with the CEOs, IT managers, and departmental managers and system users in diverse departments (i.e. sales, financial, production, and purchasing department) of the two case companies.

The interview data was analysed by using a thematic analysis approach with *a priori* coding. Thematic analysis is a process of searching, identifying and exploring codes and themes that emerged as "important to the description of the phenomenon" (Daly et al., 1997), through "careful reading and re-reading of the data" (Rice and Ezzy, 1999:258). This data-driven inductive approach can often be used together with a deductive priori coding (Fereday and Muir-Cochrane, 2006). In this study, the set of questionnaire findings used to construct the interview questions were also used as a set of priori codes, while a wide range of codes were also identified from data. Furthermore, in order to organize and represent concepts and findings derived from

the analysis, a set of concept maps was established. Concept map is a "graphical tool for organizing and representing knowledge […and includes] concepts, usually enclosed in circles or boxes of some type, and relationships between concepts" (Novak and Cañas, 2006). These concept maps were used as a means to share and represent concepts and results derived from the qualitative study, as well as the scaffolding to report findings.

3.1.5 Integration of findings

As discussed above, the critical literature review at the early stage of the study resulted in the establishment of a risk ontology, which contained 40 potential risks associated with ERP post-implementation. These 40 risk items were organised into four categories, namely operational risks, analytical risks, organisation-wide risks, and technical risks.

Subsequently, the questionnaire examined the suitability of this theoretical ontology in the context of Chinese SOEs. The survey findings identified that all of the 40 predefined risk events were perceived by the majority of respondents as risks to ERP exploitation. The 10 top prioritised risks were distributed across organisational processes and operation. Moreover, the findings also identified a set of statistically significant correlations between the 40 identified risks. The majority of these correlations occurred between analytical and organisation-wide risks. Since these types of risks seemed to be interwoven and closely related with each other, it was concluded that the occurrence of these risks is much more difficult to manage, mitigate and contain in the SOEs studied. In contrast, technical risks that are very often expected as the main perpetrators in ERP failure seem to be important but not strictly related to other risks.

These quantitative findings were then further explored, validated and confirmed in the follow-up case study. In particular, the interview findings supported that crucial ERP exploitation risks did not conveniently localise around technical aspects. In fact, organisation-wide risks are often the direct triggers for the operational and technical risks and indirect triggers for the analytical risks.

Moreover, by analysing, triangulating and synthesising the quantitative and qualitative findings, it was identified that the most critical ERP risks, which originated the entire complicated risk network, were associated with 3 main human factors, namely top management, in-house IT experts, and system users.

Overall, the study concluded that potential failure of ERP systems cannot be conveniently attributed to technical aspects, such as the software package and the ICT infrastructure, in the context of Chinese SOEs studied. In fact, the integrated findings of the study suggest that it is in organisation processes and human-oriented aspects that the more dangerous and difficult-to-manage risks can be found in these companies. Further details about the findings of this study can be found in our recent publications (e.g. Peng and Nunes, 2009a; Peng and Nunes, 2009b).

3.2 Risk assessment of knowledge exposure risks associated with 3D VRE

3.2.1 Research aims and objectives

High-tech companies (e.g. those in the Aerospace/Ship/Automobile manufacturing sector) have increasingly invested in 3D and virtual reality applications to support customers in understanding and using their products, as well as to provide complex and specialised training to employees. These applications take the form of 3D virtual reality environments (VREs) where users can navigate, browse and learn in an authentic and close to realistic contexts. However, given the fact that VRE applications are realistic, easy to navigate and contain holistic specialised and technical explicit knowledge, the use of VREs can lead to possible risks of explicit knowledge exposure and/or leakage, and thus representing a threat to internal knowledge management.

Thus, the study reported in this section aimed to explore and identify these risks. Specifically, it attempted to identify the base-events that may trigger the risks, define and characterise the risks, and finally propose solutions and recommendations on how to minimise and remediate their occurrence.

3.2.2 Research design: QUAL and *quan* approach

In fact, the original idea of the research was triggered by Dr Barry Bassnett, the Technical Director of Rainmaker 3D. Rainmaker 3D (formerly Alignment International, and has now been acquired by Smiths Group PLC) is an engineering company that provides a wide range of specialised services, including sales of metrology equipments, system integration, measurement services, and training. One of its important areas of

expertise is the creation of virtual environments and 3D models of plants, machinery, aircraft and ships that contain detailed and holistic information that can be easily navigated and queried by users or employees. However, despite the success of Rainmaker's VREs, the nature of this technology poses both potential and apparent knowledge exposure risks. The challenge for the researchers was to identify and assess these knowledge leakage risks and make recommendations on how the company could address them.

In order to explore the situation of Rainmaker and conduct in-depth investigation of knowledge leakage risks occurred in the firm, an exploratory case-study approach was adopted. However, the results of any case-study are always difficult to generalise to a wider context. In order to address this inherent limitation of the case-study approach and produce generalisable findings beyond the immediate case study, it was considered meaningful and necessary to carry out a further cross-sectional questionnaire survey.

Consequently, these considerations and the specific context of the research led to the selection and adoption of a two-phase sequential exploratory (Qual + quan) design for this study. Specifically, an exploratory case study was conducted for discovery and identification purposes. Subsequently, a cross-sectional questionnaire survey was used to validate and generalise the findings of the first phase.

3.2.4 Qualitative data collection and analysis

In order to establish appropriate understandings for the concepts being studied and support theoretical sensitisation, an initial literature review was undertaken at the early stage of the study. As a result of this literature review, the researchers established a high level conceptual framework that was adapted from the Yeates and Cadle (2001) Risks Identification Framework. This framework allows multi-characterisation of risks from three categories, namely business/organizational, project and technical categories.

Moreover, since interviews are a good source for providing insights into people's experiences, opinions, values, aspirations, attitudes and feelings (May, 2003), this method was used as the data collection tool in the case study for early identification and analysis of risks associated with the design and development of VREs. The interview questions were designed based on the conceptual framework derived from the literature review. Consequently, a set of exploratory interviews were undertaken with key management and technical personal in the case company.

The qualitative data collected were analysed by following the grounded theory approach that contains three stages, namely open coding, axial coding and selective coding. The findings derived from the data analysis were represented in a set of concept maps, which allowed a comparative analysis between the case-study results and the theoretical stance, and a constant re-interpretation of new findings and already established and accepted chains of evidence.

3.2.3 Quantitative data collection and analysis

The in-depth data gathered through exploratory interviews however are limited to the knowledge, experience and perspectives of the respondents within the case company. As discussed above, in order to validate and generalise the findings obtained for the that case-study, as well as to gain a more comprehensive understanding of the leakage risks identified, a cross-sectional questionnaire survey was carried out. 500 UK companies, which are involved in the design, development, and use of 3D models/VR environment, were randomly selected to participate in the survey. This selection attempted to produce a geographically well distributed and size balanced sample in the sector. The survey received a response rate of 10%. Subsequently, the quantitative data collected were analysed by using SPSS. The questionnaire findings were then integrated and cross-referenced with the findings of the case-study.

3.2.5 Integration of findings

As mentioned above, the conceptual framework derived from the literature review highlighted three categories for risk identification, including business/organizational, project and technical categories. By integrating the case-study and questionnaire findings, the study identified, explored and assessed a comprehensive set of risks associated with the design and use of 3D models. In particular, the integrated findings suggested that critical knowledge leakage risks could occur related to the organisation's operational and management characteristics (business risks), during the design and development cycle of the 3D models (project risks), as well as associated with the use of and the inherent nature of these models (technical risks). Moreover, the findings also identified that companies participated in the study had neither proper knowledge management nor holistic risk management and information security approach to handle the identified

knowledge leakage risks. This poses a significant threat to both 3D software development companies and their direct customers, as well as to third party companies (i.e. secondary customers).

4. CONCLUSION

This paper discussed the use of mixed-methods approach in IS research, in order to resolve the limitations of single quantitative or qualitative approach and thus lead to more comprehensive, rigorous and significant findings. As emerged from our discussion, the key determinant of the success of mixed-methods design is the researcher's ability to combine genuinely the quantitative and qualitative elements throughout the project, from design and implementation of the research to integration and reporting of findings. In fact, and as illustrated from the above IS exemplifications, a mixed-methods study can be designed in a very flexible manner (that is, either the quantitative or qualitative component can be carried out first and take the predominant position). Nonetheless, any decisions made for the mixed-methods design need to be in accordance to the nature of the research question and actual needs of the study as well as the specific context of the research. Moreover, a clear and justifiable rationale must be embedded in the design to allow that quantitative and qualitative data collection and analysis can complement each other. As demonstrated in the above examples, this can more likely result in the subsequent findings to be related and supplement with each other. To conclude, when these principles are kept rigorously and applied effectively, mixed-methods approach can be a fundamental tool in the IS researcher's arsenal.

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